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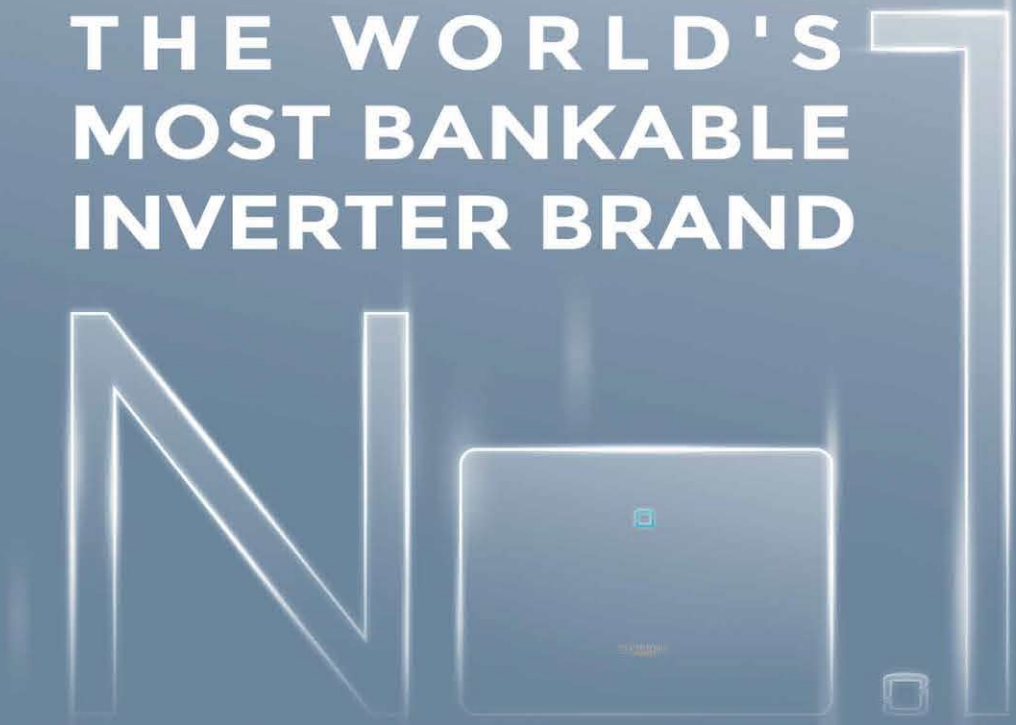
Charging ahead

EV acceleration will challenge the grid and provide a chance for solar-plus-storage to step up

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Perseverance pays off

Photo: pv magazine/Stefanie Loos



With the global pandemic showing few signs of relenting, disruption is commonplace in many parts of the world. Indeed, the dawn of 2022 is taking place against the backdrop of far more unknowns than knowns. Yet despite this, the PV industry is set to achieve another year of rapid expansion. Global installations are widely tipped to exceed 200GW for the year (pp. 12-13), and it will be one in which the milestone of 1 terawatt of installed PV capacity will be surpassed.

Making this dual achievement all the more remarkable has been the environment in which it has been achieved. And that, too, has been one in which disruption has been a major feature. A stretched supply chain, interrupted business travel, a logistics sector in tumult, shifting tariffs and trade disputes, and uncertain policy settings (pp. 10-11) have all been unavoidable – yet the PV industry can be proud with how it persevered and continued to expand.

Underpinning this perseverance has been accelerating efforts to decarbonize – still not fast enough, but moving in the right direction. But it is also informed by the passionate people in the solar and energy storage industries, and their commitment to the cause. And when challenges pop up, they innovate; in terms of business models, ways of getting solar components produced and installed, and in the technologies they supply and deploy.

Innovation is front and center of this edition of the magazine, in the form of the 2021 **pv magazine** Award. And it is an illustrious group of award winners (pp. 48-63). Congratulations go to the seven winners: CAB Solar, Fluence, Fronius, Jolywood, Sono Motors, Sungrow, and Viking Cold Solutions. They represent the breadth of the solar supply chain and new applications of our technology.

It should also be noted that the runners up in each category – termed Highly Commended – were also outstanding: Amphenol, Aristos Real Estate, Coveme, DuPont Teijin Films, Goodwe, Home Power Solutions, NYCHA, Phocos, Studer Cables, and Trina Solar.

Thanks go to all 205 entrants in 2021, and to our 19 independent jurors, who gave up their time to review the entrants. Credit must also go to **pv magazine** editor Mark Hutchins, who managed the Award process. Innovate, persevere and prosper in 2022.

Jonathan Gifford

"You've still got the challenge of installing in a way that minimizes the disturbance"

Archaeologists dig solar

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"Companies continually mine indium ore, but it often goes to refineries that cannot extract the indium"

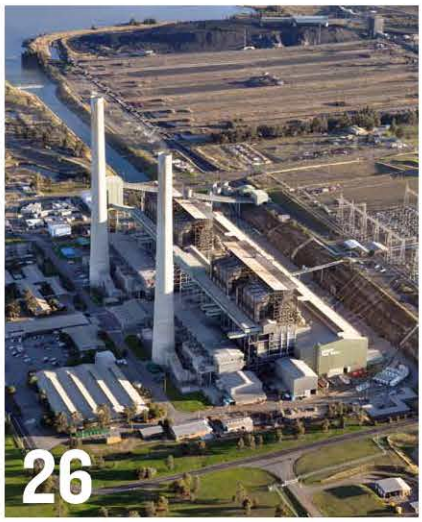
Sustainability, not supply

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Connecting MENA
With renewables growing, interconnection betweeen states could offer a solution for the Middle East and North Africa's stressed grids.



New tools for fossil fuels
Examining the retooling of Australia's coal and gas infrastructure.



Liquid light
The nexus of solar and water solves problems for remote locations and thirsty industries alike.



Driving grid changes
Trials worldwide reveal the potential value and remaining challenges of implementing vehicle-to-grid technology.



pv magazine Award winners
Decisions are in from our expert jurors, and we announce award winners across seven categories.



The actual, real demand for green hydrogen
In certain industries green hydrogen is an essential tool for decarbonization. For others it may be an expensive distraction.

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Don’t trust fairy tales. Trust the facts.



We all love a good story, but when it comes to PV safety, we stick to the truth at SMA. Let’s banish false and misleading information. The facts are these: PV systems pose less of a risk of fire than your refrigerator or tumble dryer. There was never any significant safety issue to begin with – but even so, SMA has been improving standards for the last 40 years. Consequently, SMA has developed lean PV systems with intelligent software functions. With SMA, you only install the devices you need for a reliable and safe energy supply.

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LEAN AND SMART SYSTEMS

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Contributors

Max Hall



Max Hall (pp. 30-32) worked for **pv magazine** between 2012 and 2015 on a part-time basis and returned to the fold full time in July 2018. An old-school print journalist, he has also worked in environmental consultancy, education, local government, infrastructure, aerospace, forensic science and sport. He regularly moonlights as a football writer and lives in Genoa. "As a former student of archaeology and ancient history I wanted to find out whether the claims made for solar projects protecting valuable sites stack up," he says. "I'm still not sure about that, but every little helps, right?"



Sara Fountir Benbrahim

Sara Fountir Benbrahim (pp.18-21) is an energy analyst and engineer with an interdisciplinary background in the energy sector. She holds a Bachelor's degree in energy engineering and an LLM in international and European energy law from TU Berlin. She has been active as a project developer in the MENA region's renewable energy and energy efficiency field and has worked as a part-time consultant for the German and Belgian TSO in-house consulting company EGI. "Interconnectors allow for more renewables growth in the MENA region and open the door for green electricity exports to Europe," she says. "However, such projects are prone to legal and regulatory challenges as they cross more than one jurisdiction and require the consensus among many parties."

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New inverter factory planned for Algeria

Italian inverter maker Fimer and Algerian electronic components producer Entreprise Nationale des Industries Electroniques (ENIE) have created a joint venture to set up an inverter factory at an undisclosed location in Algeria. The announcement was made in mid-December by the Italian embassy in Algeria, which said on Twitter that the agreement represents a first step for the two countries in jointly developing renewable energy. They did not disclose any other details on the deal. On the same day, Italian oil and energy company Eni and Algerian state-owned oil and gas supplier Sonatrach signed a new oil contract related to the onshore Berkine basin area, which is operated by Eni itself, and a memorandum of understanding to cooperate on unspecified initiatives in the energy transition. "The agreement provides for the assessment of joint opportunities in the fields of renewables, hydrogen, the capture, use and storage of CO_2, bio-refining, and many other initiatives in line with the companies' respective decarbonization objectives," the two companies said in a joint statement. Algeria's energy ministry is expected to launch a tender for the deployment of 1GW of solar capacity soon. The Algerian Renewable Energy Company (SHAEMS), which is jointly owned by Sonatrach and power utility Sonelgaz, will be allowed to take a share of up to 25% in the special purpose vehicles that will own the winning projects.



Photo: Fimer

Jolywood switches on 1.5GW TOPCon solar cell factory

Chinese PV module manufacturer Jolywood has commissioned a 1.5GW TOPCon solar cell factory in Taizhou, in China's Zhejiang province. "With this new manufacturing facility, our TOPCon solar cell production capacity has now reached 3.6GW," a company spokesperson told **pv magazine**. The other 2.1GW of capacity comes from another factory located in Jiangsu province. "Our new production plant will produce cells based on larger wafers with a size of 182 mm," the spokesperson added. Jolywood said the factory will produce n-type bifacial cells with fully automated production equipment relying on 5G intelligent automated guided vehicles (AGV materials) and product transmission systems.



Photo: Jolywood

Israeli tender allocates 1.14GW of PV



Photo: Belectric

Israel's Ministry of Finance has said that the winner of its PV tender, launched in January 2020 for a 330MW solar power plant in the Negev desert, is Israeli renewable energy developer Shikun & Binui Energy Ltd. The project will also include 210MWh of storage and is scheduled for completion in 2023.

"The Dimona project reflects the new spirit of the last Israeli government, seriously promoting Israel's energy security and shifting to solar plus storage," the director of Israel's Green Energy Association, Eitan Parnass, told **pv magazine**. "Our country will need eight more such projects to achieve national goals and detach from new natural gas power plants." The bid submitted by the company was ILS 0.0858/kWh ($0.0272). The other winners of the tender include Doral Energy (100MW), Zabar Solar (65MW), YVS Renewable Energy (50MW), Enlight Energy (30MW), and EDF Renewables (32MW).

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Shell buys US solar and storage company

Energy company Royal Dutch Shell has announced it will acquire US solar and storage project developer Savion LLC. The financial terms of the deal were not disclosed. The Anglo-Dutch energy business will buy Savion from the Green Investment Group owned by Australian investor Macquarie. Shell said its planned new subsidiary boasts a pipeline running to more than 18GW of solar power generation and energy storage projects across more than 100 projects in 26 US states.

Photo: Royal Dutch Shell Plc

Baywa wraps up major VPPA

Solar developer Baywa re has signed a 10-year virtual power purchase agreement (VPPA) with Finnish packaging company Huhtamaki for two new solar projects in Spain. According to the partners, it is the biggest corporate solar VPPA for the European packaging industry and the first for a Finnish company. Huhtamaki, primarily a food packaging business, has ambitions to "become the first choice in sustainable packaging solutions." The Finnish company is taking a big step in that direction with a VPPA that will see 200GWh of solar electricity satisfy around 80% of Huhtamaki's annual European power needs. The power supply deal makes possible two new solar farms in southern Spain with an aggregate generation capacity of 135MWp. Huhtamaki will buy the power from Baywa at a predetermined price. BayWa said the VPPA has been structured "with an innovative price mechanism that benefits both parties during times of high electricity costs and [the] current supply chain challenges with PV modules."



Photo: Baywa re

Wärtsilä to supply largest battery in Netherlands



Photo: Eneco

In its first foray into the Dutch energy storage market, Finnish technology group Wärtsilä will deliver the country's largest battery system to date. The 25MW/48MWh system, called the Giga Buffalo battery, will be supplied to energy utility Eneco and local developer GIGA Storage BV and co-located with wind and solar assets in the province of Flevoland. Touted as the first large-scale energy storage project based on lithium iron phosphate (LFP) chemistry in Europe, the Buffalo battery is expected to become operational in October 2022. The system will be located close to Wageningen University and Research, and will be connected to the local Windnet smart grid. Eneco will use the battery to forecast supply-demand errors on the intraday trading market. The battery will also allow the addition of more renewables to the grid, regulate frequency, and improve revenues.

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Policy headwinds

Solar stocks underperformed broader markets in December, writes Jesse Pichel of ROTH Capital Partners. The Invesco Solar ETF decreased 8.5%, while the S&P 500 increased by 2.4%, and the Dow Jones Industrial Average increased by 3.9%.

Invesco Solar ETF (TAN)

Source: Roth Capital



Company	Ticker	Close price Dec. 17, 2021	% change Dec. 1–17, 2021	% change year to date
Risen Energy Co.,Ltd.	SZSE:300118	33.66 CNY	+0.8%	+16.8%
REC Silicon ASA	OB:RECsi	17.69 NOK	–13.3%	+9.9%
Jolywood (Suzhou) Sunwatt Co., Ltd.	SZSE:300393	16.80 CNY	–5.5%	+81.1%
PVA TePla AG	XTRA:TPE	39.80 EUR	–10.4%	+103.1%
Wacker Chemie AG	XTRA:WCH	134.50 EUR	–8.3%	+15.2%
Manz AG	XTRA:M5Z	42.85 EUR	–12.4%	+26.0%
Shenzhen S.C New Energy Technology Corp.	SZSE:300724	125.07 CNY	+2.9%	–14.1%
Enphase Energy, Inc.	NasdaqGM:ENPH	189.11 USD	–20.2%	+7.8%
Applied Materials, Inc.	NasdaqGS:AMAT	146.15 USD	–3.6%	+69.4%
Beijing Jingyuntong Technology Co., Ltd.	SHSE:601908	10.14 CNY	–6.0%	–1.5%
Array Technologies, Inc.	nasdaqgm:arry	16.58 USD	–6.1%	–61.6%
JinkoSolar Hold. Co., Ltd.	NYSE:JKS	46.29 USD	–9.2%	–25.2%
Meyer Burger Technology AG	SWX:MBTN	0.39 CHF	–13.9%	+17.2%
centrotherm international AG	DB:CTNK	4.91 EUR	–11.7%	+77.9%
Hannon Armstrong, Inc.	NYSE:HASI	51.93 USD	–6.4%	–18.1%
Atlantica Sustainable Infrastructure plc	NasdaqGS:AY	36.53 USD	–2.8%	–3.8%
SMA Solar Technology AG	XTRA:S92	36.86 EUR	–16.6%	–34.1%
SolarEdge Technologies, Inc.	NasdaqGS:SEDG	288.85 USD	–8.3%	–9.5%
Sungrow Power Supply Co., Ltd.	SZSE:300274	146.50 CNY	–8.4%	102.7%
Canadian Solar Inc.	NasdaqGS:CSIQ	31.86 USD	–13.1%	–37.8%
Tianjin Zhonghuan Semiconductor Co., Ltd.	SZSE:002129	40.42 CNY	–4.2%	+58.5%
LONGi Green Energy Technology Co., Ltd.	SHSE:601012	81.90 CNY	–2.6%	+24.4%
Xinyi Solar Hold. Ltd.	SEHK:968	13.72 HKD	–3.0%	–32.2%
TBEA Co., Ltd.	SHSE:600089	23.49 CNY	+4.3%	+131.4%
Azure Power Global Ltd.	NYSE:AZRE	18.24 USD	–8.9%	–55.3%

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.

During December, the Invesco Solar ETF (TAN) experienced significant pullback, largely due to policy headwinds. These policies included the modest impact from the Uyghur Forced Labor Prevention Act (UFLPA), the delay of the Build Back Better (BBB) bill, and major changes in California's Net Energy Metering 3.0 (NEM 3.0).

On Dec. 16, US Congress passed the UFLPA, which imposes an import ban on goods mined or produced in China's Xinjiang region. The impact of the UFLPA will tack onto the Withhold Release Orders (WRO) and related supply chain adjustments already underway.

UFLPA would effectively complement the Hoshine WRO currently stopping shipments into the US market for Jinko Solar (JKS), Longi, and Trina. JKS is already shifting supply chains in non-Chinese poly to Vietnam for wafer, cell, and module production for US shipments. Others could follow suit and would ultimately implement traceability practices to ensure that even if poly originates in China, it would not come from Xinjiang.

On Dec. 19, US Senator Joe Manchin rejected the BBB due to increased inflation concerns/nation's debt level/how renewables expansion could impact grid reliability and increase reliance on foreign supply chains. While Manchin's announcement meaningfully reduces the chances of an extended Investment Tax Credit (ITC) and a manufacturing Production Tax Credit (PTC) for renewables, there is modest potential for these provisions to be included in a separate piece of legislation or a tax extenders package in 2022, though it remains too early to say.

On Dec. 13, California regulators proposed changes to the state's solar incentive program. The proposed policy, NEM 3.0, would reduce payments granted to solar customers for the excess power they generate and add monthly charges for grid connection. If said changes become final, the California market would be driven to 100% storage immediately, but could also significantly cut volumes. *Jesse Pichel*

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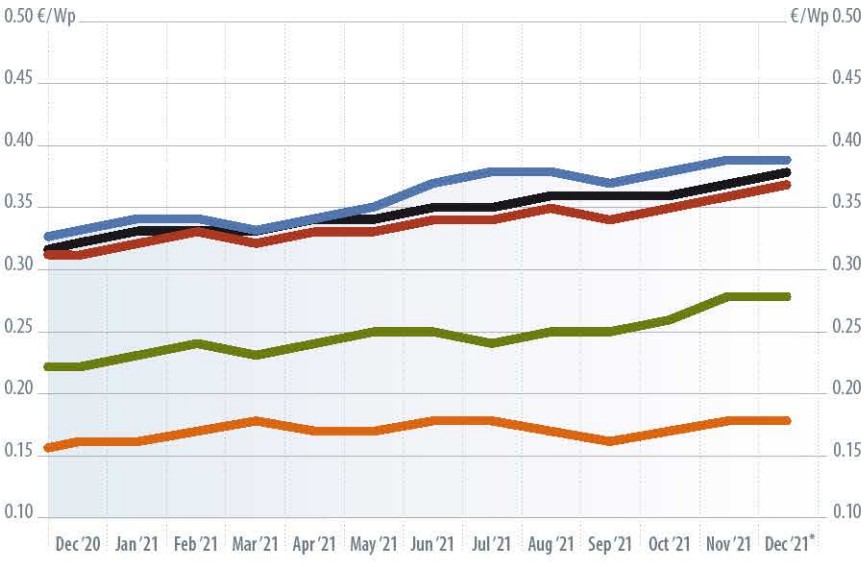
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Out with the old, in with

When module and balance of system prices are high, new installations become less profitable and the focus shifts back to renovating and optimizing existing arrays. Although there are signs that the upward price trend is slowing, Martin Schachinger and Falko Krause of pvXchange say there is still no evidence that prices are stabilizing or falling.

