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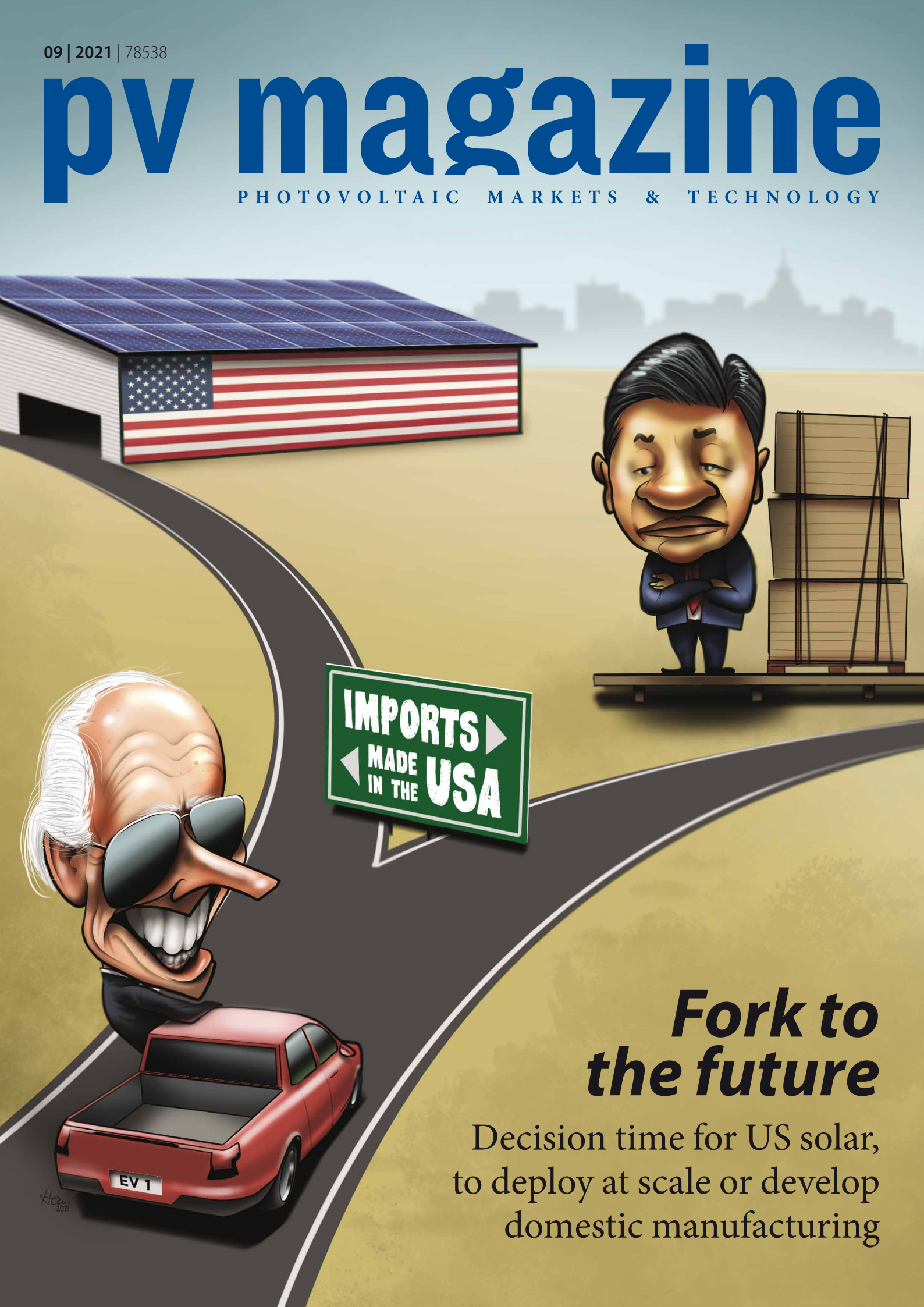

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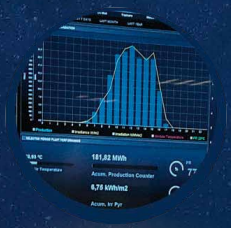

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Subscriptions/individual issues
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Number of issues Twelve per year

Purchase prices
Annual subscription for 12 issues: €199 print/€89 digital, including shipping and VAT, where appropriate. Single issue: €19 print/€9.50 digital, including shipping and VAT where appropriate. Purchase prices are applicable at the time an order is received.

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Layout & typesetting
Alexx Schulz | mADVICE Berlin

Printer
Humburg Media group,
Am Hilgeskampf 51-57, D-28325 Bremen

ISSN 1865-3138
pv magazine was founded in 2008 by
Solarpraxis AG, Karl-Heinz Remmers.

At a crossroads

Photo: pv magazine/Stefanie Loos

The rapid growth currently underway in the U.S. solar market is impressive to behold. More than 40% year-on-year growth is nothing short of stellar. Looking at the market segments, the residential rooftop business appears to be becoming more streamlined and shedding some of the overheads that had maintained relatively high prices. Innovations are being adopted in the commercial and industrial rooftop solar sector (pp. 78-80). And at the utility scale, a mix of state-level policies like Renewable Portfolio Standards, an ongoing appetite for PPAs, and the continued support of the Investment Tax Credit (pp. 20-23) look to have provided fertile turf for solar developers.

In another sense, however, supply chains remain disjointed, in light of Covid-19, and impacted by ongoing efforts to take a stance on accusations of forced labor in Xinjiang, China. There is a geopolitical aspect, too – with solar becoming an increasingly important strategic good, an unmoderated reliance on imports is less than ideal. There is a mounting sense that the U.S. market has come to a crossroads, where ramped-up domestic production or an open door to imports mark the fork in the road ahead (pp. 16-17).

Such a binary choice is likely to be overly simplistic, and if decisive action averting catastrophic global warming is to be taken, imports of Chinese PV cells and modules will be required for the foreseeable future. After all, a fully domestic solar manufacturing sector cannot be established in the United States or anywhere else overnight.

Looking more closely at the business of PV, there appear encouraging innovations making solar more efficient, robust, lower cost and flexible – and I'm pleased that many key developments are featured in this edition of the magazine. From novel approaches to mounting structures (pp. 58-61), through to the weather-proofing of arrays (pp. 38-45), the application of smart power electronics (pp. 62-64), and advanced O&M approaches (pp. 50-53).

In preparing this edition of **pv magazine**, which has the North American market firmly in its sights, I owe a debt to **pv magazine USA** Senior Editor David Wagman and his team, who have provided comprehensive and insightful coverage of this most important of global solar marketplaces.

Jonathan Gifford, Editor in Chief

"A 'win-win' could be achieved by seeking synergies with private capital instead of freezing it out"

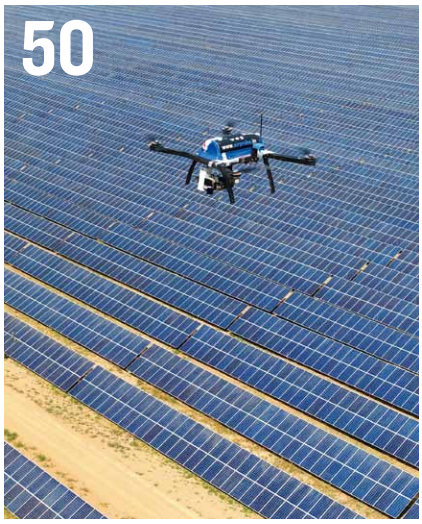
Mexico's big green chill

Page 36

"The concept of high-density solar has arrived because the cost of the panel has gotten so low, and steel so high"

Bringing costs down to earth

Page 58



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10 GW milestone for Brazil

Brazil has reached around 10 GW of installed solar PV, according to the country's solar association ABSOLAR. The Latin American country recorded 9 GW of installed PV capacity at the end of May and 8 GW at the end of March. This means that more than 2 GW of new PV systems were deployed over the past five months of this year. Strong growth in the distributed-generation PV segment, which includes all installations not exceeding 5 MW in size that operate under the net metering regime, is driving the market, along with a growing number of bilateral power purchase agreements for large-scale solar plants.

Uzbekistan to tender another 900 MW

Uzbekistan's Ministry of Energy has is planning to launch two more solar tenders for the construction of large-scale PV power plants. A first tender is planned for the Bukhara, Khorezm and Namangan regions, where the Uzbek government wants to deploy 500 MW of PV facilities and a second procurement exercise is expected be held for 400 MW of solar capacity across the Kashkadarya and Fergana regions. No more details were provided. In a separate statement, however, the ministry revealed that there are currently 1,297 MW of solar parks under construction.


Photo: Dilshod Akbarov, wikimedia commons

US customs jeopardizing 2.1 GW of solar

Around 2.1 GW of solar projects representing a total investment of about $2.2 billion are at risk as U.S. Customs and Border Protection (CBP) enforces action to stop the flow of goods that may have been produced using forced labor in China's Xinjiang region. Philip Shen, an analyst with Roth Capital Partners, offered those numbers and said that JinkoSolar has had 100 MW of modules detained by customs agents and that the company is "not able to ship from Malaysia to the U.S." In addition, Trina Solar had six next-generation test modules detained and Canadian Solar had four modules detained. Both Trina Solar and Canadian Solar said the detentions directly involved their products. In remarks given during a webinar hosted by Roth Capital, Elise Shibles, an attorney with Sandler, Travis & Rosenberg, said there was a "low likelihood" that any of the detained modules would be released. Affected importers have three months to prove that no forced labor was involved at any stage of the product's production. But Customs and Border Patrol have set a "high bar" in terms of what documentation must be produced to secure the products' release. She said that the documentation "is almost never enough" to satisfy release requirements.

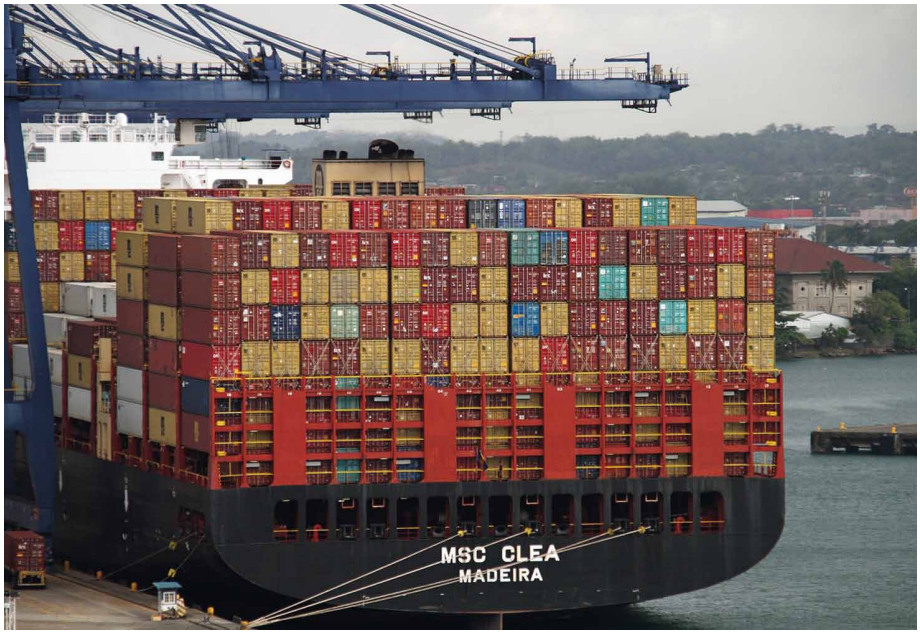


Photo: Max Pixel

Debate over France's largest solar+storage project

France's National Commission for Public Debate (CNDP) has validated the project management report of the 1 GW Horizeo solar+storage project in Saucats, in the Gironde department in Nouvelle-Aquitaine, southwestern France. Under development by French energy giant Engie and Paris-based independent power producer Neoen, the €1 billion unsubsidized project comprises a green hydrogen production unit, an agrivoltaic plant, and a data center. The CNDP said the public debate on the project will be kicked off on Sept. 9 and will be finalized on Jan. 9, 2022. According to the CNDP, the 1 GW PV plant will represent the largest part of the investment – €650 million – and could be the largest in Europe in terms of installed capacity and surface area, covering more than 900 hectares.

Photo: Eiffage

3.5 GW green hydrogen project for Oman

Indian solar developer Acme Group has signed a land agreement to install a $3.5 billion renewables-powered green hydrogen and green ammonia facility in Oman. The integrated plant, said to be one of the world's largest green ammonia projects, will be located in the Special Economic Zone at the port of Duqm. It will be powered by 3 GWp of solar and 0.5 GWp of wind energy to produce 2,400 tons of green ammonia daily and approximately 900,000 tons annually. The facility is expected to become operational by 2022. When operational, it will export green ammonia to demand centers like Europe and Asia.

Photo: Oman Ibrill

New GW factories

First Solar broke ground on its third manufacturing facility in the U.S. state of Ohio on Aug. 17. The new 3.3 GW facility is scheduled to start operations in the first half of 2023 and represents a $680 million investment. When fully operational, it is expected to scale the company's northwestern Ohio footprint to a total annual capacity of 6 GW.

In China, China Resources Power Holding, a subsidiary of state-owned conglomerate China Resources Group, has started construction on a 12 GW heterojunction (HJT) solar module factory in Zhoushan City, Zhejiang province. The planned facility includes 24 lines with a capacity of 500 MW each for both cells and modules. The total investment is estimated at $16.9 billion. The factory should operate at full capacity by the end of 2024.

Photo: First Solar

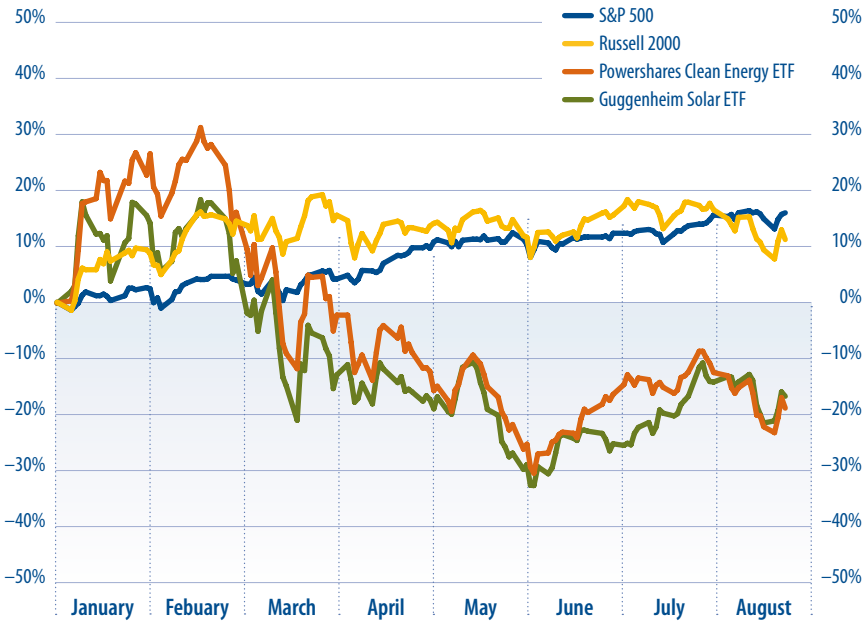
And in Vietnam, Chinese PV module maker JinkoSolar began work on a $500 million 7 GW ingot and wafer manufacturing facility in Vietnam's Quang Ninh province in the second quarter of this year. The facility is expected to begin manufacturing activities within six months and will serve the company's cell and module assembly factories in Malaysia, as well as the module assembly facility in the United States.

Supply chain shake-up

Solar stocks have underperformed in the broader market in August, writes Jesse Pichel of ROTH Capital Partners. Project delays could be on the horizon as more module imports are held up at customs, and the supply chain will start to see impacts as suppliers look for options to source polysilicon outside of China.

Guggenheim Solar ETF – TAN Holdings

Source: Roth Capital



Company	Ticker	Close price Aug 20, 2021	% change Aug 01–20, 2021	% change year to date
China Shuifa Singyes Energy Hold. Ltd.	SEHK:750	1.36 HKD	–20.9%	+70.0%
Jolywood (Suzhou) Sunwatt Co., Ltd.	SZSE:300393	11.13 CNY	–20.0%	+20.0%
Sungrow Power Supply Co., Ltd.	SZSE:300274	137.80 CNY	–17.9%	+90.6%
Shenzhen S.C New Energy Technology Corp.	SZSE:300724	201.50 CNY	+24.0%	+38.4%
Tianjin Zhonghuan Semiconductor Co., Ltd.	SZSE:002129	46.20 CNY	–7.7%	+81.2%
TBEA Co., Ltd.	SHSE:600089	16.56 CNY	+9.5%	+63.2%
JinkoSolar Hold. Co., Ltd.	NYSE:JKS	40.16 USD	–25.5%	–35.1%
Beijing Jingyuntong Technology Co., Ltd.	SHSE:601908	9.81 CNY	–8.2%	–4.7%
LONGi Green Energy Technology Co., Ltd.	SHSE:601012	79.12 CNY	–7.9%	+20.1%
Manz AG	XTRA:M5Z	54.90 EUR	–13.1%	+61.5%
Generac Hold. Inc.	NYSE:GNRC	400.32 USD	–4.5%	+76.0%
Risen Energy Co.,Ltd.	SZSE:300118	20.71 CNY	+2.9%	–28.2%
Atlantica Sustainable Infrastructure plc	NasdaqGS:AY	38.43 USD	–3.3%	+1.2%
Tongwei Co., Ltd.	SHSE:600438	48.96 CNY	+13.3%	+27.4%
Daqo New Energy Corp.	NYSE:DQ	47.08 USD	–20.5%	–17.9%
PVA TePla AG	XTRA:TPE	29.95 EUR	–12.4%	+52.8%
Hannon Armstrong, Inc.	NYSE:HASI	57.08 USD	+0.5%	–10.0%
centrotherm international AG	DB:CTNK	5.90 EUR	+35.6%	+113.8%
GCL-Poly Energy Hold. Ltd.	SEHK:3800	1.98 HKD	0.0%	+61.0%
Applied Materials, Inc.	NasdaqGS:AMAT	127.20 USD	–9.1%	+47.4%
Azure Power Global Ltd.	NYSE:AZRE	18.44 USD	–29.2%	–54.8%
Enphase Energy, Inc.	NasdaqGM:ENPH	165.99 USD	–12.5%	–5.4%
Xinyi Solar Holdings Ltd.	SEHK:968	15.34 HKD	–1.7%	–24.2%
Sunnova Energy International Inc.	NYSE:NOVA	32.44 USD	–14.9%	–28.1%
SMA Solar Technology AG	XTRA:S92	38.70 EUR	–12.4%	–30.8%

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

The Invesco Solar ETF, an ETF that tracks the MAC Global Solar Energy Index, underperformed relative to the S&P 500 and Dow Jones Industrial in the month of August. The Invesco Solar ETF (TAN) decreased 7.0%, while the S&P 500 increased by 1.1% and the DJIA increased by 0.5% in August. The top five performing solar stocks in the U.S. market witnessed gains and losses. They include Array Technologies (38.8%), First Solar, Inc. (9.9%), SolarEdge Technologies (4.0%), Hannon Armstrong Sustainable Infrastructure Capital (0.5%), and Atlantic Sustainable Infrastructure Capital, Inc. (-3.3%).

Up to Aug. 25, the Invesco Solar ETF has experienced a pullback. Looking forward, the U.S. industry outlook for the remainder of the year is uncertain. In late June, the U.S. Customs and Border Protection (CBP) issued a withhold release order (WRO) on imported silica-based products produced by Hoshine Silicon Industry Co., one of the world's largest metallurgical-grade silicon producers, for allegedly using forced labor in the Xinjiang region of China. With the CBP making more detainments this month, many major players could continue to face a negative impact, as additional detainments are likely to follow.

The WRO on Hoshine-affiliated products could shake up the supply chain. Currently, Array Technologies (ARRY), Canadian Solar (CSIQ), Daqo (DQ), FTC Solar (FTCI), Hannon Armstrong (HASI), Jinko Solar (JKS), Shoals Technologies, (SHLS), and Renesola (SOL) are facing potential project delays, as not enough modules can make it into the country in time.

Others, such as First Solar (FSLR), Sunpower (SPWR), and Maxeon (MAXN) could benefit from additional enforcement, as Hoshine is not included in any of their supply chains. While the CBP looks to define the compliance process and establish a system to trace silica-based products, delays in projects will occur. As a result, companies will look for alternative non-China options to source more polysilicon.

Jesse Pichel

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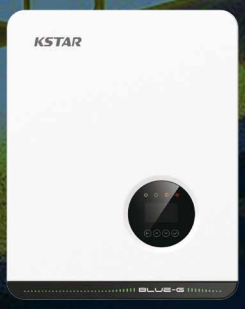
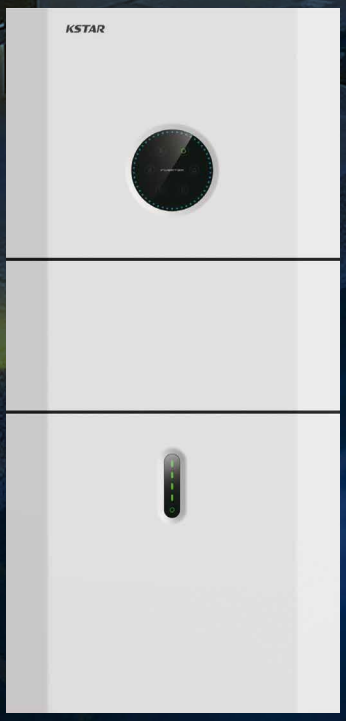


BluE-G Three Phase Series



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PV prices: high today, higher tomorrow

Some time ago, when I lived in the center of Berlin, I was a regular at the farmers' market to buy fresh fruit and vegetables. One greengrocer advertised his wares with the words "cheap today, expensive tomorrow." It would almost be desirable if we PV wholesalers could offer our modules with a similar slogan. Unfortunately, no one in the industry can currently claim that solar modules are cheap – quite the opposite. Following a brief respite, prices have climbed again in recent weeks. Since the previous low in September 2020, prices for new, grade-A goods have already risen by an average of 20% to a level not seen since April 2019.

There is no end in sight to the surge in prices for PV modules, leaving stakeholders to either postpone the construction of their PV projects indefinitely, or – like the customers of the aforementioned vegetable hawker – secure the coveted commodity sooner rather than later and avoid having to dig even deeper into their pockets. Price differences for comparable module brands and technologies are actually a function of whether they still have to be shipped from Asia. But what has gone awry here, making longer-term supply contracts no longer sensible, and planning security a thing of the past?

It all started when the international movement of goods met the Covid-19 pandemic. First, individual plants came to a standstill, preventing urgently needed goods from entering circulation. Container ships could not be utilized to capacity, and deliveries were delayed. By the time production resumed, at least in China, the virus had already reached the shipment hubs. Freight forwarders, ports and customs authorities could only operate at a much-diminished capacity, if at all. Employees were absent due to illness, seamen and dockworkers often had to go into quarantine, and the movement of goods could not flow freely. There were times when important overseas ports had to be closed and cordoned off for days on end. Due to these uncertainties, existing capacities at the shipping companies were reduced so as not to leave shippers with unused capacities and spiraling costs.

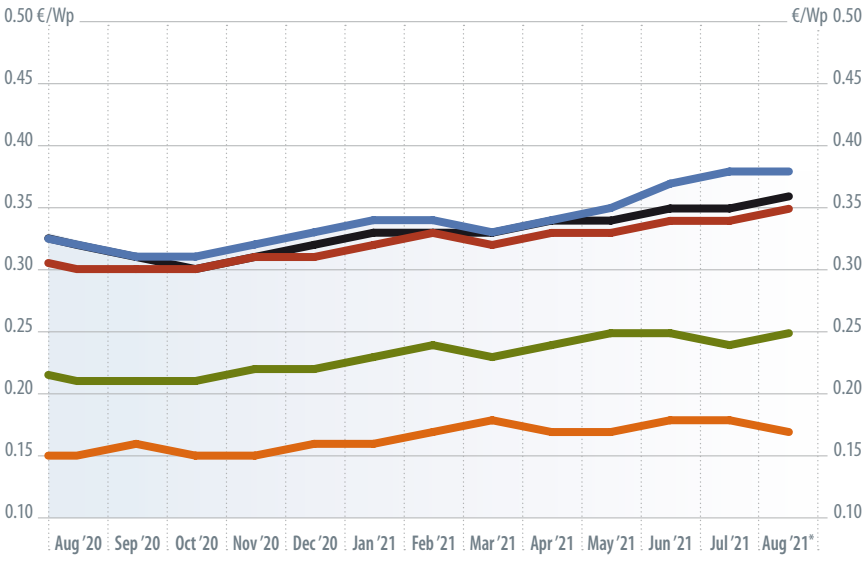
Demand comeback

Once uncertainty about the course of the pandemic had somewhat subsided in early 2021, the chaos in the global flow of goods really kicked in. As a result of lockdowns and working from home, there was a growing need to make home improvements and pursue a more sustainable lifestyle. After a lull of several months, consumption suddenly went crazy, at least in industrialized countries, and the solar industry was no exception.

Many stakeholders in Germany report a lucrative first half of the year. But shipping companies and freight forwarders had scaled back their capacities and were not prepared for a rapid increase in the volume of goods. In addition, many service providers and government agencies were still not operating at normal capacity. Within a short period, demand for transport far outstripped supply. Cargo ships were backed up outside ports, and as a result, turnaround times in the international flow of goods also increased by 20% to 30% compared to pre-pandemic levels.

The bottom line is that too many goods are waiting on too few ships worldwide, and logistics chains are not functioning as they should. As a result, freight rates have exploded since last fall. Whereas a container of sea freight from China to Rotterdam cost roughly $1,500 to $2,000 before the pandemic, prices have now skyrocketed to $15,000 to $18,000. In terms of module capacity, the freight compo-

EU spot market module prices by technology



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

- **High efficiency:** Crystalline modules **340 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 **275 Wp to 335 Wp** – the majority of modules on the market
- **Bifacial:** Modules with bifacial cells, transparent backsheet or glass-glass, framed and unframed
- **All black:** Module types with black backsheets, black frames and rated outputs of between **290 Wp and 400 Wp**
- **Low cost:** Reduced-capacity modules, factory seconds, insolvency goods, used modules (crystalline), products with limited or no guarantee

* Data as of August 18, 2021
More information: www.pvXchange.com

nent has increased tenfold from the previous level of around €0.004-€0.006/W, up to €0.05-€0.06/W. Transport costs thus no longer account for just 2% of the total price, but up to 20%.

Chinese manufacturers were quick to realize that such expensive products no longer sell well in Europe. In some cases, delivery quantities are being dialed back, and in others deadlines are being delayed until an affordable carrier can be found. The latest trick, however, is the attempt to pass on the freight risk for future deliveries to the buyer. Goods are no longer offered with the standard CIF/FCA Rotterdam or DDP Incoterms, delivery-inclusive to the building site or warehouse, but instead EXW or FOB – that is, ex-works or to the containership. This means that price increases for transport are fully borne by the customer, making it difficult or impossible to calculate the purchase price reliably or set a binding delivery date.

The concern is that few end customers will accept this uncertainty. For this reason, I strongly advise against accepting such contractual terms, at least as long as the freight traffic situation is so unpredictable. High transport costs permeate the entire value chain. Steadily rising prices for raw materials and semifinished goods are eroding the margins of manufacturers and retailers. When these costs are passed on to consumers, they fuel inflation. This is a vicious cycle that we can probably only break by increasing local value creation and reducing international freight traffic. pv

Martin Schachinger

Overview of price points broken down by technology in August 2021, including changes from the previous month (as of Aug. 16)

Module class	€/Wp	Trend since May 2021	Trend since Jan. 2021	Description
Crystalline modules				
Bifacial	0.38	0.0%	+11.8%	Modules with bifacial cells, transparent backsheets, or glass-glass, framed and unframed
High efficiency	0.35	+2.9%	+9.4%	Crystalline panels at 340 Wp and above, with PERC, HJT, n-type, or back-contact cells, or combinations thereof
All black	0.36	+2.9%	+9.1%	Module types with black backsheets, black frames, and rated power between 290 Wp and 400 Wp
Mainstream	0.25	+4.2%	+8.7%	Modules typically featuring 60 cells, standard aluminum frames, white backsheets, and 275 Wp to 335 Wp
Low cost	0.17	-5.6%	+6.3%	Factory seconds, insolvency goods, used or low-output modules, 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*

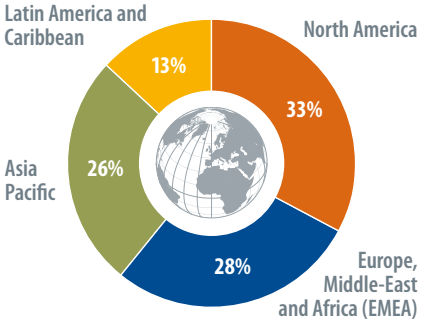
About the author

***Martin Schachinger** has been active in renewable energy for more than 20 years. In 2004, he founded the online trading platform pvXchange.com, where wholesalers, installers, and service companies can purchase standard components, solar modules, and inverters that are no longer manufactured, but are still urgently needed to repair defective PV systems.*

Global tracker shipments reached 45 GW in 2020

The global single-axis tracker market increased shipment volume by 40% year on year to reach 45 GW in 2020. This was despite significant pandemic-related supply chain turbulence that resulted in longer lead times for the delivery of components, the idling of steelmaking capacity in some key markets, container shipping dislocation, and widespread restrictions, particularly at ports. Most notably, this caused the cost of some commodities, such as steel, to more than double between 2020 and 2021. Jason Sheridan, a senior research analyst for IHS Markit, runs through some of the key developments in the tracker market.

Global tracker installations by major region 2020–2021



Notes: Installations of ground-mounted PV single-axis tracker systems larger than 1 MW. Source: IHS Markit

The United States maintained its position as the largest tracker market in 2020, with Brazil, Chile, China, and Spain making up the top five, and each recording significant year-on-year growth.

Growth of solar trackers is driven by the increasing demand from global economies for renewable energy, and the resulting rapid deployment of solar. Trackers further enable project developers in some markets to reduce the levelized cost of electricity (LCOE), enabling increased revenue potential while supporting success in competitive auctions and tenders.

The supplier landscape continued to be extremely competitive last year, with several suppliers shifting position, such as previously unranked FTC Solar entering the top 10. The top two suppliers, Nextracker and Array Technologies, maintained their ranking positions, but several other major players – including PVH, STI Norland and Gamechange Solar and – moved up the rankings as they gained market share in key solar tracker markets.

The United States saw the largest year-on-year increase for tracker shipments in 2020, boosted by trackers procured to meet safe harbor requirements prior to the expected step down of the Investment Tax Credit (ITC). As the expected ITC step down in 2021 has been extended to 2023, suppliers with a strong U.S. presence, such as Nextracker, Array Technologies, Gamechange Solar, FTC Solar and PVH, will continue to benefit from this policy.

Latin American markets such as Brazil, Chile and Mexico grew in 2020, with STI Norland taking the largest share of the Brazilian market, supporting its climb in this year's ranking. Soltec increased its market share significantly in Chile, while the European market was dominated by PVH, supported by having the largest share of the Spanish market, which made up the majority of European tracker shipments. Middle Eastern markets were dominated by suppliers to large-scale solar PV projects, such as an 800 MW installation in Qatar awarded to Ideematec. African markets remain modest, but with significant growth expected over the coming years.

The Asia-Pacific market is split in two. Australia represents a strong market for U.S.-based suppliers, while other regions, such as China and India, remain heavily influenced by Chinese and other local suppliers, namely Arctech Solar. However, Western suppliers have made inroads into India and suppliers such as Gamechange Solar had a strong presence in the Indian market in 2020.

Despite these gains, multiple suppliers have dropped down the rankings, in large part due to loss of market share in key markets and a continued competitive landscape. Other suppliers, such as Solar Steel and Convert Italia, have been relegated from the 2020 rankings, but have made recent announcements that indicate strong potential for resurgence in 2021 and onwards.

Revenues rising

North America, mainly the United States, will remain the largest tracker region globally in the forecast period, but the Asia-Pacific region will move up to second for tracker installations, driven by the huge growth of PV installations in China and India over the forecast period. This growth is driven by significant government renewable energy targets, supported by increasingly competitive auction processes, which will push developers to seek lower LCOE.

Additional growth potential exists for global suppliers in both mainland China and India, as these markets are currently dominated by Arctech Solar. Other local suppliers exist in both markets, with Trinatracker and Nengyao (formerly Kingsun Solar) representing strong challengers in the Chinese market. Gamechange Solar recently announced an office in India, cementing itself as one of the only global suppliers present in the region and a definite contender in India.

Steady tracker installation gains are expected across European, Middle Eastern and African markets through to 2025,

driven by increasing solar PV installations, but installations in Latin America are expected to plateau toward the latter part of the forecast. Modest uptake of trackers will occur in European markets such as Greece, Italy, and Portugal, while significant growth is expected in South Africa, Saudi Arabia, and the United Arab Emirates. Other growth regions include North Africa, Oman, Qatar, Jordan, and Israel.

Product innovation

Despite these clear opportunities over the coming years, the top suppliers will be challenged to hold their positions as smaller suppliers continue to grow in emerging markets and increasingly compete in established markets. This shifting landscape is aided by ever changing PV developer demands and requirements, such as the need to push into regions with harsher terrain and climatic conditions.

While cost and performance will always remain key requirements for PV developers, tracker product reliability and adaptability are becoming increasingly important for developers as flat open land becomes increasingly scarce and costly. Tracker products will be chosen based on proven ability to operate under harsh weather conditions, such as high wind and snow loads, and suitability for installation on rugged or sloped terrain.

This effectively creates a window of opportunity for innovative suppliers to promote their specific product strengths against competitors, utilizing emerging tracker technologies such as two-in-portrait configurations, dual-row configurations, advanced control software, and features which increase stability under high winds, thus enabling them to gain a foothold across global markets over the coming years.

The development of artificial intelligence-based software, which enables increased energy yields through optimization of tracker operations, is proving to be a priority among tracker suppliers as a means to achieve a competitive advantage. Many suppliers, including Nextracker, Array Technologies, PV Hardware and Soltec, have been promoting the use of software to distinguish themselves from competitors and help developers and grid operators make solar a more predictable and reliable source of energy.

Jason Sheridan

Top 10 global PV tracker supplier rankings in 2020

Shipments (MWdc) 2020	Company Name	Ranking change 2019-20
1	NEXTracker	-
2	Array Technologies	-
3	PVH	↑
4	Arctech Solar	-
5	STI Norland	↑
6	Gamechange Solar	↑
7	Soltec	↓
8	Trinatracker	↓
9	FTC Solar	↑
10	Ideematec	↓

Source: IHS Markit © 2021 IHS Markit

About the author

***Jason Sheridan** is a senior research analyst in clean energy technology at IHS Markit. He focuses his research across both the wind and solar markets. Prior to joining IHS Markit, he gained multiple years of experience in the public and private energy sector while based in London. He has worked on topics ranging from residential solar energy and storage development to electricity network distribution policy and wholesale energy market abuse investigations. Sheridan holds a bachelor of science in environmental science and health from Dublin City University and a master of science in sustainable energy and green technology from University College Dublin.*

Polysilicon amid international trade disputes

Polysilicon capacity is unable to catch up with rapid capacity expansion in the mid and downstream segments, writes Corrine Lin, chief analyst for PV InfoLink. New polysilicon capacity requires big capex investment and a lead time of more than two years to complete construction and reach full operation. With unbalanced capacity between the upstream and downstream segments, polysilicon prices have been rising since the second half of 2020, with prices for mono-grade polysilicon surpassing CNY 200/kg ($27.40) in June 2021, up more than 250% year on year.

Since 2020, the wafer, cell and module segments have been rapidly expanding, bringing total capacities to 264 GW, 322 GW, and 365 GW, respectively, by the end of the first half of 2021. Each segment is expected to reach 365 GW, 439 GW, and 463 GW, respectively, by the end of this year. The global output of polysilicon is projected to reach 550,000 metric tons this year, which can supply around 190 GW of module production.

The polysilicon business outlook seems good over the short term. However, trade disputes between the United States and China bring uncertainty. U.S. Customs and Border Protection (CBP) has issued a withhold release order (WRO) against Xinjiang-based Hoshine Silicon Industry, restricting imports of silica-based products related to the company and its subsidiaries. The U.S. Senate also passed the Uyghur Forced Labor Prevention Act to prohibit the import of all goods produced in Xinjiang. As Xinjiang is a manufacturing hub for silicon metal and polysilicon, considerable discussions on the impacts of the restrictions have begun.

Looming impacts

While the WRO doesn't restrict polysilicon imports, some module manufacturers face the risk of having their products seized, as their materials may come from Hoshine, the largest silicon metal supplier. According to the 'Reference Hoshine Frequently Asked Questions' published by CBP, importers of solar products entering the United States need to provide documents that can trace the supply chain and show that the silica used in the products was not sourced directly or indirectly from Hoshine or any of its subsidiaries.

Downstream manufacturers say it is difficult to provide such information due to the complicated nature of polysilicon production. As of August, modules of some manufacturers are reportedly being seized by CBP officers, with some being released shortly afterward. At present, the CBP scrutiny standard and specific measures remain unclear.

If the Uyghur Forced Labor Prevention Act is approved by the United States House of Representatives and signed by President Biden, the import of all goods produced in Xinjiang will be banned. Polysilicon manufacturers based in Xinjiang including Daqo New Energy, Xinjiang GCL, TBEA and East Hope, as well as manufacturers that use silica from the region, will take the first blow.

Supply/demand forecast

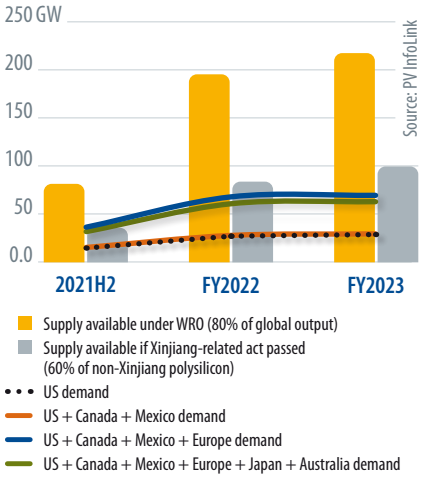
Beyond the U.S., Canada and Mexico are likely to impose similar sanctions. The EU, with several member states having recently passed or drafted laws to tackle forced labor in supply chains, might be next. Australia and Japan have also voiced concern about human rights violations in Xinjiang and may soon follow suit with restrictions on goods from the region.

Xinjiang accounts for 35% to 40% of global silicon production. Hoshine, the world's largest silicon metal manufacturer, takes up 20%. PV InfoLink estimates that 20% to 40% of polysilicon may be restricted from the U.S. or Europe.

The estimates show that around 20% of polysilicon will not be able to supply Europe or the U.S. if the WRO only applies to Hoshine. However, polysilicon production outside of Xinjiang can supply 82 GW in the second half and 196 GW and 218 GW, respectively, for 2022 and 2023, which is sufficient to fulfil demand from the U.S. and countries likely to impose import restrictions. Having said that, manufacturers should pay attention to whether CBP officers will seize an individual unit of import for investigation. Module supply to the U.S. market may be slightly impacted for the short term.

If the Uyghur Forced Labor Prevention Act is passed, polysilicon produced by Daqo, Xinjiang GCL, TBEA and East Hope in Xinjiang will no longer be usable for the modules that are exported to the U.S. In addition, after deducting around 40% of polysilicon in other regions that use silica from Xinjiang, there will be around 33 GW, 84 GW, and 100 GW of

Polysilicon supply vs. global module demand forecast



polysilicon available in the second half of 2021, 2022, and 2023, respectively – enough to serve the U.S. market.