As already predicted, a few remaining stocks of new modules – some of them quite large – have come onto the European market over the past few weeks. However, these were quickly snapped up by large developers and others wanting to restock their warehouses to be on the safe side for the next quarter. Although module prices are unlikely to rise any further for the time being, the major manufacturers' production facilities are already fully booked for months, which means that there is very little short-term capacity for new PV module orders.

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 December 13, 2021
More information: www.pvXchange.com

Springtime is maintenance time, and especially after a severe winter it is a good idea to have PV plants checked for damage. Even for smaller roof systems regular checks are recommended, along with taking care of any maintenance and repairs. This is even more important for large rooftop and ground-mounted systems with thousands of modules. Of course, installations that are getting on in years often need to be optimized. But inspection and repair work, especially on larger PV plants, is often underestimated. The technical optimization of existing systems is not just a matter of installing new parts, but also involves complex issues that can lead to serious risks for the operator. Often these risks remain undetected, and the operators are not aware of their responsibility.

In addition to technical defects and problems that lead to noticeable yield losses and erosion of profitability, product faults may also be present. And although they are not visible at first in performance analyses, they can create serious safety hazards and operator risks.

Cracks in backsheet films are a good example of an issue that is getting increased attention in the solar industry. These cracks can cause PV panels to lose their "class 2" protection rating and essentially revert to protection "class 0" devices. This has huge repercussions for the system operator, who has to ensure that only qualified electricians can enter the PV plant because it is then considered an electrical operating facility. Modules with defective backsheets therefore must be replaced, but such a large-scale replacement operation is anything but easy.

Revamping and repowering

The old module types used in plants are usually no longer available and if they are, they have to be purchased or reproduced at prices often significantly above the market rate for standard products. Such products are only economical in individual cases, which is why as a rule the only option is to replace them with

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the new

current module types that have a much higher individual output. Because the replacement products have different electrical characteristics, new calculations for current-carrying capacities have to be performed for cable and fuse design in accordance with standards. When more powerful modules are used, the strings often have to be configured differently. It is critical that the total DC output of the original PV system is not exceeded. Overshooting even by a small amount can lead to a loss of EEG feed-in tariffs, and not just in Germany.

As early as the planning phase, it is advisable to coordinate the refurbishment and optimization concept in advance with the network operator responsible for the plant. Another issue that is important to clarify is whether planned modifications to the medium-voltage system are grandfathered or new guidelines have to be met.

In Germany, while EEG conformity should be the top priority when replacing modules, an inverter replacement for systems over 135kWp will generally entail an adjustment of the system certificate required. This is always the case if the new inverter has a different unit certificate than the defective inverter. If this is ignored, then the plant certificate loses its validity. An invalid plant certificate can in turn lead to the loss of the feed-in tariff.

Of course, one can and should discuss with the network operator whether such a costly renewal of the plant certificate is really necessary, provided that the installer can ensure that the protection settings of the new inverters do not bypass the central plant safeguards and that the correct settings are made on the new inverter.

Simply adapting the plant certificate is not enough, however. After that, a new declaration of conformity also has to be issued based on the commissioning declaration, the plant certificate and an on-site inspection. The certificate and the declaration of conformity demonstrate that the plant meets the requirements of the respective application rule and the relevant technical connection conditions (TAB) of the network operator. And, of course, the refurbishing measures also have to be carried out correctly. In Germany, this includes updating the system documentation, a documented commissioning measurement, and an installer's confirmation in accordance with regulations. Other countries have similar regulations that must be observed and complied with.

Thus, major repair work is not solely a matter of installing parts but also of process reliability, conformity and minimizing operator risks. Specialized service providers can offer support in this area by carrying out measurement and documentation obligations for their customers or by conducting specialized training courses.

This will be the first part in a series of articles, where the technical and regulatory intricacies that stakeholders should be aware of in connection with the construction, maintenance and repair of medium- to large-scale photovoltaic installations will be discussed. Tune in next month for more.

Falko Krause and Martin Schachinger

Overview of price points broken down by technology in December 2021, including changes from the previous month (as of Dec. 13)

Module class	€/Wp	Trend since Nov. 2021	Trend since Jan. 2021	Description
Crystalline modules				
Bifacial	0.39	0.0%	+14.7%	Modules with bifacial cells, transparent backsheets, or glass-glass, framed and unframed
High efficiency	0.37	+2.8%	+15.6%	Crystalline panels at 340 Wp and above, with PERC, HJT, n-type, or back-contact cells, or combinations thereof
All black	0.38	+2.7%	+15.2%	Module types with black backsheets, black frames, and rated power between 290 Wp and 400 Wp
Mainstream	0.28	0.0%	+21.7%	Modules typically featuring 60 cells, standard aluminum frames, white backsheets, and 275 Wp to 335 Wp
Low cost	0.18	0.0%	+12.5%	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 authors



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.*



Falko Krause *is a co-founder and the CTO of GME clean power AG. As a TÜV-certified appraiser, he is active as a provider of technical advice, system planning, and quality assessments. GME clean power AG focuses on optimizing existing systems and developing ecologically and economically sensible photovoltaic projects.*

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A perfect storm for PV

The supply chain disruptions that started in the second half of 2020, with the economic opening after Covid-19's initial waves, reached new highs in 2021. Edurne Zoco, IHS Markit's executive director for clean technology and renewables, sees five main drivers for the disruptions of the industry throughout 2021. However, forecasts remain bullish, with more than 200GW of new PV installations expected this year.

The solar industry has faced unprecedentedly strong market demand in China and international markets. Corporations, national governments, and financial institutions have all committed to big renewable targets. But the supply chain has been running behind policy and targets in 2021. This is a short-term effect and there is no doubt that solar will be ready to support 2030 targets once it sorts out some of the current key bottlenecks.

Polysilicon has been at the epicenter of disruption. Long-term contract prices for the material have increased over 200% in the last 12 months. Polysilicon has been the key driver of higher production costs, but it is not the only one. Prices have increased for practically all module materials, most notably glass, steel, and polymers. The other key components of a PV system – inverters and fixed structures and trackers – are also being impacted by the semiconductor shortage and high steel prices.

Long-term contract prices for polysilicon have risen more than

200%

in the last 12 months

Concentrated supply

The concentration of the solar supply chain in China for all key components and materials has further aggravated shortages. There are key markets with trade barriers to import of materials and components manufactured in China (the United States, India) and, there are also increasing concerns around parts of the supply chain that are manufactured in the Xinjiang region, which represented almost 40% of global polysilicon production this year. This is triggering major headaches for large international corporate buyers and financial institutions that do not want to be entwined with potential ties to alleged forced labor production.

This year the industry faced unprecedented high transportation costs and long-lead times. The latest IHS Markit Purchasing Managers' Index (PMI) survey of global manufacturing found that the delays in delivery times are the most severe ever recorded, going back a quarter century. Freight disruption is not unique to the solar industry, but industries with strong local manufacturing concentration in Asia, like solar PV, have been the most severely impacted.

Finally, high policy uncertainty in the three major solar PV markets – China, United States and India – has created planning difficulties for the supply chain and developers. In the United States, there is no confirmation of the Investment Tax Credit (ITC) extension yet, which would certainly impact the project pipeline in the short-term and there is no official confirmation of a requested extension of Section 201 tariffs for another four years.

In India, there is an upcoming Basic Custom Duty (BCD) of 40% to all imported modules and 25% of cells that should be implemented from April 1, 2022, but will most likely be delayed. In China, the national government imposed power curtailment in early October as part of its "dual-control on energy intensity and total energy consumption level" to control high-level provincial emissions. This curtailment triggered a dramatic lowering of manufacturers' utilization rates in the final quarter for key materials such as silicon metal, polysilicon, polymers, solar glass that are all energy intense and located in the most impacted regions, triggering panic and additional price increases.

This intense logistic and supply chain disruption over the past year has pushed the cost of solar installations upwards year on year for the first time on record. The global average of PV systems costs has increased 4% year on year, impacting contract negotiations and lowering projected internal rates of return (IRRs). Many projects are being delayed or even cancelled but there is so much appetite to develop and finance renewable projects at this moment that global shipments have maintained 20% higher year on year.

Looking ahead

Supply chain tightness will persist and maintain high prices in 2022, particularly in the first half. IHS Markit does not

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Photo: Tristan Taussac/Flickr



Containers lined up at the French port of Marseilles. While new capacity and increased competition will likely see polysilicon and wafer prices begin to fall by mid-2022, IHS Markit expects little to change, given currently high shipping costs, before 2023.

expect any major changes in container freight costs until 2023. However, there is some light at the end of the (supply chain) tunnel. The ramping up of new polysilicon capacity is coming earlier than planned and the aggressive decrease of conversion rates (g/W) from wafer players implemented this year will also help to improve polysilicon availability. The entrance of new wafer players in the market will also contribute to increased price competition at the wafer level. All in all, we forecast a moderate price decline of polysilicon and a more important decline of wafer prices next year that will ultimately impact module prices, particularly in the second half.

Another factor that will increase availability relates to policy changes in mainland China. In December, the central economic work conference outlined the new guidelines for the energy consumption and energy intensity, stating that the manufacturing of renewable supply chain's materials will be excluded from the "dual-control on energy intensity and total energy consumption level" requirements and will not face power restrictions. This exception, given the low-carbon nature of renewables, is clearly aligned with recent ambitious announcements to develop solar PV in China as a pillar of the new decarbonization agenda of the national government.

Trade barriers and geopolitics will continue to be at the center of the industry, starting to reshape the global manufacturing map. Leading Chinese manufacturers with growing restrictions to export to the US and Indian market (second and third largest solar installation markets, respectively) will face mounting pressure to build new capacity outside of mainland China to continue selling into these international markets.

At IHS Markit, we remain bullish in our forecast for 2022. Despite this high-cost scenario, solar installations will still see double-digit growth next year and installations are forecast to be over 200GW with distributed generation leading most of the growth. Moreover, high electricity prices, geopolitics, and price volatility of other conventional energy sources at this moment (that is, gas) will also contribute to reduce the negative impact that short-term higher PV system capex could slow down renewables deployment next year.

Edurne Zoco



About the author

***Edurne Zoco** is an executive director for the clean technology and renewables team at IHS Markit, leading the group's research activities across renewables, batteries, and energy storage. Zoco has been involved in the solar industry for more than a decade and has presented at leading industry events and conferences since 2007. Prior to joining IHS Markit, she was employed by Trina Solar, a leading PV manufacturer, where she held global positions within corporate and strategic marketing.*

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Building back better

The United States set new plans for the energy transition and climate change after President Joe Biden took office, setting the nation on a path to achieving its ambitious goals with legislation related to renewable energy deployment. Albert Hsieh, a researcher at PV InfoLink, explores the various factors affecting solar development in the United States and the possible impacts on the PV industry if the Build Back Better Act is passed.

Some of the climate goals laid out by the Biden administration include 50% to 52% emissions reductions from 2005 levels by 2030, 100% clean energy by 2035, and net zero emissions by 2050, focused on the wider target of maintaining a global temperature increase below 1.5 C. Solar is expected to see at least 30GW of installations every year thoughout that period. Demand will mainly come from utility scale projects and PV arrays developed under power purchase agreements signed between businesses and renewable energy generators.

Currently, the solar investment tax credit (ITC) is a major driver behind growth. Last December, US Congress extended the ITC for two years, meaning that tax credits for residential projects will be available until 2023, while C&I distributed and utility-scale projects will remain available beyond 2024. Both will likely allow for a tax credit of up to 26%.

Supply issues

Module manufacturers in the United States rely heavily on cell imports due to the lack of domestic wafer and cell capacity. Since the US government imposed tariffs on solar products from China, module demand in the country has mainly been supplied by thin-film manufacturer First Solar, as well as module and cell makers in Southeast Asia.

Punitive tariffs on imports to the US from China include antidumping and countervailing duties (AD/CVD), as well as Section 201 and Section 301 tariffs. Calculations show that a 44.28% tariff rate (including 19.28% AD/CVD and Section 301 tariffs) will be imposed on modules exporting from China to the US in 2022, after the Section 201 tariffs expire. History suggests that it's hard to predict the impacts of antidumping and countervailing measures as many variables exist.

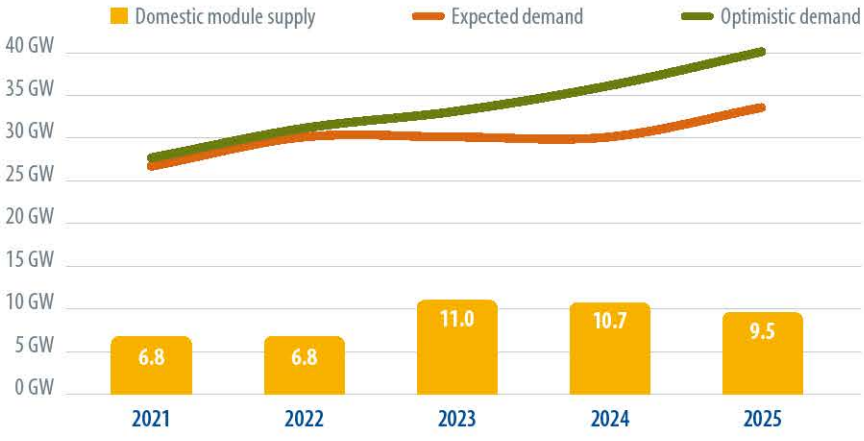
High tariffs reduce the competitiveness of Chinese modules and cells. However, the US remains appealing to module suppliers as it is the third-largest PV market after China and Europe, with higher prices than other regions. Therefore, Chinese vertically integrated companies are planning wafer, cell and module capacity expansions in Southeast Asian countries not subject to AD/CVD and Section 301, such as Malaysia, Vietnam, and Thailand.

Southeast Asia, with continually growing production capacity, has become the largest solar supply chain network after China. The region is also the biggest source of solar exports to the US. Some American PV manufacturers have therefore filed petitions requesting anti-circumvention investigations against certain Chinese PV manufacturers in the region. Although the petition was declined, risks posed by tariffs still stall some Chinese manufacturers' expansion projects in Southeast Asia.

Xinjiang, a major silicon metal and polysilicon manufacturing hub, is expected to contribute 44% of total polysilicon production in 2022. In December, the US Congress passed legislation banning imports of products made in Xinjiang citing human rights concerns. According to the latest legislation, all products made in whole or in part in Xinjiang will be banned unless companies can prove goods were not manufactured using

US demand and module capacity outlook

Source: InfoLink



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ITC timeline as of Dec. 2021

2006 – 2019	2020 – 2022	2023	2024	2025
C&I and utility projects: Construction between 2006 and 2019. Projects that start operation before 2026 can receive 30% ITC.	**C&I and utility projects:** Install between 2020 and 2022. Projects that start operation before 2026 can receive 26% ITC. **Residential projects:** Projects installed between 2020 and 2022 can receive 26% ITC.	**C&I and utility projects:** Projects that start installation during 2023 and operation before 2026 can receive 22% ITC. **Residential projects:** Projects installed during 2023 can receive 22% ITC.	**C&I and utility projects:** Projects that start installation in 2024 and operation before Dec. 2025 can receive 10% ITC. **Residential projects:** ITC ends.	**C&I and utility projects:** Projects that start operation after 2025 can receive up to 10% ITC.

Source: U.S. Department of Energy

forced labor. The bill specifically lists polysilicon and products for PV manufacturing. As measures will be implemented 180 days after the bill comes into effect, manufacturers have time to prepare documents for trace of origin.

The Withhold Release Order issued in June by US Customs and Border Protection can retain products related to Hoshine Silicon, the world's largest silicon metal manufacturer. Although solar importers in the US have been trying various methods to prove that their supply chains are not related to Hoshine, most can only provide certificates of wafer and polysilicon production, due to difficulty in tracing the source of silicon metal, which has led to the seizure of products exported to the US since June. This seriously impacted production and shipments from Southeast Asia, resulting in cell and module utilization rates of only 50% in the fourth quarter. It may become even more complex to prepare certificates of origin under the new law, thereby affecting utilization rates and pushing up costs.

Build Back Better

The House of Representatives passed the Build Back Better Act in November, the biggest budget bill in its history. The framework includes $555 billion for climate change and clean energy. If finally passed by the Senate, the bill would bring good news to the PV industry, as it restores full tax credits for solar projects and provides subsidy for the domestic solar supply chain.

Both ITC and Production Tax Credit (PTC) receive extensions under the legislation, and project owners could claim for either. The PTC allows solar projects constructed before 2027 to claim a credit equal to $0.05-$0.025/kWh for 10 years upon completion. The project is eligible for an additional 10% credit if it meets domestic content conditions. The ITC, on the other hand, is to be extended until 2035. Project owners can receive a tax credit equal to 6% to 30% of the facility costs. Projects that meet the local content requirement or are built in low-income regions can receive an additional 10%.

The extension and restoration of ITC and PTC values under the Build Back Better Act may stimulate long-term solar growth in the US. However, the extension may also cause postponement in projects scheduled to install by 2025, weakening demand in the short term. Against the backdrop of a US-China trade war, the bill includes budget for building domestic solar supply chain and manufacturing to reduce dependence on China. As for manufacturing, the Solar Energy Manufacturing for America Act proposed by Senator Jon Ossoff paves the way for subsidies from production of polysilicon to modules, based on the actual amount of production. If the products are used in the US, an additional 10% payment will be provided. The credit would phase down starting in 2029, based on information issued in mid-December.

> *"The US House of Representatives passed the Build Back Better Act in November, the biggest budget bill in history"*

The subsidy provides benefits to the establishment of domestic PV supply. However, end users may still opt for modules from China or Southeast Asia once tariffs expire, given production costs in the US are high. The bill may also prompt some manufacturers to reconsider setting up facilities or expanding capacity in the US. pv

Albert Hsieh



About the author

Albert Hsieh *is a researcher at PV Infolink. He focuses on economic and renewable policies of countries throughout the world, tracking the impacts of raw material market trends on the development of renewable energy. 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. It also offers professional advice to help companies stay ahead of competition in the market.*

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Reality check

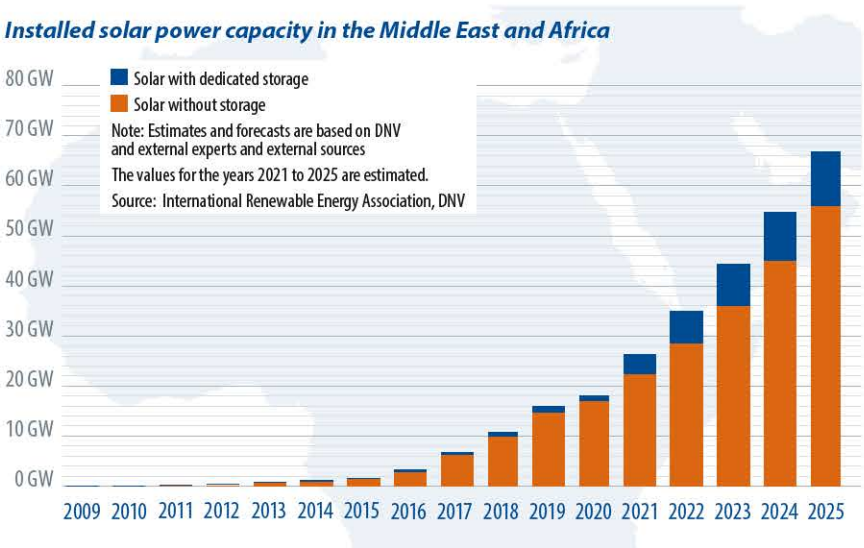
Ecstasy to agony summarizes the past year of solar. As technology evolves and materials are optimized every year, we're witnessing rapid advancements accelerating the transition to a low-carbon economy with the implementation of artificial intelligence applications, writes Denisa Fainis, general secretary of the Middle East Solar Industry Association. Real-time data, advanced analytics, and automation are essential to the digitalization of increasingly decentralized power systems.

Solar progress in the Middle East and North Africa (MENA) region is held back by global realities. Most of 2022's solar PV projects risk delay or cancellation due to an increase in the raw material and logistics costs. The cost of PV modules surged from below $0.20/W in 2020 to between $0.26 and $0.28/W in the second half of 2021 – almost a 50% increase in a year, to a peak of $0.30 to close the year. Developers and offtakers face a decision on whether to reduce their margins, delay projects or increase offtake prices. Another burden is shipping costs, with a near 500% increase. The levelized cost of electricity (LCOE) has increased between 10% and 15% for most of the projects planned for 2022.

"Developers and offtakers face a decision on whether to reduce their margins, delay projects or increase offtake prices"

In the MENA region, the total installed solar power capacity is increasing as initiatives to implement sustainability goals are approaching. On one hand, by 2025, almost 40GW of solar is expected to be added. On the other, as the chart to the bottom left shows, solar-plus-storage projects will also increase by almost 10 times. Consequently, to reach net zero, countries in the MENA region are focusing their efforts on clean, green energy.

Installed solar power capacity in the Middle East and Africa



Climate commitments

The COP 26 conference in Glasgow highlighted UAE's climate change efforts, and the country's remarkable contributions to addressing the matter. The UAE's Ministry of Energy and Infrastructure was highly commended, resulting in the UAE being appointed the host of the 28th session of the Conference of the Parties (COP28) to the United Nations Framework Convention on Climate Change in Abu Dhabi in 2023. The great recognition is a statement of the pioneering role the country is taking in reducing its carbon footprint, with a commitment of net zero by 2050. With two of the largest solar plants on the globe, the UAE's journey to a sustainable future started many years ago and will continue for future generations.

Egypt comes in strong too, as it has been selected to host the next UN climate change summit (COP 27) in 2022. Its continued reliance on fossil fuels and status as the largest oil producer in Africa will bring it some criticism at COP 27. However, the country has expressed plans to build some of the region's largest wind and solar farms.

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Photo: Nextracker



The 1GW Mohamed Bin Rashid Al Maktoum Solar Park in Dubai. The United Arab Emirates has emerged as a regional leader in addressing climate, and has been selected to host the COP 28 conference in 2023.

Saudi Arabia, another superpower of Middle East solar energy, has announced its targets of net-zero emissions by 2060. Megaprojects such as the city of Neom, incorporating green energy plans including a $5 billion hydrogen plant, and the Red Sea Project, which includes 400MW of solar PV and is thought to be the world's largest off-grid energy storage project to date, are part of the kingdom's development plans. Although controversial, the climate measures will go hand in hand with tending to the still high demand and supply of fossil fuels, which account for more than half of Saudi Arabia's revenue.

Lebanon is still in shambles, because cuts to state-run electricity supplies are at an all-time high, in addition to short supplies of diesel for back-up generators. As a result, it has turned to solar energy. The government has no resources to import fossil fuels, which made businesses and residential owners buy more than 200MW of solar equipment in the past year, and the number of solar companies active in the country has increased to more than 400. Demand is surging, as is the need for regulations.

Oman follows strong with the Manah Solar I and II parks with a combined capacity of 1GW to kick off commercial operations by the fourth quarter of 2024. The Oman Power and Water Procurement Company (OPWP) is due to select two international developers for the plants, while Iraq has signed a contract with a developer to build five solar power plants in October. The plants, with a combined capacity of 1GW would be the first step taken by the government to rely on renewable energy to meet the country's needs.

A concise overview of the MENA region's solar market is available in the "2022 Solar Outlook Report" focusing on 14 countries. For the first time, it features Lebanon, Qatar, and Sudan. In its ninth edition, the report includes more than 70 project updates on the region. It also highlights trends, technologies, challenges and opportunities in multiple sectors of the solar industry. The "2022 Solar Outlook Report" will be released during the World Future Energy Summit in Abu Dhabi, at the annual MESIA Solar Awards on Jan. 18, 2022. The report will also be available online from Jan. 17.

Denisa Fainis



About the author

Denisa Fainis, *MESIA general secretary, works on the business development team at Jubaili Bros. Solar. She is responsible for customer interaction and expansion into new markets in the Middle East and Africa. Her focus is developing the division's network and connecting with solar installers, developers and financiers, along with marketing activities. She has more than 12 years of international experience in business development in various sectors, including military contracting, diesel power generation and solar energy.*

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Connecting MENA

The spark of renewables in the MENA region has increased the need for new interconnectors. Big projects with high capacities are being planned across borders to raise electricity exchanges across the region, reviving the dream of a MENA integrated electricity grid.

Two decades ago, electricity companies of the Mediterranean Basin planned, and failed to deliver, a gigantic project called the "MedRing." The project, initiated in 2010, consisted of connecting 22 electricity networks between countries around the Mediterranean, from Morocco via Spain, crossing thousands of kilometers to North Africa and the Middle East, with loop ends connecting Syria to Turkey, and Turkey to the continental European system via Greece and Bulgaria. The objective of this unprecedented construction was to establish a Euro-Mediterranean electricity market.

The pilot project, which initiated multiple interconnection tests, didn't succeed. Although the Maghreb blocks, consisting of Morocco, Algeria, and Tunisia, had demonstrated their effectiveness, the Mashreq block, from Egypt to Syria, showed fluctuations from a disrupted electricity network in the area.

Renewable spur

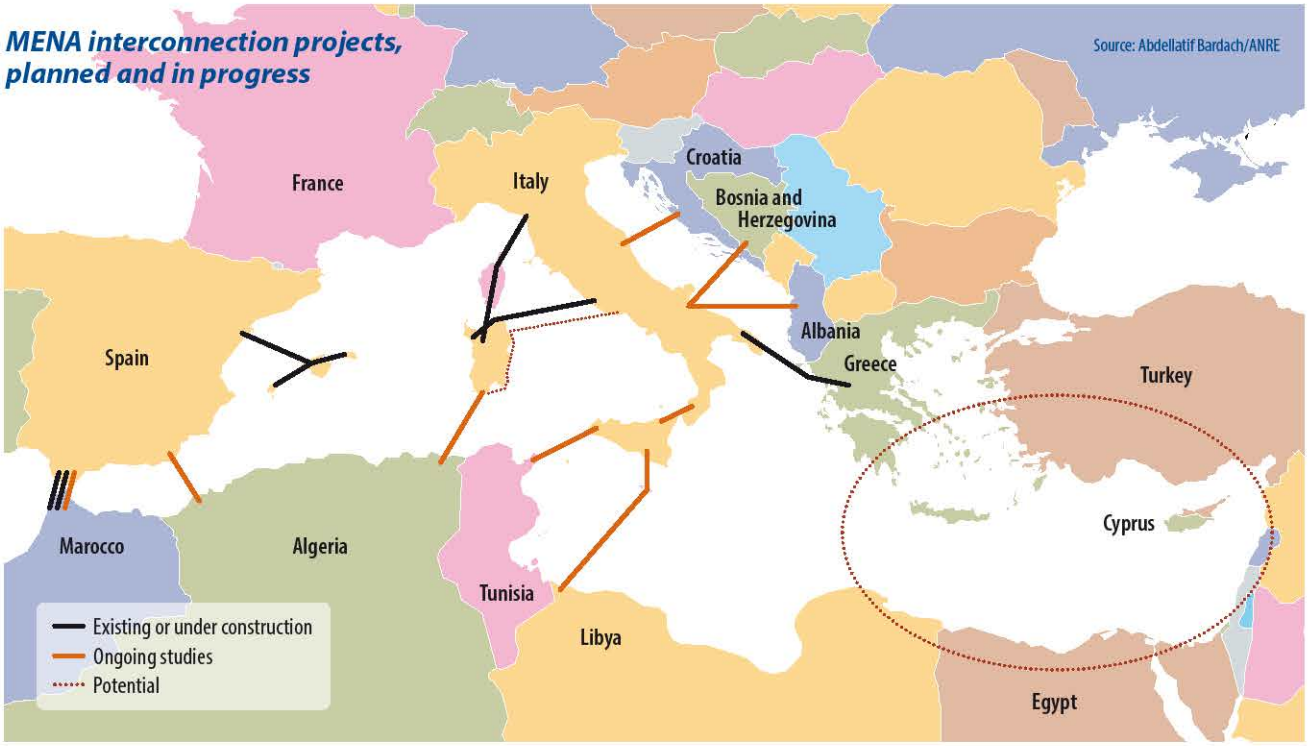
At the time of the deployment of this project, Morocco and Egypt were the only MENA countries exceeding a 10% renewables mix. Both have since set up large-scale development programs for solar and wind. The spur of renewables for the rest of the MENA countries only took place after cost reductions, primarily for PV and wind. In the case of oil and gas producers, the emphasis on renewables has emerged as countries realized that the 8% annual electricity demand growth is eating into the use of their main export commodities; crude oil and natural gas.

Today, the clear-sighted policies and the spread of ambitious renewable energy strategies have resulted in a surplus of energy. Most Gulf Cooperation Council and North African countries experienced a power surplus in 2020, while several countries in the Levant region – namely Lebanon and Iraq – experienced a deficit – according to Apricorp's "MENA Energy-Investment Outlook 2021-25."

New interconnectors

In a decade, the situation has changed. The rising share of renewables in the system is putting a different challenge to electricity networks. Grids are overloaded with renewable supply. This trend will intensify with the ambitious strategies to raise renewable generation in the global energy mix, as Wessel Bakker, DNV's business director of offshore power grids, explains.

MENA interconnection projects, planned and in progress



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"To cope with these raised issues in the grid resulting from a high renewable share, we need to figure out smart solutions enabling better use of the existing grids," says Bakker. "Applying innovative technologies such as smart censoring or adding market dynamics ensures at the first stand that the use of the grid is optimized. But, it doesn't create the ultimate solution."

The DNV consultant adds that given the pronounced mismatch between supply and demand in the MENA region at certain periods, there remains a necessity to strengthen grids through enhanced interconnection.

Besides addressing periods of surplus electricity production, interconnection also assists with relieving chronic power shortages in some parts of the region. The Iraqi grid operator has begun work on a project to connect its power network with Jordan, enabling the latter to deliver up to 1TWh per year of electricity to Iraq during the project's first phase. The plan seeks to address shortages that have forced the country to rely heavily on electricity imports from Iran. The project runs parallel to another plan to build a common power grid with the Gulf Cooperation Council (GCC), a local news agency reported, quoting Iraqi Electricity Ministry spokesman Ahmed Al-Abadi.

While the GCC interconnection infrastructure is already in place and operational since 2016, it has a utilization rate below 10%. Its main uses thus far have been for emergency and reserve sharing through bilateral contracts. Since Saudi Arabia's power system operates at a frequency of 60Hz while the other systems are at 50Hz, the interconnection includes back-to-back HVDC converter stations to connect Saudi Arabia's 380kV 60Hz system to the 400kV 50Hz power systems. This has significantly delayed interconnector projects between the GCC and the wider MENA area.

The recent interconnection project between Saudi Arabia and Egypt has opened the door to new projects in the area. The $1.6 billion project to improve system reliability and energy imports is gaining momentum in the region. Allowing the daily exchange of up to 3GW at peak times, it is expected to facilitate two complex markets to deliver both increasing cost savings and efficiency gains, especially with rising demand and growing shares of renewables in their power mix.

Europe to MENA

In addition to the cross MENA interconnector projects, more ambitious projects plan to boost EU-MENA interconnectors such as Egypt with Europe via Greece, and Tunisia to Italy. A bold plan to connect Morocco with the United Kingdom via 3,800 kilometers of HVDC sub-sea cables is also being studied.

The construction of such projects relies on the ambitious development plans of solar in northern Africa and benefits from the already quite well-integrated north African electricity markets in terms of physical interconnector capacity.

Although connecting the EU to MENA has been a much-discussed and highly attractive proposition to European markets looking to diversify their power sources, it still has many challenges.

"The sharing of energy resources and the interconnection of networks will create a new era of economic development and integration in the EU-MENA area," DNV's Bakker states. "Technological advancement has enabled us to counter many technical constraints. The latest 525kV extruded cable system demonstrates such, capable of transmitting up to 4GW of energy. These higher rates open huge opportunities for both regions." He adds that the "huge benefits" of such projects are being delayed, with approvals on the EU side particularly slow.

The Moroccan case

Morocco, which is now on track to increase its share of renewables in electricity to 60-65% by 2030, is expected to be one of the main hubs for transferring clean electricity to Europe. It has released significant funds and launched investment programs to support this strategy to strengthen its production and transit capacities. A $172 million average annual investment budget has been allocated to the development and reinforcement of the electricity network in particular for the evacuation needs of new means of production and the increase of the power transit capacity with neighboring countries.

The two 400kV submarine cables with a combined nominal capacity of 1.4GW between Spain and Morocco demonstrate that linking MENA to the EU is feasible. These links are Europe's only electricity interconnections with MENA.

The lines commissioned in 1997 and 2016, respectively, with a technical



Photo: DNV AS

"Getting the infrastructure is one of the challenges and implementing the right technology is another"

Mohammed Atif, DNV's UAE area manager

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Photo: ONEE



Reinforcement of the transit capacity of the electricity interconnection between Morocco and Spain from 700MW to 1,400MW.

capacity of 700MW each, have allowed Morocco to increase the amount of electricity it exports to Europe, from 8GWh in 2017 to 1,207GWh in 2019, according to a forecast made in 2020. Moroccan state owned power and water utility ONEE and Spainish utility REE are examining another reinforcement project with the same technical capacity to be commissioned before 2026.

In addition, a study is underway for a Morocco and Portugal interconnector of 1GW capacity. The technical-economic feasibility study of the interconnection launched on June 20, 2016, jointly by ONEE and the Directorate General of Energy and Geology of Portugal, was awarded to DNV.

Morocco has also recently released its grid code. This step allows more clearance for developers who intend to export their energy to Europe and solve any technical issues that may arise aligning with the European standard.

"Morocco aims to fully integrate its energy market into the European energy market, particularly for electricity, through the deepening and acceleration of the convergence of policies and legislative, institutional, regulatory and governance frameworks relating to the energy sector towards the mechanisms in force at regional level," says Abdellatif Bardach, president of the Moroccan authority for electricity regulation. "We believe that this regional integration will bring resilience and stability to the grid. We also are looking to integrate further into other markets in North and sub-Saharan Africa, as well as Europe. Ongoing studies are exploring the possibility to link the Moroccan grid to West Africa via Mauritania."

However, despite being a successful example, Morocco still has regulatory challenges to overcome. The Morocco-Spain interconnector capacity is forged through short-term power contracts not allowing long-term capacity bookings. This in effect leaves little to no room for the inclusion of a corporate cross-border PPA.

Moreover, ONEE acts as the sole exporter of electricity from Morocco and there is no precedent for a private operator booking the Morocco-Spain interconnector capacity.

A study conducted by RES4Africa Foundation and PwC in April 2021 also highlights the lack of a developed and mutually recognized system of Guarantees of Origin in Morocco. Although such certifications are now being granted by the regulator to renewable installations with a combined capacity of 280MW. To date, only NOOR I solar station and Khalladi wind farm, with capacities of 160MW and 120MW respectively, are certified.

> *"New interconnectors should allow the efficient use of renewable resources"*
>
> **Wessel Bakker, DNV's business director of offshore power grids**

Major constraints

The grounds are different for cross MENA interconnectors and EU-MENA interconnectors. Running transmission lines across the sea is a challenging task. On the technical level, the Mediterranean is very deep in areas, which requires extra effort in the planning and construction phase. DNV, for one, notes that the maintenance of such infrastructure should not be underestimated.

The structure of electricity demand is also very different between Europe and the MENA countries, with a peak of consumption generally in winter in the north and summer in the south. This is significant in that energy exchange in both directions at different times of the year will help secure electricity supply and reduce production costs by using at all times the sources of power that are often the most beneficial from an environmental point of view.