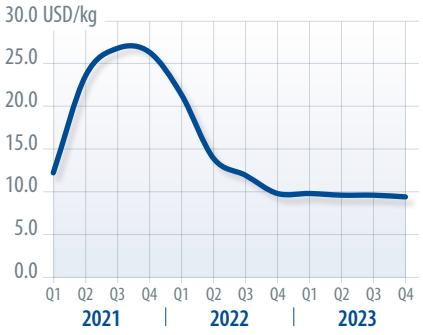
However, if Europe, the second-largest market, bans imports from Xinjiang this year, polysilicon shortages will immediately occur in regions outside of Xinjiang in the short term. If this happens in 2022, polysilicon supply outside of Xinjiang will be in a tight balance and run slightly short in the high season. Under a 2023 scenario, overall polysilicon supply will be in surplus again after large volumes of new capacity come online.

It appears that both WRO and the Uyghur Forced Labor Prevention Act will not affect U.S. demand markedly. Whether solar demand will cause polysilicon shortages due to the Xinjiang issue in the next two years depends on the actions of European countries. Currently, Germany and Norway's passing of laws combating forced labor in supply chains are variables that may impact solar exports to Europe, although Germany hasn't come out with measures on import restrictions. Meanwhile, the European Parliament is drafting Xinjiang-related regulation and policy, and polysilicon market trends are subject to their progress and decisions.

The impacts of Xinjiang-related issues on the industry will be less severe after 2023, no matter when specific legislation is passed. Polysilicon manufacturers have made large profits over the past year amid soaring polysilicon prices. Apart from Tier-1 manufacturers that are expanding capacity at a large scale, REC Silicon, CSG Polysilicon and LDK – whose lines have been shut down – are evaluating the feasibility of resuming production. High profitability attracts new players, such as Xinjiang Jingnuo, Lihao Semiconductor, Baofeng Energy and Runergy, all of which plan to expand capacity outside of the Xinjiang region to hedge political risk. If these new furnaces come into operation as scheduled, total polysilicon capacity will far exceed demand, leading to fierce price competition. If Tier-1 polysilicon makers that bring capacity online earlier cause prices to decline due to surplus, new players that enter the competition later, or Tier-2 manufacturers that plan to reopen lines, may turn conservative about their capacity expansion plans. PV

Corrine Lin

Polysilicon Price Forecast Source: PV InfoLink



About the author

Corrine Lin *is the chief analyst at PV Infolink. PV InfoLink is a provider of solar PV market intelligence focusing on the PV supply chain. The company offers accurate quotes, reliable PV market insights, and a global PV market supply/demand database, as well as market forecasts. It also offers professional advice to help companies stay ahead of competition in the market.*

Trolley car conundrum

The U.S. solar industry faces a moral dilemma, writes Paula Mints of SPV Market Research. Either continue to deploy projects and set aside concerns about forced labor in China's Xinjiang region, or source PV cells and modules from elsewhere, while bearing higher costs, in the pursuit of urgent action against climate change.

The Biden administration has big plans for fighting climate change in the United States, including aggressive infrastructure aims. Solar will play a big part in the new agenda, and participants along the value chain are optimistic.

Developers are gearing up. Residential and small commercial installers are confident. In California, mandates for solar on new residential buildings – and soon for solar+storage on new commercial and multi-dwelling residential buildings – offer a template for accelerating the move away from conventional energy. The chart below provides a view of U.S. solar deployment through 2023, but the real potential is much higher. The United States could be a 50 GW-plus annual market for solar deployment.

In 2020, 91% of U.S. installations were in the grid-connected commercial segment, which includes utility-scale installations. The top-right chart on the next page presents U.S. demand and installations for 2020. Purchases of modules define demand.

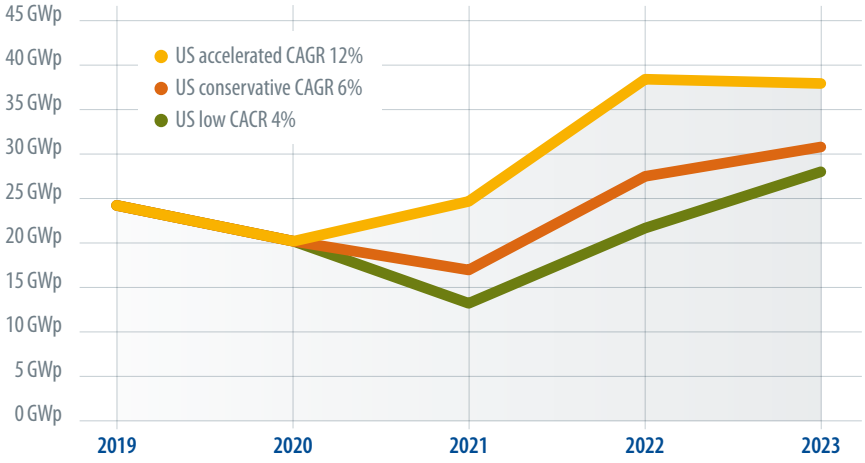
Import country

The United States has more than 20 GWp of annual demand, 2 GWp of thin-film cell capacity, and an additional 5 GWp of module assembly capacity for imported crystalline-silicon (c-Si) cells. In other words, the country does not have the capacity to serve its market. The U.S. solar market is fragile without sufficient domestic cell manufacturing, and participants have little control over module supply and price. A shock to the supply chain would likely stall market growth, at least temporarily, potentially taking that 50 GWp-plus of potential down to the low teens.

The bottom-left chart on this page presents U.S. shipments of domestically manufactured cells from 2010 through 2020. Again, close to 100% of U.S. domestic shipments are First Solar's CdTe technology.

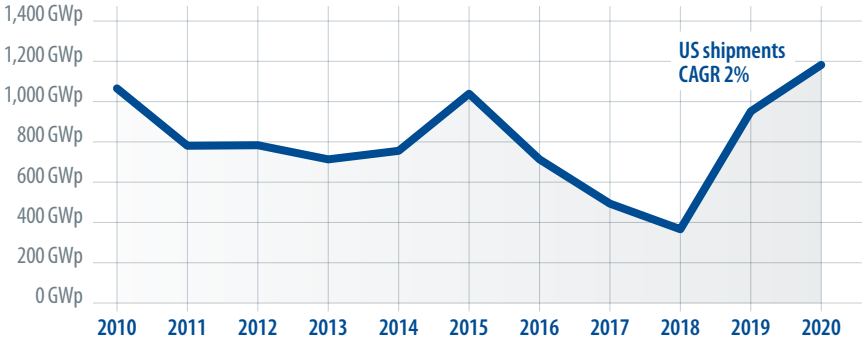
US solar deployment 2019–2023

Source: SPV Market Research



US commercial deployment, 2020

Source: SPV Market Research



System shocks

In late 2020, accidents in several polysilicon facilities in China took significant amounts of capacity offline. And repairs were delayed due to the pandemic. Add to that the Chinese government's control of glass supply, despite bifacial module demand acceleration, and prices rose.

Continuing into 2021, shipping costs increased, and a semiconductor shortage affected inverter and tracker manufacturers that were also experiencing rising costs, after years of absorbing margins and passing higher costs to customers. Developers, accustomed to years of price declines, initially tried to wait it out.

Meanwhile, the situation in the Uyghur Autonomous Region of Xinjiang, China, caught the attention of politicians. In anticipation of action from the United States and other countries, China's central government passed a law on June 10 forbidding Chinese companies from participating in audits of their materials.

Then, on June 24, the U.S. Department of Homeland Security ordered U.S. Customs and Border Protection to issue a withhold release order (WRO) to detain metallurgical silicon produced by Hoshine Silicon Industry Co., Ltd., and its

subsidiaries for the use of forced labor in its manufacturing facilities. Hoshine Silicon is the largest metallurgical silicon supplier globally. Its customers are polysilicon producers such as Germany-based Wacker, South Korea-based OCI, Daqo, GCL, Jiangsu Zhongneng, Asia Silicon, Xinjiang GCL, Xinte, and East Hope.

U.S. Customs and Border Protection has begun holding cells and modules at the border, delaying projects, and increasing costs and anxiety for solar developers and installers.

Ethical dilemma

The United States faces a moral and ethical dilemma. On one hand, after years of discussions and delayed action on climate change, governments must act decisively and quickly. On the other hand, forced labor cannot be ignored.

The English philosopher Philippa Foot developed the "trolley problem" in 1967. An out-of-control trolley car is barreling down the tracks toward five trapped people. There is no way to stop the trolley, but if you throw a switch, the trolley will instead barrel down a track where only one person is trapped. So, the choice is five or one.

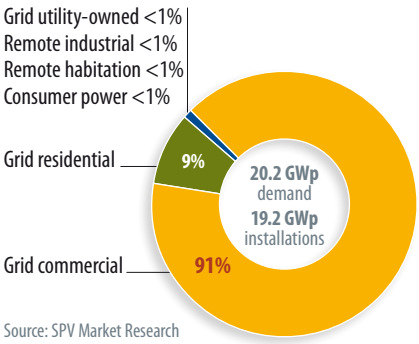
There is no bargaining with climate change. Unaddressed, it will keep barreling down the tracks. But nor is there any compromising with forced labor or other troubling measures. Nor is there any denying that forced labor may have played a part in the low cell, module, and system prices that the PV industry has enjoyed for many years.

The political timing is right for U.S. solar industry growth to accelerate beyond anyone's forecast. Behavior has changed, and there is pull from end users. Solar has moved into the political arena, with proponents on the left and the right.

Unfortunately, as indicated, the United States does not have sufficient cell manufacturing to meet its demand, and it will take years to build it. There is sufficient supply unrelated to forced labor in Xinjiang for the United States, but it will be more expensive, and there will be periods of scarcity. Growth will come at a higher cost – but not a higher moral cost. Because, again, there is no compromising with forced labor. pv

Paula Mints

US solar installations, 2020



Source: SPV Market Research

About the author

Paula Mints *is the founder and chief analyst of SPV Market Research. She began her career in 1997 with Strategies Unlimited. In 2005 she joined Navigant, where she served as director of its energy practice until October 2012, when she founded SPV Market Research, a global PV market research firm. Her areas of expertise include global markets, trends, solar product applications, cell and module costs, and system analysis – including inverters, trackers, and other balance-of-system components.*

Photo: Hanwha Q Cells

Heavy lifting required

BloombergNEF's annual New Energy Outlook (NEO) has become a clarion call to the renewable energy industry and investors – and in 2021 it has a stark message. A massive increase in investment is required to achieve net-zero carbon emissions by 2050: between $92 and $173 trillion in investment, over 30 years. For solar this translates into an urgent necessity to achieve tremendous scale.

Potential pathway to 445 GW installations by 2030

Source: Auke Hoekstra

Jenny Chase – Head of Solar Insight, BloombergNEF

This is a really big job – talking about 450 GW a year. It is not a supply-side issue, manufacturing can ramp up quickly and has done so in the past. The main limiting factors in building solar at the moment is [a lack of] sites with grid connection, permits, and investor confidence in offtake agreements.

Although the LCOE of some solar is well below spot market power prices, we do expect some cannibalization of those prices which means investors must be quite optimistic to invest in merchant solar.

In the history of solar, scaling up by a factor of three is no problem whatsoever, but we are hitting barriers that are higher than building more factories – which the industry can do very easily.

It is also a worldwide question. It is not one policy, it is lots of policies all over the world. A coordinated effort is needed or some really wild, "just let them do things" approach – which would possibly also work. People are more asking, "will you let us build" rather than, "would you pay us to build".

Photo: pv magazine/Dave Tacon

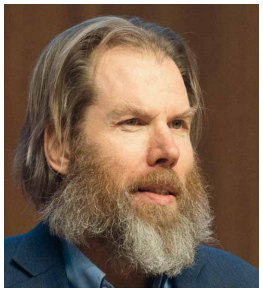


Photo: NEON

Auke Hoekstra – Program Director, NEON research at Eindhoven University of Technology

If you believe in exponential growth, these figures (what is required of solar) are not so extreme. I've been reading and writing a lot about how much exponential growth is still underestimated, although we are coming to accept more broadly as a society that things work with exponential growth – as Covid-19 showed us.

So, my message is that we can get this to work; let's just do this! As an example, I'm a vegan, and 10 years ago that was very strange or out of the ordinary, it was not something to say at a party without people reacting in shock. Now it is quite ordinary. And I think that thinking exponential growth can deliver these kind of growth rates to solar is also more mainstream.

Looking at the system level, it all feeds upon each other. We can't just install solar and leave everything else intact – but that is not what we are doing. We are developing wind as well a solar and they can really help each other out, especially in regions where there is a big variation between summer and winter.

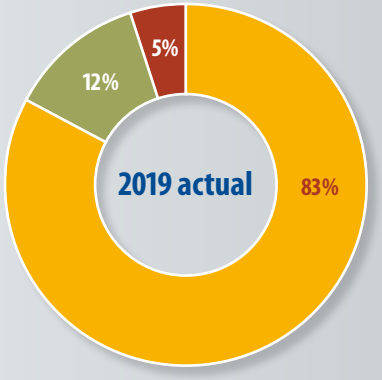
The development in batteries, not only EVs but home batteries, is a way to balance solar [energy] through the night. Actually, the sun not shining at night is a pretty trivial challenge to solve when you have batteries. And then we are seeing an enormously powerful hydrogen lobby, and I am famously skeptical of hydrogen in cars and blue hydrogen, but there is an enormously strong push for green hydrogen and if you have green hydrogen and batteries you can run your society on solar, even on existing grids.

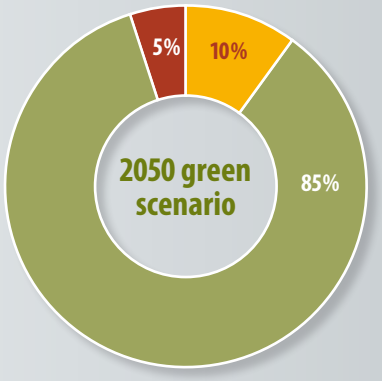
If you have enough seasonal and daily battery storage, and EVs can be a very effective form of storage on wheels, then bring on the solar.

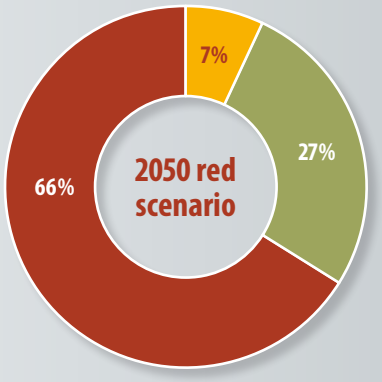
Primary energy supply in 2020 and by NEO scenario in 2050

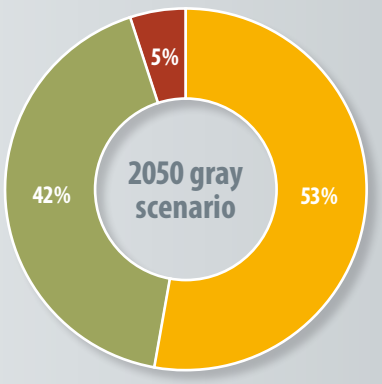
Fossil Renewable Nuclear

Source: Bloomberg NEF









Policy driving expansion

The U.S. renewable energy market is on a tear. According to the International Renewable Energy Agency, the United States added 29 GW of renewable energy capacity in 2020 – almost 80% more than the year before. But high growth rates are needed to meet the Biden administration's goal of a carbon-free electricity grid by 2035. Policymakers are now discussing a slew of measures in Washington to accelerate the clean energy transition, reports pv magazine publisher Eckhart K. Gouras.

While important, federal support for the renewable energy sector in the United States is only one part of the equation. The fifty U.S. states play a key role in driving the clean energy transition and perhaps the most important instrument at the state level has been the Renewable Portfolio Standard (RPS).

These RPS require that a specified percentage of the electricity that utilities sell comes from renewable resources like solar and wind. According to the National Conference of State Legislatures (NCSL), "half of the growth in U.S. renewable energy generation since the beginning of the 2000s can be attributed to state renewable energy requirements." As the chart on the next page shows, 30 states have adopted binding RPS, while seven have opted for less stringent, voluntary renewable energy standards or targets.

National CES

With a total of 20 U.S. states lacking binding targets, the Biden administration has been prompted to push for a national clean energy standard (CES). This would require all utilities in the United States to decarbonize their power generation fleets or face stiff offset payments.

The U.S. power sector accounts for about one-quarter of the country's carbon emissions, so getting this sector decarbonized is critical to Biden's overall quest to tackle climate change and achieve net zero emissions by 2050. While 2035 is the target for a completely carbon-free electricity grid, the end of this decade should hit the 80% mark, with fossil fuel generation in rapid decline.

Currently, the United States generates almost 20% of its electricity from renewable sources such as solar, wind and hydropower, with nuclear providing a further 20%. When nuclear power is included in the carbon-free mix (which is the prevailing assumption in the U.S.), half of the journey to 80x30 is already complete. Even with the addition of nuclear, which may be unpopular among renewable energy proponents, getting another 40% carbon free by 2030 will require at least double the annual installation rate of solar and wind.

Zeroing in on solar, that would mean going from just under 20 GW in 2020 to about 40 GW per year. This would give rise to 200 GW over a five-year period, a significant amount more than the 160 GW "high scenario" SolarPower Europe provides for the U.S. market in its recently released Global Market Outlook for the 2021-25 period.

Infrastructure investments

Of course, 2021 will be a transitional year as the Biden administration looks to advance key legislation to boost the clean energy shift. Zooming out from the solar market, the first big step in this process is the $1 trillion infrastructure bill that the President hammered out with a group of moderate Republican and Democratic senators this summer.

While the bipartisan effort to pass the infrastructure bill is a major milestone, it is a far cry from the $2.6 trillion infrastructure package that Biden had been seeking. But we can expect further fund-

The 497 MW Roadrunner project in Upton County, West Texas, began fully operating in September 2020, with a 57 MW battery set to be added at the site next year.

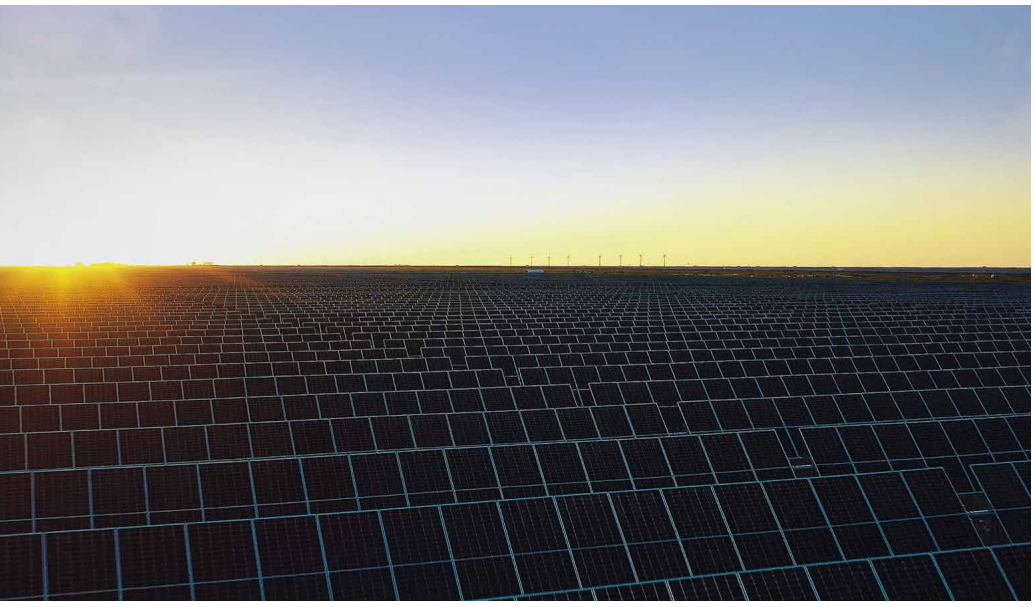
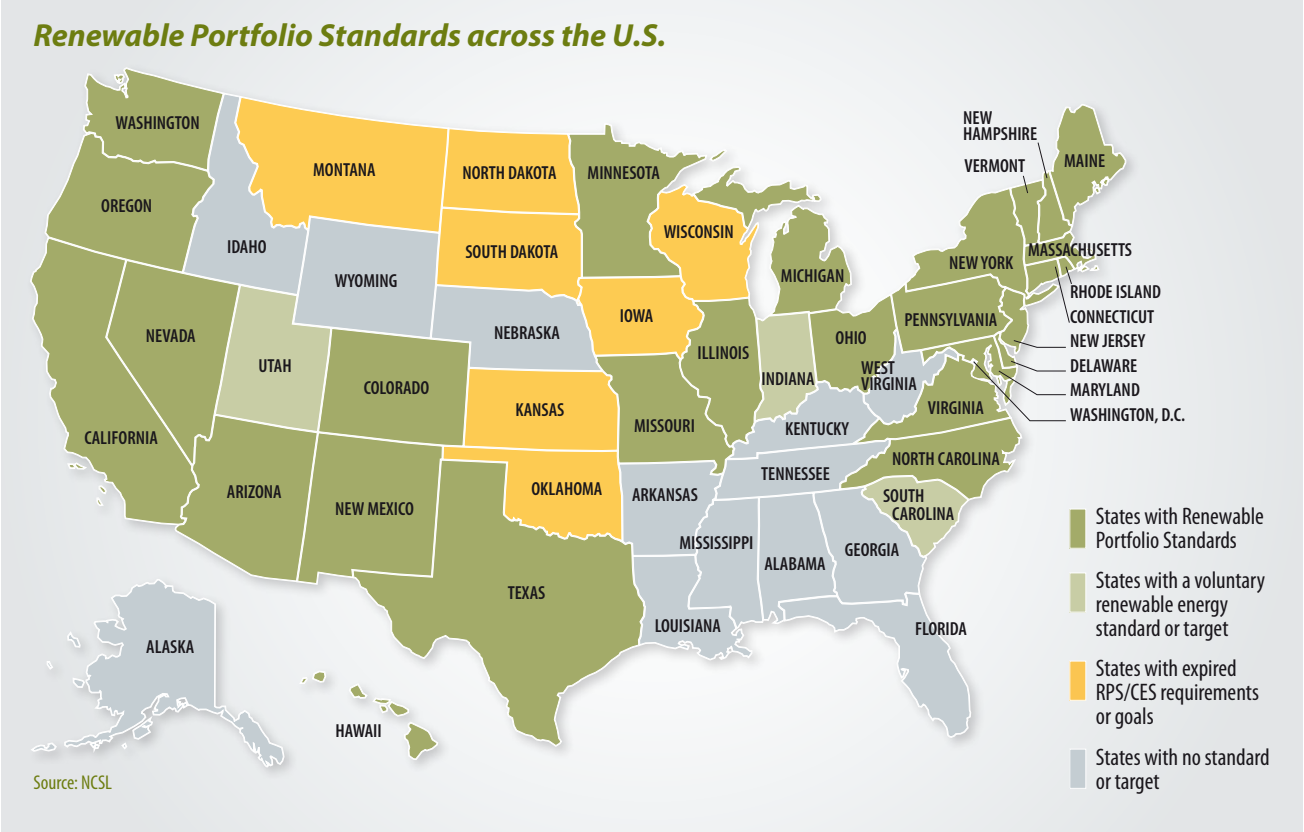


Photo: Enel Green Power



ing to be allocated in the second half of this year, as part of a budget bill Senate Democrats hope to pass with just a simple majority, through budget reconciliation.

This later bill will most likely include clean energy tax credits, which were completely left out of the bipartisan infrastructure bill. And if all goes right for Biden and the Democrats, the reconciliation bill will also include the critical national CES.

The key energy tax credit for the solar sector is the Investment Tax Credit (ITC), which dropped from 30% in 2019 to 26% in 2020. Along with state RPS policies, the ITC has been instrumental in the rise of American solar, especially in the utility-scale segment. The ITC is tailor-made for complex tax equity transactions.

But before delving into the nitty gritty of tax credits and their likely reform later this year, a closer look at the $1 trillion infrastructure deal is in order: While it has so far left out tax credits and a CES, it does provide $73 billion to improve America's aging power grid. The state of America's electricity grid was painfully exposed in February, when Texas suffered a historic cold spell that left many of its residents without power for many days. While Governor Greg Abbott first blamed renewables for the blackout, PV arrays and wind turbines were actually not the problem. Instead, the lack of a resilient grid and sufficient interstate transmission ties created the perfect storm for America's second-largest state.

The $73 billion allocated to upgrading the American electricity grid are close to the $100 billion the Biden administration had been seeking for the critical links that connect U.S. renewables to major load centers. The infrastructure bill also creates a new Grid Deployment Authority to invest in research and development for advanced transmission and other grid-related technologies.

Finally, the bill sets aside $7.5 billion for EV-charging infrastructure and $5 billion for zero- and low-emission buses, all key elements in Biden's plan to have half of all vehicles sold in the United States be electric by 2030. Obviously, an increase in the number of EVs will generate more demand for electricity, so a doubling in the growth rate of renewables will probably be the bare minimum needed to meet future demand over the course of this decade.

Tax incentives

Since the $1 trillion infrastructure package has passed the Senate and should soon

$7.5 billion

has been set aside in the Infrastructure Bill for EV-charging infrastructure

Photo: Eckhart K. Gouras

Tax equity investors and large ground-mounted PV power plants, like this one shown here in Hawaii, make a good fit, as the complexity of tax equity projects requires big investments. Driven by this investor class and an attractive ITC, this market segment dominated U.S. solar last year, accounting for 81% of the total 19.2 GW installed in 2020.

be approved by both the House of Representatives and the White House, there is considerable pressure to also include key clean energy tax provisions in this legislation and not wait for the reconciliation process. On Aug. 10, a group of lawmakers – led by Representatives Blumenauer, Levin, Barragán, McEachin and Crow – sent a letter to the House leadership urging action on this front.

The timing of the effort coincided with the most recent UN climate change report, from the Intergovernmental Panel of Climate Change (IPCC). The Solar Energy Industries Association SEIA vice president of congressional affairs, Erin Duncan, noted in response that the world "is at a crossroads" and that clean energy must be rapidly deployed to reduce emissions from electricity generation.

"This week's report from the IPCC makes it abundantly clear that we are in the midst of a climate emergency and that we need to act now … we echo their call to support policies that have a track record of driving clean energy deployment. The solar Investment Tax Credit is a proven job creator, and a long-term extension with direct pay will help create hundreds of thousands of new career opportunities while giving solar and storage businesses policy certainty to make investments at the scale needed to address climate change."

Duncan's statement focuses on two key measures, the ITC extension and the new "direct pay" feature. Both are at the core of two key bills in Congress, the so-called "Green Act" championed by Representative Mike Thompson (D-CA) and the "Clean Energy for America Act" (CEAA) introduced in the Senate by the chamber's Finance Committee chairman Ron Wyden (R-OR).

The two pieces of legislation are also key elements in Biden's own plan as recently laid out by the Treasury Department in its "Green Book." From all three corners –

the White House, Green Act and CEAA – the ITC is reset to its original rate of 30% and extended up to 10 years. The Wyden plan extends the scope to any technology with emissions at or below zero and provides the highest direct pay rate at 100% of the ITC amount. Up until now, tax equity investors needed a healthy "tax appetite" to tap this incentive. With the new direct pay option, up to 100% of the ITC can be treated as a payment of tax, entitling the investor to a refund to the extent the payment exceeds available tax liability.

Domestic content

Except for the Wyden plan, which provides no manufacturing incentive, all three policy measures being advanced expand so-called "48C" tax credits for "advanced energy manufacturing" and improve ITC conditions for energy storage projects. Onshoring renewable energy supply chains is a controversial subject since supply chains that once existed, for example for solar wafers and cells, have largely been shuttered, making the establishment of a properly dimensioned domestic supply chain a major challenge.

As the American Council on Renewable Energy (ACORE) COO Bill Parsons observed at the organization's Finance Forum on June 15 this year, a 2.5-year runway may not be enough to meet domestic content requirements that are currently being considered for these tax credits. According to Parsons, "a lot of our members would welcome onshoring supply chains, but two-and-a-half years like in the Senate [bill] is an awfully short runway to feel like there's a credible chance for people being able to comply." Parsons pointed to an ACORE member, a solar developer that was unable to source "Made in USA" modules, because they were sold out for the next two years.

There will be a delicate balancing act as these bills are marked up and hopefully emerge as legislation this year. Overly aggressive domestic content requirements could hamper the clean energy transition in the United States. On the other hand, a clean energy system built mainly on foreign components' suppliers risks becoming the Achilles heel in the long term. pv

Eckhart K. Gouras

2.5 years

is the runway proposed under current legislation for solar developers to satisfy domestic content provisions

Will Lebanon's solar rise?

A year after a sudden explosion in Beirut killed more than 200 people, destroying solar installations in the port and sending the country into a complete downfall, a question emerges: Can Lebanon use this experience to set its economy on a new sustainable pathway, supported by a viable energy sector? Solar energy offers some lessons.

In July 2020, **pv magazine** published an article on Lebanon's solar photovoltaic sector, addressing how the country's dwindling economy was affecting its renewable energy tender schemes and the overall progress toward its green energy goals for the years 2020 and 2030. The situation was already very difficult, given that Lebanon had failed to make a bond payment that led to the country's first sovereign default. However, at this point there was still a glimpse of hope stemming from the involvement of the European Bank for Reconstruction and Development (EBRD) in the design of the tenders.

PV potential

This trust in solar's potential for low-risk investment seemed to pay off. A few days after the publication of the article, Lebanon's government concluded negotiations for feed-in tariffs concerning three solar PV farms in the Bekaa-Hermel region. The three solar parks were part of a 180 MW solar tender, which aimed to auction the development of 12 PV projects, each at 15 MW, in separate regions of the country.

The design of the 180 MW tender allowed the government to negotiate a different tariff for each of the four regions (Bekaa-Hermel, Nabatieh, Akkar, and Mount Lebanon). The lowest bid submit-

Lebanon had around 90 MW of PV installed by the end of 2020 – just short of its 100 MW target. New annual installations amounted to about 14 MW last year, the bulk of which was net-metered rooftop systems.

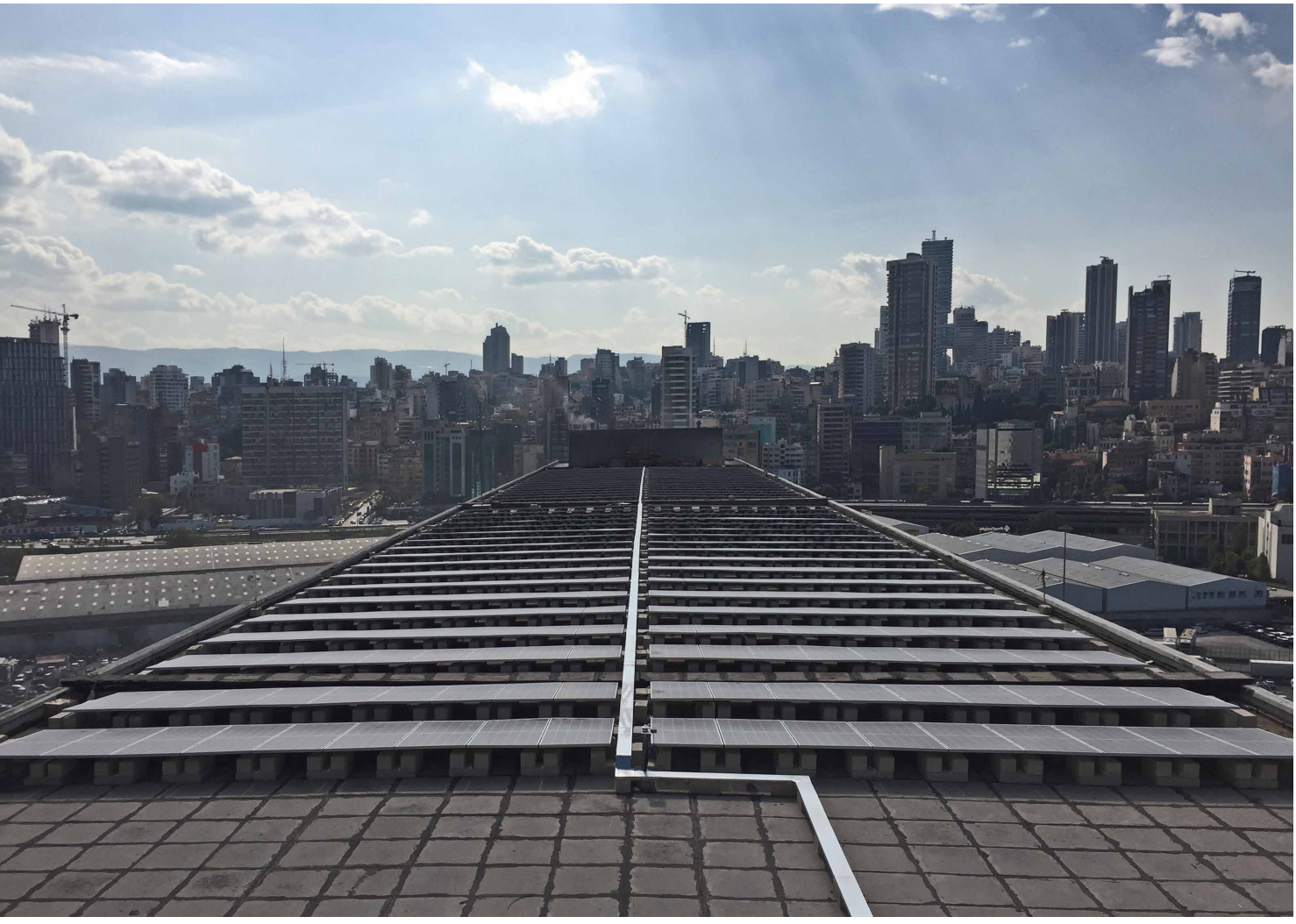


Photo: LCEC

ted in a given region would apply to all PV projects in the same region. For Bekaa-Hermel, specifically, one group had submitted a $0.057/kWh bid, so all three 15 MW farms had to accept that tariff.

Pierre El Khoury, general director and president of the Lebanese Center for Energy Conservation (LCEC) board, spoke to **pv magazine** last year about the Bekaa-Hermel tariff.

"Bekaa-Hermel has the most solar irradiance, cheap land and easy-to-install plots. The names of the three bidders (joint Lebanese and international companies) will be disclosed once the government issues the licenses; the negotiations for the remaining three regions were still ongoing," he said. "And with no surprises [the government needs] hopefully one to two months [to conclude negotiations for all 12 solar projects]."

Tip of the iceberg

That time never came. Instead, on Aug. 4, 2020, a large amount of ammonium nitrate stored illegally at Beirut's port exploded, killing at least 218 people, and leaving about 300,000 people homeless. Lebanon's citizens felt the blast was the tip of the iceberg for corruption, mismanagement, and the incompetency of the country's elite, and demanded a new government comprising figures removed from the political establishment.

Yet, although the government resigned and has acted only in a caretaker capacity since then, Lebanon has failed to form a legitimate new government. In July, the country's parliament named the third prime minister in a year, but it is far from certain whether this new attempt to form a sustainable and legitimate government will come to fruition.

The blast, combined with Lebanon's debt default and the Covid-19 crisis, has led to a situation that many argue is ungovernable. Residents face dire shortages of medicine, fuel and electricity on a daily basis, while the national currency has lost about 90% of its value against the U.S. dollar, driving hyperinflation.

Meanwhile, the international community, led by France and the European Union, have made it clear that any financial help will come only on the condition of brave political and economic reform. The immediate question is whether Lebanon will be able to form a government that pushes through reforms, saving the economy and its people from poverty.

Photo: LCEC

This 220 kWp rooftop PV system in Beirut's port was destroyed by the blast on Aug. 4, 2020, just 10 days after being commissioned.

Crisis catch-up

Gabriel De Lastours, who is the regional head for the EBRD's energy projects in the southern and eastern Mediterranean regions, told **pv magazine** that the bank is preparing for what happens when there is a stable government and Lebanon's macro-economic prospects improve. "We believe investment in renewable energy is on hold until the macro-economic situation improves. [However,] we want the independent power producers (IPP) model supporting the tender scheme in Lebanon to move ahead. So, one of the things we are now working on is how to develop bankable solar projects relying on a power purchase agreement (PPA) backed by a government in a comparable macro-economic situation to Lebanon."

For example, the EBRD is currently working closely with the LCEC to examine what happened in countries such as Argentina, where the successful development of renewable energy was possible after the resumption of access to external lending and investors, said De Lastours. "We are trying to see if we should think of an additional comfort element to back the government's obligations in the PPAs, after the macro-economic situation improves," he added.

Based on De Lastours remarks, it is no surprise that the first three projects of the

90%

value lost by Lebanese pound since 2019

Photo: European Union/Bernard Khalil

The tragic explosion at Beirut's port on Aug. 4, 2020, killed at least 218 people and left as many 300,000 homeless. The aftermath of the blast saw the country's government resign, which has slowed the development of new energy infrastructure, among other things.

180 MW tender did not move forward. Rani Al Anchkar, the executive director of the LCEC, told **pv magazine** that although the first three solar farms in the Bekaa-Hermel region reached the licensing phase, the PPA contracts were never signed. The resignation of the government played a role, but this is "mainly due to the economic situation and devaluation of the Lebanese currency," said Al Anchkar.

"Solar … with its low costs and quick project deliveries, can help the country by offering reduced risks"

EBRD's persistence

Al Anchkar added that the LCEC and Lebanon's Ministry of Energy and Water are assisted by a global consortium assigned by the EBRD to prepare all documents for a solar+storage tender, as well as a second round of wind power tenders. However, Al Anchkar noted that an official decision to launch a tender cannot be taken by a caretaker government.

Perhaps the EBRD's persistence on Lebanon is the most positive news currently in the country's energy sector. "We remain in Lebanon," De Lastours repeated more than once. "EBRD started its policy dialogue support for renewable energy in Lebanon in 2017 before the political/economic crisis hit, and we are continuing. A part of the international donor community has decided not to continue their support [to Lebanon] until the reforms take place, but the EBRD's program continues. There is no deadline for the EBRD's program in Lebanon, we remain there to help with the tenders."

Asked if, apart from the PPA projects, the EBRD plans to support "private wire" energy projects in Lebanon, De Lastours answered that the bank engaged a consultant two years ago to draft new articles that will be put into law to allow the regulation in Lebanon to do B2B, private wire renewable energy projects. "The draft is ready, and the consultant is currently engaging with the parliamentarians to promote this policy. We are hopeful that this will pass. We are keen to support this type of the market."

In line with the EBRD's persistence in the country, De Lastours aimed for a positive closing remark. "The fundamentals on renewable energy that were there two years ago are still there: the shortage of power, the good renewable energy resources, and the good team at the LCEC organising the renewables program." Especially solar, added De Lastours, with its low costs and quick project deliveries, can help the country by offering reduced risks. Of course, the crisis that Lebanon is presently facing is affecting the development of renewable energy. And while the blast had an impact on the whole of the country, it also had a dramatic impact on the country's state-owned utility, which has slowed things down. But equally, concluded Delastours, "our fundamental analysis for the need and the opportunities of renewable energy in Lebanon is still there and is valid."

The LCEC said Lebanon installed 14 MW of new PV capacity in 2020, mainly comprising net-metered rooftop systems. The country's cumulative installed PV capacity stood at 90 MW by the end of 2020, which is below the 100 MW government target for 2020. *Ilias Tsagas*

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‘Nervous but calm’ – Chile’s crucial election looms

Chile continues to lead the energy transition in Latin America, but international investors are nervous. The pandemic is subsiding, thanks to a vaccination rate close to 80%, and energy demand is showing signs of recovery. However, the political landscape still has investors on edge, reports Luisa Cabello.

Chile’s constitution is undergoing reform, and the government is already on its way out. There has also been an extreme and extended drought that has been punishing the country for more than a decade and stressing the energy grid. Chile’s electricity network is normally 30% to 40% reliant on hydropower generation, but these days it can only produce close to 20% this way.

The first signs of alarm emerged with the Chilean protests in October 2019. Shortly thereafter came the pandemic, although Chile has been affected to a far lesser degree than many of its neighbors. Carlos Cabrera, president of Chilean Solar Energy Association ACESOL, suggests that things are already going back to “normal” in terms of demand for new installations. However, as Chile’s grids become more congested, particularly in the northern regions that host the most solar PV capacity, this may not be the most important variable.

“Putting together all the technologies, we have an installed capacity of nearly 28 GW for a maximum demand of more than 11 GW. In other words, we have nearly three times what we consume,” says Ramón Galaz, executive director of Chilean consultancy Valgesta. “This will need to be adjusted along with the decarbonization process, which needs to be accompanied by an excellent transmission system to the areas of consumption, and that is where we are falling behind. It is the most important variable,” he adds, agreeing with Cabrera, who points out that “the distributors and transmitters are being overwhelmed.”

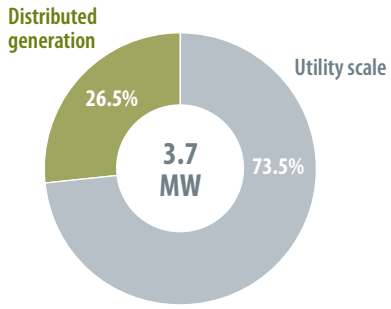
Storage and transmission

Chile is a global leader with an aggressive decarbonization program that targets the complete elimination of carbon emissions by 2040. But some are even thinking of accelerating it. “Our honorable deputies intend to accelerate the plan and are promoting a law to eliminate all coal generation by 2025. In terms of investments, 2025 is right around the corner,” points out Cabrera, who is calling for a “more cautious” decarbonization scenario that aims for 2030.

Galaz shares this commitment to responsibility. “Coal represents 18% of Chile’s energy supply and an accelerated process can jeopardize the decarbonization process,” he says.

Chile had to recommission one of the decommissioned fossil fuel generators at the beginning of August due to the severity of the drought. “This sends an incorrect and confusing message,” says Galaz,

Chile – installed solar capacity 2020



Source: Sphera Energy

Northern Chile’s desert regions offer some of the world’s best solar irradiation, but the country faces challenges transporting energy generated here to centers of demand.

who believes that 2030 and even 2035 are more reasonable dates to target. "We must ensure transmission infrastructure to relieve the system bottleneck, in order to make it feasible."

For his part, the representative of ACESOL notes that Chile has 6 GW of renewable energy projects under construction, a number that he deems "stratospheric" for a 24 GW energy grid. He notes in reference to storage, transmission, and the lack of PPAs that "25% of the grid is under construction, but there are a lot of problems with putting it into service."

Both experts agree that energy storage is a key element for decarbonization, although the road ahead seems difficult. "Excuse the paradox, but to prevent the lines from being overburdened, we would need to receive solar energy at night," says Cabrera, unafraid of being self critical. "At the national level, regulatory signals regarding storage have been unclear and difficult to explain to investors."

Modernizing DG

What is known as net metering in Chile – self-consumption projects that are less than 300 kW – represents 900 MW of current installed capacity, according to Cabrera. "The distributed-generation sector is far exceeding expectations. This industry has exceeded the gigawatt mark, and if today we have close to 4 GW from solar alone, 1 GW comes from distributed-generation projects, a figure that we deem spectacular. [And] 25% of all of Chile's solar energy is distributed," he says.

However, the DG segment is held back by the lack of a national strategy that allows for quantification of the contributions that small and medium-scale projects can make toward the carbon-neutrality goals that Chile is pursuing. In that regard, the government is still relying on larger-scale projects such as Kimal-Lo Aguirre – a 1,500-km, high-voltage interconnection cable that will connect a substation in the far north with one further south to relieve congestion – with less emphasis and promotion of smaller-scale energy projects.

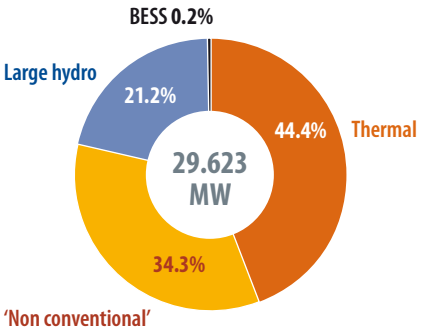
In 1982, Chile was one of the first countries to privatize its energy sector, tackle deregulation, and separate generation, transmission, and distribution. Cabrera remembers that over the past 40 years, there have been modifications to generation and transmission, laws were passed, regulations were created. But the distribution industry has remained virtually untouched. "They have the same rules and logic that they did 40 years ago," he points out. "The distribution industry is crying for modernization."

The government announced a major reform project for the distribution system that consisted of three bills to modernize and perfect the sale of energy on

Renewable energy projects by status (MW)

Technology	Under construction	Approved	In qualification
Battery storage	113	-	42
Biogas	-	14	-
Biomass	166	165	352
Wind	926	4,316	6,511
Geothermal	-	70	-
Pumped hydro	-	300	-
Small hydro (run of river)	57	278	58
Solar PV	3,359	17,441	11,178
Solar Thermal	-	2,192	840
Total	4,621	24,777	18,980

Chile electricity generation capacity July 2021



Source: ACERA

Photo: Zwansaurio/Flickr

Photo: Valgesta

Ramón Galaz, executive director of Chilean consultancy Valgesta, believes efforts to upgrade Chile's grid are now a more important concern than building out more solar.

the distribution side, improve standards for distribution networks, and lastly, a bill to incentivize and develop distributed energy infrastructure. However, the bill to improve energy sales is still bogged down in discussion in Congress and has not progressed. It now appears highly unlikely that the government will manage to progress with the other two bills.

Many projects, few PPAs

Chile has begun a call for tenders for 2,310 GWh/year, for which results had not been published at the time of writing. However, Cabrera believes that there is still too little energy capacity on offer, and too many providers.

"We are in a situation where we have many environmentally approved projects ready to be implemented, but they lack the PPA," he explains. "The energy business is a combination of price and quantity; how much energy is produced, but at what price. In the north, there is so much solar energy to inject, and without transmission, there can be hours during the day where the marginal cost is zero. And this threat is always present."

Exporters with no connection

The Atacama Desert is full of infrastructure; solar installations, desalination plants, mining, and much else besides. There is no citizen resistance there. There is practically unlimited potential for generating energy in what is the planet's sunniest area, and Chile could even better take advantage of this with more interconnections to its neighbors. "It is feasible, recommended, and convenient," Galaz categorically states. "Chile has a tremendous opportunity to move toward interconnection. It will not be able to absorb its production with its internal demand alone."

Cabrera, however, takes a less optimistic look at this dream.

"The problem is: How do we send all this energy to the consumption centers? The international dream is reasonable and competitive in theory, but experience shows that it is very difficult to come to an agreement with neighboring countries."

Hydrogen, a love-hate story

At the beginning of the legislative term, the government opted to become a major exporter of hydrogen at up to $30 billion a year by 2050 – the same amount that the country earns from its copper exports. Nowadays, enthusiasm appears to be waning.

Cabrera describes green hydrogen as a love-hate story. "We believe that it is the fuel of the future, but we should worry about other things from now until 2030 and after 2050," he explains. "Our geographic location is not the best, and transportation costs are very important. The Australians, along with the Germans, are strong competitors. It means that the renewable energy must be very affordable."

Galaz adds the cost of the technology to the list of obstacles in the way of hydrogen. "Electrolyzers are expensive and have highly flammable chemical characteristics that require very high-quality standards. It is difficult to forecast the actual potential," he indicates.

Chile will have a new president in December. "We have lost a certain sense of regulatory stability. The next government will have to work to dispel this doubt. We need judicial and regulatory certainty that sends the right messages to investors," points out Ramón Galaz, who, despite being very critical of the errors, wishes to send a message of reassurance.

"There are tons of pending issues that we need to work out," stresses Cabrera. "Investors are 'quietly worried' about what will happen in Chile over the next five, 10 years. However, there is confidence in the long-term policies that the Chilean energy industry has advanced over the past few decades." All that's left is to await the election results. pv

Luisa Cabello

Electric buses charge from distributed solar installations at the Electroterminal Los Espinos in Santiago. Chile has about 1 GW of distributed PV installed, accounting for 25% of the nation's capacity.

Photo: Tamara Merino/IMF

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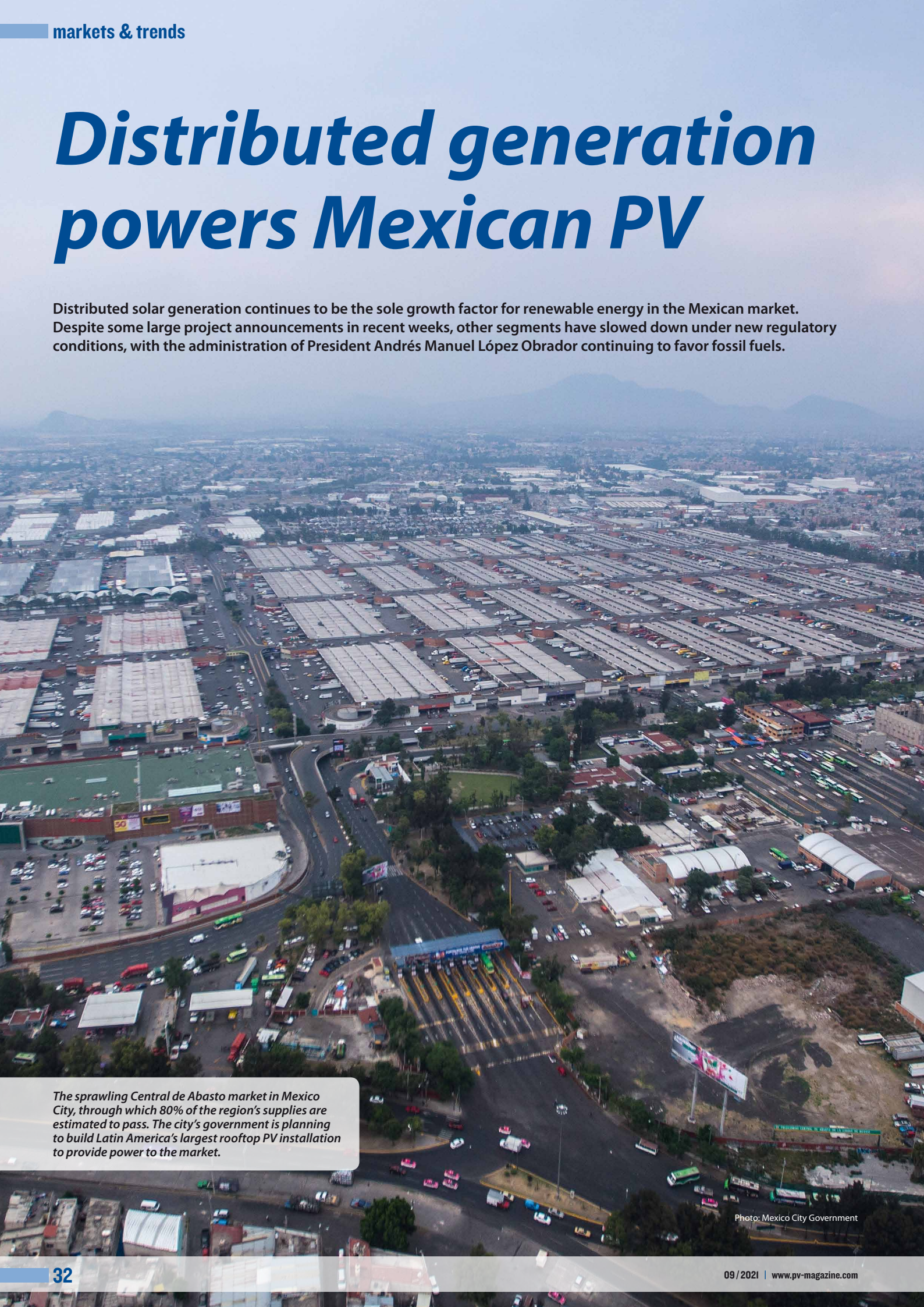
Distributed generation powers Mexican PV

Distributed solar generation continues to be the sole growth factor for renewable energy in the Mexican market. Despite some large project announcements in recent weeks, other segments have slowed down under new regulatory conditions, with the administration of President Andrés Manuel López Obrador continuing to favor fossil fuels.



The sprawling Central de Abasto market in Mexico City, through which 80% of the region's supplies are estimated to pass. The city's government is planning to build Latin America's largest rooftop PV installation to provide power to the market.

Photo: Mexico City Government

Solar under Mexico's distributed generation (DG) scheme has relentlessly grown to dominate the PV market throughout the country's 32 states, mainly among small- and medium-sized businesses across all industries, and in the residential market segment.

Three recent announcements confirm the positive development of Mexico's DG segment, and these are important to forming a clear picture of this part of the country's electricity industry. In August 2021, the state government of Sonora announced that it was planning 40 distributed-generation solar systems for the same number of municipalities.

During that same month, the mayors of Pachuca in the state of Hidalgo, and Tlanepantla in the state of Mexico, announced that they were planning distributed generation for the rooftops of public buildings. And earlier, in February 2021, the government of Mexico City announced that, under the distributed generation scheme, it would install the largest rooftop solar array in any Latin American city. It will generate power for the Central de Abasto (Supply Center), Latin America's largest wholesale market. This announcement builds on already stated plans for the installation of rooftop solar on 300 public buildings.

Despite not being the only DG PV projects that were announced by public sector entities, these three are particularly noteworthy because they reaffirmed the growth of the DG segment – which is officially defined by a capacity limit of 0.5 MW per project and that projects do not require authorization from energy regulators.

Policy environment

Further legal and regulatory aspects also serve to strengthen the importance of DG projects in Mexico. The recent Reforma a la Ley de la Industria Eléctrica Nacional (Reform to the National Electrical Industry Law), promoted by President López Obrador, has been approved by the legislative branch, and suspended by the judicial branch until the Supreme Court of Justice issues a definitive ruling. It only affects the large-scale generation scheme, and does not make any changes to the legal provisions for planning and operating DG projects as set forth in the Reforma Energética del 2014 (2014 Energy Reform).

The Programa para el Desarrollo del Sistema Eléctrico Nacional (National Electricity System Development Plan) – a Mexican government document through which objectives, goals, strategies, and actions are established for planning the electrical system, known as PRODESEN version 2021-35, predicts that distributed generation will reach 5.9 GW in 2025 and could reach 13.9 GW by 2035.

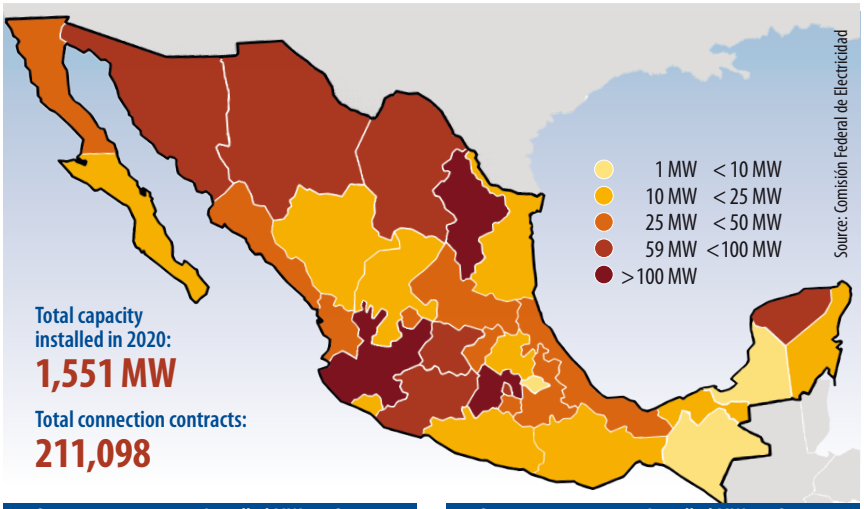
In its most recent report on the DG segment, the Comisión Reguladora de Energía (Energy Regulatory Commission) – known as the CRE – reported that 211,098 interconnection agreements with a total installed capacity of 1.5 GW were registered in 2020, with PV systems representing 99.24%. Other energy technologies such as biogas, co-generation, and biomass made up the small remainder.

Ongoing support

The report indicates that Jalisco, Nuevo León, the state of Mexico, Mexico City, and Chihuahua generated the most renewable energy via PV, collectively installing 722 MW via slightly more than 99,500 interconnection agreements in 2020.

"Mexico City announced that … it will install the largest rooftop solar array in any Latin American city"

Requests for connection of PV systems smaller than 0.5 MW in 2020



State	Installed MW	Contracts
Tlaxcala	2.58	239
Campeche	8.25	1,124
Chiapas	9.33	1,268
Hidalgo	10.05	1,076
Zacatecas	10.69	1.342
Tabasco	11.13	1,327
Oaxaca	11.72	1,292
Guerrero	12.50	1,731
Quintana Roo	19.03	3,004
Tamaulipas	22.15	2,322
Baja California Sur	23.12	1,631
Colima	23.70	4,856
Durango	24.95	3,092
San Luis Potosí	27.74	4,280
Morelos	28.19	4,365
Nayarit	28.28	4,029

State	Installed MW	Contracts
Querétaro	30.82	5,271
Puebla	31.81	4,118
Veracruz	34.72	5,001
Sinaloa	36.10	2,917
Aguascalientes	45.75	4,816
Baja California	46.79	8,363
Sonora	58.59	6,529
Coahuila	64.52	8,239
Michoacán	66.96	10,344
Yucatán	67.50	9,646
Guanajuato	72.55	9,365
Chihuahua	97.15	15,199
Ciudad de México	98.02	12,288
Estado de México	110.44	8,565
Nuevo León	175.96	22,645
Jalisco	240.01	40,814

Photo: Pera Energias Renovables

This installation powers an agricultural facility in the Mexican state of Jalisco. Jalisco has led the country in terms of distributed-generation installations, with more than 240 MW added last year.

"Jalisco takes the lead in distributed generation with more than 40,000 interconnection agreements and 240 MW installed in 2020"

Zumma Energy, a private consulting firm that analyzes the energy industry, published its "Distributed Generation in Mexico" report last July. It states that the current government has deemed DG as being important. "Photovoltaics in the distribution network could constitute an important aspect among the various generation technologies and, in the short term, become a solution in light of the lack of infrastructure projects in the transmission network and, above all, in light of the shortfall of large-scale renewable energy projects for the scheme."

This past April, Zumma Energy has reported a total generation capacity of 96.7 GW via all existing technologies, and 1.44% of this figure is attributed to the DG solar segment. Zumma points out areas of opportunity in the electrical industry such as shortfalls in the transmission and distribution networks along with a slowdown in permit management by the CRE.

One of the significant points indicated by the report states: "As the country moves forward, renewable energies help it achieve its clean energy objectives, specifically regarding the objective that it has with the Paris Agreement, to generate 35% of its energy from clean sources by 2035. However, the 2021-35 National Electricity System Development Plan predicts that at the end of this period, Mexico will only reach 31%."

In 2012, the Mexican Photovoltaic Industry Association (AMIF) was formed in Guadalajara, the capital city of Jalisco, a state that is No. 1 in PV generation under the distributed generation scheme. According to the latest report by the Comisión Reguladora de Energía (CRE), Jalisco takes the lead in distributed generation with more than 40,000 interconnection agreements and 240 MW installed in 2020.

AMIF, under the leadership of Manuel Gómez Herrera Lasso, is also bullish about the DG market's future. "According to the encouraging figures in the latest statistics published by the CRE, distributed generation has not slowed down," Lasso says. "Furthermore, the installed capacity has continued to grow at the same rate despite Covid-19 and its economic impact, and despite the confusion arising from the energy secretary's policies and the reforms to the Ley de la Industria Eléctrica that will not affect this generation model."

Growing demand

The number of DG installations will mostly continue to grow according to Lasso. However, development of the solar industry in Mexico is crucial to support this growth. PV companies must become increasingly professional and capable of completing more projects and with the required quality. New companies must emerge and train their staff, since trained outfits remain few in number and the majority have limited capacity to respond to the growing demand from the DG segment.

The continued growth of this DG segment in Mexico requires that the existing products and financial frameworks that make this model viable become increasingly more accessible and available to allow micro-, small-, and medium-sized companies of any industry to easily generate their own energy.

AMIF has a clear approach to meeting these needs. "As a business group, we have a clear vocation towards professionalization, providing services, and seeking better conditions to keep this development moving forward," says the AMIF director.

"Our association is not idle. During this difficult global health crisis, AMIF is not only operating from the city of Guadalajara. We now have offices in Monterrey, the capital of the state of Nuevo Leon, which is the entity No. 2 in the republic with the greatest number of agreements in force – 22,645 – and an accumulated generation capacity of 175 MW, according to the CRE report. And soon we will have offices to serve the major market of Mexico City and its neighboring states." pv

Jorge Zarco

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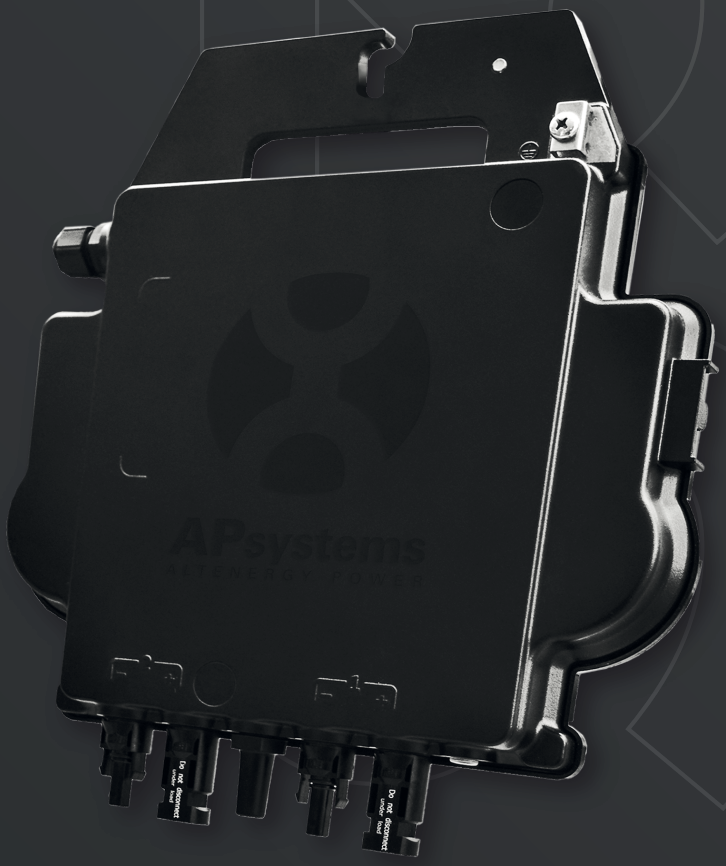

APsystems' 3rd generation of dual-module microinverters, the DS3 product family represents the culmination of years of power conversion expertise and innovation in high-efficiency, high-density power conversion to maximize the peak performance of today's high-capacity PV modules. The DS3 series reaches unprecedented levels of power output up to 880 VA and is fully backwards compatible with QS1 and YC600 microinverters and accessories. It features 2 input channels, each with independent MPPT, and encrypted wireless Zigbee communication, connecting 2 PV modules of 650 Wp each.

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Mexico's big green chill

Although Mexico is a country bathed in sunshine, the administration of President Andrés Manuel López Obrador and his Morena Party have unequivocally pivoted from the pro-renewables, private investment-friendly policies of their predecessors in the space of just two and a half years. As a result, renewable energy investment has frozen, particularly for projects that involve private capital, argues attorney and project developer Patrick C. Jordan.

The Mexican government has charted a new course in favor of the state-owned oil and gas authority, Petróleos Mexicanos (PEMEX). This means a ramping up of gas output and prioritizing grid access and energy dispatch of the fossil fuel plants of the state utility, the Federal Electricity Commission (CFE). While these initiatives should come as no surprise, given the president's longstanding advocacy for government-owned energy production, what has been somewhat surprising are the ends to which the current administration has sought to marginalize its own vast renewable energy potential and sideline private capital.

The question that is raised by these moves is whether the draconian approach has really been necessary. Or, for that matter, has it been in the best interests of the Mexican people?

Pro-Mexico

Few would begrudge López Obrador's commitment to his countrymen, and his Mexico-first approach to meeting the country's energy needs. Indeed, to govern otherwise would have been a betrayal of his mandate. On its face, the administration's strategy of blanket favoritism toward the CFE's portfolio of power plants, overwhelmingly fossil fuel generators, is an easy and unmistakable "pro-Mexico" approach, and one that is readily understood by the electorate.

PEMEX and the CFE are also some of the largest employers in Mexico, providing further impetus to López Obrador's strategy. Nevertheless, the government's energy policies come with heavy associated costs and, more importantly, missed opportunities that warrant some degree of careful reflection.

First, the low-hanging fruit: the implications of the administration's policies in environmental terms and a failure to better optimize the country's vast solar energy potential. At a time when climate change seems undeniable, the world is moving apace to green energy solutions as the only long-term and sustainable strategy. On this count, Mexico has staked an

Mexican President Andrés Manuel López Obrador, pictured here at the Generation Equality forum in Mexico earlier this year. The president's 'Mexico-first' approach has seen his administration favor state-owned utility, the CFE, which has slowed the development of renewables in the country.

Photo: UN Women

entirely different position. By incentivizing CFE thermal plants and reversing course from the prior administrations' clean energy agenda, Mexico has become a regional, if not global, outlier in terms of suppressing clean energy generation.

The problem with this approach is that investment and grid planning decisions made in favor of fossil fuel generation carry repercussions for future generations. Given this, the rationale for a more progressive and forward-looking green strategy is clear.

In fairness, the entire energy agenda of López Obrador is not stacked in favor of state-owned thermal electric plants. CFE-owned hydroelectric generation has also been pushed to the top of the dispatch totem pole. Moreover, without much fanfare, the current administration has, in fact, decided to develop some renewable energy projects.

Most recently, in July 2021, the Mexican government announced a huge $1.68 billion, 1 GW solar project, to be located near Puerto Peñasco. It is supposed to be a joint venture between the CFE (54% ownership) and the Sonoran state government (46%). Thus, ostensibly so long as private capital is not front and center, at least some renewable projects are palatable to the administration.

Investment cools

The Puerto Peñasco project aside, with the elimination of the clean energy and capacity auctions and with a legal and regulatory framework now in place which has established roadblocks for private renewable energy developers, the administration's policies have significantly chilled the entire green energy sector.

This is unfortunate and largely unnecessary. In areas such as Bajio in the north-central and western parts of the country, it is well-known that the CFE transmission system has fallen short in meeting energy demand. Potential off-takers and power purchase agreement (PPA) opportunities are available, but the network's insufficient capacity has adversely affected bringing more generation online, especially from renewable energy sources.

The proof of this grid shortfall is in the pudding: Self-supply projects, implemented by industrial concerns and other high energy consumers, have taken off in frustration over the high cost of electricity and the issues plaguing line capacity in the grid. Exacerbating this impasse further is the fact that the government's approach has been to try to shift these expenses over to the project developers – often resulting in the project development costs becoming untenable.

Then there is the issue of energy costs. Apart from their environmental shortcomings, generation costs for the CFE fossil fuel plants are higher. Thus, what is needed is a more pragmatic approach that could represent a "win-win" for all stakeholders: the Mexican government, the Mexican public, industry, the environment, private developers and capital, and most importantly, future generations of Mexicans.

Such a "win-win" could be achieved by seeking synergies with private capital instead of freezing it out. Indeed, co-investment strategies between private and government capital, emphasizing Mexican content from development to construction to operation and maintenance stages of the projects, and hardwiring in social benefit commitments including schools, community and cultural centers and health care facilities are examples of beneficial cooperation. Many of these characteristics are already being embraced in the private development world by companies such as Ballylahan Energy LLC and Ecoiberica, and others.

There are also the very real and significant benefits to the landowners through private wind and solar development. For example, in the case of "ejidatarios" (community property owners), an entire community in an otherwise rural, economically depressed area of Mexico can be transformed for generations to come by the income received – essentially an annuity, from a successful project.

It would be a glaring opportunity lost and an oversight for the López Obrador administration to fail to improve the lives of some of its most disadvantaged citizens, through fostering such land use revenue – itself a result of private capital in green energy projects.

Given the urgency of responding to global warming, coupled with Mexico's supreme good fortune in solar radiation, these irresistible forces will mean that solar energy will come back with a vengeance in Mexico, at some point. It is hoped that this resurgence will begin prior to the close of López Obrador's term in 2024. There is optimism, but that remains to be seen. pv

Patrick Jordan

With an investment of

$1.68 billion

the 1 GW solar project near Puerto Peñasco demonstrates that big PV has a place in Mexico

About the author

Patrick Jordan *is a licensed attorney in the United States and Mexico, a writer, and a senior energy professional with many years of experience in T&D, renewable energy, and gas and combined cycle power plants. He started working in Mexico in 1994, and over the past few years has put together, along with Spanish developer Ecoiberica, an early-stage solar PV portfolio of 10 projects representing more than 2 GW of energy in the states of Sinaloa and Baja California del Sur.*

Just add more mettle

The resilience of a solar installation significantly depends on its ability to withstand the effects of wind. John Fitzgerald Weaver, a regular contributor to pv magazine USA and a solar installer based in Massachusetts, presents 13 options with cost considerations for storm-hardening PV systems.

As our planet warms, severe wind events are projected to increase in strength, size, and frequency. Engineering for resilience can be easy: Just add more metal. However, since the PV industry competes with cheap fossil energy, prudent value-engineering is an essential, competing goal.

With that in mind, 13 techniques and components (along with their costs) have been proposed to harden solar power projects against severe weather. These were drawn from research by the U.S. National Renewable Energy Laboratory (NREL), the Energy Department's Office of Energy Efficiency and Renewable Energy (EERE), the Federal Emergency Management Agency (FEMA), and others.

Some baseline assumptions about costs in this article include: labor at $42.44 per hour, 385 W solar modules for ground mounts, and 320 W modules for rooftop systems. The systems referenced in this article are rooftop 100 kW fixed-tilt, two rail-mounted projects, and a 1 MW fixed-tilt ground mount.

System audit

Installers are asked to place hardware at a fast pace in order to keep installation costs down. However, the trade-off can be that meticulously engineered fasteners aren't properly installed. Loose fasteners are the leading cause of solar equipment loss. NREL's "Solar Photovoltaics in Severe Weather: Cost Considerations for Storm Hardening PV Systems for Resilience" suggests a full system audit of all mechanical connections to mitigate this risk. Spot checking can help, while saving costs. Auditors must work independently from installers.

Locking fasteners

Regular fastener retightening is costly, especially for large PV systems. That means choosing the correct fastener upfront is of utmost importance. "Solar Photovoltaic Systems in Hurricanes and Other Severe Weather" by the EERE, states, "avoid split washers, nylon nuts, serrated-flanged nuts, and doublenutting, as these technologies are proven ineffective under Junker testing."

EERE and NREL recommend "torque fasteners rated with true-locking capability." Wedge-lock washers are currently the only fastener with sufficient vibration resistance and ease of installation to earn a full-throated endorsement, though three other torque-locking fasteners are considered viable: Belleville washers, rivet lock bolts, and threadlockers.

Through bolting

"T-clamps" (aka mid/end clamps) were cited as "a core cause of equipment loss during the 2017 hurricane season." T-clamps rely on the mechanical integrity of the modules. Once glass is damaged in one panel, it can easily turn into a cascading loss of an entire row. The suggested solution is module through-bolting, which bolts modules directly to their underlying racking through the frame.

Marine-grade steel

Choosing the correct fastener material greatly improves resilience, especially in coastal areas where salt in the air accelerates corrosion. NREL notes the importance of buying products that meet the proper standards, from trusted sources. ASTM F593G-Stainless Steel Alloy Group-316 and 316L Bolts and Nuts, or the corresponding ISO standard, are required.

Innovations in racking/tracker design can increase a project's wind resistance when deployed properly. ESA Solar's solarblock solution, pictured here, blocks the trackers moving parts once the desired angle is reached, making the tracker behave more like a fixed structure.

Photo: ESA Solar

Measure	Base Case	Hardened Case	Ground Mount Premium	Roof Mount Premium
1. System Audit	No system audit	Perform a system audit	0.05 c/W (2%) 2.5 c/W (100%)	0.07 c/W (2%) 2.5 c/W (100%)
2. Locking Fasteners	Hex bolts, flange nuts, stainless steel flat washers	Several different options explored	0.1-1.4 c/W	0.1-1. 5c/W
3. Through Bolting	Top-down clamps	Through bolts	0.6 c/W	0.6 c/W
4. Marine-Grade Steel	18-8 stainless steel	316 stainless steel	1.1 c/W	1.2 c/W
5. Module Selection	Standard modules (2400 Pa uplift)	Highest rated modules (3600Pa+ uplift)	10 c/W	10 c/W
6. Three-Framed Rail System	Two-rail racking	Three-rail racking	5.2 c/W	5.7 c/W
7. Two-Pier Mounting	One driven steel pier	Dual post piers	5.9 c/W	N/A
8. Racking Design	Cold rolled U channel aluminum	Tubular aluminum	12 c/W	N/A
9. Wind-Calming Fence	Standard security fence	Wind calming fence around perimeter	6-14 c/W	N/A
10. Watertight Enclosures	National Electrical Manufacturers Association (NEMA) 3 rated	NEMA 4X rated	Recommendation only	
11. Elevated Pads	Electronic components not on elevated pads	Electronic components installed on elevated concrete pads	0.8-1.0c/W	N/A
12. Drainage	Not well-designed drainage systems	Well designed and maintained drainage	Recommendation only. Should be a standard design component.	
13. Pre- and Post-Storm Measures	None taken	Powering down, cleaning site, fault testing, repair/replace	Recommendation only. Costs are too variable based on site and which measure are undertaken.	

Module selection

Solar module structural strength is an important part of racking engineering that is often overlooked. Modules repeatedly flex in the persistent uplift forces caused by severe weather events, potentially breaking the module or the top glass. Modern module industry-standard strength is 5,400 Pa, however, hurricane resistant modules can resist upwards of 7,000 Pa.

Three-framed rail system

A third mounting rail is recommended for ground and roof mounts because it effectively increases module strength as well as overall system strength. On a roof, the third rail increases attachment points to both the roof and the module, further increasing the assembly's uplift strength. The additional rail, hardware, and labor, raise the cost of the racking by 33% to 50%.

Two-pier mounting

Adding an additional pier when installing ground-mount racking systems will increase the wind strength of a system considerably. Adding piers to a plant is a relatively simple task if it is incorporated as part of the original design, as the equipment to install this hardware will already be onsite. Project insurers often require these additional piers in hurricane-prone regions.

Racking design

When solar modules are strongly attached to the racking system, the forces they experience in a wind event are mostly transferred to the racking. These forces can act in many directions as winds shift around a facility. Industry-standard channel products, which minimize metal use to save on cost, are susceptible to twisting, deformation, and failure during storms. Tubular – or closed form – metal products greatly increase system rigidity.

Wind-calming fence

Wind forces acting on the perimeter of a solar installation can be as much as 2.25 times higher than those acting on the inner arrays. Though costly, upgraded wind fencing is an effective way to reduce those forces, and may help pay for itself by reducing dust and other debris, resulting in higher average output and reduced maintenance. Before starting a proj-

"Wind forces acting on the perimeter of a solar installation can be as much as 2.25 times higher than those acting on the inner arrays"

ect, developers, contractors, and owners should decide who is responsible for a fence's ownership and liability.

"In all regions, regular spot checking and retightening of electrical and mechanical connections are frequently cited as the most valuable preventative measure"

Watertight enclosures

Rubber-sealed NEMA 4X+ rated enclosures protect electronic components against wind driven water, submersion, and air pressure differential damage. Enclosure doors have been pulled open by winds, regularly causing damage. As a result, upgraded locking mechanisms have been integrated into higher-rated enclosures. Wind-driven water travels in all directions, making lower-rated NEMA enclosures less effective. Effective sealing also provides an extra layer of defense against flooding, at least temporarily.

Elevated pads

Another flood damage prevention measure is to ensure the proper elevation of equipment on concrete pads. Site engineers should determine the storm surge height and ensure all electronic components are installed above that level. Alternatively, where string inverters are used in place of central inverters, they are typically mounted high enough that concrete pads are unnecessary.

Drainage situation

A site's drainage situation should be carefully assessed before development. Drainage systems are crucial, and must be budgeted into design and maintenance. And while the broad variations between sites and local conditions make it impossible to provide specific recommendations or costs, NREL offers the reminder to pay attention to vegetation. Proper planning and management of a site's vegetation will reduce runoff and improve soil stability. Drainage system maintenance may also raise O&M costs.

Storm measures

Whenever it is safe to do so, a torque audit should be performed before and after a severe weather event. All components must be powered down by opening breakers, fuses, and switches. Debris and materials on site should be removed or tied down. Naturally, post-storm measures will depend on the damage done. All electrical systems will need to be cleaned and dried, and the systems should be checked for electrical faults. Damaged components must be replaced before energizing.

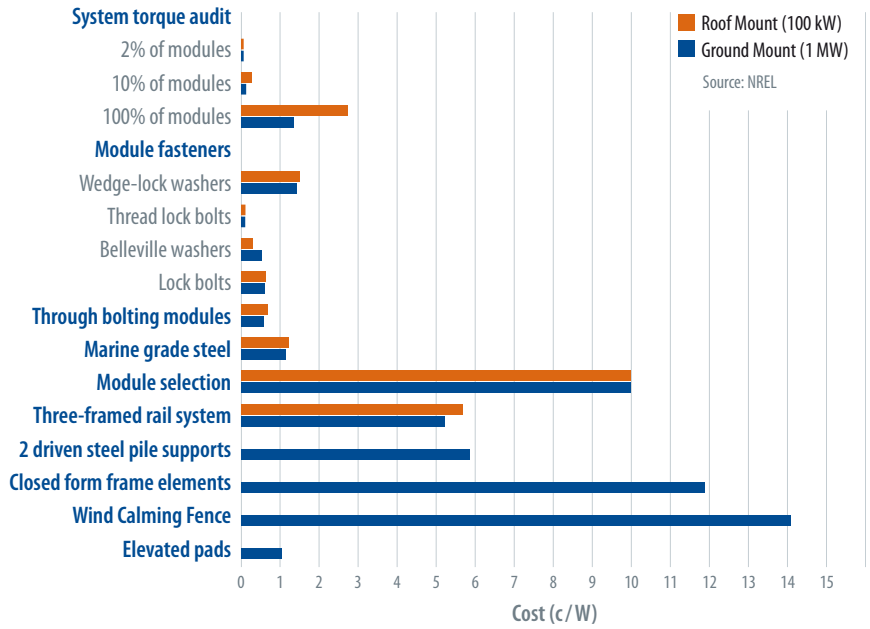
Engineers suggest analyzing sites on an individual basis to determine which of these tools are the most cost effective, based on local risk factors. In all regions, regular spot checking and retightening of electrical and mechanical connections is frequently cited as the most valuable preventative measure.