On the market structure side, the latest report published by the EU on interconnectors with neighboring countries focuses on the fact that such projects should be pursued in countries that share

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Project groups	Status	Projects composing the group	Nominal Capacity (MW)
West Mediterranean corridor	Ongoing studies	Morocco – Portugal	1,000
	Ongoing studies	Spain – Morocco	900
	Existing	Morocco-Spain 1	600
	Existing	Morocco-Spain 2	900
	Existing	Algeria -Morocco	1,500
	Ongoing studies	Algeria – Spain	1,000
Central Mediterranean corridor and North Africa Backbone	5 lines	Algeria-Tunisia	
	2 lines exist but not functional	Tunisia-Libya	
	Ongoing studies	Italy – Tunisia	600
	Ongoing studies	Algeria – Italy	1,000
		Algeria – Tunisia – Libya	1,000/2,000
East Mediterranean interconnectors	Ongoing studies	Egypt – Turkey	3,000
	Ongoing studies	Israel – Turkey	2,000
	under construction	Greece – Cyprus – Israel	1,000/1,000
	under construction	Cyprus – Egypt joined with the above project	1,000
South East Mediterranean hub	Ongoing studies	Egypt – Jordan	550
	under construction	Egypt-KSA	3 GW
Eastern Balkan corridor	Existing	Bulgaria – Turkey – Greece	500/500
Mediterranean Middle East reinforcement	Under construction/ rehabilitation	Jordan – Syria	800
	Ongoing studies		
	Under construction		
	Ongoing studies	Jordan-Iraq	114
		Syria – Turkey	600
		Jordan – Palestine	+100

a high level of regulatory convergence and have reliable and well-grounded political, technical, and environmental cooperation with the EU. Differences between the EU and MENA countries regarding power sector structure, market openness, maturity, regulations and institutions, and political stability poses in this fact major challenges.

Both on EU-MENA and cross-MENA levels, projects are prone to legal and regulatory challenges as they cross more than one jurisdiction and require the consensus of many parties. "Getting the infrastructure is one of the challenges and implementing the right technology is another, but making sure that trade can take place, rights are allocated, and sufficient investments are attracted, plus maintaining the crucial balance between the private and public sectors, are matters that are still being worked out in the MENA region," explains DNV's UAE area manager, Mohammed Atif.

Another challenge facing interconnectors is in raising adequate investment. There is no doubting the need for such investment; however, coordinating them is more complex and challenging than national infrastructure projects. From an economic perspective, the development of the interconnectors requires a business model that addresses the common regulatory challenges of grid infrastructure, such as incentives for investment and efficient operations.

This model should consider the risk and heterogeneities among countries. Local regulations and levels of energy subsidies in each country need to be adapted to provide greater flexibility and trading opportunities.

Sara Fountir Benbrahim

Advertisement



Slow progress toward

A vibrant industry across the Middle East – including manufacturers, wholesalers, and a large number of EPCs and installers – supply decarbonized electricity to meet growing air-conditioning demand, tapping the region's abundant sunshine. However, progress toward this vision of a distributed-generation solar market segment and industry in the Gulf region has been slow, according to the president of the Middle East Solar Industry Association (MESIA), Ahmed Nada.

We've seen significant progress in the utility-scale market segment in the Gulf region in recent years. But it seems the rooftop segment has been slower to develop. What would you say is the current progress of distributed-generation (DG) PV in the region?

You are right that the speed and deployment of solar solutions to the rooftops or distributed solar, including C&I, has been slower, and it's due to multiple factors. First of all, in many countries of the Middle East electricity tariffs are still subsidized. And while change is happening, subsidies have not been totally removed, making rooftop solar's competition with tariffs from the utilities still not in the best.

The countries of the Middle East have all adopted [the principle] that there has to be a reduction in subsidies. Due to the fact that utilities in the Middle East by nature have always been the sole provider of electricity to different consumer segments, it is possible that some of the utilities feel that they could be losing market share due to the monopoly situation they are in.

Then there is the [solar] technology pricing changes that happened over the past year. Currently we see prices of modules higher than expected, which has impacted any projects in the pipeline.

So, what do you believe is the most promising DG solar market in the region?

Saudia Arabia will be, as it is currently the country which has the highest subsidies when it comes to tariffs. As they [tariffs] go higher, I would expect to see this market grow. Also, by virtue of its sheer size it is promising, as it has a very big population. For sure the rooftop segment can pick up the fastest the minute you start to see subsidies going away.

The more sustainable countries and those with green energy, and ones in which they [targets] will be implemented are also promising. Both Saudi Arabia and the UAE [United Arab Emirates] have shown commitments. The UAE already has a program and maybe will accelerate it – importantly, the UAE has shown that when they have committed to something, they deliver what they have promised.

Oman is a country that is truly trying to provide unsubsidized electricity, for good economic reasons. After that come Qatar and Kuwait.



Photo: MESIA

What about outside the Gulf?

In terms of the rest of the Middle East, Jordan made very good progress and then slowed down – the utility started to feel like they would lose clients, and so reduced the capacity you can install on your rooftop. Now larger projects are not favored by NEPCO [network operator] and that has slowed Jordan down, although it is still considered to be a very good market as the tariffs were very high. When NEPCO saw that people could compete with them, they lowered capacities on the rooftop.

Although certain countries do have wheeling, such as Egypt, the implementation of these laws has been slowed. If you are allowed to produce power at one place and wheel it to somewhere else, it would help the market – but it has slowed down. For example, if you have a location where you can generate power from solar and wheel it to a factory, currently the factory is not able to pick the power up. The size of the roof [at the factory] might not make

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a big rooftop goal

Photo: Darbco



Distributed solar in Jordan has made excellent progress over the past decade, but recently development has slowed down due to additional regulations.

a solar project economical, unless it's possible to wheel extra from outside. Most projects were hoping to benefit from extra demand from wheeling, but the implementation has not been effective and it appears that Egypt and Jordan have abandoned the idea.

Would you say that the countries of the Middle East are awake to the possibility of the DG segment – not just in terms of renewable generation, but also job creation?

They are, absolutely. In Saudi Arabia, the number of EPCs and contractors is probably more than 10 times what it was three years ago. From value creation and job creation it is well understood. But there is a slowdown, a limitation or a hesitation.

Is it accurate to say that the local utilities are very influential?

They control everything. In each of these countries the utility is only one generation company, or regional companies that report to one headquarters. It is not like there is free trade of energy. And this takes us to the next point, if there is more free trading of energy then definitely, yes there will be more development.

Well, trading is also facilitated by interconnection (pp. 18-21). Do you see this as potentially accelerating the DG segment?

It may not impact rooftop PV but will impact the trading of energy for sure. But once these interconnections are established and ready to transmit power, then the utility scale [renewable energy] projects will be the mainstream energy. And as the countries become more economically and politically interconnected, then there is more space for the rooftop [segment]. It can fill the gap for the utility scale projects. Imagine if a country can sell to a neighbor at $0.04/kWh, the why sell it at home for $0.02/kWh? This could work but it is not a short-term play, it will take some time. PV

Interview by Jonathan Gifford

The number of smaller EPCs has increased by

10 x

in Saudi Arabia over the past three years

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EU works to expand on-grid renewables in Bangladesh

Off-grid solar has been a major success story in Bangladesh. The next step in the country's decarbonization journey is the grid integration of larger-scale renewables – a project in which the EU is playing a major role. Syful Islam reports from Dhaka on the programs and progress.

Bangladesh is presently leading the Climate Vulnerable Forum (CVF), a group of countries that have pledged to generate 100% renewable energy by 2050. At COP 26, Bangladesh placed a new Nationally Determined Contribution (NDC), where it set a target to develop 4.1GW of renewable energy by 2030. It also set a further target to generate 40% green energy by 2050.

Until now, Bangladesh has installed a little over 775MW of renewables, of which around 425MW are grid-connected. But the situation is improving with some large-scale solar power plants coming online and a number under construction. In addition, deals are about to be signed for a number of new projects.

Bangladesh is actively looking for foreign funds to accelerate renewable generation. Investment proposals from countries like China, member states of European Union (EU), and the Middle East are pouring in. Most recently, Bangladesh entered talks with Saudi Arabian company ACWA Power on collaboration in setting up 1GW of solar power projects, along with a green hydrogen project.

The 73.1MW Mymensingh project was connected to the grid in April 2021. So far it is the largest PV project developed in Bangladesh, but the country now has a number of PV projects under construction, with new deals expected to be signed in 2022.



Photo: Ditrolic Solar Group

EU endeavors

Lately, the EU has come up with larger efforts for Bangladesh's energy transition under its annual action program. The program is within the framework of Team Europe Initiative on Green Energy Transition (TEI GET) which is co-chaired by Germany and the EU delegation and includes several EU Member States and like-minded partners. The overall objective is to support Bangladesh in developing a power system that leads to maximum coverage of the country's energy demand through renewable energy, while reducing demand through energy efficiency.

Maurizio Cian, head of cooperation for the EU Delegation to Bangladesh and Johannes Schneider, head of development cooperation at the German embassy in Dhaka provided details and plans for the TEI GET initiative in a written statement.

They report that TEI GET brings together the best possible mix of modalities, tools and partners, including the private sector. It will deliver concrete results, in line with the strategic and national priorities, and promote the "Team Europe" brand supporting Bangladesh to restructure, modernize, and decarbonize its power system, they said.

It will lead to maximum coverage of the country's energy demand through renewable energy while reducing greenhouse gas (GHG) emissions, energy consumption and demand through enhanced energy efficiency. The TEI GET aims to promote public and private investments in renewable energy and energy efficiency measures, hence reducing environmental degradation and ultimately contributing to the global response to climate change, the statement continued.

Cian and Schneider said they are in communication with the Bangladesh government to adapt or implement national policies, for a low-carbon development and support a low-carbon power system. Also, they will support the creation of an effective market for sustainable clean energy, which sets the right incentives for the best technology at the right place.

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Photo: Embassy of the Federal Republic of Germany Dhaka



Johannes Schneider is the head of development cooperation at the German embassy in Dhaka.

Enhancing networks

Additionally, the TEI GET will work on the optimization of Bangladesh's grid to integrate the growing share of renewable energy, while at the same time adapting its operation and the provision of ancillary services. Energy efficiency in terms of existing generation, distribution and private and commercial consumption, has also been identified as a priority.

In a written response to **pv magazine**, the European spokespeople said the existing program and the upcoming financial commitments under the umbrella of TEI GET amount to approximately €920 million, covering both grants and credit finance in support of the green energy transition in Bangladesh.

They said the TEI GET is already providing consultancy and has multiple ongoing investments through existing programs. These include projects on energy efficiency, improvement of power transmission, modernization of distribution grids, safety retrofits and environmental upgrades.

Future investments might include policy advisory and consultancy for supporting the green energy transition, investments in large scale renewable energy plants, energy efficiency at consumption level, energy storage, and adaptation for renewables' integration in the grid. Cian and Schneider will work with both the public and private sector under the TEI GET.

In the specific case of energy efficiency, industries will have to play a key role and energy audits are a useful tool to encourage retrofitting. Government can facilitate investments in such a way as to provide concessional finance or reduce the interest rates for "green" investments, they said.

Cian and Schneider concluded by noting that expanding the renewable energy share in the energy mix in Bangladesh is essential to improving its competitiveness and image in the international markets.

Although Bangladesh has achieved coverage of electricity to 97% of the total population, security of supply remains a concern. Moreover, large subsidies paid to fossil fuel electricity generation limits the country in terms of resources available for renewable energy, the statement continued.

Bangladesh has already gathered experience in off-grid solar power programs. The challenge is now to bring these off-grid programs to the grid. The net-metering policy introduced by the government is a breakthrough in this regard, but implementation at a wider scale, as well as optimization of the grid to accommodate the renewable generated electricity in the national grid is being given high priority.

Lack of land is often claimed as a fundamental constraint of widespread renewable adoption in Bangladesh, but the right approach and technology has to be considered to overcome the barriers, they added.

Syful Islam

€920 million

of funding and grant commitments made to Bangladesh under the TEI GET

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New tools for fossil fuels

Long thought of as adversaries to renewable energy, fossil fuel assets and infrastructure also present opportunities for solar, its green-hydrogen output, and smart energy storage. Natalie Filatoff reports from Sydney on the opportunities and approaches the miners are taking.

As Andrew Horvath, founder and global group chairman of Star Scientific, has said, "it would be an absolute tragedy for Australia if we were to demolish our fossil fuel infrastructure." More on Horvath's gob-smackingly logical propositions later, but the fact is that Australia's fossil fuel plants – coal and gas fired – sit at the heart of existing transmission infrastructure that was built out to serve populations and industry. The industry is perfectly positioned to change its spots and support, rather than compete with, renewable energy.

Australia's traditional energy-generation companies are charged with keeping the lights on and providing services relevant in a brave renewable world. They have observed the versatility of South Australia's massive Hornsdale Power Reserve – 150MW/194MWh of Tesla lithium-ion energy storage technology, in banking and rapidly discharging the state's renewable riches as needed, keeping demand and supply in balance, and maintaining harmonious frequency control.

A portion of Hornsdale's capacity is reserved for lucrative trading on the National Electricity Market (NEM) – buying when demand and prices are low and selling at the high points. At the same time, the installation has saved South Australian energy consumers millions collectively, including AUD 119 million ($84

The Liddell Power Station in New South Wales is set for rapid closure, with the first unit to shut down in April 2022. Yet the associated assets, infrastructure, and skilled workforce may not be lost.



Photo: AGL Energy Limited

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million) in 2019 alone by significantly reducing the need to rev up expensive gas peaking plants to meet periods of high demand when renewables are becalmed.

AGL, the owner of coal- and gas-fired power stations up and down Australia's long, stringy NEM, and which acknowledges it is Australia's largest emitter of greenhouse gases by a long shot, was also an early adopter in terms of its investments in renewable energy generation. But over the past two years or so, its profits have taken a huge hit due to poor contractual commitment and outages at its fossil-fueled assets, plus remediation costs. AGL has recently announced a re-energizing fleet of battery energy storage projects. The most monumental of these are set to take up dual occupancy of fossil-fuel plant real estate: 500MW at the Liddell coal-fired plant in New South Wales, which is scheduled to close in 2023; 200MW at its Loy Yang coal-fired plant in Victoria; and 250MW at its Torrens Island gas-fired facility in South Australia.

"It's easy to forget the critical role our thermal assets play in ensuring Australians have reliable and affordable energy," Markus Brokhof, AGL's chief operating officer, told **pv magazine**. Leveraging their connectivity will help, he says, "to secure energy reliability as Australia increases its reliance on renewable technologies."

Other Australian fossil-fuel infrastructure sites set to distribute batteries include the former Kwinana coal-fired power station in Western Australia; the Western Australian Government has awarded New Horizons Ahead (formerly Engie EPS) a $155 million contract to build a 100MW/200MWh battery energy storage project. And in south-east Queensland, Stanwell Corporation is planting a 150MW battery on the site of existing Tarong Power Station.

Faking wave forms

AGL's Torrens Island battery in South Australia is at the forefront of grid-stabilizing technologies in that it will be connected to the NEM via SMA grid-forming inverters, which rather than synchronizing to the grid's voltage waveform, will set frequencies that provide the grid with "virtual inertia" that mimics the effect of the onsite synchronous gas-fired generation that the battery will eventually replace.

Joshua Birmingham, director of large-scale and project solutions at SMA Australia, said "the grid is structured around the traditional model of large generators, with the transmission network running out from them. So, providing system strength into that transmission network is absolutely critical."

Birmingham pointed out that existing power stations have grid infrastructure, such as switchyards and transformers, that renewables-based generation and storage can make use of. And not only will batteries perform like-for-like services to fossil-fueled generators, but they also actually one-up the gas turbines in that they can respond more rapidly to grid demand and system strength requirements than it takes a gas turbine to ramp up and deliver.

Birmingham said grid-forming has long been a capability of SMA inverter technology, but that its deployment in Australia has been held back by integration requirements and the need for proof of concept at scale. He said AGL's Torrens Island project is groundbreaking, both locally and in the global arena. "This will be the world's largest grid-forming plant," he said, noting that the 109 inverters SMA is connecting to the battery will solve problems of grid stability not yet experienced anywhere else in the world.

Separately, Birmingham and Brokhof agree that batteries are not a one-stop solution to replacing the spinning mass, the 2GW heft, of a Liddell or a Loy Yang fossil-fuel plant. Birmingham said the strategy of using existing fossil infrastructure to connect grid-forming battery systems will ultimately be complemented by islanded microgrids at the edges of transmission/distribution networks, running their own stable power systems using grid-forming inverters, but still connected to the grid and capable of giving and receiving reciprocal services.

Repurposing fossil sites

AGL's Brokhof, on the other hand, is thinking more in terms of repurposing fossil-fuel sites as "integrated industrial energy hubs," transforming "our large-scale thermal sites into sites with a low-carbon footprint and a highly efficient ecosystem." Part of this approach is that it helps redeploy local workforces that have long operated the fossil fuel plants in AGL's portfolio, and the coal mines that supply them. Brokhof said the hubs "will provide essential jobs and economic activity to the regions while also supporting Australia's energy transition and our goal of net-zero emissions by 2050."



Photo: Star Scientific

"It would be an absolute tragedy for Australia if we were to demolish our fossil fuel infrastructure"

Andrew Horvath, global group chairman of Star Scientific

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Photo: AGL



The Torrens Island Power Station in South Australia began a gradual shutdown in 2014, and the final unit is scheduled to be brought offline in September 2022. The gas-fired plant is now set to be replaced by a 250MW battery.

"One of the most compelling use cases for the existing coal- and gas-fired power stations … is as green-hydrogen-powered stations that will operate on the grid exactly as they do now"

In September, AGL conducted a survey of Upper Hunter residents on the impending closure of Liddell and future opportunities for the site. Its outcomes are still in the works, though a likely mix of grid-scale batteries, a waste-to-energy facility, and a potential connection to the decommissioning Muswellbrook Coal Mine are all possible.

Idemitsu Australia Resources, the new owners of the mine, and AGL are jointly investigating repurposing Muswellbrook's main void, which is capable of holding six gigaliters (Gl) of water, into a pumped-hydro energy storage opportunity. Again, its proximity to grid infrastructure, to new renewables generation, and to a skilled electricity-managing workforce give weight to the proposed $450 million, long-duration (eight-hour) 250MW renewable energy storage facility.