Asset owners will have to balance the costs and benefits of these mitigation tools with the statistical probability of a wind event in order to get the most out of their investments.

Global metal prices have increased, which provides a motivation to skimp on racking, fasteners, and other metals in efforts to shave project costs. Post-accident insurance engineers are trained to measure metal thickness and other key system properties which will determine why a failure occurred. Keep that in mind while making procurement decisions. pv

John Weaver

Comparison of estimated per-Watt premiums for some storm hardening measures



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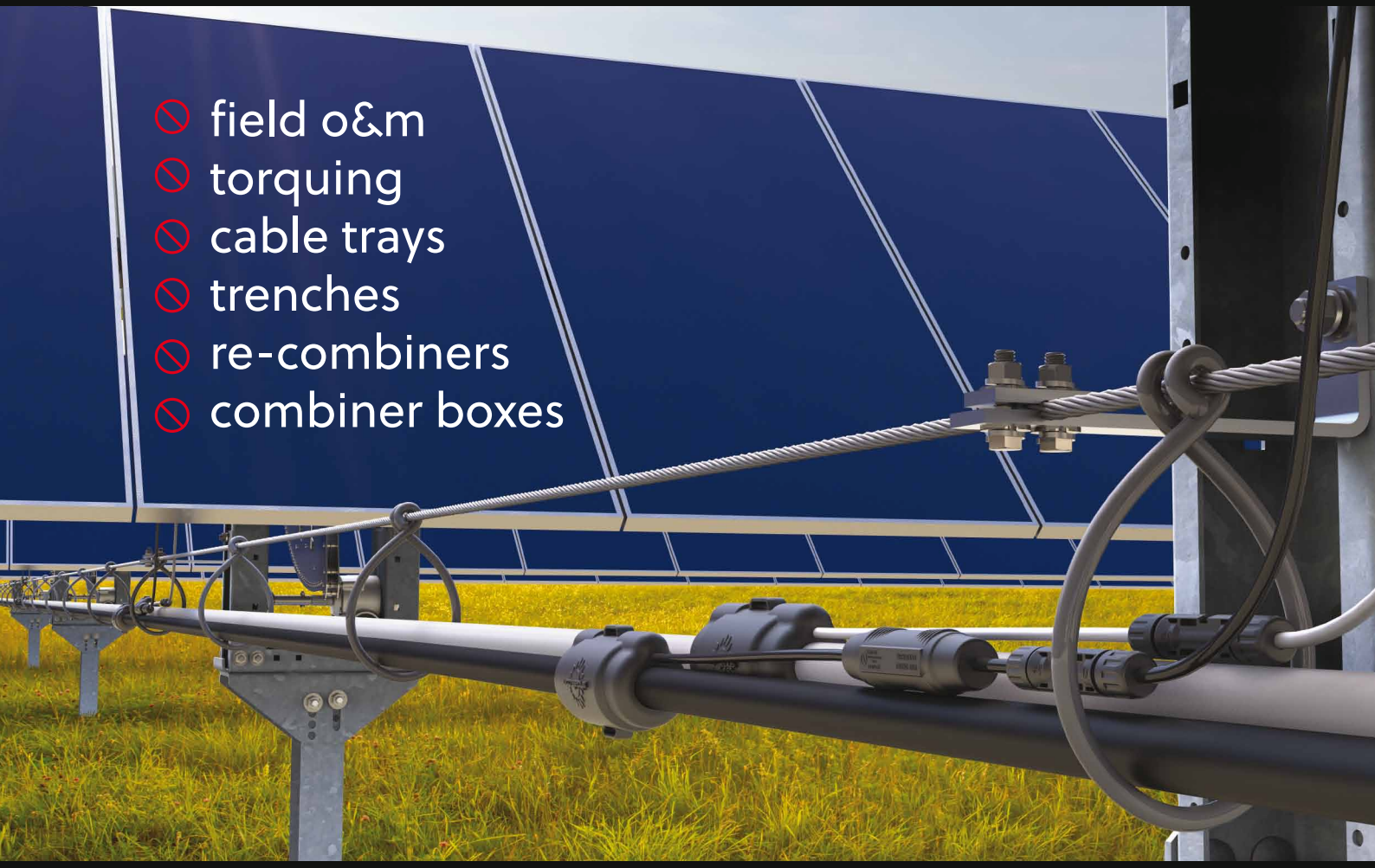

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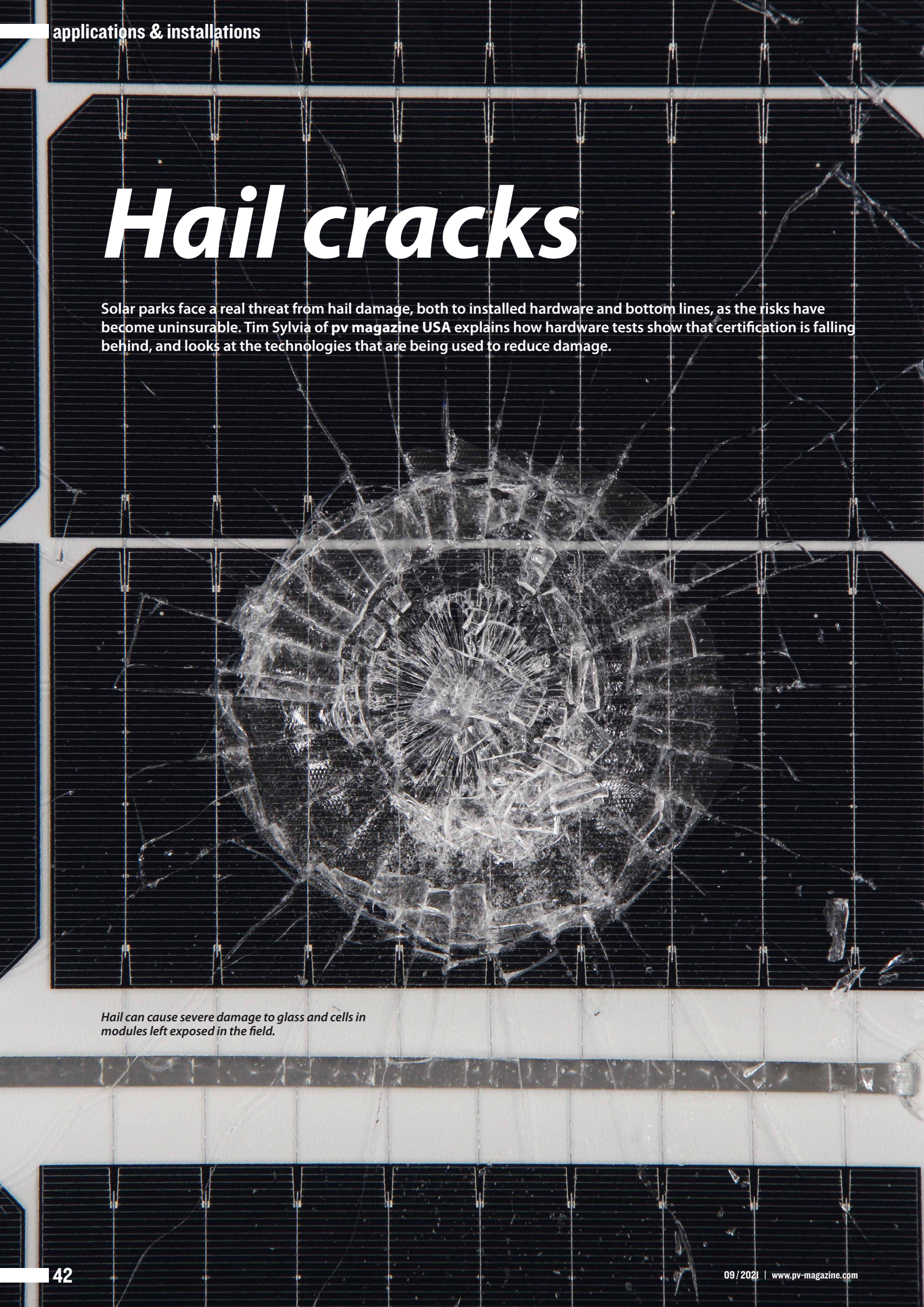
Hail cracks

Solar parks face a real threat from hail damage, both to installed hardware and bottom lines, as the risks have become uninsurable. Tim Sylvia of pv magazine USA explains how hardware tests show that certification is falling behind, and looks at the technologies that are being used to reduce damage.



Hail can cause severe damage to glass and cells in modules left exposed in the field.

Hail has always existed as a damaging weather phenomenon, but only in recent years has it become an operational concern for solar owners and operators.

A particularly destructive hailstorm in Texas turned the solar insurance sector on its head. In 2019, it ripped through the 178 MW Midway Solar Project in Midland. The pounding ice chunks damaged or destroyed more than 400,000 of the Midland plant's 685,000 modules. Insurance losses totaled $70 million.

Prior to Midway, access to insurance was seen as something synonymous with risk management: If a developer could insure a project until its sale and the buyer had reasonable access to insurance, then hail was just something to be addressed if it ever came up, or more accurately, down.

After Midway, attitudes changed. Developers looking to build solar projects in potentially hail-prone areas now include risk assessments as part of their pre-construction process. They are also adopting hardware and engineering techniques that allow them to better mitigate the potential effects of a catastrophic event like a hailstorm.

Hail damage mitigation on the hardware side has primarily come through the trackers on which modules are mounted. In the event of a forecast hailstorm, trackers allow modules to be rotated and stowed in a more safely angled position. When so positioned, hail stones deliver a glancing blow that delivers a much lower total impact, instead of a direct hit. Stowing the module protects the glass face from physical damage, and the module's inner workings from the kinds of damage that may not be readily detected.

For example, a row of modules may appear unaffected for days or even weeks after a big weather event, but the storm may have caused microcracks at the cell level. Such damage wouldn't initially be visible, but would likely result in a host of performance issues.

Hidden damage

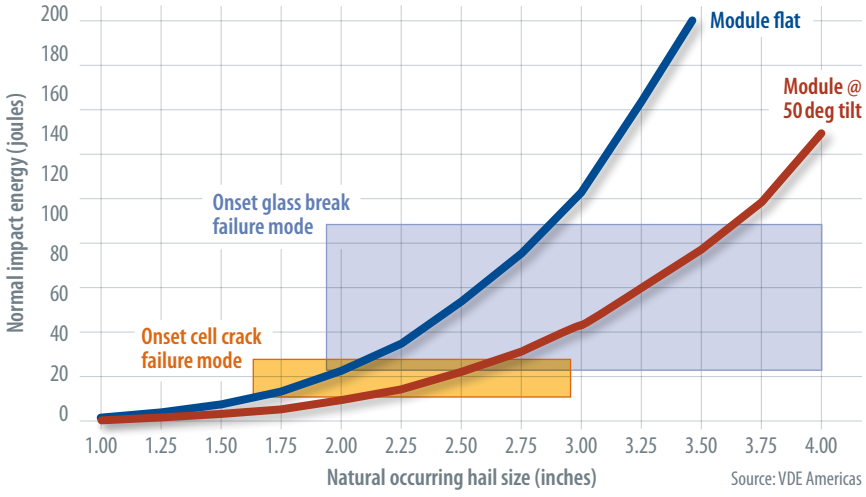
Microcracking is not a phenomenon exclusive to hail damage, and it's an issue that has dogged the solar industry for some time. One proven PV semiconductor material, however, has an inherent resistance to microcracking that is being increasingly highlighted, given these hail events: thin film.

$70 million

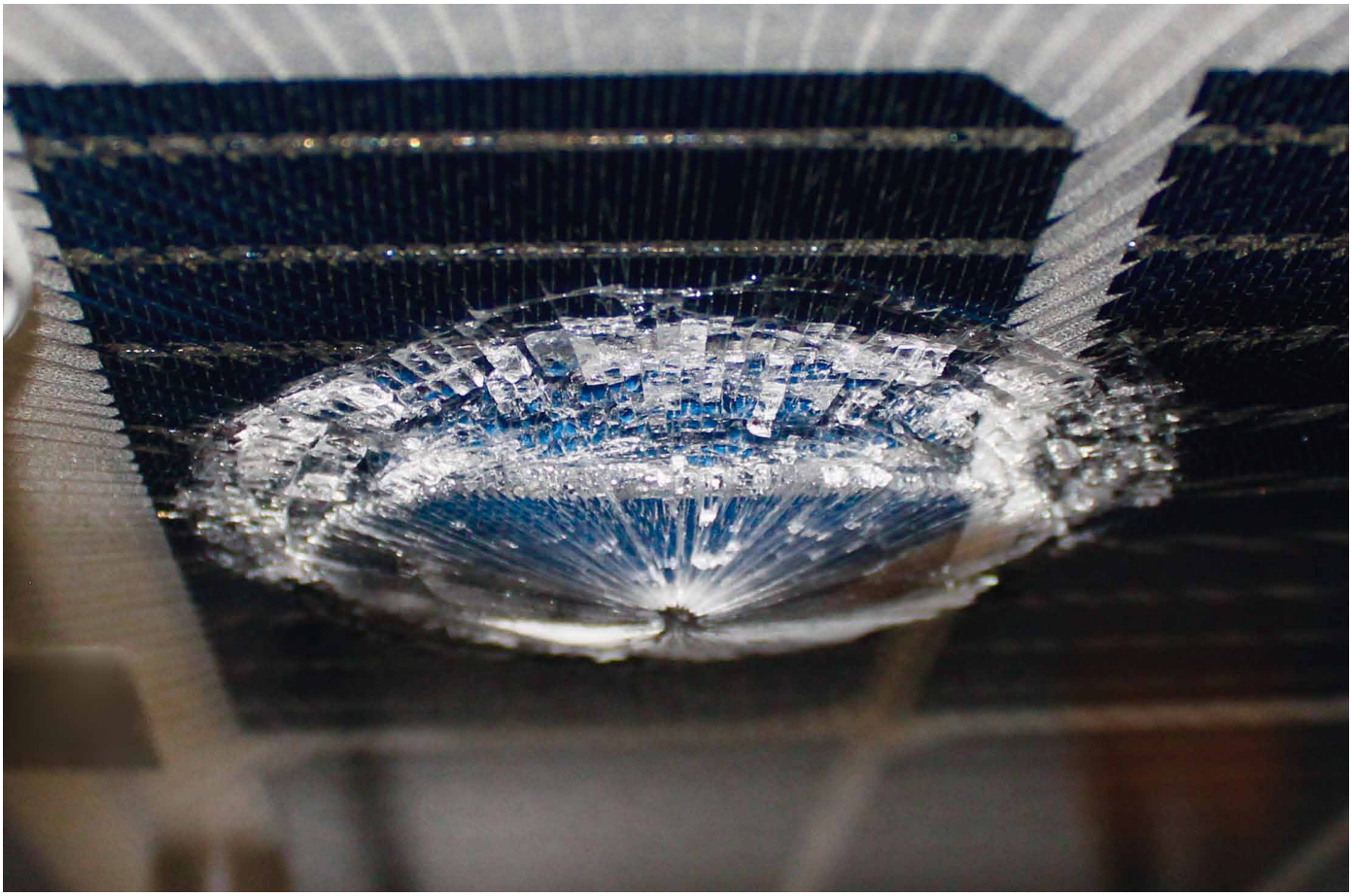
insurance payout from the 2019 Midway Solar Project hailstorm

The semiconductor stack used in thin-film modules is deposited at a thickness of a few microns. So unlike a crystalline silicon cell, it is no more brittle than the substrate it is deposited onto, and without separate cell pieces can also spread the impact of hail over a larger area.

Cell cracking and glass break vs naturally occurring hail sizes (no wind)



Source: VDE Americas



Photos: RETC

In severe cases, hail can fall hard enough to damage glass on both sides of a glass-glass module, as well as the cells in between.

Because thin-film is inherently more strike-resilient, the potential for cell-level damage is reduced, so long as the module glass remains intact. Even under extreme hail conditions, thin-film manufacturers say that their technology remains virtually uncompromised at the cell level.

As glass is the module's first line of defense against hail damage, the underlying worry then becomes the overall integrity of the glass.

Ice vs. hail

Current testing standards require modules to be able to withstand 11 strikes from a frozen ice ball (FIB) at a speed that corresponds to the diameter the manufacturer uses to test. IEC certification covers a range from 25 mm to 75 mm in diameter. For certification, there must be no visible damage to the module and a less than 5% loss of output, tested shortly after the FIB strike test.

The metric is somewhat incomplete, as naturally occurring hail (NOH) is both less dense and less aerodynamic than test-case ice balls. That means there is less impact energy for a hail stone that is the same size as a test-case ice ball. Additionally, damage at the cell level can take weeks, months, or longer to develop and worsen, a time range beyond IEC certification.

25 mm to 75 mm

are the hail diameters covered by IEC certification

In the last two years, VDE Americas has focused on the effect that hail can have on solar installations to develop predictive models that can be used to pre-assess project risk. VDE provides technical due dil-

igence and engineering services for solar power and energy storage systems.

The chart on p. 43 highlights the known ranges of the onset of cell crack failure modes and glass break failure modes for crystalline silicon modules, relative to NOH size and the hail's accompanying impact energy. The ranges were visualized by VDE using data compiled by the Renewable Energy Test Center, PV Evolution Labs, and Core Energy.

The blue line in the chart represents the scaling in energy as hail size increases, assuming the module is struck in the flat position. The orange line represents the same scaling impact energy, but this time for a module sitting at a typical stow angle – 50 degrees in this scenario. These graphs assume no wind effects.

Testing also was done with hail striking the module face at a 90-degree angle. Post-Midway, however, this kind of strike is becoming rarer in real-world scenarios, as developers increasingly use trackers with stow functionality.

The chart to the top right shows how the return interval for NOH as a function of hail size can be converted into a return interval for normal impact energy. It can vary from one part of Texas to another, and is intended to provide a reference, rather than a concrete prediction.

The normal impact energy of NOH for a given size has an equivalent FIB. The ice ball is smaller than the NOH given its density and aerodynamic nature, and in turn more energetic. VDE has converted the return interval for NOH into a return interval for an equivalent FIB. That size was then related to the sizes used in IEC certification.

In short, these relations allow for a view of how current testing standards, with 25 mm being the minimum requirement and 75 mm being the maximum rating per IEC 61215, stack up against the real-world return intervals for hail of that size. As far as **pv magazine** is aware, 55 mm is the largest diameter of testing currently undertaken in a commercially available module. The bar graph serves as a visual representation of how a testing standard that is suitable for California doesn't represent the reality on the ground in Texas.

Tim Sylvia

Sample year-events in Texas / California vs. IEC certifications FIB size Source: VDE Americas

Big enough, already

Large-format solar modules are big in size, big in promise, and a big topic on the minds of many. Aaron Hall, president of Borrego, outlines his company's experience with larger modules and explains the advantages and potential pitfalls.

Large-format modules may save

$0.03 to $0.05/W

for 16-20 MW (DC) projects

Large-format solar modules have captured the collective imagination and energized procurement activities among utility-scale and distributed-generation solar project stakeholders. The higher power output of these mega-sized, 182 mm and 210 mm wafer-based, 500-600 W-plus modules allows developers and EPCs to potentially achieve a big reduction in the amount of balance of systems (BOS) and electrical BOS components needed, as well as lower installation costs.

The math is fairly straightforward – fewer modules to ship, fewer modules to mount, fewer strings to connect for the same PV system capacity, and fewer arrays to operate and maintain. No wonder this potent, bankable combination of decreased capex, lower levelized cost of energy (LCOE), and higher net present value has intrigued solar developers and asset owners.

As one of the first EPC companies to procure and deploy large-format, high-power modules in the United States, Borrego works with many of the leading module and BOS suppliers, which gives us a nuanced understanding of the evolving technical and economic benefits and challenges of large-format modules.

Significant savings

Cost-benefit scenarios comparing 500 W-plus large-format modules and smaller-dimension, 400 W-range modules reveal significant BOS cost savings of $0.03-0.05/W for 16-20 MW (DC) projects using either single-axis trackers or fixed-tilt racking. The higher-powered modules allow a reduction in racking, foundation, DC electrical wiring and associated installation labor costs (see table, bottom left). These BOS cost reductions combined with yield improvements and system size enhancements translate into six- and seven-figure savings.

Bigger, but better?

One might think that for reasons of sheer power, the bigger the module, the better. We've discovered recently that for certain site designs, that perspective may vary. Sometimes, a smaller-format large module (545 W vs. 645 W) turns out to be a better fit because of the specific form factor and its electrical characteristics. It also offers a good example of why an informed, detailed analysis is important.

The table (bottom left) includes the important specifications of the two modules referenced in the analysis. Note that both modules have the same length, but the higher-power module is significantly wider. What this means, ignoring efficiency for a moment, is that for a given single-axis tracker-row length, you can get the same number of watts per row. The 545 W module is actually a bit more efficient, so you could get slightly more watts for the same row length, or have a slightly shorter row for the same number of watts. On a per-watt basis, the racking and foundation costs should be very similar (although one would have to buy a few more clamps with the smaller module – due to the larger number of modules).

The next part of this calculation is project and racking specific. Because of the open-circuit voltage and temperature coefficient of Voc of the modules, tracker-row length limitations, and the general practice of targeting the use of a whole number of full strings of modules per tracker row, you can end up with scenarios where you have more watts per string and more watts per tracker row with smaller modules compared to the larger ones. Keep in mind that this does not take space constraints into account.

This design reduces DC wiring costs as well as racking costs for the 545 W mod-

		Tracker ~20 MWdc		Fixed Tilt ~ 16 MWdc	
		450-->540	450-->575	450-->540	450-->575
Racking	Rack material	$(0.013)	$(0.021)	$(0.005)	$(0.006)
	Rack install	$(0.002)	$(0.003)	$(0.003)	$(0.004)
Foundations	Foundation material	$(0.005)	$(0.007)	$(0.002)	$(0.004)
	Foundation install	$(0.001)	$(0.002)	$(0.003)	$(0.004)
Mod set	Module installation	$(0.002)	$(0.002)	$(0.003)	$(0.003)
Electrical	DC electrical material	$(0.007)	$(0.007)	$(0.008)	$(0.009)
	DC electrical installation	$(0.003)	$(0.003)	$(0.003)	$(0.002)
Contingency	Contingency	$(0.001)	$(0.001)	$(0.000)	$(0.001)
	TOTAL	**$(0.033)**	**$(0.045)**	**$(0.027)**	**$(0.033)**

545 W module	645 W module
Length: 2,384 mm	Length: 2,384 mm
Width: 1,096 mm	Width: 1,303 mm
Open-circuit voltage (Voc): 38.1 V	Open-circuit voltage (Voc): 45.3 V
Temperature coefficient of Voc: –0.25%	Temperature coefficient of Voc: –0.25%
Efficiency: 20.86%	Efficiency: 20.76%

ule, relative to the 645 W one. While these savings are not large, they are enough to offset the increased cost of having to install more modules and clamps with the 545 W modules.

Size limit

While we do expect large-format modules to continue to gain market share in the utility-scale and distributed-generation sectors, we do not expect to see even larger panels. The largest are already nearly 8 feet tall by 4 feet wide (2.4 m by 1.22 m) and weigh more than 85 pounds (39 kg). Anything larger would be even more difficult to handle and mount, and would likely not be able to meet the minimum load requirements for modules.

Independent lab testing suggests that large-format modules can be susceptible to some of the same issues as smaller form-factor modules, but their larger size could amplify the impacts.

For example, some large modules subjected to rigorous potential-induced degradation (PID) tests have experienced a 15% loss. A 15% hit on a module with a nameplate of 550 W is a big number and could have a larger impact on modeled and measured system performance.

Larger modules may also be susceptible to additional mechanical stresses due to their increased surface area. Tests have revealed microcracking and more module flexing during mechanical loading. It's important to know what conditions might subject the larger modules to potential damage – such as high wind or snow loads – and how to mitigate those risks. Of course, the key for procurement teams is to source quality modules from companies with proven track records.

After the recent torrent of module technology, architecture and size innovations, we do expect module manufacturers to focus more on efficiency and design in the coming years. The multiple offerings of 182 mm and 210 mm wafer-based modules provide platforms for integrating new, higher-efficiency cell technologies such as n-type monocrystalline TOPCon architectures capable of pushing panel efficiencies to 23% and beyond. pv

Aaron Hall

Photo: Borrego

Borrego's 14.3 MW sPower Shoreham solar project in Suffolk County, Long Island.

About the author

***Aaron Hall** is the president of Borrego, a nationwide developer, EPC and O&M service provider for large-scale renewable energy projects throughout the United States. He re-founded Borrego in 2001 after consulting with the original founder (from 1980), James Rickard, and drafting a business plan at Northwestern. After helping to build many departments, he now has executive responsibility for procurement and serves on the committees overseeing EPC contracts, development investments, and product approvals.*

Enhanced standard for

An update to the IEC 61724-1 standard for PV monitoring systems has been published. Bifacial performance ratios now fall under scrutiny with these maturing standards, writes Christopher West, who heads the central solar and storage engineering team at Norwegian state-owned utility Statkraft.

In July 2021, the most recent version of IEC 61724-1 was published; the standard lays out the monitoring requirements for PV systems. It covers several topics, the key ones being the number and types of sensors to be installed in a PV plant depending upon its classification and size. Specifications to which the sensors should adhere are also covered. The standard also includes the key definitions of performance ratio (PR), both with and without temperature correction.

With the new edition of IEC 61724-1, a few technical changes have been introduced. Class C monitoring systems have been eliminated to simplify the selection process, soiling measurements have been updated along with the introduction of optical soiling sensors, and the requirements for irradiance sensors have been updated.

Monitoring requirements

Perhaps the most significant change is the introduction of monitoring requirements for bifacial systems and the introduction of bifacial performance ratios.

> *"Bifacial systems introduce more uncertainty"*

With respect to the monitoring requirements, the standard recognizes that there are two ways of determining the irradiance falling upon the rear side of the PV modules. You can either measure this directly, or you can measure the ground albedo, and use that to derive the rear-side irradiance. Consequently, the standard allows the EPC to choose one of two types of sensors when installing bifacial systems, either using horizontally installed albedometers, or by using irradiance sensors at the back of and in the same plane as the PV modules.

The implications of the changes to PR in the updated standard are significant, as failure to meet a PR guarantee can be costly, in terms of incurring heavy damages. EPC contractors typically sign up to performance guarantees where they guarantee PRs. As such, the consequences of higher uncertainties on the yield can be very expensive.

Bifacial systems introduce more uncertainty. They rely on ground cover albedo that can vary from season to season, and throughout different parts of the plant. A system designer can take into account a margin on the PR, but an over-conservative estimation of bifacial yield can undervalue a project and make it seem less financially viable than it really is. The only way to balance these two factors is to reduce the uncertainty by moving away from traditional PR. There are two good candidate methods for doing so on bifacial systems: the existing energy evaluation method from 61724-3, or the new bifacial performance ratios that are introduced in the latest version of 61724-1.

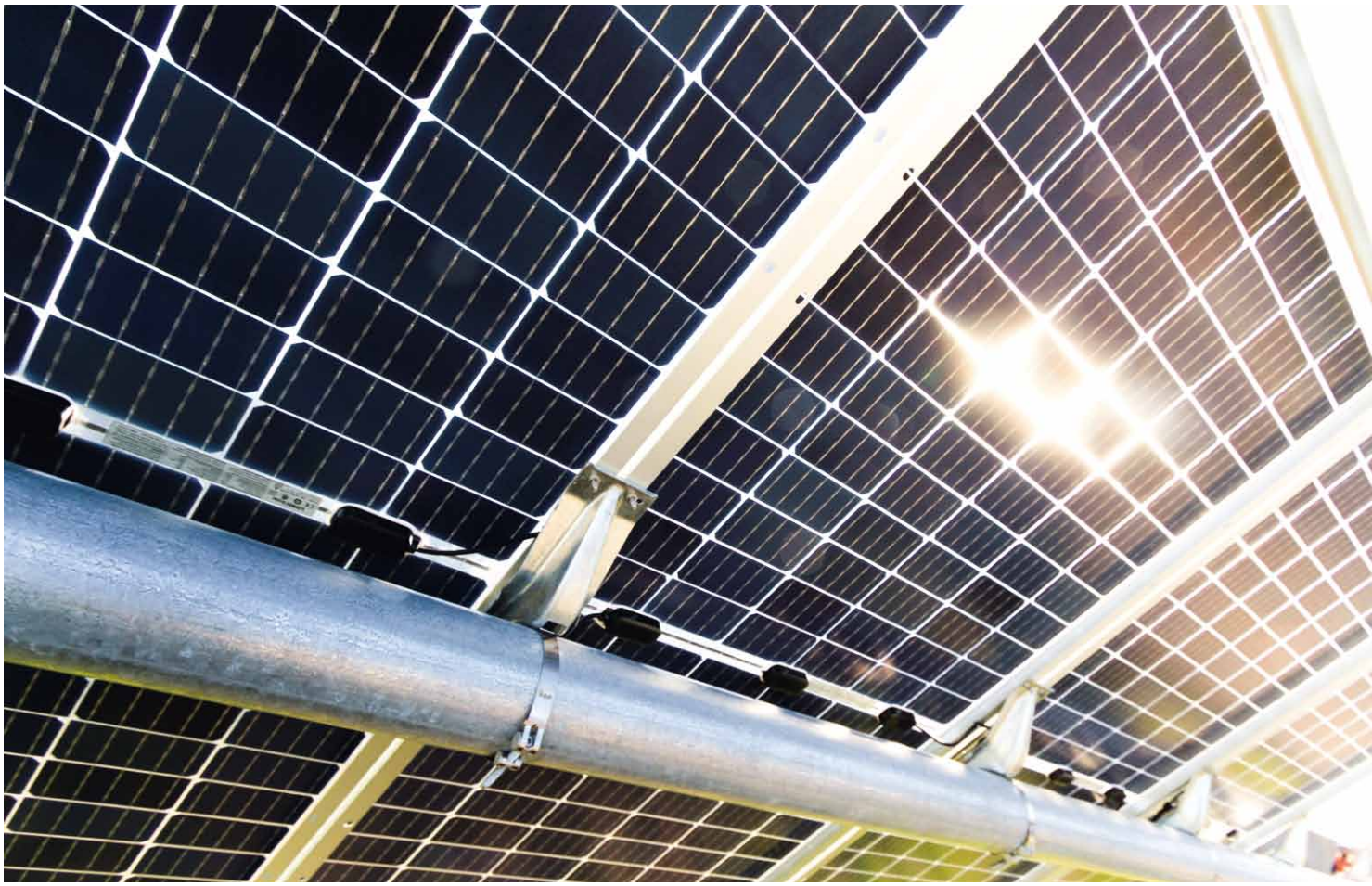
Bifacial details

IEC 61724-3 has been published since 2016 and is a method for evaluating system performance by taking the real, on-site measured data, and running it back in the simulation model that was used to perform the initial simulation, to calculate a "performance index." The power of this method is that it considers anything that is in the model, including losses on higher irradiance years due to higher temperatures or high DC/AC ratios.

If the intention is to use the performance index method as set out, the project stakeholders must understand the limitations of the software they intend to use. Many models will use global horizontal irradiance and ambient temperature as inputs, and may allow albedo as well, but they may not allow measured rear-side

monitoring

Photo: Nextracker



Accounting for non-uniform rear-side irradiance has been one of the biggest challenges in developing standards and forecasts for PV installations that utilize bifacial modules. A recent update to IEC standards for monitoring PV plants should help to reduce uncertainty.

irradiance to be directly put into the software model.

In this case, albedometers might be a better choice than in-plane irradiance sensors, because the model can use the albedo, but not the rear irradiance. Another consideration is that this model will transpose the global horizontal irradiance to derive the front- and rear-side irradiance values. So in some ways, the software model and tracking algorithms are being assessed as much as the system, as it is not as "direct" as PRs are, where it doesn't matter how accurately the software is modeling the tracking algorithm.

Alternatively, stakeholders can use the newly introduced bifacial performance ratios from 61724-1. Here, the traditional calculations are modified to take into account the sum of both the front-side and rear-side irradiance. Because the sum of the two irradiances is higher, a bifacial performance ratio is a smaller number than a traditional PR, but the number is essentially "albedo-corrected" and shouldn't go up and down if the albedo changes. In reality, there is still a variance due to clipping. On systems where the peak PV capacity is higher than the inverter capacity, there is a clipping loss, and as albedo increases, the clipping does also, adversely impacting the PR. It is therefore important that contractual measures consider this variable loss.

Simulation software may evolve to better allow the methods already laid out in IEC 61724-3, as well as the new concepts of bifacial PR in 61724-1. This would assist the industry to continue to reduce the uncertainties associated with bifacial systems, and guarantee numbers that balance the need to properly value the projects without taking on unwanted risk. pv

Christopher West

About the author

Christopher West *is the head of central engineering for solar PV at Statkraft, and has worked on utility-scale PV plants across Europe and Latin America. He is a contributor to IEC international standards for PV plant design and installation.*

Game of drones

Drones have already established themselves in industries as disparate as warfare, wedding photography, and burrito delivery, and increasingly the solar sector is taking the high road, too. Combined with thermal imaging, drones have the potential to obviate expensive maintenance costs for large-scale solar plants, as well as C&I and growing niches like floating PV. But how useful are they, and what role does AI play in making the most of a bird's eye view?

Drone supplier Above is participating in an Innovate UK-funded project in Britain that aims to automate drone flights at solar sites.

Photo: Above

Photo: AgEagle

Falling sensor and drone prices have enabled their more widespread application.

The efficacy of drones is perhaps nowhere more demonstrable than in comparison to handheld thermal inspections. Without drone accessibility, solar technicians have to walk the rows of solar farms with handheld thermal cameras in order to manually collect data, or at least, collect the data they can reach. This is no small task considering the size of some solar farms, but it's only a small buzz for a drone capable of carrying normal visual, thermal or electroluminescence (EL) imaging cameras.

Jesse Stepler, president and co-founder of Measure Global, a U.S.-based aerial intelligence company that builds software to automate drone operations, told **pv magazine** that drone technology has made "massive advancements" in recent years. Stepler added that given the U.S. solar industry's current growth rate, there will only be more demand for inspections, and these inspections are only becoming more "seamless."

India-based solar drone inspection firm AirProbe reports that more O&Ms and IPP's are "jumping into the picture with in-house drone operations as the cost of drones lowers with new models coming into the market every year." The reason being that, by utilizing drones with normal visual and infrared cameras integrated with AI algorithms, project developers and managers can more easily detect deterioration or other abnormalities such as string issues and failures, blocking diodes, hotspots, PID, soiling, and storm damage, and can provide additional data for things like an antireflective coating application.

AI advancement

According to AirProbe's co-founder and CEO, Aditya Bhat, it is "mainly advancements in deep learning that have helped to automate analytics in solar," with companies working to increase the accuracy and data intake. This means there is "great promise in terms of deploying analytics on the edge to help technicians identify and resolve issues in the field."

Stepler added that "drone data is currently driving advancements in artificial intelligence" through the sheer size of aggregated data sets. "Because of these advancements, we soon won't need to schedule inspections and maintenance according to a common schedule," he said. "We'll be able to optimize based on a more detailed set of site and environmental conditions." This is to say that drone data will soon have a predictive function, an ability to forecast potential issues and needs ahead of time.

There are also those hard at work on the development of solar specific drones with advanced spatial awareness. Will Hitchcock, founder and CEO of U.K.-based solar aerial inspection and data analytics company Above, told **pv magazine** about a new Innovate U.K.-funded project in partnership with the University of Essex and the University of Loughborough, which allows for increased automation and detail in the images.

"[The project] unites experts in solar, robotics, AI, sensors and embedded systems to develop a spatially-aware drone that can rapidly process and make in-flight corrections using AI and sensing technology," said Hitchcock. "This will enable the drone to better capture the condition of PV modules in greater detail by flying closer to the panel's surface."

Drones first

While working on existing arrays appears an obvious use case, PV drones are being utilized across the entire project lifetime, from pre-planning to post-construction. Indeed, pre-construction imaging is also increasingly reliant on drones.

> *"PV drones are being utilized across the entire project lifetime, from pre-planning to post-construction"*

Photo: AirProbe

AI and deep-learning technology allow the huge amounts of data collected by drones to be processed, says Indian drone specialist AirProbe.

> *"The solar industry is moving forward, and drones are right here with it"*

Stepler noted that the surveying of a potential solar farm site can "be one of the more time-consuming, laborious processes." But drones "can collect data for topographic modeling, site shading assessment, water body proximity and soil type analysis to understand how optimized a site is for power generation."

German project developer and IPP Enerparc, which has its own drones and performance optimization team, uses Lidar/Radar drones for all its sites before the final design. "In the development phase, we use this drone for difficult sites, so that we get a better understanding about the additional cost for the site preparation," said Enerparc COO Stefan Müller. "Mainly sites with trees, bushes and very unclear landscape. With this information we can manage the commercial discussions about the land in a much more transparent way."

AirProbe's Bhat pointed out that "drones have been widely used for topographical surveys across the world. Usage in forested areas and undulated terrain has helped asset managers use 3D models generated from drones before design to be used as a base and develop precise shading analysis as well as generating practical yield models."

Enerparc has extended the use of drones in its solar arrays and has even started using drones to replace visual inspections of backsheets – by flying the drones behind the module rows, a technique Müller said inspects a project "faster and easier."

Of course, one of the periods in a solar installation's lifetime that is most critical, and most ameliorative, is the first year. Drones help to "identify problems right after commissioning" continued Bhat. "In terms of module batch issues (one case was observed where a certain batch had junction box insulation issues while others did not), installation-related problems such as broken PV panels, disconnected strings/burnt connectors, MPP tracking issues and so on."

In-house or outsource?

For many, the question as to whether to develop drone expertise in-house or to contract with third parties will be an important one. After all, everyone wants to be able to say they have their own drone air force. But whether or not drone inspections are carried out by an in-house drone and pilot department or an outsourced firm is highly project and company dependent.

In January 2020, South Australian government-owned water utility SA Water announced that it would invest more than AUD 300 million ($215 million) in the installation of more than 500,000 solar modules to produce 242 GWh of energy and 34 MWh of energy storage annually. Installation is underway, including the "world's largest" portable solar array, 12 MW of prefabricated 5B Maverick solar modules installed at the Happy Valley Reservoir, near Adelaide.

SA Water partnered with Above for the solar drone inspections of their ambitious layout and have opted to use their own drone pilots where possible, though Above has led the training program.

"With the vast distances in Australia, this model works really well for them," Hitchcock said. "We then do the processing and interpretations to ensure they derive maximum value from the data they collect. As their portfolio grows we may call on our local drone partner, AUAV, to deal with volumes that exceed the SA Water internal team."

However, many companies don't have drone licensed technicians on the payroll and other companies prefer the independence and impartiality of an outsourced inspection service.

Above water

Floating PV (FPV) is a growing niche, but perhaps requires more inspection than any other type of solar array, and yet those inspections, obviously, must take place on the water. For FPV, then, inspection drones are perhaps more useful than other systems. Stepler also noted that all the challenges faced by ground inspections are also faced by FPV inspections, only more so, meaning the efficacy of drone inspections is even higher.

"We have quite a lot of large-scale floating PV systems coming online right now and utilizing drones for regular inspections is quite obvious in this case," said Bhat. And as to whether drones are suitable to FPV, he said "definitely, yes."