The project requires a 1.9Gl-reservoir to be excavated 2,000 meters up nearby Bells Mountain. Excess energy from renewable generation will be used to pump the water from the Muswellbrook void up the incline; then when energy in the region is insufficient to meet demand, water will be released to flow through electricity-generating turbines.

Digging-in the data centers

Meanwhile, strategic energy consulting firm Energy Estate sees global data centers taking root in disused Australian coal pits. In underground bunkers, backfilled for insulation, the data processors could operate in a colder, more stable environment than surface temperature, said Simon Currie, principal at Energy Estate. They would create a flexible load if enabled with battery energy storage, to help balance demand and supply near energy nodes such as Liddell.

Currie and his team are also working with AGL, in the context of its plans for Liddell, on a blueprint for a Hunter Valley hydrogen network, dubbed H2N. In one scenario, pipelines for hydrogen produced in the budding Renewable Energy Zones of New South Wales, could follow existing transmission easements to the Liddell site/Energy Hub for use in heavy industry in the region, or for processing and export via the Port of Newcastle.

"Existing transmission becomes an investment attraction," Currie told **pv magazine**. "And that completely changes the narrative – one organization's trash becomes someone else's treasure." On that topic, he noted that Australia's first two proposed offshore wind

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developments – the 2.2GW Star of the South project off the Victorian coast, and the 7.5GW Oceanex distributed floating-wind project in the waters off NSW – are planned to take advantage of LaTrobe Valley grid connections around Loy Yang, and defunct coal-fired power stations, and those connected to existing NSW fossil-fuel plants, respectively.

One of the most compelling use cases for existing coal- and gas-fired power stations that have up to a decade of life still in them, is as green-hydrogen-powered stations that will operate on the grid exactly as they do now.

Earlier this year, a report by Green Energy Markets and the Institute for Energy Economics and Financial Analysis showed that up to five of Australia's 16 remaining fossil-fueled power stations scheduled to close between 2029 and 2043, could become financially unviable within the next four years, due to the influx of cheaper renewable energy generators.

Andrew Horvath, global group chairman of Star Scientific, said stability of the grid will be seriously at risk if these stations simply shut down before alternative sources of inertia and system strength have been established.

Steam for turbines

Star Scientific has developed a solution that depends on a reliable supply of cheap green hydrogen. Its Hydrogen Energy Release Optimiser (HERO) won the S&P Global Platts Global Energy Award late last year for its technology – a substance that can be distributed across a substrate such as ceramic or particular metals. "When it comes into contact with hydrogen and oxygen it goes from zero to over 700 C in three minutes," explained Horvath. HERO has been translated into what Horvath calls a "plug-and-play" device that can be retrofitted to power-station turbines to create the steam needed to turn them and generate electricity. "Take the existing boiler offline, put HERO online, and your pollution issues stop, but you maintain those big spinning mass turbines" at the heart of existing infrastructure, providing stability during Australia's energy transition, said Horvath.

Natalie Filatoff

Photo: AGL



A depiction of AGL's large battery setup planned for the site of the Torrens Island gas-fired power plant in the state of South Australia.

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Archaeologists dig solar

Solar's benign infrastructure means it might be able to play a role in key areas where archaeological interests need protection. With minimal land disturbance and an installation process that can be adapted to any finds, solar parks may protect valuable sites. But are those claims overblown? Max Hall digs into the issues.

When the UK government in September published a draft policy document concerned with upgrading its 10-year-old rules for planning energy infrastructure, it had plenty of good things to say about solar. With a nod to the potential biodiversity and water management benefits of PV farms – as well as a note criticizing the claim that glare from panels can interfere with aviation – the document also gave the impression the officers responsible for drafting it had their attention caught by a press release issued just days earlier by Danish renewable energy developer European Energy.

With the solar project company having touted its best practice in uncovering and displaying a significant pre-Roman complex at the site of a big PV project in the Italian region of Puglia, page 90 of the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), published by the Department for Business, Energy and Industrial Strategy (BEIS), stated: "Archaeological finds may be protected by a solar PV farm as the site is removed from regular plowing, and shoes or low-level piling is stipulated."

That potential benefit of large-scale solar was offered up in the section of the document – which was due to remain open to consultation until Nov. 29 – devoted to the impact of solar sites on cul-



European Energy has proudly proclaimed the cultural and economic benefits of its 103MW solar park in Troia, Italy. The developer discovered an ancient archaeological site during surveys for the project.

Photo: European Energy

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tural heritage, an issue that is gaining in prominence across Europe.

The European Energy project appears to have given weight to the argument solar panels can offer protection to sub-surface archaeological remains, after the company released details of the ancient basilica and necropolis it discovered during surveys of the site where it had planned its 103MW solar farm.

The developer, in an Italian-language press release issued on Aug. 26 2021, spoke of its cooperation with local government and archaeological authorities to decide how best to proceed with the solar farm. European Energy said it stumped up "close to €1 million" to fund the resulting survey of the find and an excavation. The developer added in the press release that it spent even more displaying the resulting discoveries in a manner likely to attract tourists to the settlement of ancient Daunia, thus benefiting the local economy. When contacted by **pv magazine**, European Energy did not reveal how much extra had been spent on the exhibition, nor whether part of the cost was borne by the Italian public authorities.

With valuable treasures including ceramics, coins, bracelets, rings and buckles unearthed – particularly from the 117 burials excavated at the early-to-middle Neolithic hypogeum, or underground chamber – the solar industry's claims to be a friend to archaeologists appear to have some basis, even if corporate press releases are seldom shy of exaggerating any positive PR.

Veracity of claims

Ken Whittaker, a UK-based archaeologist and historic environment specialist, believes large-scale solar can help protect sub-surface treasures, and even provide funding for digs. On the plowing issue, Whittaker said, the short answer is "yes." Inevitably, however, there are caveats.

"You've still got the challenge of installing in a way that minimizes the disturbance," said Whittaker, who is director of the Quota Heritage consultancy. "It's not entirely straightforward but it is achievable, in terms of construction."

European Energy did not provide any information to **pv magazine** about the type of pilings used at its Puglia site. Whittaker said there is more to consider than just the type of footing used under the panels, however. The heritage consultant said: "It's not just about how panels are secured in the ground, it's also a question of how panels are connected to the grid and the requirements during construction for site components, access roads, all that needs to be taken into account."



Photo: Ken Whittaker/Quota Heritage

Heritage consultant Ken Whittaker has expressed skepticism about how much protection solar farms might offer underground archaeological sites.

Whittaker is well-placed to provide informed opinions on the draft policy addressing archaeology-related concerns at potential solar sites, as he was involved in the preparation of the set of National Policy Statements for energy infrastructure, which the new publication aims to update.

Referring to the recent consultation paper, Whittaker said: "It reflects the wider policy framework that relates to archaeology and the historic environment. It goes as far as it does, but individual [planning] applications will be judged on a wide range of factors."

The central issue when it comes to heritage and the historic landscape – in Britain just as much as in the culturally rich historic area of "Tuscia," which could potentially be a solar hub in Italy – is that resistance to solar farms often hinges on the issue. While advising planning officers of the benefits solar can offer in addition to clean energy may be helpful, there is a much more effective approach to removing such opposition, said Whittaker, who added that "it's all about creating a dialogue with communities."

> *"The solar industry's claims to be a friend to archaeologists appear to have some basis"*

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Photo: European Energy

European Energy said it worked alongside the local authorities to unearth the ancient archaeological site in Troia. Treasures found at the site included ceramics, coins, bracelets, rings, and buckles.

Ancient sites

The heritage expert offered a warning about simply accepting the idea that planning officials will actively encourage solar parks to protect ancient sites.

Referring specifically to the brief mention made of the topic in the BEIS policy document, Whittaker said: "The policy writers here are making a claim to a benefit that doesn't really bear a great deal of scrutiny. In the context of national planning statements such as this, it's rather opportunistic to make that point. If one takes the issue of the impact of plowing on archaeological sites, it's been known to be a major problem for decades."

While he professed skepticism of the full extent of the claims made by policymakers, Whittaker was keen to stress his support for clean power and emphasized that when it comes to planning decisions, "solar panels are producing renewable energy – that is their chief public good."

The fact remains, though, that the European Energy dig revealed precious finds that may otherwise have lain dormant. The site was being surveyed in preparation for the installation of 275,000 solar panels in a construction project which generated more than 400 jobs. That benefit to the local economy was further boosted by a visitor attraction which presents the impressive sixth to eighth century basilica, and the even more ancient, fourth-century BC necropolis.

As Alessandro Migliorini, European Energy's country manager for Italy stated in that August press release: "We like to think that this model, that sees renewables and archaeological sites as a lever of local economic development while contributing at the same time to the recovery of cultural heritage, can also be replicated in the future and is a further positive sign of the path towards the Italian Green Deal."

Whittaker concedes that the heritage claims of photovoltaics in the United Kingdom are not entirely without merit. "You could find yourself in a position that you know there's a historically important archaeological site at a piece of land and decide the best approach is to install solar panels there, instead of the traditional approach of then avoiding that site," he added. "It's great, from the solar industry's point of view, that it's been given prominence in this policy statement."

Max Hall

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In pictures: Roundtables USA

pv magazine roundtables

Back in November, pv magazine's Roundtables USA 2021 event brought together 29 speakers for more than four hours of in-depth discussion on energy in the United States. The participants talked about how to accelerate the deployment of PV, storage and other renewable energy technologies in pursuit of national and global goals.



The Roundtables were moderated in-studio by pv magazine editors Tim Sylvia, David Wagman and Jonathan Gifford, with speakers and audience members joining virtually from all over the United States and further afield.



The event was divided into two sessions, with the overarching theme being solar opportunities in an age of extremes.

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A panel discussion featuring Chris Tellen of Endurans Solar, John Sedwick of VDE Americas, Jenya Meydbray of PVEL, and Nicole Jackson of Sandia National Laboratories, during the first Roundtable session on optimizing solar systems and hardware.



The second session on ways to accelerate solar PV deployment featured a panel discussion with Clean Energy Associates CEO Paul Wormser, Shoals Technologies CEO Dean Solon, SunPower Head of Policy and Strategy Suzanne Leta, and SEIA Executive Director Elizabeth Sanderson.



November's Roundtable USA brought 1,248 registrants and almost 500 live attendees. The pv magazine team will be back with even more roundtables and great events in 2022.

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On track for cost reduction

Large-format modules have become the industry standard for new utility-scale solar installations, with the conversation now shifting to the optimal wafer size: 210 mm or 182 mm. However, some difficulties persist in switching to the new standard, and a significant portion of the effort has fallen to tracker manufacturers. To gain a better perspective on what has changed, pv magazine's Tim Sylvia sat down with three of the largest tracker manufacturers – Trina Solar, Nextracker, and Array Technologies – to discuss the common themes of availability, optimization and standardization.

Potentially the greatest selling point of a large-format module is the considerable reduction in project costs achieved through the simple idea of purchasing fewer, more powerful solar modules to reach a given capacity and installing them on longer strings. Fewer modules means fewer trackers, fewer inverters, and fewer components overall.

Yet, as long as a range of form factors exist, tracker manufacturers have to devote valuable production capacity to each little variance from module to module, as well as time and resources to testing the effects that these small changes bring. "What's really important to us is the location and dimensions of actually mounting the module onto the tracker," explained Array Technologies' senior product manager for PV module interfaces, Jim Sorensen. "What we want to do is to have a gap between the modules. And if the whole dimension varies from the edge of the module to where the hole is – where we mount that module in order to maintain that gap, and to prevent modules from touching – it becomes really important."

Sorensen explained that the variance then becomes an issue of supply chain complexity, which is not an area any manufacturer wants to stress in the current environment. The variances mean that manufacturers have to keep diverse product inventories. As a result, both production and storage capacity, as well as component supply, become strained. This is eventually reflected in higher tracker prices and an overall increase in levelized cost of electricity (LCOE).

Looming standards

Those who spoke with **pv magazine** all shared optimism that some sort of standardization is coming, with hopes that the industry-wide benefits will outweigh specific manufacturer preferences.

In May 2021, Trina participated in a seminar on the standardization of module sizes, organized by the China Photovoltaic Industry Association, alongside other major industry players. During the seminar, all parties present agreed on the overall dimensions of modules, technical specifications of mounting holes, and smaller details like cell spacing and design reference standards – a significant step toward greater standardization.

"When we think back to 156 mm or 158 mm cells, at that time, pretty much all the modules were also standardized in size, in distance between mounting holes," said Mireia Beltrá, product marketing manager with Trina Solar. "That broke up after this era.

"I think we have found an optimum on the size," Beltrá added. She echoes a popular sentiment, considering that any further increase in size would likely require three-person installation crews, as well as greater reinforcement of mounting systems, both of which would contribute to increased LCOE.

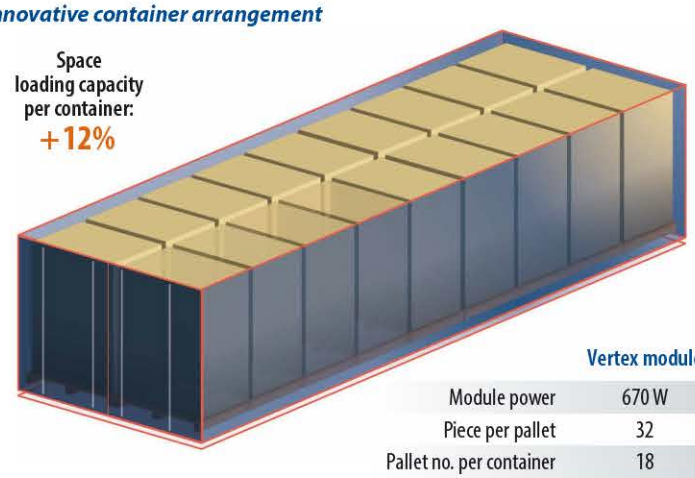
Shipping and supply

According to Beltrá, the form factor of Trina's Vertex products has allowed the company to pack modules vertically into shipping containers rather than horizontally. With the Vertex 670W module, Trina says it can fit 10% to 15% more watts per standard shipping container. Just by providing a more optimized fit within containers, Trina claims an average transportation cost reduction of between 10% and 12%.

Compared to a 540W module, Trina is able to fit one extra module per standard pallet, loading up each pallet with 32 modules, rather than 31. Not as many pallets of 670W modules fit in a shipping container (18) as would 540W modules (20),

Innovative container arrangement

Source: Trina Solar



	Vertex module	other module
Module power	670 W	540 W
Piece per pallet	32	31
Pallet no. per container	18	20
Power per container	373,860 W	334,800 W

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but the overall wattage contained in each container is still higher, at 373,860W for the 670W modules and 334,800 for the 540W modules.

However, these cost optimizations may take some time to be seen as the availability of shipping containers has been a major challenge throughout the Covid-19 pandemic, and backups and delays at ports have been a significant issue for the past 24 months. As was outlined in the May 2021 edition of **pv magazine**, the per unit cost of shipping modules has quadrupled from a steady recent average of around $0.005/W to $0.02/Wp in 2021.

Not only have shipping costs increased for all products, but availability has become an issue, as modules languish in ports. According to Nextracker's director of global sales engineering, Nick Price, production slowdowns and shipping delays have made it difficult for developers to even source the modules they've built their projects around. "We're seeing a lot more [projects] right now that are actually going in with 182mm," Price said. "210mm is still a little bit on the horizon for us. We have projects that are designed for 210mm, but as far as the delivery and installation of 210mm, it has not really hit the ground yet, from what I've seen."

These constraints are temporary and not exclusive to large format modules, but time lost on project construction is money lost and, according to Price, it has already has led to situations where an entire project is all but complete, and left as a skeleton waiting for modules. "Because we're a self-powered tracker, we can commission the whole site prior to any modules landing," Price said. "We can do everything self-powered, including our communication and our network systems. So we can have full-scale rows ready to go and hit the ground as soon as the modules get delivered."

Small future

While large format modules have supplanted themselves as the standard, their smaller counterparts may not have been entirely invalidated in the eyes of tracker manufacturers. Both Sorensen and Price believe usage scenarios still exist for smaller-format modules, and hope that their production doesn't cease outright.

"I struggle with how it's gonna work down the line," Price said. "There's got to be some module manufacturer who has the foresight, that there's enough volume to keep producing the 2 meter by 1 meter, smaller form factor. There's going to be O&M issues down the line where these things need to be replaced, regardless of the projects that are being built right now."

Photo: SEI



This 2MW project was connected to Australia's grid in October, and is one of the first to be installed with the latest generation of larger modules, with many havng been delayed due to backlogs in shipping and disruption further up the supply chain.

According to Price, most of the module manufacturers that Nextracker works alongside haven't been too keen to keep producing smaller-format modules, nor have they been reserving production for any issues down the line.

Areas with extended, intense wind loads present another scenario where smaller formats may still be needed. "We talk about large format modules as reducing structure costs and total LCOE," explained Sorensen. "One component of that is wind speed and wind pressures. What we're finding is that projects in the mainstream, you get that benefit, but as you get to higher higher wind pressures it kind of goes away."

> *"Cost optimizations may take some time to be seen"*

Larger modules take wind and snow pressures and turn them into higher forces levied against the module and the tracker structure. This has required additional reinforcement of tracker mounting systems, and, in some cases, the installation of additional hardware to support the module. And as components are added, the LCOE savings presented decrease.

Tim Sylvia

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Dealing with dust

Sand and dust are a PV plant operator's worst nightmare. Performance losses due to soiling, or "the dust effect," are a cause for innovation among O&M providers, particularly in dry and dusty regions that are otherwise ideal locations for large-scale solar installations. Yazeed Al-Mousa examines the latest robotic cleaning solutions, as well as the software and sensors that help plant operators with the tricky economic decision of when to actually start cleaning.

For PV power plants, soiling is a highly location-dependent issue, with loss rates due to dust and dirt on solar panels varying from 5% in temperate climates with moderate rainfall, up to as high as 50% in particularly dry and dusty parts of the world.

The most common way to deal with soiling is still manual washing of the panels. However, for large PV power plants, this is an expensive and labor-intensive process. And in the arid regions where soiling presents the biggest problem, water is often in short supply, creating an additional sustainability concern.

Soiling detectors carefully distributed around a PV plant can be a great indicator of how cleaning should be scheduled. Dutch company Kipp & Zonen developed its DustIQ soiling detector, which uses an optical sensor to measure soiling and determine transmission losses for a whole project. DustIQ works independently of the solar irradiation and the sun's position, and can deliver information on soiling at one-minute resolution.

Solar is regularly a feature of dry and dusty climates, so regular cleaning of panels is key, but new cleaning methods are now on the horizon.



Dry climates

India, which has an ambitious target of 450GW of cumulative PV installations by 2030, has already seen many large solar plants deployed in arid, dusty regions. And operators in the country are realizing the importance of module cleaning in keeping this capacity fully operational.

Solavio Labs, founded in 2017 by Suraj Mohan and Prashant Goel, designs and manufactures autonomous solar panel cleaning bots that clean solar panels to ensure high energy generation by dry cleaning and servicing. It has received support from the governments of India, Dubai and Canada. "We were inspired by the simple floor-cleaning Roomba, We came up with a solution of autonomous robots to clean solar panels faster and more efficiently. These robots are deployed with our in-house sensor algorithm to take care of obstacles, collision, and accident control," Mohan told **pv magazine**. He adds that the brushes on the robots are designed with a patented bristle technology that is both non-abrasive and UV resistant.

The bristles are made from a nylon microfiber similar to those used in toothbrushes, and are designed not to scratch module glass or remove the anti-reflective coating. Solavio's robot is also carefully designed with weight distribution in mind, to avoid stress and potential cracking of the cells. The robot rests on the module frame rather than the glass surface, touching the module at 20 different points.

Cleaning robots

Jordan, which is already generating almost 20% of its electricity from solar and wind, is another country with big PV ambitions and a dry dusty climate. Studies carried out by local cleaning-robot producer Darbco on some PV projects in the Jordanian desert show that without a cleaning schedule in place, more than 50% of a plant's output might be lost to soiling. And this can be reduced to 10% with cleaning scheduled once a week, according to the company's calculations.

Darbco has opted for a wet cleaning process in its robots, as part of a three-

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Photos: Darbco



The Fraunhofer Center for Silicon Photovoltaics predicts that soiling could cause €4 billion to €7 billion of global losses by 2023.

stage system. In the first stage, water is used to soften all hard soil and dust particles, and to remove any sticky material. In the second stage, the brushes remove dust with the help of water, which guarantees 99% removal of the dust. The last stage is wiping off the water and any particles on the surface of the module.

The robots have been developed and tested for more than four years in harsh conditions and to clean all types of solar panels. The company claims the approach reduces water usage by 80% compared to manual cleaning.

Money talks

Monitoring is an essential soiling mitigation tool, as it helps to detect extreme soiling conditions and to adapt the cleaning schedule depending on variability of the climatic conditions, or to other exceptional soiling events, such as nearby road or building works. And for larger projects, soiling non-uniformity can be mapped to identify sections that are economically worth cleaning more or less regularly.

Although several mitigation approaches are available, the PV industry's soiling problem is far from being solved, particularly in high-insolation, arid and semi-arid climates. In 2019, scientists led by German research institute Fraunhofer Center for Silicon Photovoltaics published a research paper, 'Techno-Economic Assessment of Soiling Losses and Mitigation Strategies for Solar Power Generation," in *Joule*.

"Soiling reduces the current global solar power production by at least 3% to 4%, with at least €3 billion to €5 billion annual revenue losses, which could rise to 4% to 7%, and more than €4 billion to €7 billion losses, in 2023," concluded the study. That situation will be worsened by the rising volume of solar capacity in highly soiling-affected regions such as India and the MENA region.

A case study from German company OTT Hydromet, presented in a **pv magazine** Webinar earlier this year, sought to visualize the impacts of soiling and benefits of cleaning. This study was done using real soiling data collected from Kipp&Zonen's DustIQ monitoring system at a project in Almeria, Spain. The size of the plant is 100MW, with a PPA value of $28/MWh. The case study compared different cleaning strategies: no cleaning, manual cleaning, and cleaning with a tractor. It revealed a 1.6% loss from soiling and cleaning in the project's total revenue under optimal conditions when using the tractor cleaning method, compared to 2.9% with no action and 3.8% when using manual cleaning.

NOMADD, another cleaning robot producer based in Saudi Arabia, has partnered with OTT Hydromet to evaluate product cleaning performance in real desert conditions in another case study. These experiments took place at a test field at the King Abdullah University of Science and Technology (KAUST) in Thuwal, Saudi Arabia. The test field hosts a 100kW PV plant, and represents an ideal environment for testing the efficacy of different module cleaning approaches. Methods of manual cleaning, automated robot cleaning and no cleaning were each evaluated, measuring the short circuit current of a module, combined with DustIQ mounted on the side.

Measurements have been taken over one month from November to December 2019. The data month was acquired and processed to calculate the soiling ratio of the PV modules. The study revealed little difference in efficacy between manual cleaning and robot cleaning, but clearly showed that taking no action will quickly result in losses as high as 6%.

Yazeed Al-Mousa

> *"The situation will be worsened by the rising volume of solar capacity in soiling-affected regions such as India and MENA"*

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Liquid light

Once thought of in a niche sense, the solar-water nexus is a rapidly expanding network of applications. They include practical tools capable of solving persistent issues like water scarcity, as well as newly pressing issues like overcoming the water challenge of green hydrogen production.

In December 2021, *The New York Times* described it as "A Slow-Motion Climate Disaster: The Spread of Barren Land." Across the world, from Brazil to northern China, and from the American Southwest to North Africa, desertification is a creeping catastrophe impacting more than half a billion people. However, with the search for scarce water – an increasingly harsh reality – the solar-water nexus is proving an especially practical relationship.

But perhaps what is most striking about the raft of off-grid solar-water solutions in remote areas is the distinct lack of battery energy storage systems (BESS). While the cost of BESS has decreased dramatically in recent years, remote communities, particularly in developing countries, can still find the costs prohibitive, the lifetimes short, the inconsistency debilitating, and the maintenance difficult. After all, water is a necessity for survival and systems which provide it must be robust and dependable for long periods of time.

Desalination station

In the western Sool region of Somaliland, the town of Ainabo/Caynabo has long been home to the Aynaba Well, one of the most famous wells in an arid country where wells are celebrated by poets. But severe drought has been putting heightened pressure on this storied water source, and in May 2021, the government of Somalia declared its drought situation a national emergency. The dependence of the Aynaba Well means that people's source of drinking water is also the source for agricultural irrigation and local wildlife, and as a result it has become more brackish and less potable.

Thanks to Genius Watter's holistic solar solution, King Fisher Village can style itself as the first eco-boutique hotel in Cape Verde.

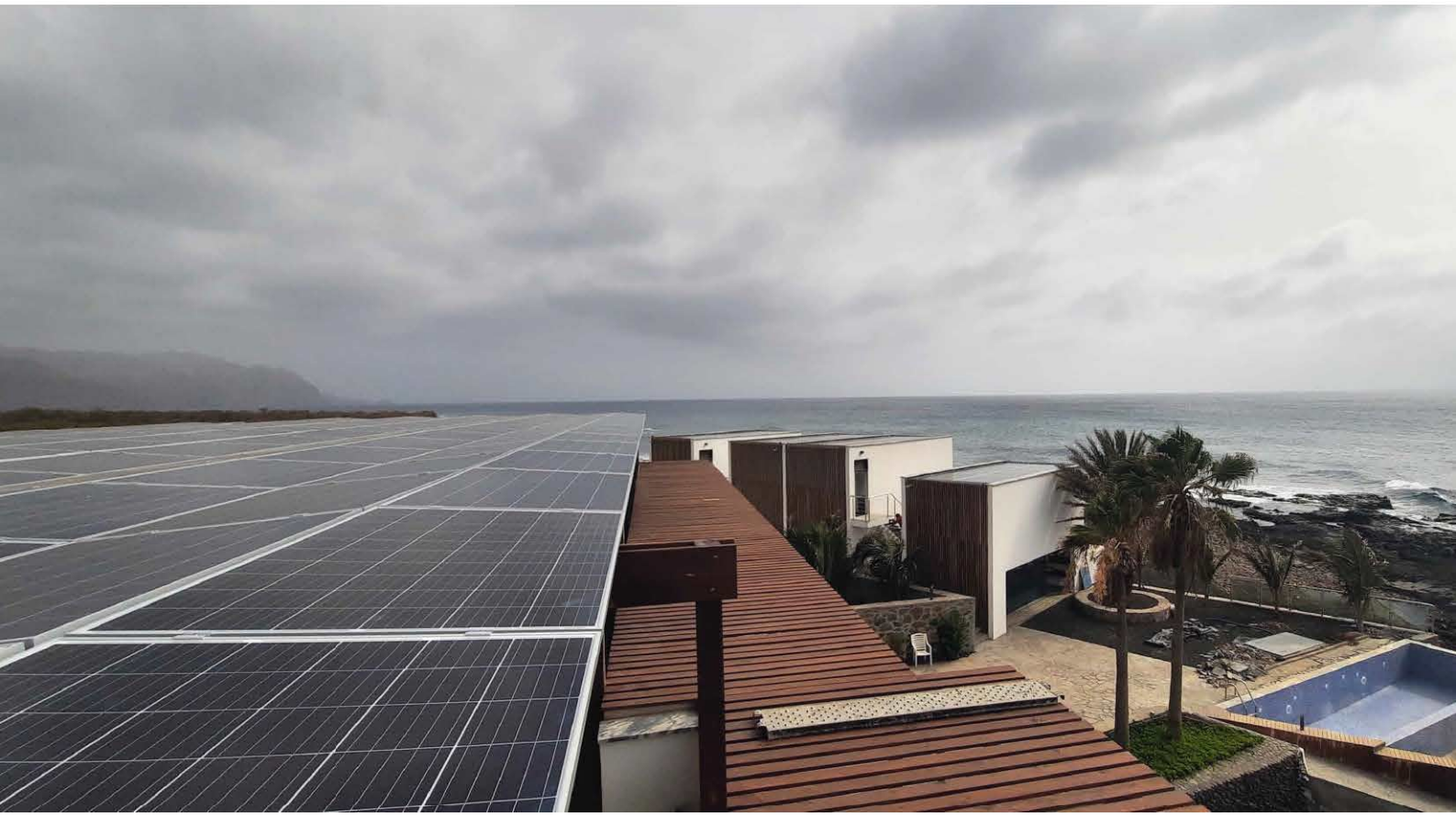


Photo: Genius Watter

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Enter Italian-headquartered company Genius Watter, a subsidiary of US-Canadian solar module manufacturer Silfab. Genius Watter's "zero battery" solar water desalination solution won a United Nations Development Program (UNDP) tender last year for a minigrid and drinking water project in Caynabo set for commissioning this month. With the help of its partner, Uganda-based renewable energy company Aptech Africa, Genius Watter's solution is a 41kWp minigrid and high-efficiency reverse osmosis plant capable of supplying 30,000L of desalinated drinking water each day from brackish wells.

The project needs to deliver fully automatic clean and affordable water to 15,000 people for at least 30 years, requiring only minor maintenance. Thanks to the plant's 90% harvest rate on available PV net power the solution doesn't require batteries. Genius Watter CEO Dario Traverso told **pv magazine** zero battery solutions were preferred because batteries remain expensive in this market and they also have a short lifespan compared to solar.

"Instead of storing energy we store water, either by gravity, as demonstrated in one of our projects in Kenya, in which we pump the water uphill when the sun is high, or in storage tanks," Traverso said. "If unavoidable, small batteries for pumps can be used, but it's far less expensive than incorporating a full energy storage system."

The key to making these types of desalination solutions affordable is trying to get the least salty water possible. "It is much smarter to find ground-water than seawater, much less capex/opex and better ROI," said Traverso. He noted that if you desalinate 100 liters of seawater, you'll use more energy and end up with 40 liters of clean water and 60 liters of brine, while 100 liters of brackish water uses much less energy and returns 70 liters of clean water. In both circumstances, the brine can be dumped at sea without environmental damage, or used for applications like fish farming.

Not so boring

Genius Watter uses drones with electromagnetic signalling to find groundwater-sources, but on the archipelago of Zanzibar, Tanzania, the problem isn't finding water (they have over 400 bore holes). The problem is generating the energy to pump the water, treat it and then distribute it.

Currently, the Zanzibar Water Authority (ZAWA) uses diesel generators to pump the often quite brackish water through rundown pipes at a cost of over $200,000 a month. The expense drove a delegation from ZAWA to the Off-Grid Expo and Conference in Augsburg, Germany, in December 2021, to announce its ambition to overhaul and extend its water service by making it 100% solar powered.

ZAWA Director General Salha Mohammed Kassim said that currently only 36% of Zanzibar's households are water connected. Zanzibar is home to 1.7 million people and Kassim understands that "we have a long way to go to get to 100%, but for this reason we are looking to off-grid solar."

The idea is to use off-grid solar systems to operate the water pumps used at bore holes, as well as the treatment reservoirs and the distribution network. Not only will off-grid solar be able to achieve this, but it will also allow ZAWA to save on the cost of the current system, savings which could be used to upgrade and expand the water network. "We need to cut those costs and make our islands more sustainable," Kassim said. "We need to be a role model for water solutions."

Tourist trap

Like many tropical settings, Zanzibar's tourism sector brings a lot of money into the economy, but tourism is also a thirsty industry. One of the companies ZAWA invited to Zanzibar was Genius Watter, which has experience in solar solutions for the tourist industry in Cape Verde. Key to these projects, said Traverso, is providing an integrated solar and water solution, meaning not just electricity, but drinking water, hot and cold showers, water for air conditioning systems, freezers and kitchens.

To achieve this level of efficiency with just solar panels and thermal storage for hot water, requires smart management and an efficient use of space including canopy structures and bifacial modules. "A number of small things add up to make a big difference in the end," Traverso said.

What this water-solar solution was able to achieve for the King Fisher Village, which now advertises itself as the first eco-boutique hotel in Cape Verde, was a reduction in operating costs of 85% and a significant improvement in the quality of water. The 72kWp solar plant (with plans for an extension up to 130kWp) provides 100% of the energy for desalination and 80% of the resort's other electricity needs.

Water-energy-food nexus

The importance of the water-energy nexus is increasing thanks to applications in hydrogen production and industries like mining. But as shown by projects in some of the world's most drought-stricken regions, perhaps the most prescient applications are found in the nexus of water, energy and food. The Water and Energy for Food Grand Challenge (WE4F) from the Southern and Central Africa Regional Innovation Hub (S/CA RIH) has opened its first call for innovations in the water-energy-food nexus space – innovations which can help smallholder farmers cultivate their crops sustainably. One such innovation would be Genius Watter's featured solar desalination microgrid solution. CEO Dario Traverso told **pv magazine** that in just six to eight months on the island of Boa Vista in Cape Verde, it has brought farmers back to agricultural lands previously destroyed by the use of highly saline brackish water, "and more are coming back still, and female farmers, too." The WE4F Challenge will support up to 30 organizations working on sustainable water or energy solutions for climate-resilient agriculture, with grants of up to $200,000 and winners to be announced in May 2022.

The Aynaba Well is one of the most famous in Somaliland, but severe drought has driven overdependence on this increasingly brackish water source by a growing number of people and animals.



Photo: Genius Watter

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Photo: Genius Watter



This is a rendering of what the UNDP-sponsored Genius Watter solar desalination and microgrid solution will look like upon commissioning this year.

Thirsty industry

Perhaps what is most encouraging about the solar-water nexus is its extraordinary potential at both ends of the economic spectrum. Solar-powered desalination can be affordable in drought-ridden Somalia, and also supply the water needed for large industry and green hydrogen production.

Recent analysis by McKinsey & Company shows that companies with water-intensive operations can reduce their risk by switching to renewables. From analysis of 1,500 companies in the chemicals and food-and-beverage processing industries, it found that a considerable amount of the energy purchases came in countries with low renewables uptake and high levels of water stress, resulting in disproportionate impacts for water and emissions. The analysis showed that a 50% increase in renewables purchasing, would provide a 60% reduction in water consumption in both sectors.

Not only is this significant for existing industries, but also for the emerging green hydrogen industry, as the best solar resources tend to be in regions of water scarcity. Therefore, being able to get the requisite water needed for electrolysis sustainably and without impacting local reserves makes sense. That's what Spanish PV project developer Gransolar is planning to do at the port of Almería in Southern Spain. A company spokesperson told **pv magazine** that it is in the permitting stage of a project that

Aqua Aerem's 10GW Desert Bloom Hydrogen project plans to use solar to power the extraction of water from the atmosphere, and produce green hydrogen in a single modular solution. The project has received 'Major Project Status' from Australia's Northern Territory government.

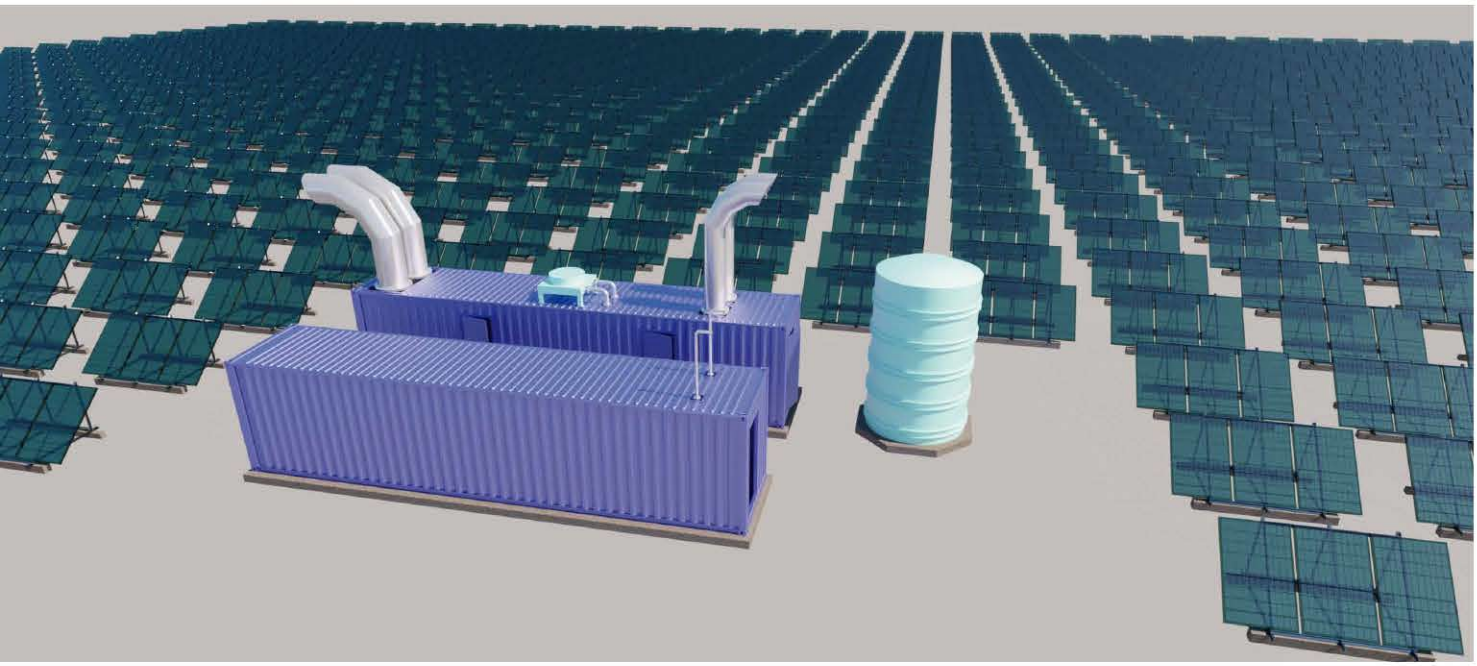


Photo: Aqua Aerem

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will produce hydrogen from seawater through 30MW solar, 20MWh of energy storage, and a PEM electrolyzer with a 20MW capacity. But the project requires a boost from the European Commission's Recover and Resilience Facility if it is to be operational by 2025. For coastal projects the "sea is an inexhaustible source of water that will require desalination plants to generate green H2," the spokesperson said.