Above's Hitchcock agrees. "Like ground-based and rooftop solar, drones are the most effective inspection method for floating arrays, perhaps even more so with floating solar as the presence of water adds more health and safety risk. Regular visual inspections of floating solar systems are important due to the added

complexity of the mounting structure and wet environment. Drones are an effective tool for visual inspections where they can identify discoloration, cracks and corrosion and also reduce health and safety risks in doing so."

Future of flight

The large-scale, open, or remote nature of solar installations ensures drones are an especially useful tool, particularly as PV continues to expand globally. "The solar industry is moving forward," said Stepler. "And drones are right here with it."

But what's next? Many foresee the use of autonomous drones. "One day, your solar system may detect an issue and automatically send out a drone to investigate, delivering the information to your cell phone before you even knew there was a problem," Stepler said. "We're getting there."

Hitchcock is similarly "convinced that in the coming years, every utility-scale solar plant will have its own drone stationed on-site." He added that they would be as "ubiquitous as the SCADA system." Indeed, Above has recently partnered with Herotech8 to develop a trial "drone-in-a-box" solution for the solar PV industry. It is basically a birdhouse in which the drone can autonomously take off, land and store itself.

Hitchcock sees the drone as a staple of the solar industry going forward. "Once regulations allow, it will be common to see drones based at large, remotely located assets and fulfilling targeted missions; flying intelligently and processing data in real time." pv

Blake Matich

Photo: Above

Drones can be used to monitor the construction of solar parks as well as their maintenance.

Revamping complexity

Revamping, or plant modernization, is starting to come into vogue in some mature PV markets, and asset managers are beginning to rethink their operational strategies. Asier Ukar of PI Berlin details the strategic considerations, benefits, and risks of investing to extend the life and boost the returns of a solar asset.

Revamping considerations begin with the question of "when." When does it make sense to upgrade? The first case is one in which there is a large technological leap between the network connection date and the present day. Projects in Spain and Italy are a good example, as both countries experienced their first solar boom between 2006 and 2008 and between 2009 and 2011, respectively.

During these relatively early days for the modern solar market, it was common to build PV plants using products that are practically extinct in utility-scale applications today. Such defunct technologies include dual-axis trackers, 60-cell crystalline modules, galvanically isolated inverters, and thin-film modules with amorphous silicon or CIGS technology. These older technologies often had lower efficiencies as well as reliability issues that affect the performance of the PV plants and are difficult to replace, due to the non-existence of spare parts.

Lost kilowatt-hours

A second case in which revamping would be justified is when a PV plant is operating under a historical feed-in-tariff scheme, and its performance is compromised due to poor execution during the original installation. In this case, the asset owner is missing out on significant potential revenue from lost kilowatt-hours.

The problematic execution of the plant was likely caused by a combination of factors related to design, equipment deficiencies, and installation quality. Some typical examples from older PV plants are the poor design of dual-axis trackers, excessive cable accumulation in trenches, poor handling of modules, absence of a SCADA system to properly monitor a plant, and previously unknown module degradation phenomena such as PID.

It is not uncommon to find some plants installed in Spain or Italy between 2006 and 2011 with disoriented or inactive dual-axis trackers, incorrectly labeled mod-

PI Berlin has observed that some modules installed on dual-axis trackers are showing premature degradation, primarily due to being exposed to so much solar irradiation.

pv magazine roundtables

ules, or detached diode boxes. In these countries, plants suffer where the performance ratio (PR) is not monitored or where incorrectly installed inverters deliver poor grid synchronization. Many PV plants operate well below their theoretical yields, but revenues can be substantially improved through revamping.

Aging effects

The natural aging of inverters and PV modules presents a third case in which revamping may be appropriate. The 10- to 12-year threshold is commonly considered as the point at which the replacement of the most sensitive inverter components (mainly IGBTs, capacitors, and filters) will be required.

In the case of string inverters, the replacement of these parts requires almost a complete component replacement, while for central inverters it would mean the replacement of the degraded parts while maintaining other more durable components such as busbars, racks, and certain protection systems. High temperatures and humidity as well as high DC/AC ratios can shorten the lifetime of inverters.

As for PV modules, different degradation types and rates occur depending on the technology used and the location of the plant. Most commonly, accelerated degradation occurs when higher environmental stress factors such as high temperatures, humidity, and UV radiation are present.

Modules on dual-axis trackers in southern Spain and Italy can show accelerated degradation. Subjected to high levels of direct irradiation at high temperatures, PI Berlin teams have observed modules after 10 years of operation with yellowing, corrosion of busbars, backsheet chalking, and fraying cables and connectors. It should not be overlooked that product warranties provided by module manufacturers in the early days of PV rarely exceeded five years and the power warranties were less favorable. Therefore, the incentive to repower the modules is greater to improve plant performance.

Fleet harmonization

Some PV plant asset portfolios owned by an independent power producer (IPP) can be made up of smaller assets of different

Module efficiencies have increased from 14% in 2008 to more than

20%

in 2021

Photo: Diego Delso Cariñena



Photos: PI Berlin

A PV plant in Italy in the process of revamping, following six years of service.

Combined revamping measures can increase a plant's PR by

5%–15%

ages, multiple technologies, and various suppliers. Due to the heterogenous nature of the PV plants, there is additional complexity and cost associated with spare parts management and maintenance. By streamlining the technology types and equipment suppliers through revamping, a standardized O&M program can be implemented to optimize costs.

When one or more of these cases are evident in a project, revamping can be worthwhile. Currently, the main revamping activities include the replacement of the original modules and the inverters with state-of-the-art components.

Revamping rules

Replacement of the modules while maintaining the original installed rated capacity can significantly reduce the total number of installed modules due to the improvement in module efficiency – efficiencies have increased from 14% in 2008 to more than 20% in 2021.

The replacement of modules has two direct benefits. Firstly, the O&M costs can be reduced by reducing the number of modules, structures, trackers, and cabling that require ongoing maintenance. Secondly, the initial rated capacity is reset to the original nominal value by recovering the accumulated degradation of the module since the commissioning date.

Replacement of inverters with galvanic isolation with transformerless inverters can immediately increase efficiency by around 2%, translating to an increase in the energy production of the plant. If this option is also combined with the implementation of 1,500 V multistring inverters or with the grouping of string inverters in a single central inverter, there can be a significant reduction in O&M costs through the reduction of electrical circuits.

The combined use of these measures can increase the PR by 5% to 15%, depending on the quality of the original PV plant. Adding to this improvement is the reduction in O&M costs due to the above factors, which will undoubtedly contribute to reducing the LCOE of the PV plant.

Strategic complexity

To implement successful revamping of a PV plant, it is necessary to adopt a strategy that takes into account a number of technical, commercial, and legal factors. The approach is multifaceted, and each plant must be treated as a unique case. Situational obstacles must be identified from the outset.

One of the paramount considerations is the loss of lucrative feed-in-tariffs if revamping is carried out – whether the revamping is justified as an essential change or not. This may even apply if the original nominal and peak powers of the project are not exceeded.

Ideally, modifications should be as non-disruptive as possible to make the process with regulators and administrators as smooth as possible. Certainly, legal advice familiar with the local legislation is strongly recommended before starting the application process with local regulators and grid operators.

Of course, when replacing modules, the most straightforward process would be to replace the originals with those which have similar electrical characteristics and dimensions. The main challenge is finding the right types of modules on the market today, due to the technological advancements already mentioned. If appropriate modules can be sourced, the prices could be quite high, and they may not even come from a well-known or reputable supplier.

If, instead, an upgrade from 230 Wp to 450 Wp modules is undertaken, it will save on the number of modules needed, but technical factors will emerge. The operating current increases from about 7.5 A to more than 11 A, values for which the original wiring and DC protections, as well as potentially the inverter, are not sized.

Connecting too many modules in series can lead to problems with the MPP rating of the original inverter. The larger physical dimensions of the modules can alter the static loading of the mounting structures. Larger overhangs can create higher bending moments and increased weights can overstress the screw connections, beams, and foundations. And, in the case of dual-axis trackers, the drive motors may not be able to perform with the higher static and dynamic loads.

Inverter upgrades

As far as inverters are concerned, there may be issues with updating due to fixes carried out at an earlier date. Some older plants that were affected by modules with PID feature inverters that have a transformer with galvanic isolation, and they can potentially have the negative pole grounded. This measure was introduced to stop the degradation caused by PID in both crystalline and thin-film modules.

Current transformer-less inverter models without galvanic isolation can increase the electrical risk caused by functional grounding since there is no physical separation between the DC and AC circuits. In addition, these inverters may not even be compatible with negative pole grounding. Therefore, the PID solution employed at the park may need to be re-addressed and the operational safety procedures revised to ensure that the performance deficits due to PID do not begin to reoccur.

Selecting the right revamping strategy requires analysis of the various options in terms of engineering, procurement, labor, and operational costs compared to the energy yield benefits over the remaining lifetime of the plant. If the changes are adopted to a large portfolio comprising multiple plants, there may be some economies of scale realized that will reduce the size of the investment and optimize O&M costs going forward. pv

Asier Ukar

About the author

***Asier Ukar** is a senior consultant at PI Berlin and the managing director of its Spanish subsidiary, PI Berlin S.L. He has 14 years of experience in the deployment of rooftop and multi-megawatt, grid-connected PV systems in Europe, Asia, Latin America and Africa. He has been actively involved in the design, supervision and refinancing of approximately 6 GW of installed PV capacity since 2007. Ukar holds a diploma in engineering from the University of Applied Sciences Karlsruhe.*

Bringing costs down to earth

Rising efficiencies and the plummeting cost of solar modules over the past few years, recent months notwithstanding, are leading innovators toward ideas that may look unusual in the current tracker-dominated world of large-scale solar parks. Advocates of the new approaches argue that they leave traditional models looking decidedly flat by comparison.

The ever-falling prices of solar modules over the past few decades experienced a blip in early 2021. Recent price rises look to be an anomaly of pandemic-related supply chain issues. These issues have spared few in our globalized world, as shipping costs have exploded. The Harpex Index, published by shipbrokers Harper Petersen, tracks worldwide price developments on the charter market for different types of container ships. It shows an almost exponential rise in shipping costs, with the index rising by a factor of 8.6 between May 2020 and August 2021.

A similar tracker, the Xeneta Shipping Index, showed a more than $6,000 rise in shipping costs per container since the end of April for the Asia-to-Europe route – the obvious way to move solar modules to the European market. The increases in materials and shipping costs have naturally seen solar modules rise in price for the first time in many years, after a decade in which costs have fallen by around 90%.

EU spot prices tracked by pvXchange had their first fall in July, after rising all year. Since the start of 2021, increases have tracked between 6% and 12%, depending on module technology, with bifacial modules seeing the largest jump, at 11.8%.

Module price increases are unavoidable for solar plant developers – projects quite simply can't exist without them. Therefore, in pursuit of savings elsewhere in system procurement, industry innovators are looking at rising prices of steel as a key risk for bankability. Cormac Gilligan, an associate director at IHS Markit, explains that for tracker makers, this is a material concern. "Global steel prices increased two times to three times between Q3 2020 and Q2 2021, with steel in the United States experiencing the most significant gains," Gilligan tells **pv magazine**. "As solar trackers consist of 95% steel by mass, relating to approximately 50% of overall tracker costs, such price volatility represents a significant risk to both tracker manufacturers and PV developers looking to reduce levelized cost of electricity (LCOE)."

Grounded approach

With changing cost structures come new ideas. U.S.-based startup Erthos, at first glance, looks like the opposite of innovation. The Erthos approach is to place solar modules flat on the ground: no tilt, no motorized tracking, no pitch distance calculations. Just a lot of panels, fixed together, flat. The radically simplified process eliminates a range of costs: Erthos quotes a greater than 20% reduction in LCOE, along with faster installation, and less land usage.

To prove the model, Erthos built its first 200 kWac project near Bakersfield, California, making use of ZNshine modules. Three further C&I projects are in pre-construction totaling 1.5 MWac, with each set to be completed by the end of 2021. Jim Tyler, CEO of Erthos, explained the concept, early signs of success, and driving the need for Erthos-style innovations to utility-scale solar – starting with why no one had done this before.

"The simple answer is that the cost of the panel was too high relative to every-

U.S. startup Erthos is convinced that by foregoing traditional racking systems and placing modules flat on the ground with only wires to hold them in place, it can achieve more than a 20% reduction in the levelized cost of electricity.

Photo: Erthos

Photo: 5B

Australia's 5B provided its Maverick solution to SA Water for this 12.8 MW system in Happy Valley, near Adelaide. With a fully prefabricated approach, the system promises to greatly reduce installation times compared to traditional trackers or fixed-tilt arrays.

thing else. You needed to point the panel at the sun in order to extract the maximum energy out of it, because that panel cost was too high. That's the historical, engineering, fundamental reason," says Tyler, an energetic executive, previously VP of engineering, procurement and construction with First Solar, before leaving to helm Erthos alongside a team of experienced executives.

The "ErthCompatible" specification that is licensed by Erthos requires the use of IP68 glass-glass modules. Module suppliers have mostly used bifacial modules to fit that requirement. Another feature of the specification is using aircraft cable threaded through the sides of the module, to prevent movement both up and down or side to side. Keeping the panels secure and flat allows the utilization of another innovation of Erthos: an autonomous cleaning robot. The robot, or fleet of robots, runs nightly, and a single robot can clean up to 2 MW every day.

Tyler describes the system as an "industrial Roomba," with extra features, including a thermal camera to analyze module and cell health. Erthos was funded through an initial $700,000 investment in a family and friends round, before receiving Series A funding of $7.4 million in August 2020. A large proportion of the Series A was provided by "the largest electrical sub-contractor [in the U.S]." Daniel Flanigan, chief marketing and product officer at Erthos – and previously a co-founder of Zep Solar, which was acquired by SolarCity – notes that the company has a project pipeline of more than 2 GW.

Dirt threshold

Tyler, brimming with assured confidence, explains the processes involved in taking the leap to the dirt, which starts with an assumption.

"The question I asked when I started the company was: If the panel were free, what plant would you design? When that's the case, the answer is obvious: You'd put them flat on the ground," states Tyler, the final words a motto he emphasizes more than once.

"At that zero-cost principle, I worked my way back up: At what price does it tip back to a single-axis tracker bifacial module? The answer to that, depending on your latitude, is between 38 and 42 cents per watt. If you're honest with yourself, and you run the real numbers, which is what I did, you come to that same conclusion."

Tyler's run of the numbers in May 2019, when the business was started, showed the price of panels was at $0.32-0.33/W. Even with the recent rise in module prices, panel costs are now below $0.30/W in the U.S. marketplace. At that price, it's still

more efficient just to add more modules to make up for losses without tracking.

Industry skepticism

Erthos knows the questions that are being asked by the industry. **pv magazine** spoke to experts about the concept, who offered similar questions and themes. Nicolas Chouleur, partner at Everoze, had concerns over environmental impact, soiling, and maintenance. IHS Markit's Cormac Gilligan says the same, with "concerns around weather impacts such as hail, snow or areas prone to flooding, land availability constraints such as preference for flat land and other considerations such as vegetation mitigation." Another experienced solar consultant focused on bird soiling, especially with flat panels, and points out that such soiling could be very difficult to remove.

Erthos has an abundance of answers. "The number of questions we're fielding is just crazy, and everybody asks exactly the same questions every time. What about water? What about wind? What about erosion? All those questions. That's the reason it wasn't done before." On soiling, Tyler says: "The rough cost to clean a tracker plant, one time, is about 50 cents per kW. We clean our solar plant every day for a year for 50 cents per kW." Tyler explains his one concern: temperature, a thought that easily comes to mind, given that he resides in Phoenix, Arizona.

"I did a fatal flaw analysis on the idea. The only fatal flaw of concern that I had personally was temperature. And so once I proved the temperature performance of max cell temperature of the module, I was satisfied. I happened to live in Phoenix which is one of the highest temperature places on the planet. And it happened to get to 118 degrees (47.8 C) outside when I was running our first plant in 2019. And sure enough, the module cell temperatures don't even approach maximum cell temperature. And I said: That's the answer.

"We are now in exclusivity on a 150 MWac project [in the U.S.], and that project is the lowest PPA that we've ever seen. The developer would literally lose money if he sold the plan. With Erthos, we've been able to get that project right side up. Ultimately, the uptake of technology such as Erthos will depend primarily on its technical capabilities being confirmed, along with overall project costs and energy yields resulting in favorable LCOE's compared to tracker or fixed tilt mounted PV projects."

High density

Other companies have taken less radical, though still novel, approaches to utility solar. While Belectric's well-known PEG substructure system has a high-den-

Harpex Index, worldwide shipping price (August 2018–August 2021)

Xeneta Shipping Index (XSI) for Asia-Europe, Ocean Freight Contract Market (August 2020–August 2021)

Cold Rolled Steel Index (August 1990–August 2021)

Source: Bloomberg

Photo: Erthos

Installation demonstrating Erthos' approach in Bakersfield, California.

sity solar approach, and the backing of one of the world's larger solar players, startup 5B has taken a portable approach to a similar east-west, densely packed, fixed-tilt design.

5B, an Australian company, was a winner of the 2020 **pv magazine** Award, impressing jurors with its prewired, prefabricated and portable solar-in-a-box approach that it calls the Maverick. Its largest installation, dubbed "the world's largest portable solar array," consisted of 30,000 modules installed for a 12.8 MW system for South Australian utility SA Water.

After seven years of development and growth in the Australian market, 5B now reports it has global opportunities in Chile, and the United States, and growing interest. Chris McGrath, CEO of 5B, said during the Awards that 5B saw making solar cheaper as the "critical frontier … we're really picking up off decades of work that's been done in the module and PV space, making solar modules themselves so low cost, and driving that to new frontiers."

Another fixed-tilt and portable innovator is Smartvolt, which developed a unique mounting system coupled with a special crane beam. The package facilitates both speedy deployment and dismantling of ground- or roof-mounted PV systems. This has created opportunities for Smartvolt's system on mixed-use land. A creative application was alongside wind turbines: utilizing the crane parking area of a wind turbine, which must be free for use, but outside of unexpected maintenance, is accessed by necessity once every 20 years. Westfalen Wind, a German wind specialist, added 96.8 kW of PV generation to compliment a pilot turbine. Andreas Fankhauser, owner of the Swiss company, explains that the pre-assembly means the company "can install 100 kW in 6.5 hours, and remove 100 kW in 6.5 hours."

Combined effort

Asked about Erthos' place alongside 5B, Belectric's PEG system, Smartvolt, and others, Tyler says: "I'm rooting for those companies, just like I'm sure they're rooting for us, right? The concept of high-density solar has arrived because the cost of the panel has gotten so low, and steel so high. We just took it to the final stage, which is to put the thing on the ground."

Tristan Rayner

US states get smart on

As residential smart inverters and their grid services continue to offer more capabilities to the grid, U.S. states are going about regulating their installations with the best intentions. But delays in ensuring that smart inverters are active and operating to a common standard will be costly.

Smart inverters for distributed solar and storage make room for more solar on distribution circuits, enable distributed solar and storage to provide grid services, and open the door for owners of distributed solar and storage to be compensated for those grid services.

A handful of U.S. states are already adopting a new global standard for smart inverters, and advocates say that all states could benefit by requiring the inverters for new distributed resources.

Hawaii and California, both leading markets for rooftop solar in the United States, were the first states to require the use of smart inverters. They didn't wait for the international engineering body IEEE to finalize a new smart inverter standard, but instead set their own requirements, based on the capabilities of smart inverters available at the time.

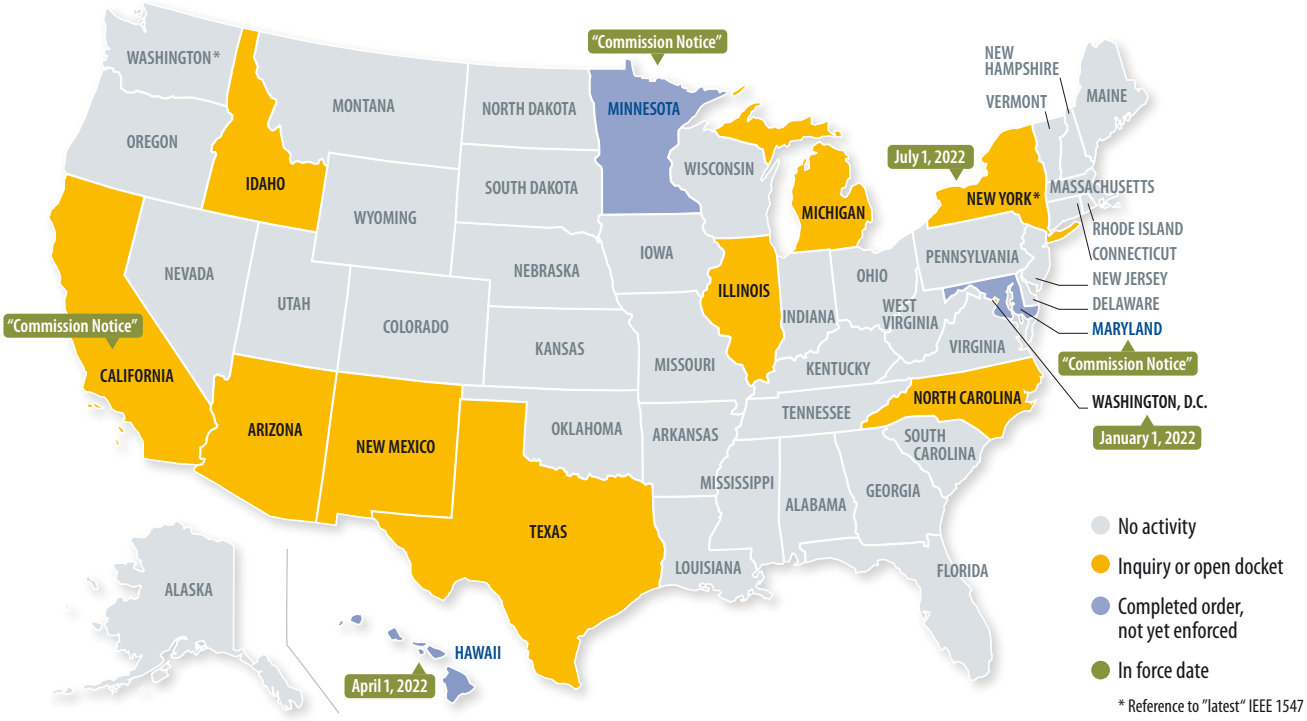
Now that IEEE has finalized its work on IEEE-1547-2018, the states of Minnesota and Maryland will soon require new distributed solar and storage installations to use inverters that meet the standard. Hawaii is also adopting the new standard, while California is expected to implement it sometime next year, said Midhat Mafazy, regulatory program engineer for the Interstate Renewable Energy Council (IREC). Eight other U.S. states and the District of Columbia have opened dockets to consider the standard, as shown on the below map.

Endorsing Maryland's new requirement were solar installer Sunrun and the Energy Storage Association. The National Association of Regulatory Utility Commissioners has recommended that states implement the standard in unanimous votes by the board of directors and two committees. The IREC backs smart inverters as well, and has prepared a primer for state policymakers who are considering adopting the new standard. The National Renewable Energy Laboratory has compiled a list of 29 educational resources on the standard.

Other states should join those that have adopted the standard or are considering doing so, says Harry Warren, a grid consultant at the Center for Renewables Integration. A state-level requirement to use inverters compliant with IEEE-1547-2018 for new distributed solar and storage is especially important for states that already have high levels of solar and storage on

U.S. State-by-State adoption of smart inverter standards

Source: EPRI (2021)



smart inverters

Photo: Sunrun

Sunrun has endorsed new standards regulating smart inverter operation in the United States. These are soon expected to be adopted by several states, including Hawaii and California, both of which have jumped national body IEEE to publish their own standards.

distribution circuits, or that plan for high levels of distributed resources, he says.

As the amount of solar and storage on distribution circuits grows, having a substantial installed base of these smart inverters on a circuit can increase the circuit's hosting capacity, making room for more solar on the circuit without the need for costly voltage regulation equipment. That's because each inverter that's compliant with IEEE-1547-2018 can regulate voltage.

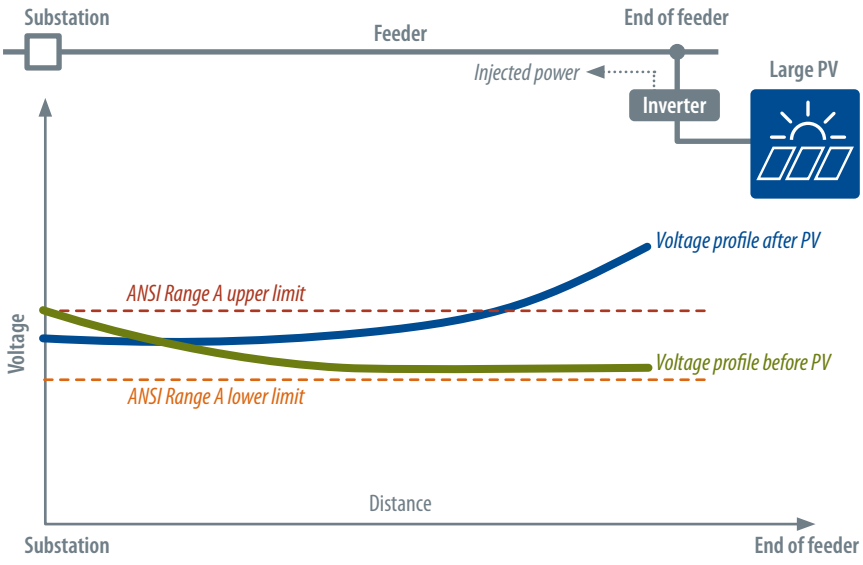
The voltage issue is illustrated in the image on the right from consultancy GridLab. At the top right, the illustration shows "large PV" added at the end of a distribution circuit, or feeder. The graph in the image shows that the voltage profile, as it approaches the end of the feeder at right, exceeds the recommended upper limit for voltage. That problem needs to be avoided.

GridLab says the solution is to use smart inverters and harmonize smart inverter settings, so the smart inverters can help regulate voltage on the circuit and increase the circuit's hosting capacity.

GridLab recommends that each state should specify the use of two smart inverter capabilities: first, Volt-VAR, which requires no communication signals from the utility, and second, Volt-Watt, which GridLab calls a backstop for voltage events. California requires both of these settings – Volt-VAR and Volt-Watt – while Hawaiian Electric requires Volt-VAR.

The Center for Renewables Integration phrases its advice a bit differently, saying that the voltage control capabilities of IEEE-1547-2018 inverters should be

Voltage issue for a large PV system without smart inverter capabilities Source: GridLab



> *"It will be harder for inverters installed in the future to make up for the earlier inverters' lack of voltage control"*

used, as well as the inverters' ride-through capabilities.

"It's important to act sooner rather than later" in utilizing smart inverters' voltage regulation capability, says IREC Chief Regulatory Engineer Brian Lydic. As more inverters that don't regulate voltage are installed, he says, it will be harder for inverters installed in the future to make up for the earlier inverters' lack of voltage control.

And if smart inverters are installed without their voltage regulation capability turned on, it will be more expensive to turn on that function later, he says, suggesting that it may require site visits.

Smart inverters also can provide grid services, for which owners of solar and storage deserve compensation.

Grid consultant Michael Milligan has said that inverters form the basis of the grid capabilities of solar and storage: the very fast response of inverters enables rooftop solar, for example, to interact with the power system.

The table below, developed by Milligan, shows the seven types of grid services that various types of generation can provide. The second and third columns of circles show that both solar PV and battery storage can provide good, very good or excellent grid services in all seven areas.

One existing means of accessing the grid services capabilities of distributed solar and storage involves a utility or an aggregator issuing communications calling on grid services. This approach requires distributed solar with hardware responsive to a utility's or aggregator's communications.

GridLab is developing a case for an autonomous grid to allow distributed resources to respond to passive signals: price, voltage and frequency. GridLab's executive director Ric O'Connell has said "we believe these three are all you need for most distributed energy resources."

The IEEE-1547-2018 standard comes with grid-supportive features that allow distributed solar and storage to autonomously respond to grid signals.

Pennsylvania's pilot

A contest is playing out in Pennsylvania over whether distributed solar and storage must be centrally controlled – for example, to manage voltage – or may provide such grid services autonomously. Also at issue is whether owners of distributed solar and storage will be compensated for the grid services they provide, and at what price.

The contest began in 2019 when solar installer Sunrun challenged a plan by investor-owned utility PPL to "monitor and manage" all new distributed energy resources. Sunrun said in a state regulatory filing that PPL aimed "to require customers to relinquish control" of new distributed solar and storage resources, and allow the utility to manage these resources without compensation.

The environmental group NRDC, joined by solar industry representatives, also objected to PPL's plan, saying in a filing that "nothing in the plan seems to contemplate that distributed resource owners and operators would be compensated."

Last December the Pennsylvania Public Utility Commission approved a settlement – to which Sunrun was not a party – that sets up a three-year pilot test of two approaches. One approach will be that proposed by PPL, which requires the use of inverters that enable the utility to manage distributed resources – in what is often called a distributed energy resource management (DERM) system.

The other approach will allow new distributed resources with smart inverters to respond autonomously to voltage signals. The smart inverters used in this approach will have the Volt-VAR setting selected, and may use Volt-Watt if the interconnecting customer agrees, says Harry Warren. Ride-through settings, he adds, will be in accordance with recommendations from the PJM grid operator. pv

William Driscoll

Smart Inverter grid service capabilities

Source: Michael Milligan, Milligan Grid Solutions

● Excellent
● Very good
● Good
● Limited
● Incapable

	Inverter-based			Synchronous				Demand response
	Wind	Solar PV	Storage / Battery	Hydro	Natural gas	Coal	Nuclear	
Disturbance ridethrough	●	●	●	●	●	●	●	●
Reactive and voltage support	●	●	●	●	●	●	●	●
Slow and arrest frequency decline (arresting period)	●	●	●	●	●	●	●	●
Stabilize frequency (rebound period)	●	●	●	●	●	●	●	●
Restore frequency (recovery period)	●	●	●	●	●	●	●	●
Frequency regulation (AGC)	●	●	●	●	●	●	●	●
Dispatchability / Flexibility	●	●	●	●	●	●	●	●

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PV for biodiversity

PV's contribution to a cleaner future can go well beyond generating emissions-free energy, but maximizing the opportunity is not always straightforward. Ragna Schmidt-Haupt, partner at Everoze and a board member at Skyray, argues that investors and lenders have to start making decisions today to fulfill the required disclosure regulations and make sure their fleet has a positive impact on biodiversity. The key challenge is to weigh the techno-economic-ecological risks, opportunities, costs and revenues.

SFDR and NFDR, EU taxonomy, Green New Deal, COP15 and COP26, Equator Principles, TCFD and TNFD – keeping track of the whirlwind of ecological sustainability regulations and recommendations can be a real challenge. One thing is clear, though – the application of the do-no-significant-harm principle of the EU taxonomy means that, while solar PV significantly contributes to at least three of its six environmental objectives, it still needs to prove no significant harm to the other three. Given the scale and demand for land resources, a particular focus for PV is likely to be the protection and restoration of biodiversity and ecosystems.

Since publishing the "PV for Future" article in the January 2021 edition of **pv magazine**, which argued that putting ecological sustainability at the heart of PV project planning and operation should become the new industry standard, the situation has already changed.

Given that the first EU Taxonomy disclosures are due by the end of 2021 and throughout 2022, it is key to start aligning with its rather complex and extensive framework. In the near term, the financial industry will allocate capital predominantly toward the best of the best in terms of biodiversity and wider ESG aspects (environmental and social governance).

PV projects have been recognized by multiple studies as a contributor to improved biodiversity outcomes, when done right. Aside from the German and Spanish solar industry associations BNE and UNEF – both of which have published best practice checklists for PV developers and owners to incorporate environmental benefits – further industry guidelines have followed. In May 2021, Everoze co-authored the sustainable agrisolar best practices guidelines and the sustainability best practices benchmark, published by SolarPower Europe. Both emphasize biodiversity measures and environmental and ecosystem services of solar parks.

So what can solar investors and lenders do to provide evidence of their biodiversity actions? What will the "best of the best" projects be doing for biodiversity?

To start with, there is low-hanging fruit at low cost and small effort. On the other side, there are big impact measures that may require a painful cut to installed capacity, and hence revenues. With a current lack of revenues attributed to necessary biodiversity measures, the decision is complex. On the one side it depends on the level of commitment of the investor or lender, but on the other, the decision may be influenced by the potential need to make up for a more harmful impacts across the portfolio.

Low-hanging fruit

Which measures actually enhance the biodiversity of a solar park, going beyond the mitigation requirements from the environmental impact assessment?

Studies have shown the clear benefits of less frequent grass cutting, mowing later in the year or changing the mowing techniques to more insect -friendly methods, for example, by leaving the clippings or using specialized machines. It has also been shown that not using fertilizer and pesticides, as well as planting and maintaining wildflower and nectar seed meadows (with local seeds), are beneficial to fauna and flora. Clear commitments to not using toxic and only environmentally degradable cleaning products are clearly linked to biodiversity and ecosystem enhancement. Allowing safe wildlife corridors for crossing animals to connect habitats are also in the range of easily implementable measures. Other cheap and easy measures include installing and maintaining animal shelters such as bird houses, ponds, bat boxes, insect hotels or stone piles for lizards.

A detailed understanding of the local environmental conditions is critical to ensure that a given measure delivers max-

Strategies such as spreading wildflower seeds beneath an array mean that solar can make a significant contribution to a region's biodiversity. The best approach will be highly site-specific, supported by careful management.

Photo: Christina Grätz/Nagola Re GmbH

imum ecological benefit, and even to mitigate against potential harm from badly designed or implemented interventions.

Big decisions

Some of the big impact measures, however, such as more panel row spacing or the reduction of ground cover ratio, stir up heated debates, since these have a direct impact on the installed capacity of the plant. How much light is required to spur biodiversity, and what about differing climates? The benchmark of 1 hectare for 1 MWp installed PV, as recommended by the German BNE guidelines, seems unambitious. The recommendation from the Spanish solar association UNEF of 2.5 hectares per MWp installed on flat terrain takes into account the use of tracking and bifacial technology and higher irradiation angles. It also allows for more sunlight to hit the ground. Or should the limitations be related to the module cover, as outlined in the SolarPower Europe agrisolar guideline, of 50% for south-north and of 60% for east-west facing ground-mounted systems? And what does this cover include, exactly?

In light of competitive PV tenders, cut-throat negotiations around corporate PPA terms, and a lack of compensation for biodiversity and ecosystem protection measures, efforts to reduce the installed capacity for biodiversity measures are clearly hot potato issues.

PV for today

With the "EU sustainable finance disclosure regulations" coming into force last March, new transparency rules on sustainability risks in financial investment products and adverse effects have been established. With the recent publication of the "biodiversity target-setting" guide as part of the UN principles for responsible banking, it is recommended to assess and improve all solar PV projects to ensure that they are truly sustainable across the spectrum of ecological objectives and financeable into the future. Simply relying on the belief that solar is "green" enough because of the zero-carbon emissions from its generation is no longer enough.

A holistic techno-commercial-ecological approach is required. With the help of a recently developed biodiversity decision management support tool, Everoze can add ecological perspective to the technical due diligence scope of reviewing technologies, production, contracts, permits, financial models, or business cases, aided by external experts where required.

This is the first step for solar in minimizing damage or regenerating the depleted environments of a world in climatic and ecological crisis. Moreover, further action is required around wider ESG aspects, such as carbon footprint accounting, supply chain tracking and lifecycle assessment. The key is looking ahead and a holistic mindset. PV *Ragna Schmidt-Haupt*

About the author

Ragna Schmidt-Haupt *is a partner at Everoze, a technical and commercial energy consultancy specializing in renewables, storage, and flexibility. Schmidt-Haupt has a strong background in finance and strategy consulting across renewables technologies, with an emphasis on solar PV.*

Rethinking solar sustainability

There's more to solar sustainability than recycling, energy intensity, and materials, argues Jan Mastny, a PV industry veteran and the head of global sales, wind and solar, for Studer Cables AG. He argues for the notion of sustainability within PV to be radically expanded.

"We must examine more aspects for the unique PV industry, including political sustainability, corporate sustainability, and industrial sustainability"

When using the word sustainability in the PV industry, most industry participants would relate it to the technical or quality aspects of a PV system, along with the commercial (bankability) aspect. However, these are just two elements of sustainability. We must examine more aspects for the unique PV industry, including political sustainability, corporate sustainability, and industrial sustainability.

Political sustainability becomes evident with perspective. Looking back some 15 to 20 years ago, countries like Japan, Germany, and the United States were the global leaders in solar. Why? Their technological and manufacturing structure was on a level that allowed, what was at the time, large-scale production. It is worth noting that 50 or 100 MW of production capacity was a decent-sized manufacturer in those days.

At that time, such large-scale production would have little value if the governments in those countries didn't demonstrate sufficient enthusiasm to politically support the commercialized use of PV technology at both residential and industrial scale – essentially, market-forming subsidy programs. Members of the German PV community might still remember the "1,000 roofs" program to support residential installations, which was later replaced with the "100,000 roofs" program as a sign of the great success of the original idea.

I am not a supporter of political interference in the PV market. In saying that, however, I understand the importance of subsidy programs. Especially at the point that an entirely new technology is introduced, like solar, which offered the potential to be a game-changer in a reasonably short period of time.

It is also key to understand that sustainability in the political perspective also necessitates the ability to politically withdraw from the evolution of the industry at the moment the market can stand on its own feet. It should then continue to develop on the basis of standard market-driven mechanisms.

Political influence

It should also be acknowledged that during the early stages of development of the PV market, there were also occasions when political action or inaction caused enormous shakeouts of the industry; some markets collapsed quite literally overnight. The experience of Spain or the Czech Republic some 10 years ago are perfect examples. The scars from those experiences are still present, and some could argue these markets have not fully healed, and continue to present some obstacles in today's booming PV industry.

Of course, there are additional aspects to "political sustainability" that includes anti-dumping and other trade related disputes. But from these examples alone, the importance of this, at times overlooked, aspect is clear.

Corporate sustainability is another factor which played an important role in the evolution of the PV industry. The history of Berlin-based manufacturer Solon is an illuminating example. Solon used to be one of the synonyms for high-quality, made-in-Germany modules. They grew from a garage-sized company up to a sizable corporation with manufacturing across several continents. Sadly, the company's fall was about as fast as its growth.

Highly regarded cell producer ErSol is another example. The company was sold to the Bosch conglomerate at a peak time for the PV market (in terms of profitability), only then to be sold on again by Bosch to SolarWorld when prices were in rapid decline.

There are hundreds of other examples right around the globe. After enormous industry growth there was decline, which was sad to witness. Regardless of whether it was a startup or a large corporate conglomerate, and independent of location, product portfolio, or business structure, companies fell. Each one had its own story and an argument as to its viability.

Photo: dhp echnology AG

Integration with e-mobility will likely be a component of the sustainable solar industry of the future.

Lessons from failure

For many of the fallen, there was one common aspect at play, which was an inability to survive rapidly changing market dynamics. These companies were unable to maneuver aspects of political sustainability in various countries, and unable to create a loyalty-bond with their customers. Finally, many of the failed companies failed to manage cashflows, making ill-timed investments that were instrumental to their downfall.

The message here is that a dominant focus on creating profit cannot be the core definition for a successful solar company. A company that doesn't pay attention to its social influence, which does not make the effort to think outside of the box (which is not a cheap endeavor) loses the ability to differentiate itself from the competition.

Given this, such a profit-focused company has no right to survive in today´s aggressive global solar marketplace. This naturally applies to most companies worldwide. What is different in the PV industry is the exceptionally fast-paced, cost-sensitive, and at the same time, expensive innovation. If we add the fact that the industry is very young and inexperienced, then a small mistake can lead to enormous damage in the not-too-distant future.

Industrial sustainability can also be interpreted as industrial adaptability and integrity. The evolution of the PV industry is not a standalone project. Luckily, over the decades, the industry has benefited from many visionary people. We do not speak of PV in order to have an "exotic" way of sourcing electricity for our homes and lives. We also do not speak of PV as an instrument for generating profit for speculative investors. Rather, the core of the PV industry is the potential to be a trendsetter.

The PV industry should and must be one that has the ambition and potential to replace a significant portion of fossil fuel energy. The solar industry has the potential to be both beautiful and functional as a part of modern architecture. It is an industry that is driving new concepts such as energy independence and the storing of energy in a distributed fashion. PV is undoubtedly one of the most important factors if the vision of "Smart Cities" is to become a reality.

If we look over all the PV-related companies around the world, what would be the predominant characteristic? Production of super cheap products alone is not sustainable. In such a case, future growth, innovative thinking, and a sustainable pathway cannot be assured.

This means that the companies that have the ability to produce more than just a module of laminated cells will be writing the future of further industrial growth. It is not about collecting the sun's rays and generating DC power. It is about bringing fast, reliable and safe ways of generating and storing power. Sustainability from an industrial point of view is about bringing new solutions for energy systems. One example of many, e-mobility networks, illustrates how PV has the potential to be an integrated part of the wider technological ecosystem. pv

Jan Mastny

> *"Sustainability from an industrial point of view is about bringing new solutions for energy systems"*

About the author

Jan Mastny *has been active in the PV industry since 2005 and has worked with several leading PV components manufacturers – previously with Onamba Japan, since 2015 with Leoni, and now with Studer Cables AG. He is currently responsible for global sales and support for wind and solar and market development. He has worked in R&D and product development and is involved with several international working groups and task forces.*

Bridging the BIPV gap

Architects and construction companies are being offered an ever growing array of Building Integrated Photovoltaics (BIPV) products, with their needs for safety, speed of construction and aesthetics in mind. But can it drag BIPV beyond niche status?

Earlier this year, Toronto-based Mitrex was involved in quoting for the supply of limestone cladding product. Instead of the conventional cladding, company CEO Danial Hadizadeh instead offered a BIPV product, "at a competitive price, that can give you the same look and have a faster installation," says Hadizadeh. "This is the construction world, not the PV world."

Mitrex Integrated Solar Technology released its BIPV product portfolio in early 2020. The products were some five to six years in development, with Hadizadeh having identified a gap he thought could be bridged – that between the construction industry and the makers of BIPV products.

CNBM expects some

750 million m²

of new building facade in China to utilize BIPV over the next five years – around 100 GW in generating capacity

"Our main difference is knowing how to install these panels. The real advantage is the installation method – how fast we can install them and how close they are to other [construction] products," says Hadizadeh. "They [construction companies] don't care about how to run the wires, they want to look at the building and make sure it is done in two or three months or two or three days, depending on the project."

Mitrex modules

With an eye to the exacting demands architects and builders have, Mitrex has developed a frontside coating technology and deployed a novel backsheet concept on its cladding product. Encapsulating crystalline silicon cells in a glass frontsheet, the product uses a honeycomb backsheet material – delivering light weight, strength and also an ideal material for affixation onto a building surface.

"By adding the honeycomb, we can control better the temperature on the solar cells and at the same time create a hanging system for a facade," says Hadizadeh. Alongside its facade product, Mitrex also supplies more conventional modules for roofing, semi-transparent modules for windows and a BIPV railing solution for balconies and balustrades.

While it won't reveal much detail, the Mitrex coating technology allows its facade modules to be produced with a range of colors and textures – so that they resemble stone textures like limestone or granite, along with a wood finish and a wide range of colors. Mitrex says that it is a multi-layer coating process, whereby the color and texture elements are introduced into the front glass, rather than on the surface, for durability.

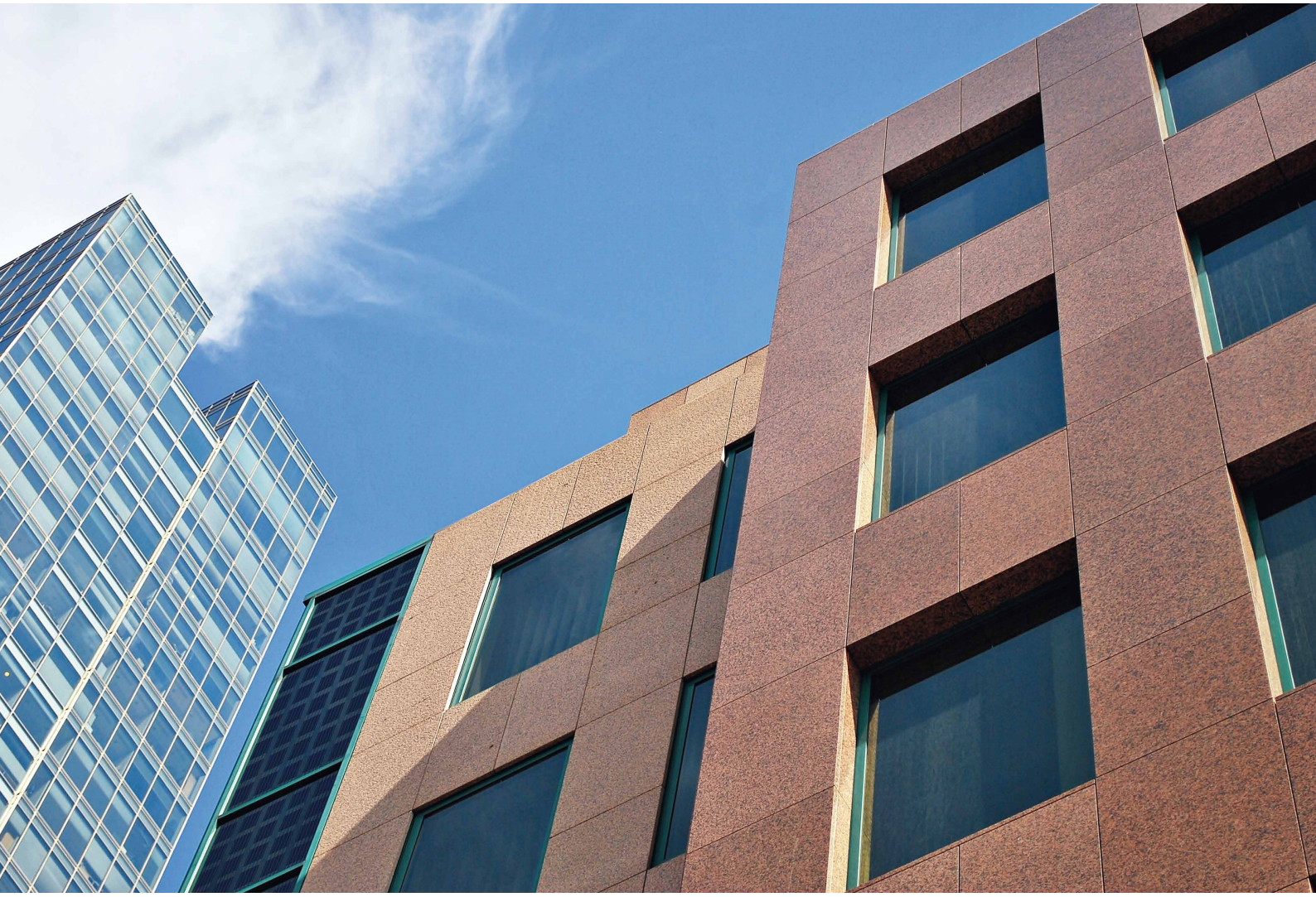
"Our coating is actually within the layer of the glass," says Hadizadeh. "Sometimes we are 2 microns within the glass, it all depends on the type of coating and the colors that we are creating." While some efficiency is lost due the light reflected by the coating, the Mitrex CEO reports that by tuning the material to allow for light waves of a certain bandwidth to pass through, modules with some patterns achieve close to 99% of the power output of a conventional solar panel.

Construction mindset

Mitrex is a part of a group of companies active in developing and manufacturing construction materials including Cladify and Stone Lamina – under the GCAT Group. Cladify has almost 20 years of track record in the construction industry.

Hadizadeh reports that Mitrex initially addressed the Canadian construction market after its launch, but has just opened offices in Los Angeles and New York. It targets 4 million square feet (1.2 million m^2) of BIPV installations through to 2023.

Photo: Mitrex



Mitrex says that it has developed its cladding BIPV product so that it can be installed quickly and that it is almost unidentifiable as a solar product.

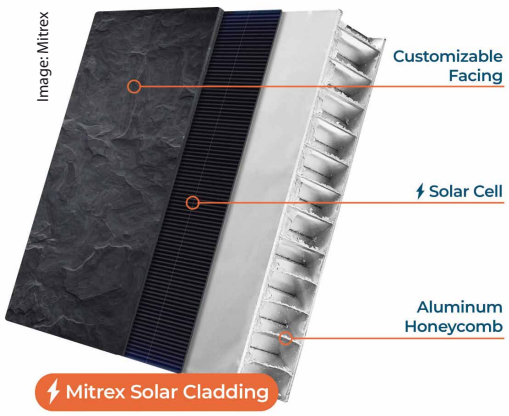
The arrival of building material companies to BIPV is not entirely new. China's CNBM Group entered the segment with its acquisition of CIGS pioneer Avancis in 2014. It maintains some German production capacity for its Skala module series, which comes in 11 colors, ranging from black and grays, through to blues, greens, gold and bronze.

CNBM operates three production sites across China for its CIGS BIPV modules – a combined nameplate capacity of 600 MW. However, it has recently pivoted to cadmium telluride (CdTe) and intends to establish CdTe manufacturing facilities for its new Colored Solar Glass product, with a capacity of 1 GW "across several sites" in China.

The Colored Solar Glass product from CNBM is a large format, at 1.92m², and comes in power classes from 110 W through to 180 W. Using 3.2 mm tempered glass, the module weight comes in at around 31 kg.

Regarding aesthetics, the CNBM CdTe glass features "controllable color and adjustable light transmittance" by virtue of a "triple lamination" of the front glass, using "high temperature color glaze and UV photosensitive ink" – according to CNBM. Patterns can also be applied to the front glass. The company reports that the new product has already been supplied to building projects in Shanghai, Sichuan and Hebei.

The traction that CNBM has had in the construction sector with its CIGS and, now, CdTe modules is difficult to ascertain. But its expectations for the segment are clear. CNBM says that over the next five years, some 10 billion square meters of building surface area is expected to be added, to an existing 60 billion. Of that, CNBM anticipates some 750 million m² to utilize BIPV – for a generation capacity of some 100 GW. It says 3 billion m² of BIPV could be added to existing buildings in the same, representing 400 GW of PV capacity.



The front coating and honeycomb backsheet are illustrated here.

"This product can be directly used as the roofs and walls of the buildings and has the advantages in terms of structure, function, appearance and power generation compared with other products," says CNBM.

New frontiers

While the construction companies add another quiver to their bow with BIPV, some PV producers are choosing to optimize their products for integration. Russian heterojunction (HJT) producer Hevel Solar is attempting to foster BIPV deployment in its home country and among the nations of the Commonwealth of Independent States (CIS) and bring their product to intenational markets.

Vasiliy Shikin, the head of export sales for Hevel Solar, says that the long, snowy winters in parts of Russia and CIS countries can be advantageous for BIPV. "In Russia, in some regions with the snow loads, BIPV is actually more efficient than rooftop PV – because there is difficulty to have access to the roof and clear the snow," says Shikin. "But on the vertical facade BIPV modules can be even more efficient that rooftop modules."

"When there is snow, there can be the reflection from the snow [onto the vertical surfaces] and that can boost the output and it can also be interesting." Shikin says that Hevel is expecting demand for its BIPV product from Russian and international companies active in the region that are looking to reduce their carbon emissions – although he notes that the regulatory framework in the region for BIPV is still under development. Shikin adds that Russia's so-called "green taxonomy" may be overhauled to incorporate carbon footprint monitoring – to encourage companies to reduce their emissions.

Hevel partnered with a Russian construction company to develop its BIPV product. It involves a ventilated facade mounting structure that closely replicates the system already used by construction companies for glass or other facade materials. Frameless, dual-glass versions of Hevel's HJT can then be affixed to the ventilated facade mounting system.

"We have expertise in manufacturing highly efficient HJT cells," says Shikin. "We also have customized, non-standard modules – that is why entering the BIPV segment seemed like a logical step for us." By virtue of the high efficiency, Shikin says that even with patterned or colored front glass, the Hevel modules can still deliver high power output.

Hevel's coating process involves applying ceramic to the front glass, reports

A Moscow high-rise building that will deploy the Hevel BIPV product.

Photo: Hevel

Photo: Mitrex

Daria Zhilina, a leading specialist at Hevel's R&D center in St. Petersburg. "It is ceramic ink, which is fused into the glass at high temperature during the manufacturing of the glass, making it resistant to water, to scratches, UV and to other impacts."

IHS Associate Director Cormac Gilligan says that BIPV applications have remained "relatively niche" due to the complexity of the installation process and the "increased capital cost of the BIPV system". However, he is positive about the collaborations between the construction segment and BIPV suppliers.

"Partnerships between solar technology manufacturers and roofing companies and leading homebuilders will accelerate the rate of adoption of BIPV," says Gilligan. He adds that public incentives such as tax credits or "additional payments for upfront costs" are likely required for the segment to expand – and to fund ongoing innovation. He points to SunPower spinoff Mexeon's new, lightweight "Air" module as likely opening up new applications.

The Sunrun of BIPV

In terms of business model, there is also room for innovation, and here Mitrex is introducing a leasing model that it believes will entice more building owners to adopt BIPV. While it does allow for the purchase of its modules outright, it intends to partner with the construction companies and owners through a 30-year lease.

"Not everyone wants to be the utility company, and this will limit the market and increase the prices," says Hadizadeh. "We want to switch to a model where the majority of the product we are providing is under a PPA. We will become the energy company. That is our ultimate goal and that has been our goal from day one."

"Not everyone wants to be the utility company, and this will limit the market and increase the prices"

Mitrex CEO Danial Hadizadeh

Legal frameworks for BIPV remain an impediment to more widespread BIPV adoption – and there is a decided lack of uniformity across markets. Across Europe alone, says German lawyer Sebastian Langer, there are a myriad of both construction and energy laws with which to contend. Lange is the chair of the BIPV body, the Allianz Bauwerkintegrierte Photovoltaik e.V.

"The thing is if we talk about PV, when it comes to a legal question, it is all about the energy law," says Lange. "If I talk about building integration, I talk also about all of the regulations for the buildings. It makes it very complex and you hardly find any specialist that is prepared to deal with both aspects – the energy and building side."

Lange notes that while leasing may be a promising solution for building owners, there are impediments in some countries, including Germany. "This is where it's not so easy," says Lange. "If using ordinary PV then I can just use the roof and never mind who is the owner of the PV installation. If it is within the building skin then the ownership cannot be separated, the owner of the building is automatically the owner of the PV installation. That cannot be separated." pv

Jonathan Gifford

First Solar goes to India

First Solar has announced plans to establish a new 3.3 GW manufacturing facility in India. Representing an investment of $684 million, the move demonstrates the thin-film PV manufacturer's confidence in India's solar growth and the increasingly favorable policy environment for domestic solar PV production.

Over the last few months, India has seen several announcements for PV module capacity expansion or new fab establishment by domestic manufacturers. Among these announcements for crystalline silicon cells and modules, the entry of U.S.-based First Solar has added thin-film technology to the Indian manufacturing landscape, which is currently dominated by crystalline silicon.

The U.S. manufacturer, which is also working on a 3.3 GW fab in Ohio, recently announced plans for an additional 3.3 GW factory in India at a capital investment of $684 million. The India fab, to be located in the southern state of Tamil Nadu, is expected to commence production by the end of 2023. Together with the new Ohio fab, it will double First Solar's nameplate manufacturing capacity from approximately 8 GW at present to 16 GW in 2024.

First Solar states that its cadmium telluride (CdTe) panels will be ideal for the high temperatures and humidity of India. It also claims that its PV manufacturing has a carbon footprint that is 2.5 times lower than that of crystalline silicon tech-

First Solar's new factory in India will produce its Series 6 modules, which the company says are ideal for the hot, humid conditions throughout the country.

Photos: First Solar

This project in Telangana, India, features First Solar modules. Thin-film technologies had a strong share of the Indian market share in the early part of the last decade, but they have since lost ground to rapidly expanding Chinese crystalline silicon manufacturers.

nology. More than 90% of the materials used in thin-film panels can also be recovered through recycling.

First Solar's upcoming factory is sure to reset the PV market dynamics in India, where thin-film solar products enjoyed a strong market share in the early years (2011-13) of the last decade. However, they later lost ground to cheaper crystalline silicon products from China.

The last decade

As Bridge to India reports, around 45-47% of the PV modules used in India in 2011 and 2012 were thin-film panels. At that time, First Solar was the leading module supplier to India, commanding more than 20% market share.

"In fact, First Solar had a very good market share in India until 2016-17. The company has kept on growing year on year worldwide on a total volume basis. The only reason why their business almost completely stopped in India after the 2017-18 timeframe, was their small manufacturing capacity in comparison to the Chinese companies," Vinay Rustagi, the managing director of Bridge to India, told **pv magazine**.

"At that time, thin-film technology was very popular, and there were lots of manufacturers from U.S., Korea, and Japan," he added, in reference to CdTe PV's stronghold in the early years of the last decade. "The share of thin-film versus crystalline silicon solar was much higher. The crystalline technology capacity was very small because the Chinese companies had not started setting up mega plants at that time. Technology- and cost-wise, the two technologies were on kind of equal footing in the early days."

First Solar was bidding in Indian tenders, winning utility-scale PV projects and also doing project development with its modules. However, the share of thin-film solar in India shrank as much cheaper crystalline silicon panels from China made their way into the market.

"The Chinese companies started investing heavily in the crystalline silicon solar technology. They expanded their capacities and brought down the cost. And that wiped out all the thin-film manufacturers, one by one from Korea and Japan. And so, First Solar was the only remaining company in thin film but they could not expand as rapidly as some of the Chinese companies. So, they also lost their market share in relative terms [in India]."

Under such a scenario, First Solar's focus shifted away from the very price-conscious Indian market to other countries where it could get better prices for the modules.

"Even today prices in India have always been the lowest in the world. Until one year ago, even the Chinese companies were selling modules in India at prices lower than in their own country. So, if First Solar doesn't have enough capacity, and they can sell everything in the USA and Europe at higher prices, obviously that is what they would prefer. So that is the only reason why they stopped selling in India. There is no policy reason, and there are no operational or performance reasons," said Rustagi.

Current business

Like other PV module manufacturers throughout the world, First Solar later decided to sell its developed assets in India, as in other parts of the world, and focus on its core strength of module making. With this approach, it got to recycle capital for future expansion while creating a portfolio of de-risked assets with predictable, reliable cash flows for financial investors in renewable energy.

For instance, in 2017, IDFC Alternatives, one of India's largest alternative fund managers, completely acquired 190 MWac of operating solar projects owned and operated by the First Solar Group

> *"Together with the new Ohio fab, it will double First Solar's nameplate manufacturing capacity from approximately 8 GW currently to 16 GW in 2024"*

First Solar plans to expand its manufacturing base into India, with a 3.3 GW plant to be built in the southern state of Tamil Nadu.

in the Indian states of Andhra Pradesh and Telangana. All of the projects utilize First Solar's CdTe based thin-film modules, and sell the power generated to state utilities under long-term power purchase agreements.

At present, First Solar is believed to have an installed base of about 1.8 GW of modules in India.

> *"The policies by some countries (including India) to promote their domestic manufactruing provide a major opportunity for expansion in such markets"*

Local manufacturing

The India fab move comes at a time when the U.S. government has imposed restrictions on crystalline silicon module imports from China in view of alleged forced labor practices in polysilicon factories in China. As a result, demand for First Solar modules is expected to increase domestically in the United States. At the same time, the rise of Covid-19 cases and potential preventive restrictions in other countries where First Solar operates PV factories (Malaysia and Vietnam) present risks to the company's production, supply chain, and technology implementation plans.

Expanding manufacturing to other locations will help First Solar to mitigate such risks. The policies by some countries (including India) to promote their domestic manufacturing provide a major opportunity for expansion in such markets.

Further, locating additional manufacturing capacity near to the source of demand provides First Solar with the advantage of reduced sales freight costs.

"Whether it is the U.S., Europe, Japan, or India, they're all in the same boat. They're all coming on to all kinds of policies to restrict the use of Chinese modules. The U.S. is basically suspending Chinese modules because they're concerned about labor issues. India has imposed [the requirement for module suppliers to get enlisted in] the Approved List of Models and Manufacturers (ALMM) and basic customs duty (BCD) from next year onwards."

"First Solar is one of the very few non-Chinese module companies today … It is almost the only non-Chinese company in the top 10 largest PV manufacturers. With all these kinds of restrictions, the market suddenly looks much better for them [First Solar] and they believe that they can get better prices in all these countries."

Rustagi estimates the price differential between First Solar modules and imported Chinese modules to be around 10-15% in India. The cost challenge should be overcome as basic customs duty on panel imports from China comes into effect from April next year. Furthermore, manufacturing locally, on a large scale, should make thin-film modules price-competitive with other domestically produced modules.

First Solar says its technology is uniquely advantaged in the Indian market due to its temperature coefficient and spectral response advantages, which can result in higher energy per watt installed than crystalline silicon due to the effects of heat and humidity.

The investment looks all the more promising going by First Solar's announcement at a recent meeting of investors. "The next-generation factory [planned in India] represents a significant leap forward in our technology roadmap and will produce our most competitively advantaged modules with an expected lower cost per watt and environmental footprint compared to our existing fleet," stated First Solar. pv

Uma Gupta

U.S. SOLAR AT A GLANCE

19.2 GW

solar **installed in 2020**

In 2020, 27 states installed over **100 MW** of **new solar capacity**

AND THE MOMENTUM CONTINUES INTO 2021

Q1 2021 **installations up**

46%

from Q1 2020

Cumulative solar capacity is expected **to pass**

100 GWac

in 2022

Solar made up

58%

of all new generating **capacity added** in the U.S. in Q1 2021

Utility-scale solar **set a record** for first-quarter installations at **3.6 GW**

Texas added **more than**

1.4 GW

of solar in Q1

TOTAL OPERATING PV FLEET WILL TOP 250 GW BY YEAR-END 2026.

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Both sides for C&I

The commercial and industrial sector has been called the underdog of the U.S. solar market, as it usually plays second fiddle to its larger, more visible residential and utility segment siblings. But C&I's ultimate multi-gigawatt potential has never been in dispute. Aaron Thurlow, general manager at Longi Solar, makes the case for bifacial technology in the C&I segment.

A 2020 report by Wood Mackenzie has estimated that there is enough unused commercial rooftop space in the United States to accommodate 145 GW of solar. Some 600,000 sites, or about 70% of the total commercial real estate building stock in the U.S., could be solarized.

"There is enough unused commercial rooftop space in the United States to accommodate 145 GW of solar"

The latest U.S. Solar Market Insight report shows commercial solar experiencing a serious growth spurt. Several factors are at play in the growth trend, including an extended federal Investment Tax Credit, multiple state-level incentive programs, and an increased interest in environment, social and governance (ESG) investments.

Years of industry efforts to reduce friction points and create more compelling system economics in the C&I sales and development process are also finally helping the sector achieve its long-term promise. Better financing options, the emergence of energy storage, advanced software modeling and sales tools, construction efficiency, and the streamlining of permitting and interconnection are all contributing factors as well.

On the module level too, there is an innovation that is already changing the utility solar space, which shows the potential to help take the commercial sector to the next level of system performance as well – bifacial solar modules.

Already compelling

Bifacial solar modules are not new, but have only recently emerged at scale and at a price point that is competitive with monofacial modules. They offer several key advantages on which the utility segment quickly focused. The same value propositions that make bifacial such a compelling option in the utility space could apply to the C&I market and its core rooftop segment, which is often overlooked for bifacial.

More energy density, lower labor and balance-of-system (BOS) costs, increased lifetime plant performance and the like combine to make bifacial an attractive, bankable option offering better returns for larger rooftops. Because bifacial modules generally produce more kWh/kWp, there is built-in design flexibility and optimization possibilities – system output could be upsized, or keep the rated output achieved using fewer modules and BOS components.

There is a misconception that the backside performance of a bifacial module must be optimized to have a better project return; however, this is not the case now that bifacial module pricing has come down to within a penny or two per watt of monofacial. Bifacial provides real value to rooftop installations today even without backside power optimization.

Enhanced resilience

Since many bifacial modules use a glass-glass design, they are sturdier and more resistant to fire. Bifacial modules also degrade more slowly than standard monofacial modules, resulting in performance warranties being extended to 30 years. A slower degradation curve coupled with five more years of warrantied power makes a major impact on the system LCOE and lifetime output; and may also allow for better financing options.

Of course, the largest potential benefit is the inherent bifacial energy gain – somewhere between 5% and 25%, depending on albedo, site design and other factors – coming from the rearside of the module. Keep in mind that the bifacial gain is not included in many modules' spec sheet

power rating (including the specs from Longi, the world's largest bifacial manufacturer): The gain is additive to nameplate. So a 445 W bifacial module is effectively more like a 490 W module.

Using an example where less capacity needs to be built, a 500 kW bifacial PV rooftop system with 8% average gain, built at a cost of $2/W, would actually end up with a saving of $80,000 compared to a monofacial system of the same size. A 500 kW install would require 1,124 445 W monofacial modules, but a bifacial array would only require 1,034 bifacial modules. Plus, this back-of-the-envelope calculation does not factor in a longer system lifetime or a slower degradation curve.

Photos: Longi Solar

Results from test arrays have shown that bifacial modules can offer a 5-15% boost to energy yield on commercial rooftop installations. Racking system designers will need to design new solutions that place the modules slightly higher off the rooftop, while taking into account wind effects.

Better option

Mainstream bifacial-on-rooftop applications are still in their infancy. If the industry pools its resources, bifacial could become a significant optimization change-maker for future commercial projects. There are several areas where the industry can come together to accelerate the growth curve of rooftop C&I by leveraging bifacial's full set of advantages.

Bifacial modules have the ability to disrupt the C&I rooftop segment and catalyze significant market growth. For this to happen, there needs to be the same kind of focus that we have seen in the utility sector.

Ultimately, determining the bankability and suitability of bifacial modules for C&I projects must include accurate inputs on both site and design conditions as well as the modeled and actual performance benefits of additional backside generation. Holistic analyses of these factors will allow for the superior LCOE of bifacial modules over monofacial to be demonstrated.

Optimizing racking

There are a handful of options for bifacial-optimized racking on the market today, however most if not all of the top-tier racking and mounting suppliers have yet to offer a true bifacial option.

Just as the major solar tracker companies have been working closely with the module suppliers to integrate and optimize the two components into one harmonized system to maximize bifacial production, the rooftop hardware community and module companies also need to collaborate and join forces. The reward will be faster growth and a larger rooftop C&I segment.

Although there is plenty of bifacial testing, it is nearly all ground-mount based, either on fixed-tilt arrays or single-axis trackers. There are few third-party testbeds looking at bifacial on rooftops.

The Renewable Energy Test Center (RETC) has a small rooftop bifacial test system. Results shared at the National Renewable Energy Laboratory's Reliability Summit earlier this year revealed the array was customized with a fairly extreme tilt of 30 degrees (something that would hamper the frontside energy harvest) and height of about 1-1/2 feet. This configuration is better suited for measuring bifacial gain than for providing data to inform a model for a practical bifacial rooftop mounting and racking system.

Nonetheless, the data is encouraging: across different albedos and seasonality irradiance scenarios, the RETC test array showed an average rooftop bifacial energy gain of 5-15%. This is on par with

> *"Mainstream bifacial-on-rooftop applications are still in their infancy. If the industry pools its resources, bifacial could become a significant optimization change-maker for future commercial projects"*

Photo: Longi Solar

Bifacial modules have proven advantages in ground-mounted PV projects. With the right racking structure and system design, similar boosts in energy yield from light reflected onto the rear side can be achieved in rooftop installations.

results found in comprehensive ground-mount testing. If the conditions are right, whether on the roof or the ground, bifacial technology does enhance the energy harvest of solar modules.

Another area the industry needs to examine is the potential wind-load effects on rooftop-mounted bifacial module arrays. The modules are slightly heavier than monofacial units, which creates an advantage in hauling less ballast onto a roof for current system configurations.

However, since bifacial-optimized racking is likely to be mounted higher off the roof deck (at a roughly 15-degree tilt), this results in a different wind envelope than would be seen in a standard ballasted or roof-penetrating mounting system. Rack designers will need to optimize tilt and open-back designs with wind loading to find the best solutions.

Model evolution

Performance modeling is another area where more resources should be devoted. For example, while PVsyst 7 includes features to help site designers model for bifacial PV integrated on ground-mount trackers, it offers no options for rooftop bifacial systems. Folsom Labs' Helioscope design software does not yet support bifacial calculations although it's a leading feature request.

Modeling tools should be developed, but the stakeholders have yet to mount a concerted effort to make bifacial on rooftops a priority. Perhaps some variation on ray tracing and view factor bifacial performance modeling approaches would be applicable for rooftop systems, for example. pv

Aaron Thurlow

About the author

***Aaron Thurlow** is the general manager of distributed generation for Longi Solar U.S. He has more than 20 years of experience driving new technology and product adoption in the solar industry.*

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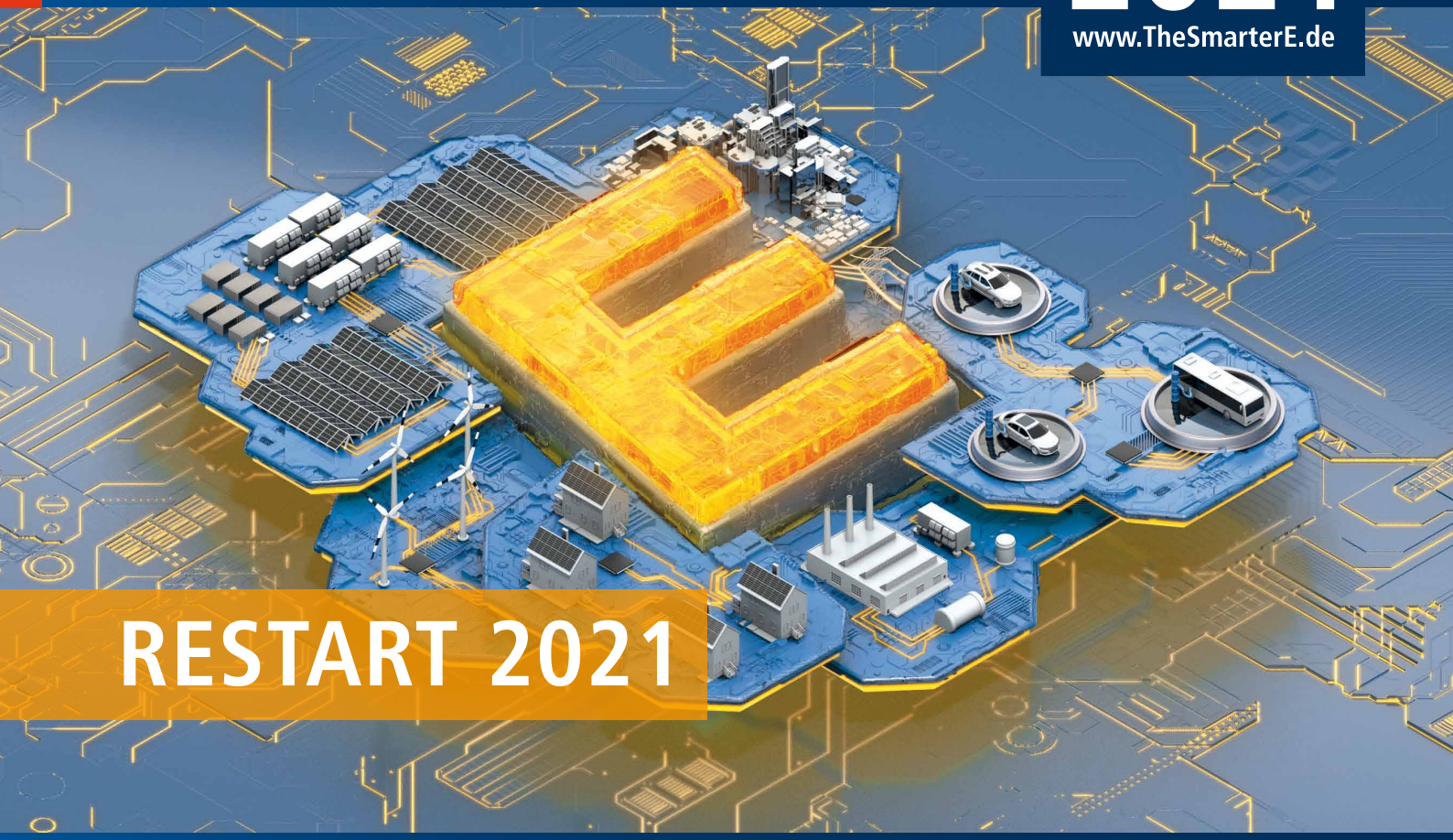

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Current affairs

The PV manufacturing industry's switch to larger wafer formats is already having impacts all the way down the supply chain – some of which are still emerging today. For junction boxes that house bypass diodes and other components that keep the power flowing out of a module, handling the higher currents produced by these larger products has been a challenge requiring a quick response. Meanwhile, a notable number of failures and quality issues with junction boxes new and old suggest that the design and processing of this vital component could be in need of renewed attention.

Though not often afforded a lot of publicity, junction boxes are vital to the safe operation of a PV module; housing all of the connections that ensure electricity can make its way out of a module, and ensuring that this flow stays in the right direction. And like many of the components along the PV production line, recent developments in cell and module technology have placed new requirements on the junction box (JB).

"The biggest challenge with larger cell formats is the increased electrical current," says Roman Giehl, technical business development manager at JinkoSolar Europe. "Connectors and diodes must be adapted, the junction box itself must cope with higher currents, and heat dissipation must be improved."

"Developments in cell and module technology have placed new requirements on the junction box"

Giehl goes on to note that earlier changes in module design have also led to changes in the junction box, for example with the introduction of half-cut cells. And though the challenge this time is much bigger, with the combination of both large format and bifacial pushing the rated currents beyond 25 amps for some modules, manufacturers have already been able to produce junction boxes suitable for these conditions.

Canadian Solar, a module maker that also manufactures junction boxes through its TLIAN subsidiary, says that the increased current in its latest BiHiKu7 range of modules, which utilize 210 mm wafers, required it to redesign the junction box with particular attention to thermal runaway requirements.

"Higher module currents require new junction box designs (both structure and diode) to meet reliability requirements according to the IEC standards," Canadian Solar Chairman & CEO Shawn Qu told **pv magazine**. "We started module and junction box development at the same time, and have overcome these challenges before mass production."

Big or bigger

In a white paper published in August, module manufacturer JA Solar and TÜV Nord examined the impact of higher currents across PV system components. For junction boxes, the paper finds that the largest modules being introduced to the market would require a junction box rated to 30 amps, and would still offer a lower safety margin than a smaller module with diodes rated for 25 amps.

"To ensure the current-carrying capacity of the junction box diode, it is recommended that the rated current of the junction box should be greater than 1.25×Isc (short-circuit current) for monofacial modules. In terms of bifacial, we should also consider 30% gain as well as approximately 70% bifaciality," states JA Solar. "Even if a 30 A junction box is adopted, the safety margin for super-large current module B is still significantly lower, and the risk of overload in environments with high irradiance and high temperature is significantly increased."

JA Solar compared modules utilizing the 182 mm wafers with those of an unnamed manufacturer working with

Photos: PVEL

Junction box defects can lead to heat buildup, with damaging consequences for the module.

the larger 210 mm size, again raising the question that has seen the industry divide into two camps backing either format. JA Solar found that 25 A diodes allowed the 182 mm modules to operate with a 15% safety margin, while the 210 mm modules exceeded the safety margin for 25 A by 11%, and would operate with 7% margin using a 30 A diode (see table, p. 85).

JinkoSolar has opted for the 182 mm wafer, reasoning that this offers a significant boost in energy yield over earlier module formats, with minimal disruption to other components in the module and system. "We are confident in our cell size selection, as the M10 format is compatible with existing junction boxes designs," says Giehl. "Larger sizes require new solutions due to the increase in electrical current."

Canadian Solar, and other companies backing the larger 210 mm format, are confident that the design changes needed to accommodate the high currents and other issues raised by the bigger jump up in size. China-based junction box manufacturer QC Solar also says it is ready to meet the demands of modules requiring requiring JBs rated at 30 A or higher with its new 3Q-Axis product. "QC Solar has changed the design of junction boxes, launching our 'axis diode central placed' product," QC Solar sales specialist Bruce

If the lid falls off a junction box in the field, the pottant and inner components are left exposed, and moisture can get into the circuits, causing damage and performance losses.

Xu told **pv magazine**. "Along with other design innovations this can offer high current rating and good thermal runaway capability in a very small box."

And although the diodes rated for the highest currents produced by the largest modules are slightly more expensive, the increase in module power output should more than make up for this. "Junction box costs for higher current modules are slightly higher in $/set terms, as the diodes are a little more expensive," says Alex Barrows, research director at manufacturing analyst firm Exawatt. "However, from what we've seen, this is more than offset by the module power increase – so the cost-per-watt is a little lower for the new large modules."

Quality concerns

Junction box manufacturers have quickly been able to react to the changing needs of their module manufacturing customers, and only time will tell whether the higher currents or smaller safety margins in operation lead to problems further down the line.

But other evidence suggests that even the current generation of junction boxes may not be getting the attention they deserve on some production lines, and that the component is responsible for a significant portion of issues in production and later on in the field. In the 2021 edition of its Module Reliability Scorecard, testing specialists PVEL found that one in three participating manufacturers saw a safety failure due to a junction box defect, and that the majority of failures occurred "out of the box" before any testing had begun.

The most common failures seen by PVEL were leakage currents coming from the cells and ribbons, due to faults that could be traced to the junction box. They also observed diode failures leading to loss of at least one third of the module output, and in many cases the junction box lid had simply fallen off. "I can't say that every JB issue we identify is like a ticking time bomb – the lid could fall off and nothing happens, you don't see any issues even after 25 years," says Tristan Erion-Lorico, head of PV module business at PVEL. "But your risk of having issues is higher, the modules are designed for the lids to stay on and that they don't fail wet leakage current tests."

In the most common JB designs, the electrical components are sealed inside a pottant, so should still be protected when the lid falls off, but leaving the pottant exposed to the elements, where it can eventually degrade and allow moisture to reach the electrical components increases risk – even a few drops of dew inside the circuitry could cause hours of lost output, as the inverter's ground fault checks won't allow the system to switch on until this has fully evaporated.

Manufacturing solutions

Where JB problems are spotted in the field, some basic repairs might be possible. In many cases, however, even the cost of sending workers out to walk around a

project replacing lids or diodes could be enough to make full replacement/repowering of the site the more attractive option. "At the point where you've already taken it off the rack, its going to make more sense to put back a brand-new module," says Erion-Lorico. "From an environmental perspective that's quite upsetting, that those diodes which probably cost fractions of a cent each are enough to impact a project, and you decide to throw it all out because of this tiny component."