In Chile, US company Oceanus Power & Water (OPW) is planning a 200MW Integrated Pumped Hydro Reverse Osmosis Clean Energy System (IPHROCES) with a 100 MLD desalination plant powered by solar and wind energy to deliver energy storage and desalinated water services. OPW CEO Neal Aronson said the project is currently completing feasibility studies and will submit its environmental impact statement in 2022.

In a decade-long drought, Chile is facing the challenge of water scarcity. But Aronson said the IPHROCES project would be able to "deliver fresh water for human consumption and a HV transmission line to interconnect the project to the regional substation." The dual function of the solution is becoming more attractive, Aronson continued, as the negative effects of climate change accelerate. "Our solution can help provide water and energy resilience, as long as we can find approximately 400m of elevation within a few kilometers of the coast."

Aronson added that this type of project is ideal for green hydrogen production as well as numerous other industrial and farming applications if the cost and location stack up. But the best market case for the technology is long-term storage, Oceanus South American President Joan Leal said that is exactly what Chile needs.

Water from air

In Australia, the Northern Territory government has given "Major Project Status" to "water-from-air" technology company Aqua Aerem's $10.7 billion 10GW Desert Bloom Hydrogen project which has commercial ambitions by 2023. According to CEO Gerard Reiter, the project uses solar energy to power a system which absorbs water from air in arid climates, water which can then be used for the production of green hydrogen below $2/kg.

Atmospheric water capture is not new technology, but Aqua Aerem's patented system extracts water with solar energy. "Water is critical to generating hydrogen," said Reiter. "We have managed to overcome the water supply and solar/electrolysis integration problems that have held back global renewable hydrogen production."

The atmospheric water extraction system and hydrogen generation units are contained in multiple modular and portable solar-powered Hydrogen Production Units (HPUs) capable of generating "water, heat, electricity, and hydrogen, meaning each is a set of containerized solutions that can operate independently." This independence garners versatility as well, and outside of green hydrogen Aqua Aerem sees potential applicability in mining and agriculture, as well as the alleviation of water scarcity.

Unlike desalination, Reiter says the advantages of generating water from air means no grid connection is required, there's no brine to dispose of, it has fewer inefficiencies and fewer ongoing costs. Considering the water challenge is one of the biggest barriers to green hydrogen production in water-stressed regions with the best renewable resources, this technology could prove a breakthrough.

Blake Matich

Photo: Zanzibar Water Authority / Facebook



Zanzibar Water Authority Director General Dr. Salha Mohammed Kassim believes that extensive off-grid solar solutions can replace the water system's expensive diesel dependence.

Zanzibar's freshwater comes from approximately 400 bore holes like this one. Some are in good working condition, but others, like the distribution network, are in dire need of repair, upgrade and expansion.



Photo: Zanzibar Water Authority / Facebook

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V2G driving grid changes

The uptake of EVs in the years ahead will add up to staggering battery capacity, mostly sitting idle on driveways. The two-way flow of electricity from EV batteries, known as vehicle to grid, could not only enable power systems to rely on intermittent renewables, but could also be the trump card for network operators to respond to grid disturbances. However, there are still a few catches to be worked out, as Marija Maisch explains.

Gigawatt-hours of batteries on wheels are expected to enter electricity markets around the world this decade. A fraction of this battery capacity equipped with vehicle-to-grid (V2G) technology would already be a game changer at grid level, opening substantial opportunities for both soaking up excess renewables generation and releasing electricity back into the grid to manage issues in real time. While conceptually a simple proposition, deploying V2G services at scale has proven complex. The technology has been around for over a decade, but the sector is still struggling to identify a viable commercial model.

"Invaluable battery capacity in EVs can be put to work to address real-time issues on the grid"

"Today, most V2G work has been in trials," says Laura Jones, senior analyst in the Battery Storage and Grid Integration Program at the Australian National University. "Capable chargers are still expensive so it's probably not going to pay for itself yet. People make decisions based on a whole bunch of reasons and many aren't financial so I think we will see some uptake pretty quickly."

Jones is currently involved in Australia's biggest V2G demonstration to date, the Realizing Electric Vehicles-to-grid Services (REVS) project. It uses 51 Nissan LEAF vehicles to show that EVs can deliver frequency support to the live power system via Australia's National Electricity Market.

Milliseconds away

When it comes to managing frequency, V2G equipped vehicles can provide inertia, regulation, and contingency services, all of which must be delivered within state of charge constraints. Generally, services that raise frequency are higher value than those that lower it, and similarly, shorter time contingency bands are worth more due to difficulties in responding to events quickly. For frequency control in the REVS project, the response needs to be within six seconds (fast FCAS). Currently, the response time of chargers varies between zero and 10 seconds for the same charger. "It is just the way the firmware works," explains Jones. "It's not out of the ballpark and is pretty good actually for a first attempt, but still not quite where we need it to be."

This particularly applies to grids that are increasingly dominated by renewables, where grid response times will need to get much faster. To perform virtual synchronous machine control, the response needs to be extremely fast: under 100 milliseconds, and ideally within one or two cycles (20 ms each). From a physical hardware perspective, a V2G equipped vehicle can do this since it is not that different to a large battery. However, chargers were not built for millisecond response times. Originally, they had to respond to things like load management in buildings, where a few seconds are no big deal.

"Right now, V2G infrastructure can provide very fast response times," says Russell Vare, director of automotive partnerships for San Diego-based EV charging solution provider Nuvve. "In fact, we've achieved response times below four seconds for grid services. But it's important to note that EVs don't necessarily need millisecond-level response time to deliver value to the grid. Demand response is one great example."

Current speeds still provide energy price arbitrage and congestion management, which can unlock significant value for both EV owners – in the form of financial rewards and for society as a whole – putting downward pressure on wholesale energy prices. Vare explains that outside of driving duties, batteries in EVs have

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Photo: Nuvve



US-based Nuvve has deployed vehicle-to-grid tech in schoolbuses. The vehicles are often left parked for extended periods during school holidays, making them suitable for demand response. They can also be used for peak shaving during the school year.

specific use cases. "For example, in the US, we've deployed V2G-enabled school buses which are focused on demand response because they are parked during summer months where energy loads peak and can be used for peak shaving during the school year after they've finished their afternoon routes."

Finally, the nature of portable EV batteries is not only important for grid services, and they can also play a role in microgrids. "Imagine a bunch of electric vehicles providing power to communities during bushfires. That is where mobility is an advantage because you can charge the car at a nearby place where there is power and drive it to the community to transport energy to it," Jones says.

Value vs. costs

Technically, V2G has already reached maturity. Many models with CHAdeMO charging plugs have been able to charge bidirectionally for a long time, and V2G capable chargers are now standardized. The list of technology needed to provide grid services is not that long: a V2G enabled charger and appropriately equipped EV, a communication platform to control charging and discharging, and metering and auditability of services rendered. But, to ensure a sufficient impact on grid operations, large deployment volumes are necessary.

What's holding this back are upfront costs that come from additional hardware that needs to be added both to the vehicle and the charge point. As is usually the case, the key to cost reduction lies in widespread adoption, but for this to happen people would need to see enough value in it, and for some, the obtainable revenues may turn out to be insufficient.

In recent years, various models for remuneration have appeared in the V2G space. Some incentivize customers offering cheaper energy prices, such as AGL's V2G trial in Australia. They let you bring your own car, but sometimes provide a free charger. Others offer discounted leases for cars and chargers, such as Octopus Energy's Powerloop in the UK, which has lease contracts with an app, 100% renewable energy, smart meter, and cashback bundled in. Valuable insights into costs and customer satisfaction are already available. For example, a three-year trial in the UK called Project Sciurus, one of the larg-

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Photo: ANU



Laura Jones, senior analyst in the Battery Storage and Grid Integration Program at the Australian National University, and part of the Realizing Electric Vehicles-to-grid Services (REVS) project, which uses 51 Nissan LEAF EVs.

est domestic V2G projects in the world, with 320 units installed in homes throughout the country, showed that aggregated EVs participating in Dynamic Containment, the UK grid operator National Grid's most recently launched frequency regulation service, could earn consumers up to GBP 725 ($958) a year. It also found that hardware costs must decline to make this attractive enough for consumers.

> *"The issue at the moment is speed. Chargers weren't built for millisecond response times because they have never had to do it before"*
>
> **Laura Jones**

The project, run by a consortium including energy supplier OVO Energy and carmaker Nissan found that V2G chargers could save consumers GBP 340 compared with GBP 120 when using one-way smart charging. Additionally, by enabling the V2G chargers to provide grid services via aggregator Kaluza's platform, the figure rises to GBP 513 for Firm Frequency Response and GBP 725 for Dynamic Containment. "Over the course of the program, V2G owners earned on average GBP 420 a year, with some customers earning up to GBP 800," says Alice Goodman, director of communications at Kaluza. "Customer research also showed that 93% of V2G owners felt satisfied with their charging experience."

Meanwhile, some of the challenges the project identified had to do with cost and complexity. It found that by the end of the trial V2G hardware and installation cost was around GBP 3,700 higher than that of a smart charger. In addition, there were a few conditions that had to be met for the provision of Direct Containment – the initiated response must be within 0.5 seconds, with full response by 1 second, assets need to be aggregated up to a minimum of 1MW, 20 Hz settlement metering must be installed, among other requirements.

Obstacles on the road

A key hurdle is concern about the lifespan of the EV battery due to potential accelerated degradation from increased cycling. This has been repeatedly refuted: battery health is not solely about minimizing how often you use it. Its lifespan is the shortest when the battery is left fully charged most of the time. V2G can help keep the battery state of charge at an optimal level thanks to the integrated battery management systems, responsible for controlling the current flow for both charging and discharging, as well as managing temperatures to maximize health and longevity. On top of that, some services, like fast frequency control, mean the EV battery would be called upon very infrequently and only be used for short periods.

Previous extensive lab tests run by RWTH Aachen University and other institutes have shown that the battery lifespan is hardly affected by the additional activity if up to a maximum of 20% of the battery's energy is drawn in one cycle. This shows that with its smart control algorithms, V2G can even slow the rate of degradation. Big batteries in EVs are more like an underutilized resource. They are often designed for hundreds of thousands of kilometers, but the average annual distance is only around 15,000km. With a service life of 10 years, for example, and the 150,000 kilometers traveled with it, thousands of cycles remain unused.

There are also other challenges to tackle. In the US, interconnecting EVs as a grid resource is seen as the most challenging aspect of deployment, according to Nuvve. In many other markets, the reg-

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ulatory framework doesn't recognize EVs as distributed energy resources. In Germany, for instance, anyone who wants to feed electricity from their EV battery into the power grid is subject to numerous levies – both when storing and discharging.

"There is unequal treatment in the context of the Renewable Energy Sources Act (EEG) levy where hydrogen suppliers, for example, are exempt, and in the tax treatment compared to stationary storage systems, which can supply their energy to the public power grid," says Marcus Fendt, managing director of Munich-based technology company The Mobility House. "EVs with appropriate V2G technology should be recognized as mobile regulating power plants and remunerated accordingly, so that V2G becomes an attractive option for anyone owning an EV."

In addition to double taxation, other challenges in the regulatory framework include inadequate and expensive metering concepts for distributed energy resources and lack of dynamic tariffs that reflect grid congestion. Moreover, there is a lack of globally valid standard interface in the global EV market. Real-time communication between grid operator, charging equipment and vehicle requires unified standards, and this is not always the case. On the other hand, the goal of grid operators is clear – they want to offer a stable power network with a high share of cheap, green power and to control their grid investments and operating costs.

"In principle, V2G is already in the starting blocks," Fendt says. "With the upcoming publication of the ISO standard 15118-20 the players promise an essential prerequisite for scalable V2G applications. This globally valid standard interface in the global vehicle market brings an affordable solution for individual customers. This development must quickly be considered in the relevant laws and regulations to avoid the wrong infrastructure investments." *Marija Maisch*

"Despite significant financial rewards, the cost of V2G hardware is still too high for most customers"

An entirely CO_2-free island – the Portuguese island of Porto Santo is making use of PV, wind power, conventional and V2G-equipped EVs, and second-life batteries, orchestrated by The Mobility House's charging and energy management system with a smart marketplace, to make this a reality.



Photo: The Mobility House

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pv magazine Award 2021



205 *entries*

32 *finalists*

19 *independent jurors*

7 *winners*

The past year has seen both solar and energy storage continue to thrive, despite challenging circumstances. Behind this success is the constant drive for new innovations to overcome existing challenges, open up new use cases, drive down costs and ultimately get more renewable energy into the mix worldwide. Across seven categories, pv magazine's Award winners for 2021 demonstrate industry leading technical expertise, practical problem solving and market-transforming impacts from components through to energy supply. And the winners are...

The Award winners here demonstrate the most important trends in solar and energy storage over the past year. From high-efficiency n-type cells moving toward mainstream production, to innovations in energy supply ensuring that every watt of renewable power generated is put to good use, these are the solutions pushing renewable energy forward, and the companies behind them deserve recognition.

Vital industry trends are on show across this year's winners: 2021 has been a breakthrough year for n-type cell technologies, with major cell and module players committing to TOPCon and heterojunction at scale, and major market growth now all but assured. As well as an excellent crop of high-efficiency cells and modules, award entries this year revealed a wealth of new solutions pushing building-integrated, floating, and even vehicle-integrated PV. We also saw new solutions enabling more renewables to be integrated into the energy supply, as well as an increasing focus on sustainability that goes well beyond the energy system.

For the **pv magazine** Award itself, 2021 was our biggest year yet. Across all categories, we received 205 entries from 30 countries. These entries were pored over by six juries made up of independent experts. These individuals brought a wealth of experience and industry knowledge to the process, and the editorial team thanks them kindly for their time and sharing their expertise.

In the following pages we announce the winners in each category. Join us also on Thursday, Feb. 3, when all will be honored in a virtual Award Ceremony. It is free to attend, and will offer our readers the chance to hear from both the jurors and the winners themselves. Visit pv-magazine.com to register for the ceremony – we look forward to welcoming you.

Selection criteria for pv magazine Annual Awards

- **Efficacy of the solution:** What problem does it solve for the industry? How well does it do this?
- **USP:** How does the approach differ from other solutions in the same market segment? How effective do you believe it is?
- **Economic feasibility and market impact:** How significant is the market impact and how does it contribute to reducing costs or improving quality in the solar/storage industries?

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Modules Winner
Jolywood, Niwa Black
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Sustainability Winner
Viking Cold Solutions
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Inverters Winner
Sungrow, SG350HX
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BOS Winner
CAB Solar, Integrated grounding messenger wire cable management system
Page 56

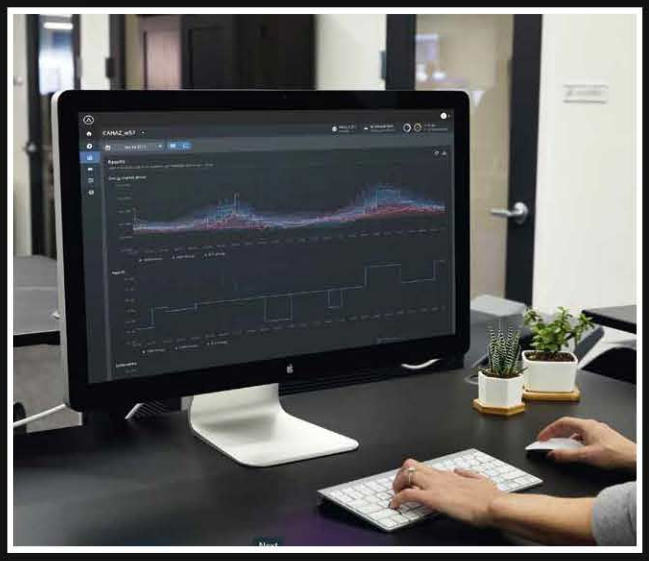




Manufacturing Winner
Sono Motors, Vehicle-integrated PV solution
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BESS Winner
Fluence, IQ Bidding Application
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Publisher's Pick Winner
Fronius
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Modules: Cell innovation up for recognition

The crystalline silicon solar cell is the foundational building block of the PV industry. And the latest round of the Modules award category has seen innovative new processes for cell production recognized, with the cells packaged into a slick, high-efficiency module, in the form of the Jolywood Niwa Black. Alongside the winner, Trina Solar has been recognized for its Vertex panel, with the company making a compelling case for its large-format module with a 210 mm cell.

The Jury



Yali Jiang
Yali Jiang covers the PV manufacturing sector, tracking supply and price dynamics along the value chain from BloombergNEF. She also keeps an eye on technology trends that might impose near-term impacts. She started her career in a PV and battery company in 2009.