Ensuring that JBs can match the increasing lifetime expectations for all of the module components is by far the better solution, and here the responsibility is on the module manufacturer not to cut corners in quality control or look for the lowest cost option. "The junction box accounts for around 3-4% of total module manufacturing cost; and will be more like 4-5% once polysilicon prices drop back to more reasonable levels," says Barrows. "There seems to be a reasonably wide range in costs for junction boxes – we have seen anywhere from $2.40 to $4.00 per set. No doubt some of the failures will be manufacturers opting to cut costs by going for a cheap option."

At PV manufacturing's current scale, if manufacturers can cut the cost per box even by half a penny, using a thinner plastic for example, this could save them huge amounts in production – but these savings are worth little if they lead to product recalls or widespread warranty claims later on. Module makers and buyers also need to be sure that junction boxes meet agreed-upon criteria upon delivery.

"A sample of junction boxes selected from every shipment following predefined sampling rules undergoes checks at the IQC (incoming quality control) lab, for appearance, size, connection strength between cables, box and connectors, length of cables, water ingress protection, insulation, forward voltage drop of bypass diodes," says George Touloupas, director of technology and quality at CEA, outlining the company's procedures for monitoring junction box shipments. "If these inspections fail according to the IQC criteria, the incoming shipment must be quarantined, segregated and clearly marked, until more detailed investigation decides if it can be used in production or returned to the supplier."

Even where a manufacturer has chosen the right junction box, they still need to connect it and take care of the potting. On many production lines this is one of the last remaining processes that's still carried out manually. And recent developments – such as the use of more than one junction box per module and the need for even more precise placement that comes with bifacial to avoid shading, mean quality control here is of even more concern.

"A good quality junction box can still malfunction if the soldering was not done competently or the pottant did not cure properly, so process control is equally important to material control," says Touloupas. He goes on to note that when monitoring junction box attachment processes, engineers would monitor both operators and inline quality control measures, as well as checking the soldering temperature and the weight of the pottant, among other criteria.

Junction box safety margin comparison

Module	Isc (A)	1.25×Isc	Backside gain factor	Design current	Current (junction box)	Safety margin
182	13.86	17.3	1.21	21.0	25	16%
210	18.35	22.9	= (1+30%×70%)	27.8	25	-11%
					30	7%

Source: JA Solar

> *"It's clear that the challenges can be overcome"*

While the number of junction box faults seen in PVEL's scorecard is surely concerning, Erion-Lorico is keen to point out the positive side, that two out of three manufacturers tested did not have any junction box issues. Whether the additional requirements placed on the component by this latest round of module technology upgrades leads to more failures down the line remains to be seen, and it's clear that the challenges can be overcome. "As you increase current you are losing some headroom, and my biggest concern is the diodes and their capability to be robust at higher currents and higher temperatures within that circuitry," explains Erion-Lorico. "But we have enough examples of manufacturers doing it right to know that everyone should be doing it right. It shouldn't be that complicated." pv

Mark Hutchins

pv magazine Award: Sustainability

There is increasing pressure, globally, for companies to be held more accountable, particularly when it comes to sustainability. This topic is only growing in importance, particularly with changes to regulations in the works for issues like supply chain transparency and new environmental, social, and governance criteria. The applications for pv magazine's third sustainability award highlight the pioneering companies that are devising strategies to not only improve their internal business operations, but to also come up with innovative ways to address some of the industry's, and the world's, biggest challenges, like waste and electrification for all.

Truly circular

Flaxres

Flaxres claims to have created technology to support a truly circular manufacturing process for all types of PV modules, where all materials aside from foils can be reclaimed at the same quality and limitlessly reused as raw materials to manufacture new modules. It has received certification from France-based Veolia's U-Start program and is investor-funded.

The Germany-based technology provider says the recycling process is chemical-free, employing high-intensity, low-energy light pulses to separate the modules layer by layer. Currently the process takes 120 seconds and "a very small amount of energy" per module; however, its target is to achieve a cycle rate of 10 seconds. Furthermore, its solution is mobile, meaning module recyclers can procure the containerized technology and deploy it directly onsite at solar PV installations, regardless of where they are located.

Mission: Electrification

Ignite Power

Ignite Power began life in 2014 in Rwanda. Since then, the company says it has created over 3,500 local jobs across 10,000 villages in Sub-Saharan Africa and given 1.5 million people access to solar electricity via the installation of solar home systems, solar home appliances, clean cooking solutions, solar systems for businesses, solar-based medical solutions, and solar irrigation systems. One of the criteria when choosing suppliers, says Ignite, is the recyclability of components. "We also work with recycling companies to recycle as much material as possible, including every plastic component within the system," says a company spokesperson.

It operates on a mobile pay-as-you go service, charging as little as $1 month and then a monthly subscription fee of $0.001/hour for the electricity. The company claims a return on investment of two years. "Ignite is set to connect 1 million people in the coming year, and 12 million people in the next five years, multiplying the current 120tCO_2e tons CO_2 by 12 by 2026," it says in its award application.

Uncurtailed microgrids

eleXsys Microgrid Technology

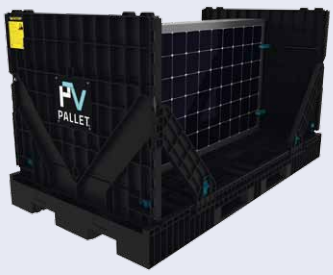
Australian company eleXsys Microgrid Technology has designed a platform that enables a "massive increase" in the amount of renewable energy on local electricity grids by eliminating export curtailment and facilitating a two-way flow of electricity. The product has been described as an advanced, grid-forming power electronics, Internet of Things device, integrating a suite of artificial intelligence software applications. It can increase the size of grid-connected C&I microgrids by up to 10 times. The company claims that over 70% of the energy from its device can be exported "uncurtailed" into the grid and that this makes projects bankable. It will also reportedly create "a whole new institutional-grade DER asset class," with ownership undertaken by third-party financiers under long term PPAs.

It is currently working with Ikea at one of its retail outlets in Adelaide, South Australia, on a commercial-scale microgrid project. It will reportedly combine commercial-scale solar PV and batteries with the energy management system to provide up to 100% of the store's energy requirements. Overall, eleXsys aims to deploy 1,000 similar microgrid sites across Australia in the next 10 years, which would represent 2 GW of rooftop solar, 3.2 GWh of batteries behind the meter, and $5 billion in total assets. It has also identified business opportunities in France, the United Kingdom, Ireland, the United Arab Emirates, and the Asia-Pacific region. It has offices in Singapore and the United Kingdom.

More palatable

PVpallet

Established in late 2020, U.S.-based PVpallet aims to eliminate single-use wood pallet construction waste in at least 10% of the country's PV construction sites by 2025, with its custom-designed, reusable plastic pallets. "We expect full adoption by the domestic solar PV industry by 2030," it says. So far, the company has created both desktop and full-scale prototypes, undergone Finite Element Analysis testing, and has produced its first limited production run of PVpallets manufactured by Iowa-based 20/20 Custom Molded Plastics. Full-scale production is scheduled to start in early 2022.



Although it is not yet up and running, it claims the pallets can be reused up to 20 times "under typical conditions" and can be fully recycled into new pallets. "We also plan to put a refurbishment and replacement program in place. This program will pay customers for any old or damaged pallets so that we can collect and recycle them into new PVpallets," according to the award application. The pallets are adjustable to accommodate different PV module sizes, it says, and feature side walls and protective cross braces to provide better protection. They can also be adjusted to account for partial loads, and are stackable, which the company claims, reduces warehouse space by up to 50%.

Pivotal progress

Pivot Energy

Pivot Energy develops, finances, builds, and manages solar and storage projects across the United States. Its business model is based on a triple bottom line of people, profit, and planet, on which it measures success. A certified B Corp., its performance is also externally evaluated on an annual basis in the fields of governance, workers, community, environment, and customers. In addition to donating to a range of causes that promote workplace diversity and education, among others, the company shares its profits with employees and encourages them to sign up to community solar programs.

In 2020, Pivot completed 116 solar projects across nine U.S. states, totaling 64 MW of commercial and community solar capacity, which it says is nearly triple the installed capacity from the previous year. It now aims to include agrivoltaics packages in all applicable ground-mount PV projects, expand solar access with residential solar system donations, and lobby for more positive solar legislation at the federal level in at least three "key" U.S. states. It claims to also be reducing its suppliers' carbon footprint through incentives, including a protocol to recycle all materials for future projects.

It's all in the science

Dow Inc.

Recognizing its position as one of the world's largest producers of plastic, Belgium-based Dow Inc. has set itself the ambitious goal of becoming "the most sustainable materials science company." Among other initiatives, it aims to reduce net annual carbon emissions by five million metric tons or 15% from its 2019 baseline by 2030, reach 100% recyclability by 2035, attain carbon neutrality by 2050, and sign power purchase agreements for 750 MW of renewable energy by 2025. Dow further claims that 80% of its R&D projects focus on climate protection, the circular economy, and "safer materials," while 48% of its 2020 sales were from products addressing "world challenges." In 2021, it published its first environmental, social, and governance (ESG) report. It also co-founded the Alliance To End Plastic Waste in 2019.

Dow manufactures products for many diverse industries. One business arm focuses on PV, where it offers its Engage PV polyolefin elastomers for PV encapsulants. It claims that Agility, a plastic film that enables repair or preventive maintenance of PV modules with degrading backsheets, purportedly produces a lower environmental impact, requires less materials, and is easier to implement than replacing entire modules with faulty backsheets. And Dowsil 7094 is a flowable sealant, a protective silicone coating, which may be used for the in-field repair of PV modules showing backsheet degradation and requires no unit dismantling.

One step further

Maxeon Solar Technologies

Singapore's Maxeon Solar Technologies launched in 2020, after being spun-off from U.S.-based SunPower Corp. While the PV module manufacturer already had a big sustainability head start under its former owner – SunPower won **pv magazine**'s first sustainability award (see **pv magazine** 12/2019, pp. 58-59) – it has taken several new steps to become more ecologically responsible.

These include establishing a formal environmental, social and governance function, signing up to the United Nations Global Compact, and committing to the Ten Principles and Sustainable Development Goals (SDGs). To structure its ESG program, Maxeon aligned its materiality assessment to Global Reporting Initiative and SASB international sustainability reporting standards, and voluntarily complies with the Singapore Exchange sustainability reporting requirement, despite being listed on the Nasdaq stock exchange.

Evaluating performance

Fronius

Austrian PV inverter manufacturer Fronius says it has initiated several sustainability measures. These include replacing fossil fuels with geothermal and biomass energy and increasing efficiency via measures like reusing waste heat and thermal isolation. It has also worked on reducing emissions in its car fleet with EVs. It says it focuses on European and Austrian suppliers and transports products within Europe by rail and road and, when it comes to intercontinental freight, opts for sea rather than air transport.

Fronius says it employs several KPIs to measure progress, including total annual energy consumption from renewables, total annual output from self-generated PV, annual share of PV energy supplied to the grid, and total square meters of PV by area installed at its global sites. Specifically, it says it has reduced its energy use by 41% since 2019, from the base year 2014, and increased its self-produced PV energy by 155% between 2014 and 2019. Meanwhile, its share of renewable energy usage was 83% in 2019. It has a goal of using 100% renewables for the energy it uses in its buildings for heating, cooling, and processes. In terms of its products, it says all comply with the WEEE directive. It adds that 90% of cardboard or plastic packaging used for transport are recyclable. In the product development process, Fronius says it uses Life Cycle Assessment to evaluate ecological performance.

Cold hard facts

Viking Cold Solutions

Viking Cold Solutions is a thermal energy management company offering long-duration thermal energy storage (TES) systems for protecting food quality. It claims to have developed the "only proven, environmentally friendly way to store solar energy in the cold storage market."

"TES allows energy-intensive refrigeration equipment in C&I facilities to be cycled down during peak hours of the day, effectively cutting the production of carbon emissions and reducing carbon footprints by tens of thousands of metric tons," according to the company. In addition, TES technology reportedly maintains temperature stability and has a 20-year life with no mechanical components. Users can expect to save between 20-35% of their energy expenses and see refrigeration system efficiency improve by 20-30%, says Viking.

The system is comprised of deionized water and inorganic salts, which it says, makes it 100% recyclable. It is also said to provide a 100% round-trip efficiency that equates to a levelized cost of energy of less than $0.02 per kWh. The U.S. company adds that its customers have seen a total energy savings of approximately 23 million kWh and avoided more than 17 MT of greenhouse gas emissions as of April 2021.

Still time to enter!

There's still time to join almost 200 hopefuls in Sustainability and five other categories being considered for the **pv magazine** Award. Throughout 2021 we have gathered the latest innovations from across the renewable energy industry. Leaders are emerging in each category, but it's all still to play for and a new entry now could change everything. There will be a final chance in November to get your entry in front of our independent jury, before the winners are announced in January 2022.

The **pv magazine** editorial team is excited to report that during the three windows held so far – in February, April, and July – an unprecedented number of entries has been submitted. This reflects the vibrant confidence and momentum the industry is carrying into the decade. **pv magazine**'s 2021 Annual Awards are shaping up to be bigger, the entries more innovative, and the platform given to winners more prominent than ever before. Don't miss out on the latest chance to go into the running to be a winner.

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Trends in sustainable debt

While sustainable debt issuance has historically been dominated by the Europe, Middle East and Africa region and mostly driven by green bonds from the energy and financial sectors, it has diversified in recent years and is now a global market with a huge range of issuers, thanks to the variety of instruments that have been created since 2007. As part of pv magazine's UP Initiative quarterly theme on sustainable electricity and corporates' critical solar role, Maia Godemer, BloombergNEF (BNEF) research associate, discusses this growth and its implications.

In early June 2021, the total sustainable debt market reached $3 trillion of issuance – a milestone since its inception in 2007, when the World Bank issued its first "Climate Awareness Bond." The most recent trillion dollars of issuance was achieved in just eight months, compared to just under two years from the previous trillion dollars, demonstrating the pace at which the market is developing.

Indeed, almost $825 billion of sustainable debt – borrowing activity via loans and bonds which is used to finance environmental or social improvements – was issued in the first half of this year. This is an 8% increase over the $759 billion issued through all of 2020.

BloombergNEF splits sustainable debt into two main categories. There are activity-based debt instruments, like green, social and sustainability bonds and loans, and there are activity-based debt fund projects, or activities with an environmental benefit or social benefit. They can be raised to finance new projects or refinance existing ones. There is also behavior-based debt, which encompasses sustainability-linked bonds and sustainability-linked loans. Contrary to activity-based debt, the activities performed with the raised money are not what earns behavior-based debt types their "sustainability" label. Behavior-based debt is dubbed "sustainable" when its coupon or any other financial characteristic is tied to a sustainability target for the issuer, requiring them to modify their behavior. This could be a greenhouse gas emission reduction goal, a quota for diversity in the workforce, or many other types of behavior.

While green bonds still represent almost half of the total sustainable debt issuance, other instruments, such as sustainability-linked loans and social bonds, are also gaining interest, accounting for 16.7% and 10.8% of total issuance, respectively. The most impressive surge has come from sustainability-linked bonds, where issuance in the first half of 2021 rose by 282% compared to total volume through all of 2020.

Green bonds require issuers to segregate the funds for environmental projects and activities, meaning they sometimes restrain access to certain issuers in sectors undertaking low-carbon activities. On the contrary, sustainability-linked bonds allow any issuer to raise financing for any purpose and link the repayment of the debt to the achievement of a sustainability target. Sustainability-linked bonds appeal to a larger group of borrowers. Even heavy-emitting issuers such as British Airways and Repsol have turned to this market in 2021.

Greenwashing threat

While the rapid growth of sustainable debt allows market participants to recognize which debt instruments are going to finance green and social projects, there is still little transparency with regard to the additional benefits brought by these instruments. Issuers are not legally bound to publish impact reports or the exact allocation of the bonds.

Even if this practice is now more broadly followed by organizations, the reporting frameworks lack consistency, making it very difficult to compare the environmental or social additionalities brought by the different sustainable debt instruments. Sustainable debt can also be used to refinance existing projects, rather than funding new ones, raising concerns about the actual additional funding that green debt is unlocking for new environmental projects.

The emergence of transition bonds is also raising new greenwashing concerns. They are a sub-category of sustainable debt that was initially created to allow heavy-emitting issuers, which had a difficult time coming to market with green bonds, to raise an alternate form of sustainable debt. They do not bring any pricing benefits to issuers, but instead allow them to signal to their investors that they are allocating some funds to their low-carbon transition,

in turn taking advantage of the sustainable investment trend. The existence of transition bonds remains much debated in the market, further fueled by the fact that they lack a clear definition.

Need for regulations

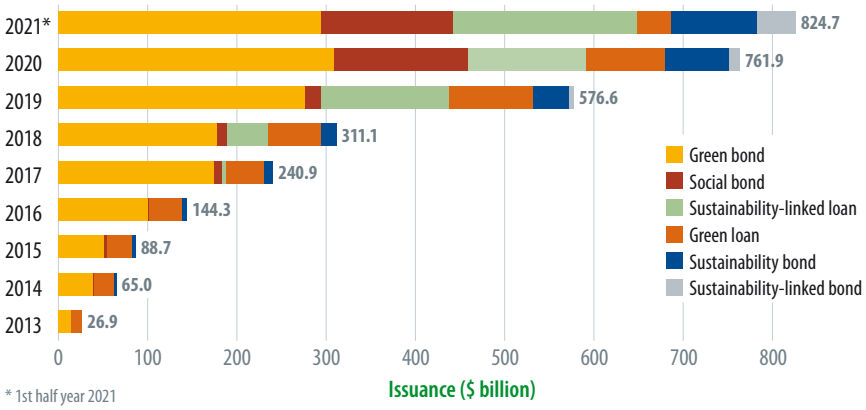
The sustainable debt market is still lacking regulations that would define the conditions of issuance for any sustainable debt instrument, but that may change in the future. Until now, some industry organizations, like the International Capital Market Associations (ICMA) or the Loan Market Association (LMA), have published voluntary guidelines to issue green, social, and sustainability bonds and loans. These principles have brought more credibility and robustness to the sustainable debt market, but they still leave room for interpretation, as eligible green and social projects and activities remain quite broad.

Regulators are now developing new legislations to supervise the development of sustainable debt. It starts with environmental and social taxonomies, which define the conditions under which economic activities and projects can claim to be environmentally and socially sustainable. The European Union was the first to enforce its environmental taxonomy, but since then more countries like the United Kingdom, South Africa, China, and Singapore have been either working on their own taxonomies or are already publishing their first drafts.

Once sustainable activities are defined, it is easier to create legislative frameworks for the issuance of sustainable debt, as is the case in the EU, which published the first draft of its green bond principles on July 6, 2021. The EU intends for it to be a voluntary "gold standard" for green bonds and it will be open for EU and non-EU issuers to use. However, if issuers decide to call their bond a "European green bond" or "EUGBS" then they will have to abide by the European standard. The EUGBS mostly relies on the existing pillars of the green bond principles from ICMA, showing the pre-eminence of this framework.

Sustainable debt annual issuance

Source: BloombergNEF, Bloomberg Terminal



* 1st half year 2021

> *"Once sustainable activities are defined, it is easier to create legislative frameworks for the issuance of sustainable debt"*

The creation of rules for the sustainable debt market has historically boosted issuance, as they bring confidence to the investor community and remove the greenwashing risk for issuers. PV

Maia Godemer

Sustainable debt labels and characteristics

Debt type	Debt style	Purpose	Market size ($ billion)	Proportion of sustainable debt
Green bond	Activity based	Environmental projects	1,458	45.7%
Green loan	Activity based	Environmental projects	550	17.3%
Sustainability linked loan	Behaviour based	Institutional ESG targets	532	16.7%
Social bond	Activity based	Social projects	343	10.8%
Sustainability bond	Activity based	Environmental & social projects	246	7.7%
Sustainability linked bond	Behaviour based	Institutional ESG targets	60	1.9%

Source: Bloomberg NEF, Bloomberg Terminal, Note: Instruments included are from 1996-June 30th, 2021

About the author

***Maia Godemer** is a research associate in sustainable finance for BloombergNEF. In particular, she focuses on sustainable debt, derivatives, and market regulations. She is part of the EU Platform on Sustainable Finance as support for Bloomberg member Nadia Humphreys (also known as the "Sherpa role"). She is also a member of the advisory council to the International Capital Markets Association on green bond and social bond principles. Godemer holds a bachelor of philosophy from Université Pierre Mendes France, as well as an MSc. in management and an MSc. in finance from Grenoble Ecole de Management.*

Different shades of green

Most long-term power delivery contracts with renewable energy systems involve the delivery of electricity through the public grid via off-site power purchase agreements. This leads to a key question: "How do I as a customer know when and if I am really using renewable electricity, and how can I prove that?" Simon Göß and Michael Claußner from Energy Brainpool GmbH & Co. KG, a European market research firm focused on energy trading, address these questions. They note how the development of green hydrogen is an opportunity to create more flexible power markets by fostering the adoption of renewables.

Regardless of the power purchase agreement (PPA) contract structure for the procurement of renewable electricity, for each MWh generated, producers can claim green energy certificates. In Europe, they are the so-called Guarantees of Origin (GOOs). These digital tokens prove that the generated MWh are from a renewable power plant. Typically, they are transferred to an offtaker of electricity, so that consumers can claim to have procured a certain amount of green electricity over a certain period, most often a year.

For the actual contracting of power delivery through the public grid, two possibilities exist: virtual or physical PPA agreements. In a virtual PPA, the two parties agree on a predefined price for the electricity and set up a financial contract for difference. The seller markets the renewable generation on their domestic spot market, while the buyer buys electricity from their domestic market.

When the average market price the generator attains differs from the contracted PPA strike price, the two parties exchange the difference accordingly (higher price, the generator pays to offtaker; lower price, vice versa). Both parties end up with the contracted strike price they agreed on in the PPA. By signing a virtual PPA, offtakers thus finance the construction of new renewable energy projects, which represents a stronger commitment than the procurement of green certificates alone.

Cross-border contracts

Through financial agreements, offtakers can procure electricity from renewable energy projects outside their market or grid. This is why such models were initially used in countries with different submarkets or grid areas, such as the U.S. or Australia. Recently, offtakers in Europe have started applying a similar approach to cross-border PPAs. Meaning they can source green energy Europe-wide without confronting interconnector bottlenecks between single power markets.

Under a virtual PPA, the generation and the consumption of electricity from the PPA is not necessarily taking place at the same time, but the amount of contracted GOOs and/or the total annual production output commercially matches the annual consumption volumes on a balance sheet.

A physical PPA counters this shortcoming. As all consumers and generators in Europe are part of the balancing group system, which allows for demand and supply to be balanced in time windows of 15 or 30 minutes (market-dependent), the generated electricity in a physical PPA agreement can be scheduled for the balancing group of the buyer on a much finer time step granularity. That means that within a physical PPA agreement, generation and consumption can both be tracked and can thus be concurrent, at least on a time window basis.

Case for hydrogen

In many jurisdictions, the procurement of GOOs, with or without a virtual PPA, is enough to claim procurement of green electricity. However, with the advent of increased sector coupling and thus additional, potentially flexible consumers to the grid (e.g., electrolyzers), the simultaneous generation and consumption of green electricity becomes more important.

Simultaneity will help to balance the grid, but it will also help renewables integrate into the market, as additional demand in hours of high wind and solar feed-in increases the market price and thus revenues that such technologies can obtain in their production hours.

This is why the development of green hydrogen is a big opportunity for creating more flexible power markets fostering a faster or more market-integrated renewable energy expansion. To exploit this opportunity, however, regulators need to ensure that electrolyzers (and in

The development of green hydrogen is a big opportunity to create more flexible power markets and foster faster, more market-integrated renewable energy expansion.

Photo: TÜV Rheinland

the future, other sector coupling technologies) exploit their technical flexibility by setting the right incentives.

Optional coupling

Green hydrogen classifications are currently being drafted in the European Union, while the German government has already adopted its own. So far, both approaches offer the possibility for electrolyzer operators to directly source renewable energy from on-site systems, as well as from systems installed in market areas with grid connections. For public grid deliveries, similar conditions are prescribed when it comes to classifying the hydrogen as "green."

Germany requires that a minimum of 85% of consumed electricity used for "green" hydrogen must stem from subsidy-free renewable energy suppliers located in the same market area. This is guaranteed by the "optional coupling" mechanism for German GOOs, i.e., the corresponding electricity from which the GOOs stem needs to be delivered into the balancing group of the electrolyzer. Similar mechanisms are yet to be developed on the EU level. The EU draft contains similar conditions, but the major difference to the German approach affects power plants that are now subsidy-free but have been receiving feed-in tariffs in the past. In the German regulation, these plants are eligible to provide electricity to produce green hydrogen, but in the EU draft they are not.

Irrespective of this detail, the prescribed balancing group condition allows for simultaneity between generation and consumption in both cases, reducing the risk of new grid congestion as well.

From a PPA perspective, only physical pay-as-produced PPAs provide proof of green hydrogen classification. Thus, for the first time in Europe, regulations differ between different qualities of green power deliveries. The development of green hydrogen regulations, however, may only mark the start of a focus shift in green certification policies from mere renewable capacity addition toward incentivizing synchronized supply and demand. In the coming years, regulations on other sector coupling technologies could follow this pathway (e.g., Power-to-Heat). pv

Michael Claußner & Simon Göß

About the authors

Michael Claußner *studied international business (B.Sc.) and integrated natural resource management (M.Sc.). He wrote his master's thesis on portfolio strategies for renewable energy. He began his professional career at Energy Brainpool, with a focus on energy policy. He works on consulting projects for the public and private sector and is an expert in risk management and sales options for renewable energy, especially PPAs.*

Simon Göß *studied environmental resource management (B.Sc.) and sustainable energy technology (M.Sc. honors). He started his professional career as a research associate at the SCUT/TU-Delft Research Centre on Urban Systems and Environment. Since 2016, he has worked with Energy Brainpool. He handles consultancy projects and writes scientific articles on blockchain and its impact on the energy sector, energy market design, the economics of innovative business models in the energy transition, and price effects on European and international energy markets.*

Photos: Energy Brainpool GmbH & Co. KG

pv magazine

Corporate acceleration

With solar declared the cheapest form of power in history, and wind prices following a similar trajectory, corporate energy users are buying renewable power and investing in new capacity at scale. But more companies need to step up. Governments around the world must remove policy barriers and open new markets to competition from renewables if we are to reach the scale of investment needed to achieve a 1.5-degree world, according to Sam Kimmins, the head of RE100.

The scale of RE100's mission was spelled out in the International Renewable Energy Agency's (IRENA) 2021 World Energy Transitions Outlook, which estimates that 27,700 GW of renewable energy capacity will be required by 2050 to keep the climate within 1.5 C of change. Just under half of this, or 12,800 GW, will be required to meet corporate electricity demand.

To put this challenge into bite-size terms, we will need 420 GW of corporate-driven renewable electricity capacity additions per year. That's around 22 times the volume of corporate power purchase agreements (PPAs) signed globally in 2020.

Purchasing power

The most visible and tangible way to achieve this is the purchase and investment in renewables by RE100 members. With a combined electricity demand larger than that of the United Kingdom, members have considerable direct buying power. Most "tangible" purchases are through PPA deals, which are increasing in scale each year. The record is currently held by TSMC for a single-site offshore wind deal totaling 920 MW, and Google, for a combined multi-site deal totaling 1.6 GW of capacity.

Self-generation is also important, with 40% of RE100 members reporting that they want to increase self-generation, pre-

Photo: Clif Bar

About 40% of RE100 members say they want to increase self-generation, predominantly with onsite solar. U.S. food producer Clif Bar included a pollinator habitat at its onsite PV installation to support local biodiversity.

dominantly with onsite solar. For example, Mindspace REIT, PVH Corporation and Clif Bar have all installed onsite solar either on rooftops of corporate buildings or on their business properties. In doing so, what these businesses have shown is that it's not just about the size and scale of an installation. It's also about presenting achievable, commercially viable leadership solutions to their peers and the global community.

These tangible, individual investments are critically important. Nevertheless, while member demand is large, it still only represents 2% of global electricity demand. We need a step change if we are to achieve the over 400 GW of capacity additions required each year. Recognizing this, the work at RE100 is increasingly focused on multiplier effects.

Achieving scale

Many RE100 members have achieved their goals in more mature renewable electricity markets like the United States and Europe and are now looking to achieve 100% in markets such as Japan, South Korea, Russia, and South Africa, which are currently more challenging. Others have already reached their 100% goal globally, but are looking to improve access to more commercially attractive sourcing options. This requires the removal of the policy barriers that are preventing the development of just and open markets in which renewables can compete fairly with fossil fuels.

RE100 has established policy working groups with members and partners in key geographies to remove these barriers. By working together, members can achieve their 100% goals, and take corporate sourcing mainstream.

We're calling on governments worldwide to implement policies that:

- Create a level playing field on which renewable electricity competes fairly with fossil-fuel electricity and reflects the cost-competitiveness of renewable electricity.
- Remove regulatory barriers and implement stable frameworks to facilitate the uptake of corporate renewable electricity sourcing.
- Create an electricity market structure that allows for direct trade between corporate buyers of all sizes and renewable electricity suppliers.
- Work with utilities or electricity suppliers to provide options for corporate renewable electricity sourcing.
- Promote direct investments in onsite and off-site renewable electricity projects
- Support a credible and transparent system for issuing, tracking, and certifying competitively priced Environmental Attribute Certificates (EACs).

The great news is that governments are listening. RE100 policy working groups and local partners are gaining strong traction in Japan, Korea, India, the European Union, and Taiwan. In Korea, for example, the importance of corporate sourcing has been recognized with incoming "RE100 Policies" to help companies to buy renewables and meet their RE100 targets.

Available procurement options include a "green premium," a type of green tariff offered by state-run electric utility KEPCO, renewable energy certificates, self-generation, equity investments, and third-party corporate PPAs for companies using more than 1 MWh of electricity. South Korea's National Assembly also passed a bill this spring to allow direct PPAs – something that would have been unheard of even a year ago. This means that come October, Korean companies will be able to work directly with renewable energy generators.

Given that more than half of Korea's electricity demand comes from the industrial sector, these market developments are encouraging, and the country's zealous adoption of RE100 is very welcome.

Urgent action

Encouraging progress has been made in South Korea, and this is also reflected in our work in India and Japan. However, these initial steps are just the start of the process, and ongoing improvements and refinements are required even in mature markets to ensure that renewable electricity is readily and cheaply available to all corporate electricity users.

RE100 is looking to build on the success by significantly stepping up policy work over the next 18 months. We are currently seeking to fund the growth of our small team to help markets around the world open for renewable buyers, and to ensure that corporate sourcing of electricity becomes the norm.

To do this, we need more companies to make strong commitments to use renewables, and more governments to make ambitious steps in opening markets to renewables – we don't have a moment to waste. pv

Sam Kimmins

> *"To put this challenge into bite-size terms, we will need 420 GW of corporate-driven renewable energy capacity additions per year"*

About the author

***Sam Kimmins** is the head of RE100. He has 20 years of experience leading sustainability projects in the shipping, aviation, food, construction, and NGO sectors. Prior to joining RE100, he spearheaded Forum for the Future's Sustainable Shipping Initiative. While there, he spent two years as an adviser for Air New Zealand, steering the development of a pioneering sustainability strategy. He is also the non-executive director of the Ethical Consumer Research Association. He has a master of science in pollution and environmental control from the University of Manchester and a bachelor of natural environmental science from Sheffield University.*

Photo: Climate Group

Urban solar

Buildings are considered to be a major driver of emissions. In addition to the predicted billions of square meters of space that will be built across the world over the next decade, most developments standing today will still be around in 2050. Thus, retrofitting existing structures is seen as a key sustainability target. In the fourth quarter of 2021, pv magazine's UP Initiative will focus on the role that solar and energy storage can play in greening the world's urban spaces.

"Solar and energy storage have a fundamental role to play, particularly when it comes to cooling and heating"

Humans spend much of their time inside. Buildings are key to our daily lives and significantly impact our health and well-being. Most have substantial carbon footprints, employing heavy use of fossil fuels from their construction, through use and demolition phases.

According to Project Drawdown, a non-profit organization established in 2013 under a collaborative effort involving 200 researchers and advisers to model solutions to reverse global warming, 230 billion square meters of building space exists worldwide and another 65 million could be added this decade. Currently, it says, buildings account for 32% of energy use and 19% of energy-related greenhouse gases in the form of heating, cooling, lighting, appliances and machinery.

Energy efficiency

While innovative green plans are being formulated for new builds, there are significant gains to be reaped from retrofitting existing buildings, particularly as many of those standing today will still be in use in 2050, according to the International Energy Agency (IEA).

It adds that in 2019, almost two-thirds of countries lacked mandatory building energy codes. To be in line with the Sustainable Development Goals by 2030, it says all countries must adopt such codes. In addition to "high-performance" construction, it believes energy-efficiency renovations of existing buildings must double from 15% to at least 30% to 50%.

"Improving building energy efficiency is one of the most cost-effective and fastest ways to reduce electricity demand and associated fuel imports, while indirectly slashing carbon emissions as well as improving local air quality and public health," says Project Drawdown. It believes enhancing energy efficiency, shifting energy sources, and addressing refrigerants are key to transitioning buildings from being carbon intensive to potentially net-positive.

In this sense, solar and energy storage have a fundamental role to play, particularly when it comes to cooling and heating and, due to their increasingly small costs for low-income households struggling with high energy bills.

Obvious choice

Representing an annual increase of 46%, 60.6 GW of residential and commercial and industrial (C&I) solar PV rooftop systems were deployed globally in 2020, reports SolarPower Europe (SPE) in its Global Market Outlook for Solar 2021-2025. Looking ahead, SPE predicts these figures will grow to nearly 96 GW in 2025.

This sector is perhaps the most obvious way to help green buildings; and with the right conditions, it can evolve very quickly. As SPE notes, "Vietnam is a very encouraging example, showing that the solar industry is now ready to develop even more sophisticated market segments like rooftop PV from basically zero to world record levels in a very short time – all it needs is the right policy and technical framework conditions, and a workforce with the right skillset."

Already, steps are being taken to improve the policy landscape. For example, last year, the U.S. state of California introduced a new law, which made solar a mandatory part of new-build homes, while in some German states like Berlin, it is now compulsory to install rooftop PV on all new and renovated buildings.

Solar solutions

SPE adds that with the evolution of residential and commercial power consumers into prosumers, PV panels will also positively contribute to building materials. Still a niche industry, building integrated photovoltaics (BIPV) has inventive solutions, like solar facades, tiles, and windows, which can improve energy efficiency. However, the technology is relatively nascent, and the industry faces many hurdles, like certification and approval processes, as **pv magazine** reported in the July edition (pp. 34-35).

The PV and energy storage industries, along with digitalization and electric vehicles, will also play a strategic role in the development of such things as district heating, energy communities, smart cities, and microgrids. Innovation will be key to driving such initiatives.

Australian company eleXsys Microgrid Technology, for example, has designed a platform that enables a "massive increase" in the amount of renewable energy on

local electricity grids by eliminating export curtailment and facilitating a two-way flow of electricity (pp. 86-89).

The product is described as an advanced grid-forming, power electronics Internet of Things device, integrating a suite of artificial intelligence software applications, which can increase the size of grid-connected C&I microgrids up to 10 times. It is currently working with Ikea in South Australia to combine commercial-scale solar PV and batteries with its energy management system to provide up to 100% of the Ikea store's energy requirements. EleXsys aims to deploy 1,000 similar microgrid sites across Australia and has identified business opportunities in France, the United Kingdom, Ireland, the United Arab Emirates, and the Asia-Pacific region.

The U.S. city of Ithaca, New York, meanwhile, plans to eliminate or offset all its carbon emissions by 2030 by retrofitting existing buildings with electric heating, solar PV, and battery storage, and greening the electricity grid, reported *The Guardian* in August. It is exploring private equity to help building owners decarbonize. The goal is to create 1,000 new jobs and redirect 50% of the financial benefits of the city's Green New Deal plan to low-income residents.

Pump it up

The heating and cooling of buildings is another area where solar and energy storage can reduce emissions. Project Drawdown says of the around 32% global energy generation the global building sector uses, more than one-third goes to heating and cooling. It adds that at the end of 2015, an estimated 1,350 solar thermal cooling systems had been installed worldwide, with Europe comprising around 80% of the market.

The IEA calculates that cooling energy use in buildings has doubled since 2000, "making it the fastest growing end-use in buildings." It estimates that by 2050, around two-thirds of the world's households could have an air conditioner (AC). "China, India and Indonesia will together account for half of the total number," the IEA says.

Solar cooling can include the direct use of PV with a heat pump or AC, or solar thermal collectors that use a thermally driven cooling device such as a sorption chiller, says the IEA. Heat pumps are an interesting solution because they can easily replace gas fired heating. To be effective, they must be able to reach high temperatures of up to 75 degrees; however, currently the higher the temperature, the lower the efficiency. Technological progress is being made, though.

For example, this August, Norwegian independent research organization Sintef, Norwegian compressor manufacturer Tocircle, and the Norwegian University of Science and Technology announced a high-temperature industrial heat pump than can work with pure water and reach a temperature of up to 180 C.

PV in the city

In the fourth quarter of 2021, **pv magazine**'s UP Initiative will discuss the role solar and energy storage can play in greening the world's urban spaces. We will investigate the technologies in the BIPV and heat pump industries, examine supporting policies and initiatives emerging worldwide, and look to those markets, like Scandinavia, which have successfully built district heating systems, to see if their knowledge can be transferred.

We will also feature innovative projects that are attempting to change the urban status quo and, ultimately, seek to answer how a step change can be made in the overall electrical grid system supporting buildings and their inhabitants. Because to achieve real change, we cannot just focus on the individual level, but must understand how all these buildings tie into the wider system. As the saying goes, united we stand, divided we fall. If you want to contribute, contact up@pv-magazine.com.

Becky Beetz

Photo: Pxfuel

"Improving building energy efficiency is one of the most cost-effective and fastest ways to reduce electricity demand and associated fuel imports, while indirectly slashing carbon emissions as well as improving local air quality and public health," says Project Drawdown.

> *"Heat pumps are an interesting solution because they can easily replace gas-fired heating"*

A state of flux

Since 1901, German company Emil Otto has manufactured high-quality flux products used in various applications across the electronics industry. In recent years, the company has expanded into producing fluxes for the soldering processes that connect PV cells into strings and modules, and it expects this market to play a growing role in its future. pv magazine recently spoke with Markus Gessner, director of sales and marketing at Emil Otto, about the need for flux manufacturers to keep up with the latest innovations in cell technology, and the continuing challenge posed by the pandemic, as well as rising raw material costs.

Photo: Emil Otto

Emil Otto has been manufacturing industrial soldering products for more than 120 years. But how long have you been supplying the solar industry, and how did the company get started in this field?

It stands to reason that Emil Otto, as an innovation and quality leader in the field of fluxes, also supplies the solar industry with soldering products. In 2015, a module manufacturer approached us looking for a special solution for its module production. Since Emil Otto develops customized products in addition to series products, we were able to find a solution that the latter found to be pretty good. Since then, we have significantly expanded our research and development activities for the solar sector. Well-known, international solar cell manufacturers now obtain their fluxes from us.

How big/important is the solar market in Emil Otto's future plans?

With the urgent need for change in energy production, solar will play a decisive role. The solar and PV industry is an important building block for the successful implementation of the energy transition worldwide. As a result, the solar market is naturally also gaining in importance for Emil Otto.

What were the challenges in adapting the products to the specific requirements of solar module production?

It was important for us to offer the customer added value compared to the fluxes traditionally used in solar production. Our fluxes, which were specially developed for the solar industry, are based on organic acids and special resin complexes that are specifically adapted to the requirements of module production. This results in adaptation options with regard to process time, soldering temperature, type of metallization, the application technique, or the residue behavior. Particularly noteworthy here is our EO-S-002. This flux is much cleaner, both in soldering and in residues in the system. The soldering results are also significantly better than with the fluxes conventionally used on the market. With EO-S-007, Emil Otto has another flux that is increasingly used in the solar industry. Like EO-S-002, EO-S-007 also has a solids content of 2.0 %. Unlike EO-S-002, however, it is completely resin-free.

Do you see new requirements for fluxes in the solar industry, with new cell technologies and interconnections?

Yes, without question. As cell technology and compounds and production equipment evolve, so must the fluxes. The auxiliary materials must also adapt to the new technologies. But this is nothing new for us, as we are already familiar with this aspect of electronics production and have been implementing it for a long time. Unfortunately, this has not yet reached many manufacturers in electronics or solar module production. Many of them claim to produce state-of-the-art technology with the most modern equipment; but use auxiliary materials which were qualified 10 or 20 years ago and no longer meet the requirements of today's processes.

How difficult has it been to keep up with the cost reductions that are taking place in other areas of the PV supply chain?

It is not possible to keep up with this development with conventional products. What is required here are ideas and concepts that go far beyond the usual. Which ultimately

leads to new, innovative and more affordable products. Another trend that is becoming stronger and stronger is the use of partially or fully water-based fluxes. There are also price reasons for this, as water lowers the direct product costs compared to isopropanol, and thus purely water-based fluxes are price-stable. Especially in times of the Covid-19 crisis, when the prices for isopropanol rose sharply, many companies switched to the water-based alternatives, which achieved equally good soldering results. In addition, water-based fluxes reduce consumption, are non-flammable and therefore not subject to the hazardous goods regulations.

Recently, the prices of many components have skyrocketed, mainly due to Covid-19. Are flux materials affected by these price increases?

A resounding 'yes.' Since the global pandemic, raw material costs have become extremely expensive. In addition to alcohols in 2020, the cost of all raw materials and packaging has become significantly more expensive. In addition, delivery times for raw and auxiliary materials have increased significantly.

> *"The use of water-based fluxes in the manufacture of inverters is unprecedented"*

You mention that Emil Otto also supplies flux for the production of inverters – is this more of a standard product for electronics applications, or are there also special requirements for the production of inverters?

Our fluxes of the GSP series are used very successfully in the production of inverters. For example, very good soldering results are achieved with the GSP-2533/RX, irrespective of the application and type of use. In the meantime, however, our purely water-based flux EO-G-003 is also used in the production of inverters for solar modules. The flux has passed various tests with flying colors. The requirements for these various tests were far above the usual dew formation test in the automotive industry. The use of water-based fluxes in the manufacture of inverters is unprecedented.

And you now supply the flux as a concentrate – what does that mean for customers in manufacturing?

Emil Otto is the only manufacturer in the world to offer flux as a concentrate, including for the solar industry. Since conventional alcohol- or partially alcohol-based fluxes are dangerous goods in the sense of transport regulations, requirements have to be met that make the product even more expensive, especially due to the more costly transport. Shipping by air freight is also impossible, as in these cases the fluxes may only be packed in small containers. This restricts large quantity purchases. In order to circumvent these problems, Emil Otto has been developing flux concentrates on a granulate basis for some time, which do not represent hazardous goods. Mixing the flux on site is very simple. Each product comes with the necessary information about which liquid to add to the concentrate and in what dosage.

Interview by pv magazine staff

pv magazine test

July 2021 results

We are pleased to present the latest batch of energy yield results from the outdoor test field in Xi'an, China. In this issue, we look at the July results, alongside additional analysis from George Touloupas, director of technology and quality at CEA.

The first chart to the right shows the meteo station data (irradiance and ambient temperature) for July 2021. Four new products were added to the outdoor test field for this month: #32 Risen- RSM150-8-500BMDG, #33 Trina- TSM-450DE173(II), #34 JA- JAM72D20-445MB, and #35 JA- JAM72S20-445MR. As mentioned in the previous month's article, products 12 and 17 showed abnormal underperformance. As we are still investigating the root cause, they've been removed until the issue is resolved.

The average bifacial boost is 5.7% for July 2021. Bifacial boost is defined as the extra energy yield of the bifacial products compared to the average energy yield of all mono-facial mono PERC products.

The chart to the bottom right shows the comparison between different PV module technologies for July 2021. Bifacial modules are steadily performing above all the other technologies, with mono-facial multi modules having the lowest yield.

We have observed that three newly installed mono PERC bifacial products (32, 34 and 37) have relatively low yield and have dragged down the overall bifacial boost. We will be closely monitoring these products and the metering set-up to understand the underlying cause.

Notes on energy yield

- The energy yield comparison among various technologies, including bifacial boost, will be analyzed using products installed after the beginning of 2019.
- The energy yield is given in Wh/Wp and is 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 the sun angle and diffuse irradiance. The ground in this case is gray gravel. pv

George Touloupas

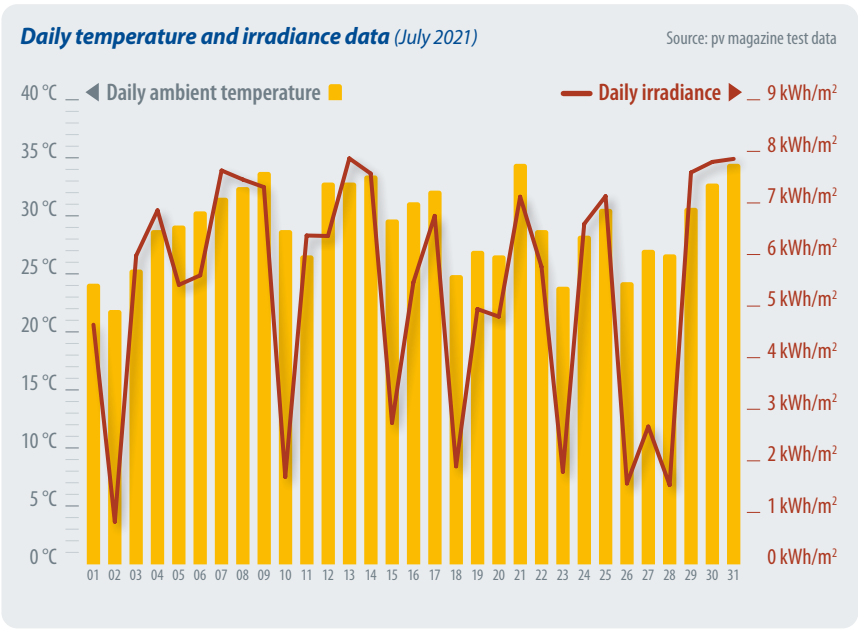
Bifacial boost

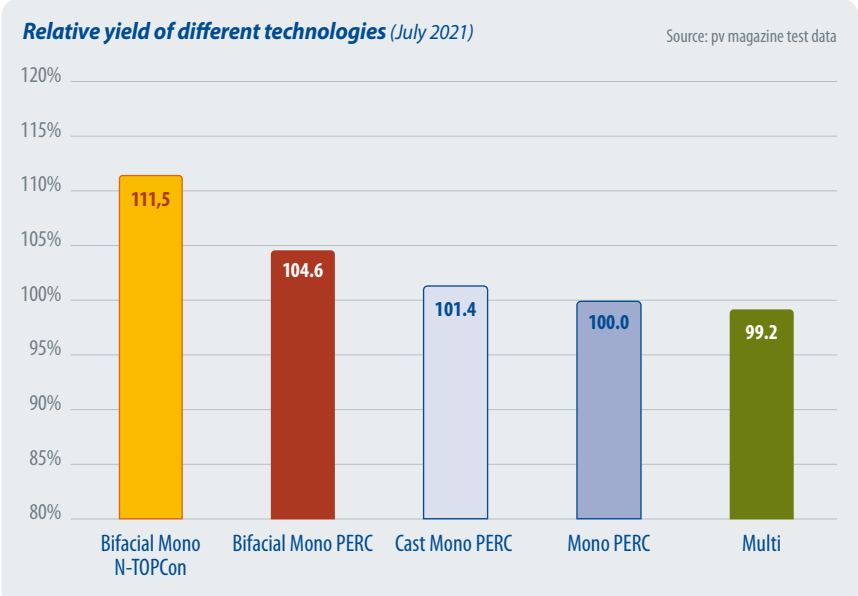
all in Wh/Wp	Total Mar 2021	Total May 2021	Total Jun 2021	Total Jul 2021
Average monthly yield	32.89	114.26	120.62	116.63
Average monthly bifacial yield	33.99	120.69	128.22	120.54
Average monthly mono-facial Mono PERC yield	32.52	113.45	117.35	114.00
Operation days	10	25	30	29
Average daily yield	3.29	4.57	4.02	3.66
Average daily bifacial yield	3.40	4.83	4.27	4.16
Average daily mono-facial Mono PERC yield	3.25	4.54	3.91	3.93
Bifacial boost	4.5%	6.4%	9.3%	5.7%

Energy yield ranking

#	Installation Month	Product	Type	Total Mar 2021 Wh/Wp	Total May 2021 Wh/Wp	Total Jun 2021 Wh/Wp	Total Jul 2021 Wh/Wp	Mar 2021 Rank	May 2021 Rank	Jun 2021 Rank	July 2021 Rank
26	2019/8/28	LONGi LR6-72HBD375	Bifacial Mono PERC	35.206	123.901	132.251	128.866	2	1	1	1
27	2019/12/31	Jolywood JW-D72N-400	Bifacial Mono N-TOPCon	33.835	119.471	128.329	127.086	5	2	2	2
28	2020/4/15	Risen RSM114-6-405BMDG	Bifacial Mono PERC	32.927	118.699	126.678	121.783	11	3	3	3
31*	2020/10/1	JA JAM60S10-345/MR	Mono PERC	32.010	114.297	122.531	118.050	20	4	5	4
21	2019/3/1	Risen RSM120-6-320M	Mono PERC	33.023	112.605	120.063	115.711	9	5	6	5
20	2018/11/21	Phono PS380MH-24/TH	Mono PERC	33.207	107.533	116.580	115.690	7	8	8	6
32	2121/7/1	Risen RSM150-8-500BMDG	Bifacial Mono PERC	-	-	-	115.626	-	-	-	7
30	2020/7/7	GCL GCL-M3/72H380	Cast Mono PERC	31.872	109.589	115.429	115.613	21	7	10	8
34*	2121/7/1	JA JAM72D20-445MB	Bifacial Mono PERC	-	-	-	115.271	-	-	-	9
37	1900/1/0	LONGi LR4-72HBD-445M	Bifacial Mono PERC	-	-	125.617	114.612	-	-	4	10
29*	2020/7/7	CSI CS3U-390MS	Mono PERC	32.065	104.378	110.206	114.448	19	9	11	11
10	2018/5/24	Recom RCM-275-6MB-4-BB21	Mono	32.952	99.448	116.186	113.445	10	10	9	12
22	2019/5/4	ZnShine ZXP6-60-275/P	Multi	32.219	111.144	117.425	113.108	17	6	7	13
35*	2121/7/1	JA JAM72S20-445MR	Mono PERC	-	-	-	111.108	-	-	-	14
33*	2121/7/1	Trina TSM-450DE173(II)	Mono PERC	-	-	-	108.969	-	-	-	15

**Purchased products from the market, which bypassed the random sampling process. The rest of the products were provided by the suppliers.*





Test cooperation

pv magazine test is a cooperative effort involving **pv magazine**, APsystems, 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.

APsystems ALTENERGY POWER

CEA Clean Energy Associates

GSOLA®

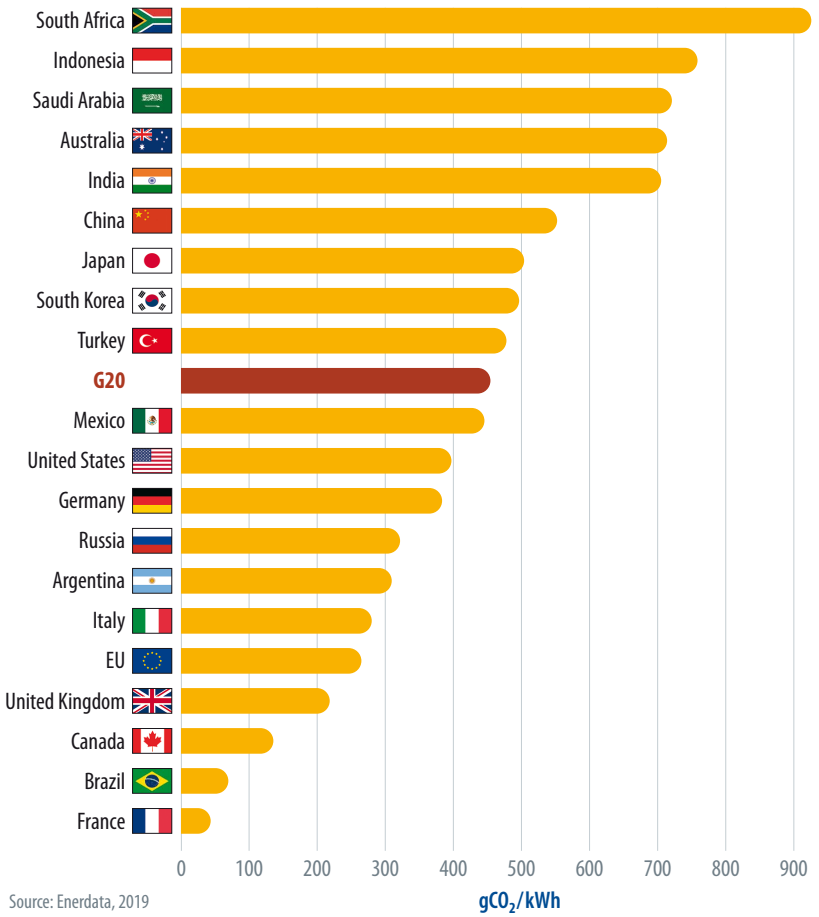
The untapped potential

The electric vehicle conversation is dominated by all-electric options, and sales figures back up the shift from the age of the Prius to the age of Tesla. However, the timeline for the Global South is very different and hybrid EVs are better than ever. Hybrid EVs shouldn't be considered a legacy technology, and may be greatly significant for their role in the path to decarbonization, explains Gautham Ram, assistant professor at TU Delft.

To make the energy and mobility transition successful, we need to switch to vehicles with net-zero emissions. Net-zero refers to emissions at both the tailpipe of the vehicle, as well as the electricity power plant/source. And this transition is not just about zero emissions from new vehicles being sold, but the entire vehicle fleet.

The graph on p. 105 (top) shows the global sales of fully electric and plug-in hybrid electric vehicles, indicating a dramatic increase over the last decade. But to get to net-zero, there are several key challenges, especially in price-sensitive developing economies, as well as in developed economies. It is in this context that there is a significant opportunity for hybrid electric vehicles (HEVs) as we transition to 100% emission-free mobility. The opportunity for hybrids comes from the transition challenges we face.

Emissions intensity of electricity generation, G20 (2018)



Source: Enerdata, 2019

Fast charging

First, the successful transition to fully electric vehicles (EVs) needs extensive EV fast-charging infrastructure in many places, including along highways. By fast charging, we are referring to power levels of 50-350 kW for cars (and up to 1,000 kW for heavy-duty vehicles). This will enable users to make long-distance trips using their EVs by stopping for 10 to 20 minutes to gain 300-400 km in range.

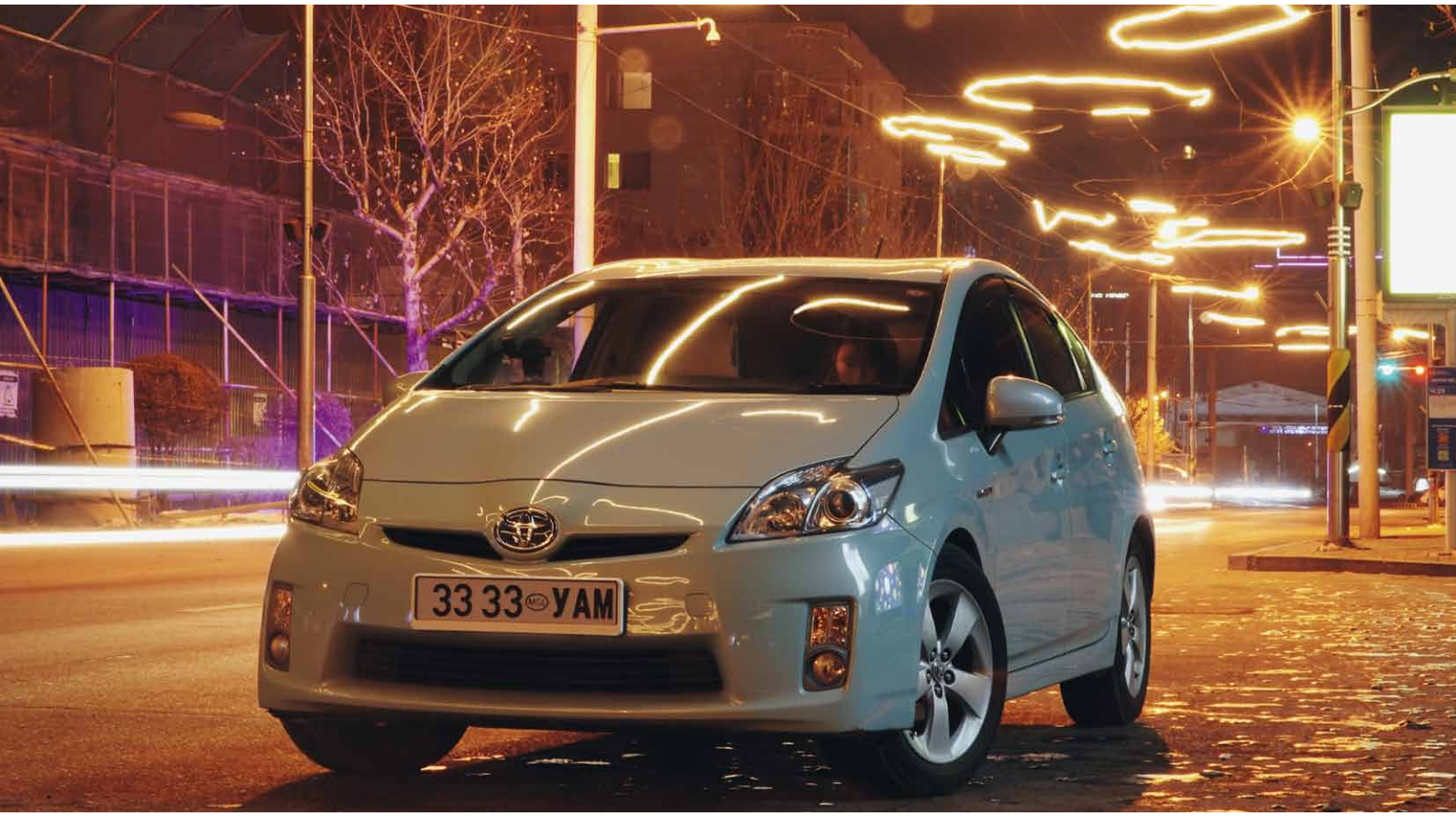
The lack of fast-charging infrastructure could be determinantal in motivating people to buy an EV. We have to bear in mind that people generally want to own one affordable car that should cater to both short and long-distance travel needs over the next five to 10 years, and want to drive without range anxiety.

Indicative prices for EV fast chargers are a capital cost of 500-1,000$/kW, service and maintenance 5%/year, and installation costs of approximately 50% of the charger cost.

The high cost and wide variation are mainly due to several factors, including the necessary high-capacity power connection, costs of a new transformer plus cabling and installation, service-level agreements, DC charger plug options

# of hybrid EVs

Photo: Darkhanbaatar Baasanjav/Pexels



Although all-electric vehicles are rapidly gaining market share, the transition to e-mobility still leaves plenty of spaces for hybrids like the Toyota Prius.

(one or more of: Tesla, CHAdeMO, CCS/Combo, Chinese GBT, AC plugs), number of chargers installed at that location, costs for customization, and the necessary labor costs and permits.

The high costs of fast charging infrastructure and the need to "electrify" every highway, not just specific corridors, are significant costs for countries.

Grid decarbonization

As the graph (left) shows, many electrical grids are far from decarbonized. Well-to-wheel emissions of fully electric cars will only be drastically lowered if we move away from fossil fuels for our electricity production, and for many countries this

EV, HEV, PHEV: Confused?

Any vehicle propelled by an electric drivetrain taking electric power from a portable, electrical energy source (like battery, fuel cell or solar panels) is referred to as an electric vehicle (EV):

- **Hybrid electric vehicle (HEV):** An internal combustion engine in combination with an electrical generator is used to produce electricity to power the electric drivetrain. Small batteries are used in HEVs to act as an energy buffer to store the electricity, but the batteries cannot be charged from the grid. A mild hybrid is a type of HEV in which the electric powertrain is not sized to fully propel the vehicle independently.
- **Plug-in hybrid electric vehicle (PHEV):** Still an HEV, but the battery is much larger and can also be charged from the electricity grid.
- **Fuel cell electric vehicle (FCEV):** A fuel cell using hydrogen, for example, is used to produce electricity to power the electric drivetrain, in combination with a small battery buffer.
- **EV:** A fully electric vehicle, also referred to as battery electric vehicle (BEV) or plug-in electric vehicle (PEV), which has no internal combustion engine. The battery is much larger with more capacity and can only be charged from the grid.

Cars sold in US market, with fuel economy in miles per gallon equivalent (MPGe)

	2021 model	Fuel economy in MPGe		
		City	Highway	City/Highway Combined
Conventional	Hyundai Elantra	33	43	37
	Honda Civic	32	42	36
	Kia Forte	31	41	35
	Honda Accord	30	38	33
	Toyota Camry	28	39	32
	Toyota RAV4	28	35	30
Hybrid EV	Hyundai Ioniq	58	60	59
	Toyota Prius	58	53	56
	Honda Insight	55	49	52
	Kia Niro	53	48	50
	Honda Accord	48	48	48
	Toyota RAV4	41	38	40
EV	Tesla Model 3	150	133	142
	Tesla Model Y	140	119	129
	Chevy Bolt	127	108	118
	BMW i3	124	102	113
	Nissan Leaf	123	99	111

	2021 model	City/Highway Combined (MPGe)	
		Electric	Hybrid mode Gasoline + Electric
Plug-in HEV	Prius PHEV	133	54
	Kia Niro	105	46
	Honda Clarity Plug-in	110	42
	Chevy Volt (2019)	106	42
	Chrysler Pacifica	82	30

Source: www.fueleconomy.gov

Miles per gallon of gasoline equivalent (MPGe) is an estimate of the average distance (in miles) traveled per 33.708 kWh of energy consumed from the vehicle fuel source. We use 33.708 kWh as a reference, as it is the energy equivalent of 1 gallon of gasoline. MPGe helps to compare the fuel economy of various alternate fuel vehicles.

more prominent on the distribution and transmission level. This has resulted in a severe amount of concern amongst grid operators and vehicle owners about whether to transition to battery EVs.

Furthermore, the mass-market price point of cars in the developing world is much lower at $6,000-12,000. While EVs with a range of 300-400 km will reach purchase price parity with conventional vehicles in the developed world at a price point of $25,000-35,000, this will still be unaffordable for the developing world. The high price of EVs continues to be driven by battery costs, ranging between $130-200/kWh at the pack level. And EVs with a higher range will need larger battery packs and hence have higher purchase prices.

Considering the above, HEVs (mild, full hybrids or plug-in hybrids) represent a massive opportunity to lower emissions in the interim period between the age of Internal Combustion Engine (ICE) vehicles and a future with fully electric vehicles powered by 100% renewable energy.

However, the dominant focus in media and industry is currently on fully electric EVs, which may not be practical in developing countries for years or decades to come; given grid reliabilities, expensive charging infrastructure requirements, and of course, prohibitive EV costs.

Hybrid's role

There are several key technical and economic reasons that make hybrids attractive as an excellent interim step towards decarbonization:

> *"The dominant focus in media and industry is currently on fully electric EVs, which may not be practical in developing countries for years or decades to come"*

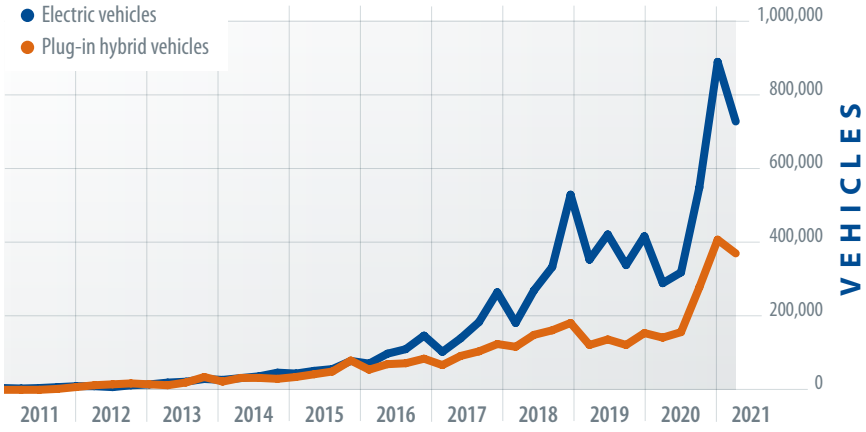
process is going very slow. This ultimately results in the far lower emission benefits of total electrification of mobility.

In addition, large parts of the world, especially in developing nations, are missing access to a grid, or the grid is not yet 100% reliable. The relatively high power needed for EV slow charging (<22kW) and fast charging make the problem even

The optimal matching of the ICE and electric power in a hybrid vehicle results in the ICE operating close to its optimal efficiency point. This results in the fuel economy of hybrids being 1.5 to two times higher than conventional ICE vehicles for city driving and one to 1.5 times higher for

Fully electric vehicle sales vs. Plug-in hybrid vehicles

Source: BloombergNEF



> *"HEVs represent a massive opportunity to lower emissions"*

Want to learn more about electric cars?

The massive open online course (MOOC) for electric cars consists of four sections (Introduction, Technology, Business, Policy) for free on the edX platform. Each course is four weeks long, with a workload of four to five hours per week. The program has been very successful, with more than 165,000 registrations from 175 countries since 2018.
Sign up via www.tiny.cc/ecarsx

highway driving. The table above shows popular HEVs sold in the United States and their fuel economy in miles per gallon equivalent. Evident is the four to five times higher fuel economy of EVs compared to ICE vehicles.

Going further, a plug-in hybrid electric car combines the best of both the HEV and EV. Using a small battery (<10kWh) that can be charged from the grid can cover 90-95% of all short, day-to-day commutes in fully electric mode, with three to four times higher fuel economy than ICE vehicles.

Regenerative braking in HEVs, recovering the kinetic energy instead of dissipating it as heat can further improve fuel economy especially in urban areas with frequent stop-go patterns. Engine start-stop mechanism can save fuel in traffic lights and heavy traffic. Electric torque-assist can improve fuel economy in acceleration and hill-climbing conditions by ensuring that the ICE operates at its most fuel-efficient point while the electric machine provides varying power demand.

Finally, the purchase price of hybrid cars is not much higher than conventional vehicles; ranging between 15-25% higher, independent of the vehicle range. pv

Gautham Ram

About the author

Gautham Ram *completed an electrical engineering degree in his home city of Chennai, India, and won a scholarship to complete a master's degree at TU Delft in the Netherlands. He subsequently completed a PhD on the topic of charging EVs with solar.*

Two-wheeled solutions

Electric two-wheelers could transition to fully electric within a relatively short time span in many parts of the world. For example, in India, more than 70% of all registered motor vehicles are two wheelers. This is because they are typically used for short-distance commutes in urban areas, have a much lower energy consumption per kilometer than cars, and have lower requirements for acceleration and top speeds compared to cars. This means a small and hence cheaper battery of 1-3 kWh would be sufficient for a range of 60-100 km and the electric motor is rated for only 4-10kW, bringing down the purchase price. The small batteries also mean that fast-charging infrastructure is not needed.

The ideal future is one where all our electricity is made from renewable sources like solar and wind, and we power our EVs using solar energy in the day and wind energy at night. For those countries that can already work toward this goal now, the priority must be to realize this vision.
On the other hand, in places where transitioning to renewables and building fast-charging infrastructure would take a decade or longer, we need to seriously consider and move to hybrid electric cars as an intermediate solution, due to the fuel economy and emission benefits. With the effects of climate change already being felt globally, acting now is even more critical.

Gautham Ram

Price cannibalization threatens PV growth

As solar deployment increases, concerns about price cannibalization continue to be more and more relevant. Large-scale solar generation during midday hours may result in curtailment or unprofitable wholesale power prices. As supply increases, the economic viability of solar PV projects could fall into question.

Significant market price fluctuations and risks will threaten investor appetite, potentially hurting the long-term large-scale deployment of solar power. This has already been seen in California, with Karen Edson's notorious 2012 "duck curve" showing the disconnect between generation and demand. Already, increases in renewable energy penetration in the state, as high as 26% of the energy market, have resulted in returns lowered by around 30%.

Jenny Chase, head of solar at BloombergNEF, believes this is a significant issue for every market seeing rapid solar penetration, and a threat to a subsidy-free solar future. "Large-scale solar generation depresses power prices, which can hit zero or even negative points during sunny periods," said Chase. "This is not an imaginary problem, and it's not a market design problem – the only way to solve this is to shift demand."

Michele Scolaro, senior analyst at Aurora Energy Research, agrees that price cannibalization is a risk for developers of subsidy-free solar projects. "Due

BayWa r.e.'s 175 MW Don Rodrigo project in Southern Spain sells electricity to offtaker Statkraft under a 15-year PPA. Falling PPA prices in Spain this year have reopened discussions about curtailment and solar's potential for price cannibalization.

Photo: BayWa r.e.

to its nature, price cannibalization has first hit the markets where the business case for merchant projects was stronger, as the penetration of solar PV increased and eroded the revenues captured by the assets," Scolaro told **pv magazine**.

PPA mitigation

One obvious solution is power purchase agreements (PPAs). Under these contracts, the price risk is partly transferred to the offtaker, facilitating the financing of the project as well. For renewable energy developers like BayWa r.e., most of the corporate PPAs they undertake are subsidy-free, meaning that the company is exposed to market fluctuations.

Benedikt Ortmann, global head of solar projects at BayWa r.e., said curtailment and negative pricing are concerns. However, he pointed out that normal market fluctuations depend on so many variables at any one time across the overall electricity market. The reality is that solar developers are "the generators producing the cheapest source of electricity." Ortmann added that there are already measures in place to counter these market challenges.

LevelTen Energy produces the P25 index, a quarterly update on PPA prices. It showed Spain to be the most rapidly growing market in Europe in the second quarter of this year, taking over from Italy in the first quarter. One in three offers on its marketplace were for Spanish projects. A change in average PPA pricing triggered the latest cannibalization discussion. In the second quarter of 2021, renewable PPA prices for Europe held largely steady, as in recent previous quarters, but Spanish P25 solar PPA offer prices fell 10.3% to reach €30.50/MWh.

The reasons for the fall in Spanish project prices range from the obvious, including an abundance of resource during midday hours, to a maturing industry with a strong pipeline, plus competition. Luis López-Polín, senior business development manager at LevelTen Energy, said that another factor is that an increasing number of corporates are using the competitiveness of the Spanish markets to get a pan-European PPA on favorable terms.

Chase agrees that project lifetime PPAs provide a different experience to the spot market, but warns that increasingly, buyers are aware of the potential price differential and are looking at short-term contracts at around €35/MWh. "You have to be really optimistic about the residual value in the investment," she said.

It's not all bad news, however. For example, Danish P25 solar PPA offer prices rose more than 14% in the second quarter. "Investors into merchant-based solar may see this as a short-term worry today," said Harald Överholm, CEO of Nordic PPA provider Alight. "We're not experiencing this as a major investor issue in Northern Europe, and not for the contracted solar build-out that represents most of the solar deployment in these markets."

Georgios Gkiaouris, regional head of the European Bank for Reconstruction and Development, said that while price cannibalization is not yet being seen in the EBRD region, the bank does expect to see it if the electricity price continues to be set by marginal cost. "We expect the capture price will be lower than the average wholesale price," he said. "Our projects have a 20 to 25 year lifetime so we're already taking this into account."

Like other risks though, price cannibalization can be addressed. "It is important for developers to quantify this risk," Scolaro said. "Price cannibalization will impact markets … depending on factors

Photo: EBRD

Georgios Gkiaouris, regional head of the European Bank for Reconstruction and Development, believes that new business models and revenue streams for solar PV projects will be needed to address the issue of price cannibalization.

> *"Price cannibalization is a risk for developers of subsidy-free solar projects"*

such as solar PV penetration, size of the market, interconnection to neighboring markets, and so on."

The probability of curtailment and negative pricing are already being built into project cashflow estimates. Mike Bammel, managing director of JLL Valuation Advisory, said that all investors want the highest price for the lowest risk. While Bammel admits to having seen a drop in return on solar, he's hesitant to put a concrete figure on it. He emphasized that it is necessary to take a longer-term perspective, especially regarding growing pressure in the U.S. market from carbon and ESG concerns from investors intent on protecting or improving their climate position.

Sector coupling

Dan Bates, CEO of clean energy supplier Rebel Energy, said that solar must be looked at as part of a greater whole. He says, "Solar is part of a bigger picture – the question is how it combines with wind, batteries, EVs, and so on," he noted.

The next solution to the cannibalization problem is revenue stacking, with storage a key differentiator. "Cannibalization will happen, and its effect will remain with us. Therefore, looking into the future, we need to channel investments into innovative technologies designed to provide flexibility measures," said Merce Labordona, senior policy analyst at SolarPowerEurope. "We should maximize sector coupling, adopt the right mechanisms to encourage renewable energy generation to respond to market signals for flexibility, and provide incentives to end-users to absorb oversupply."

A smart grid with storage can allow for demand shift and aggregation, while sector coupling of combined projects from desalination, water treatment, agriculture, local deliveries with EVs, and more could be transformational.

Ortmann is clear in his belief that the market will respond to quality over time. In terms of environmental impact, durability, and price, he believes that solar still beats alternatives. While batteries mean a higher capex for solar projects, BayWa r.e., for example, is already applying for battery permits with its plants, even if they're not planning on immediately integrating storage.

Gkiaouris said that in many markets, an integration focus should be on connectors, system balance, and rule synchronization. In addressing cannibalization, however, the market needs to see new business models and explorations of how solar plants can be remunerated, dependent on storage, carbon costs, and potential changes in system pricing.

This is increasingly important as the question of cost and value is being reassessed in many sectors, beyond the potential impact of carbon. The New York State Energy Research and Development Authority, for example, already has policies in place to take social benefits such as cleaner air into consideration with pricing. This will play out in the utility market, rather than the wholesale market, and is going to become increasingly important as solar builds out in the United States. The federal Energy Information Administration's long-term plan is for 45 GW of solar, at about 50% of new capacity additions. The continuation of the local production tax credit (PTC) is also going to be beneficial for longer-term stable U.S. solar growth.

Regulatory risk plays an important role in the solar market and the biggest danger is a change in thought leadership. "Generally there is a push for action, although how the powers that be implement necessary changes can be challenging," said Bammel. He adds that regulatory risk is simply one of many market risks, with new or renewed government support in regions that must do more for climate ambitions a positive upside consideration.

While there are reasonable concerns about cannibalization, Ortmann said, these are the challenges that come with a more mature market. Identifying and addressing market risk is a positive and necessary step. The carbon price is already playing a significant role in the growth of solar PPAs and the days of selling green certificates and electricity separately seem a distant memory.

No matter what happens there is so much emphasis on decarbonization that LevelTen's López-Polín believes that governments and the sector will find a way to continue the rollout. He added that we are looking at a fundamental shift in market dynamics – corporate PPAs are being signed because of long-term sustainability targets and it is still uncertain whether cannibalization will have a major impact or not.

Chase, meanwhile, warned that investors today must be optimists to fund solar: "We all have to be optimists in order to have a future." pv

Felicia Jackson

In Q2 2021, Spanish P25 solar PPA offer prices fell

10.3 %

to €30.50/MWh

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The climate challenge raises the stakes for solar and storage to deliver reliable and cost-effective carbon-free energy, even as those same resources face increased risks of their own from fires and storms, as well as component failures and long-term system performance.

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Battery energy storage systems (BESS) are charging forward Down Under, with batteries big and small required on both the electricity transmission and distribution network. Alongside the growing need, a business case is also building with both high and negative prices becoming more common on the wholesale electricity market. Batteries are emerging as the perfect tool to provide the necessary grid-stabilizing functions as coal generators continue to exit the electricity system.

However, the rollout of batteries at the distributed level and utility scale presents safety concerns. Recent fires and product recalls have brought the issue to the attention of consumers and regulators alike.

What is the outlook for BESS in Australia? How can battery safety and durability be assured? And how can risks be mitigated, both technically and legally?

Leading Australian analysts and international storage-solar experts will address these questions in **pv magazine's** Insight Australia event.

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Final thought

Just what the doctor ordered

Laura Stachel, executive director and co-founder of We Care Solar, and a former obstetrician-gynecologist

Electricity is a critical enabler of healthcare, required for medical lighting, diagnostics, procedures, surgeries, and laboratory equipment. The WHO estimates 1 billion people are served by health facilities without access to electricity globally. In sub-Saharan Africa, 72% of health facilities lack reliable electricity; one in four have no power at all. Without reliable power, health workers use candles, kerosene lanterns, and cell phones for light. Cheap, clean solar can be the difference between life and death as health providers screen for Covid-19, enforce infection control protocols, administer vaccines, and treat patients.Additionally, lockdowns, supply delays, and a diversion of resources to Covid-19 have interrupted essential services for women and children, threatening hard-earned gains in maternal and newborn health, and raising concerns about a "shadow-pandemic."

Off-grid solar systems can help midwives and doctors provide life-saving care for mothers and newborns by solving one of their biggest problems – energy deficiency. Solar electricity offers an immediate and sustainable solution to the dual challenges of universal health care and access to electricity.

In June, global leaders endorsed a strategic road map for energy and health, calling for the acceleration of sustainable energy for health care. International commitments are needed to mobilize resources to respond to this challenge.

We Care Solar launched the "Light Every Birth" initiative to ensure that every woman can deliver safely in a well-lit health facility. To date, more than 6,000 health facilities have been equipped with rugged Solar Suitcases for maternal and newborn health care. Yet, there is urgent need for thousands more.

Distributed solar has proven to be a reliable solution in saving lives of mothers and babies and all stakeholders must engage to accelerate its implementation to address this urgent public health problem.

Photo: We Care Solar

Preview of issue 10/2021

Photo: LG

End-of-life concerns

Australia's residential rooftop PV segment has been a world leader, but discarded modules heading to landfill are a drag.

pv magazine Award: BESS

Our jury of independent battery experts reveals the storage superheroes selected as finalists in the BESS category.

Photo: Artsolar

Backsheet failures

An investigation of the latest data from Europe on backsheet failures, the common causes, and remediation efforts.

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