Jay Lin
Jay Lin is the chief consultant at PV Guider. He has more than 15 years of experience in photovoltaic research, production and system integration. PV Guider is a consultancy offering quality assurance services for investors, insurers and banks.



Pierre Verlinden,
Pierre Verlinden is a veteran PV researcher, having carried out fundamental solar cell research at both KU Leuven and Stanford University. He has led R&D teams at SunPower and Trina Solar, the latter as chief scientist.

The new year will see a continuation of the wafer and cell size war, as 182 mm and 210 mm are now the new industry standards on the cutting edge of module power output. The mainstream PV manufacturing sector has formed two camps around the two sizes, with welcome standardization efforts underway, but it's still anyone's guess as to which will win out.

"The competition on cell size is still there and we hope it will be finalized soon, so the industry can travel in one direction," said Modules juror Jay Lin during the deliberations to select a winner. The extent to which the matter remains unsettled was evident in that the jurors themselves were split as to which size they believe will prevail.

Although the issue of cell formats remains unresolved, the progress being made in the industry in terms of boosting power outputs and efficiency has continued. "I am very impressed to see the industry moving rapidly into developing new technologies including new formats, new cell technologies and new module assembly technologies," noted juror Pierre Verlinden. "The rapid change in technology is very impressive." He added that innovation is not only in terms of cost reduction, but in delivering higher power output, and therefore reductions in balance-of-systems costs.

When surveying the list of finalists, all the major innovations for 2021 are present. These include high-efficiency cells such as TOPCon and heterojunction, high-density cell layouts, large formats for utility scale, and slick all-black appearance for the rooftop. Interestingly, BIPV and modules looking to unlock tricky C&I applications also feature among the finalists, indicating that module makers are looking to expand PV's reach beyond conventional applications – although they missed out on the top gong this time around.

"I also see some special products [among the finalists]," said Lin. "But the market impact is smaller because they are mostly niche markets and cannot compare to standard modules."

2021 Modules finalists

- Canadian Solar: HiKu 7 & BiHiKu7
- Hevel Solar: BIPV HJT
- JinkoSolar: Tiger Pro N-type with TOPCon
- Jolywood: Niwa Black
- Maxeon: Air solar panel
- Mitrex: Solar Cladding
- REC: Alpha black
- Trina Solar: Vertex Series

Winner

Jolywood: Niwa Black

What is going on within the cell and, indeed, new cell production lines truly set apart the 2021 Modules award winner. Chinese n-type specialist Jolywood came out on top of the deliberations, with its 182 mm, TOPCon cell delivering both high efficiency and the company convincing the jurors of its ability to scale the technology.

The Niwa Black has a module efficiency of 21.94% and the glass-glass, bifacial module is notable for its classy, black appearance. The module hits 405W to 430W in a 60-cell (120 half-cut cell) format. With its high efficiency, the module can achieve 50 watts more power output when compared with mono PERC across the same surface area.

The J-TOP 2.0 cells inside are what powered ahead the Niwa Black. Jolywood reports its TOPCon cells can achieve 24.5% efficiency in mass production, with 85% rear-side conversion efficiency, while all but eliminating the risk of degradation effects such as LID or LETID. And the company's POPAID production technology holds considerable promise. POPAID

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stands for plasma oxidation and plasma assisted in-situ doping deposition.

While precise details about POPAID remain a closely held secret, it appears likely it is an inline physical vapor deposition (PVD) process for the polysilicon deposition. By applying PVD, Jolywood has eliminated the need to etch off polysilicon wraparound that occurs with the more commonly used low-pressure chemical vapor deposition (LPCVD). Jolywood notes POPAID allows it to reduce the production steps required for TOPCon cell production from 12 to nine. The company will deploy POPAID on its new production lines.

Jury comments:
Yali Jiang: I have to go with Jolywood's Niwa as the winner considering its high efficiency, readiness for mass production, and improvement in production process.
Pierre Verlinden: Jolywood is one of the leaders in TOPCon and it has made a courageous commitment on n-type technology a long time ago, which is impressive. Their results in TOPCon development are highly valued by the entire PV industry.
Jay Lin: Overall the performance of the product is very good and the high efficiency will reduce the LCOE. We expect the cost of this product will not be too high, so it is really promising.

Highly commended

Trina Solar: Vertex Series
The selection of the winner was a close-run thing, though, and Trina Solar provided ample evidence of the LCOE savings that are delivered by its large-format Vertex series. Trina has verified its claim of LCOE reduction of 1% to 4% using its Vertex, when compared to modules using 182 mm cells. The cheaper electricity is a result of BOS savings of 1.3% to 3.6% on a tracker and 1.7% to 6.0% with a fixed-tilt system, Trina claims. The company has worked with DNV, Fraunhofer ISE, Black & Veatch, Enertis Applus+ and Chinese inverter supplier TBEA to verify these figures. The large-format Vertex exceeds 600W power output, with a conversion efficiency of 21.4%.

Jury comments:
Pierre Verlinden: I highly commend Trina for its Vertex module, but also for providing the community with a Sustainability Report [in 2021], which is probably the best in the industry in terms of its commitment to sustainability, particularly in the reductions in consumables, electricity, water and embedded CO_2.



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Sustainability: Above and beyond

Two key aspects of sustainability are circularity and systemic thinking, or looking beyond your own environmental impact to understand how your actions affect the wider ecosystem and its many participants. Thus, while pv magazine's UP Initiative aims to address verifiable sustainability within solar and storage, it is also important to recognize how these industries function as part of a whole – something that has been reflected in this year's jury selection.

The Sustainability award attracted a high number of entries from established industry players like First Solar and Maxeon, as well as new entrants like reusable pallet company PV Pallet and circular module recycler Flaxres. It also drew entries from businesses that are not directly related to energy, but which are starting to embrace clean alternatives and have the potential to broaden PV uptake, like Grupo Aristos El Salvador and the New York City Housing Authority (NYCHA). All the entrants appear to have made impressive strides to drive the energy transition forward; however, there can be only one winner.

Winner

Viking Cold Solutions

The winner of this year's annual **pv magazine** Sustainability award is US-based Viking Cold Solutions, a thermal energy management company offering long-duration Thermal Energy Storage (TES) Systems for protecting food quality. Juror Jenny Chase's initial comment on the Viking approach was: "You make ice, dudes!" However, during the ensuing discussion it became clear that Viking offers an effective sustainable solution to a major environmental challenge: food wastage. Indeed, the company 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," explains Viking in the award application. In addition, TES technology reportedly maintains temperature stability and has a 20-year lifetime with no mechanical components. Users can expect to save between 20% and 35% of their energy expenses and see refrigeration system efficiency improve by 20% to 30%, says Viking.

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

As Chase noted, Viking Cold Technologies merits a positive mention for its technology to store abundant daytime solar electricity as a cold salt solution, deployed in refrigerators for commercial use. "This is an ingenious and very efficient solution to solar's 'duck curve' problem and we hope to see widespread deployment," she said.



The Jury



Jenny Chase
Jenny Chase joined BNEF in mid-2005 and launched the Solar Insight Service in early 2006. She has conducted or overseen all the research, including PV experience curve analysis, which enabled the team to make a definite prediction of an upcoming sudden 35% to 40% fall in crystalline module prices a year before it happened, while most analysts were expecting a slow 5% to 10% annual decline.



Nancy Gillis
Nancy Gillis has more than 20 years of experience leveraging sustainability to increase competitiveness, reduce risk and foster innovation in both public and private sector organizations. Prior to joining the Green Electronics Council, she was the Global Lead for Resilient and Responsible Supply Chains with Ernst & Young (EY). She joined EY from the US General Services Administration, where she served as the director of the Federal Supply Chain office, responsible for expanding the use of sustainability criteria and ecolabels in federal procurements.

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Highly commended

Aristos Real Estate, NYCHA

This year, two entries in the urban solar space caught the attention of the jurors who, for different reasons, wanted to highlight their achievements. First up is Aristos Real Estate, a part of Grupo Aristos from El Salvador, which powers 100% of its industrial buildings with rooftop PV.

Meanwhile, in the United States, NYCHA, the nation's largest public housing authority, has released a new sustainability agenda, which among other goals, aims to host 30MW of renewables on its properties by 2026.

It has also joined the Department of Energy's National Community Solar Partnership as part of the Multifamily Affordable Housing Collaborative, thus allowing people who cannot host solar on their property to purchase power at a discount off the normal utility rate.

Jury comments:

Jenny Chase: This commercial real estate company [Aristos Real Estate] is using solar on all its properties as a selling point. The result is a genuinely additional 45.8MW of solar in El Salvador, which has



a population of 6.5 million and only about 500MW of solar capacity in total to date.

Nancy Gillis: NYCHA is combining being a demand driver with social equity – bringing the opportunity of solar power to individuals who do not have that access choice.

Highly commended

Fronius International

Fronius received special mention for adopting a range of sustainability measures in its transportation, servicing and electricity sourcing. The Austrian PV inverter manufacturer is replacing fossil fuels with geothermal and biomass energy, and increasing energy efficiency via measures like reusing waste heat and thermal isolation. It has also worked on reducing greenhouse gas emissions in its car fleet with electric cars and focuses on working with European and Austrian suppliers. It transports its products within Europe by train and road; when it comes to intercontinental freight, it opts for sea rather than air transport.

Fronius says it has reduced its energy use by 41% since 2019, from the base year 2014, and increased its self-produced solar PV energy by 155% between 2014 and 2019. Meanwhile, it says its share of renewable energy usage was 83% in 2019. It has set a goal of employing 100% renewables for the energy it uses in its buildings for heating, cooling, and processes.

Jury comments:

Nancy Gillis: It's the best example of walking the talk by preferring more sustainable transportation options within its supply chain, engaging in circularity via repair centers, and boasting a good percentage of renewable energy usage.



2021 Sustainability finalists

- Aristos Real Estate,
- Dow Inc., DOWSIL 7094 flowable sealant
- eleXsys Energy, Microgrid technology
- First Solar, Overall company sustainability
- Flaxres, circular recycling concept for PV modules
- Fronius, Overall company sustainability
- Ignite Power, solar electrification projects in Sub-Saharan Africa
- Maxeon Solar Technologies, Overall company sustainability
- New York City Housing Authority (NYCHA),
- Pivot Energy, US developer, financer, builder, and manager of solar and storage projects
- PV Pallet, Inc., Reusable plastic pallets
- Viking Cold Solutions, long-duration Thermal Energy Storage Systems
- ZonNext, social platform for "orphaned" PV panels

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Inverters: High-powered strings to the solar bow

There was a clear trend towards string inverters in the 2021 Inverter award entries. Among the 24 machines entered only five were central inverters. With weight a limiting factor in the future, and with manual installation no longer an option with the most powerful string inverters these days, the question being raised is how big is too big? An additional trend was also an inverter's ability to withstand the most extreme of environmental conditions.

The Jury



Cormac Gilligan
Cormac Gilligan is responsible for managing research on the global PV inverter and balance-of-system markets at IHS Markit. He supports detailed coverage of the energy storage industry, carrying out research and authoring reports on the quickly growing market for storage inverters.



Marco Jung
Marco Jung serves as department head for power electronics and electric drive systems at Fraunhofer IEE. Recently, he was appointed professor for e-mobility and electric infrastructure, with a focus on power electronics, at the University of Applied Sciences Bonn-Rhein-Sieg.



Hakki Karacaoglan
Hakki Karacaoglan is the founder of KRC Energy. Since 2005, he has trained utilities, solar associations and universities about integrating PV into national grids in the Middle East, Central Asia, Turkey and the Balkan countries. KRC is wholesaling NMC-based pouch cells and NMC-based high-dense battery modules.



Jenya Meydbray
Jenya Meydbray co-founded PV Evolution Labs in 2010 and now serves as CEO. He developed the first extended reliability and performance test protocols for the downstream PV industry. He began his career at NASA Ames Research Center's hyper-gravity facilities.

Winner

Sungrow: SG350HX

Among all entries, the jury was most impressed with Sungrow's SG350HX. The most powerful string inverter available on the market addresses the issue of higher operating currents when large-format modules are used. With 20 A input current per DC-input channel, this inverter can connect pretty much every module now on the market – a feat not achieved by all its peers. And those string inverters that have achieved this featured only a single MPPT, following the concept of a central inverter. By contrast, Sungrow's inverter counts 16 MPPTs, allowing for higher yields especially when the field isn't plain or there is non-uniform shading.

On top of that comes the inverter's strong performance when it comes to grid support. With a built-in virtual synchronous machine, the jury recognized that this inverter is trailblazing a technology that will be critical if the power supply is to come from 100% renewables. A virtual synchronous machine lets the inverter control voltage and frequency of the power it feeds into the grid. And it can deliver virtual inertia, replacing a physical phenomenon of the giant rotors in thermal power stations, without which a grid cannot function.

With a short circuit rate of just 1.16, it will work even in extremely weak grid conditions and provide a reactive power



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response within 30 seconds, adding to the machine's grid stability functions.

Jury comments:
Cormac Gilligan: It is a competitive power rating capability, so the ability to be competitive on a cost per watt basis is pretty good, also it can provide a whole range of grid stability functions.

Marco Jung: The virtual synchronous machine is a really impressive feature. Integrating synchronous machine behaviors into inverters is still a hot topic in research at the moment and for good reason. They allow having inherent grid ancillary service function and grid forming properties.
Jenya Meydbray: Recently, we've seen higher operating currents from larger wafer format modules. This inverter seems to be one of the only ones that can handle the input current of new large modules without a problem.
Hakki Karacaoglan: With IP66 protection it is slightly better than average protected, which is nice for an inverter that spends its life out in the field. Also, it can operate at 3,000 meters of altitude before derating, which can be useful.

Highly commended

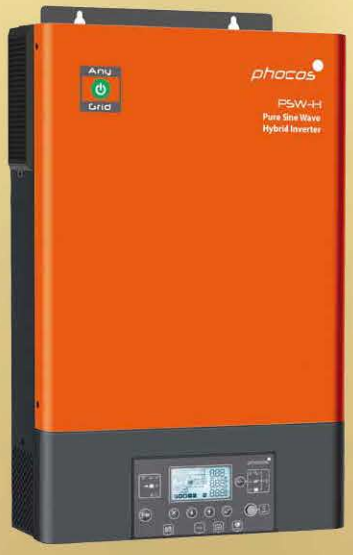
Goodwe: GEH 5-10kW
Goodwe's residential product, the GEH 5kW to 10kW, is a single-phase hybrid inverter for residential use. Among the set of features, the jury highlighted this inverter's uninterrupted power supply systems, which can supply a full backup capacity in just under 10ms. That is a speed at which the user will not notice any flickering in the lights or appliances shutting off momentarily when the grid fails. Another feature the jury pointed out was the inverter's ability, to use a wide range of high voltage batteries. The battery voltage range is said to reach from 80V to 495V. An important capability, as there are more high voltage batteries from the EV industry making their way into the residential PV sector.

Jury comments:
Hakki Karacaoglan: The battery voltage range starting from 80V already, is really good because high voltage batteries are getting very popular, especially from the EV industry, so with this inverter you'd also have the chance to connect EV batteries.
Marco Jung: I really like that they included a real uninterrupted power supply function, which can supply the loads within 8 milliseconds.
Cormac Gilligan: I do like the four MPPTs, so for customers who have a multiple-pitch roof, this would be really useful. Also, the ability to select different mode options such as self-consumption or back-up via an app, make it quite versatile.



HIghly commended

Phocos: Any-grid PSW-H
Phocos sent its Any-Grid PSW-H hybrid inverter into the race. With a power rating between 3kW and 5kW, this product is designed for residential use cases. However, the inverter can be extended by another eight units of the same inverter to achieve a higher power rating. Also, it can work grid-forming and grid-following depending on whether the grid is available or not. Coming with a true backup power function, suppling loads within 10ms, this inverter can run on just the PV generator or just the battery should that be necessary. On top of that comes the possibility to connect multiple generators, such as a backup diesel generator, providing an added safety option for some real off-grid use cases.



Jury comments:
Hakki Karacaoglan: I remember Phocos from 15 years ago when they were supplying solar chargers. I would say Phocos' new inverter-charger has more a charger touch, but still adding a lot of flexibility.
Jenya Meydbray: It offers a lot of flexibility for its owner, which makes it a product to consider.

Other finalists

- Ampner 300 PV/ES
- Fimer PVS 10-33TL
- Ginlong Solis RHI-3P/ Solis-255K-EHV-5G-Plus
- Sungrow SG125HX
- Growatt SPF-3000T-HVM
- Power Electronics HEM

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BOS: Cabling systems key for quality

The category for balance of system (BOS) catches those system-level innovations that support the core components of modules and inverters, and brings cost reductions, boosts to energy yield, and solutions to many PV array challenges. Key trends among this year's entries include artificial intelligence and innovations to enable floating PV and building integrated PV. And the 2021 winner shows that simple and practical solutions can be every bit as valuable as the highest of high technology.

Entries in the BOS category came from a wide range of market segments, reflecting the growing diversity of PV applications, and growing interest in tackling the challenges that remain in developing practical PV applications beyond the usual rooftop and ground mounted installations. In the large-scale PV segment, meanwhile, we see ever-more sophisticated software solutions promising to automate and optimize every aspect of power plant operations, and plenty of new solutions to make life easier in the field as well.

Winner

CAB Solar: Integrated grounding messenger wire cable management system

This solution from US non-profit Cambria County Association for the Blind and Handicapped (CAB Products) combines cable management and system grounding. The wire hangs below the mounting system, supporting hangers keep cabling neatly organized and also serve as both grounding electrode conductor and equipment grounding conductor.

CAB first introduced the cable management system in 2014 and has now added the grounding function by using a copper composite messenger wire. The company says its solution is already widely accepted in the large-scale project space and has been used in gigawatts of projects worldwide.

The system promises significant savings throughout a PV system's life, simplifying the processes of installation, and opera-



The Jury



Nicolas Chouleur,
Nicolas Chouleur is a partner at Everoze, a technical and commercial energy consultancy specializing in renewables, energy storage and flexibility. He has been working on designing, engineering and operating all kinds of PV systems throughout the world since 2006, from residential arrays through to large, utility-scale power plants.



Lida Jauregui-Rivera
Lida Jauregui-Rivera is the director of engineering at RES Americas, where she leads the design and plant performance functions for all projects across the development, pre-construction, and construction stages. She has 13 years of energy industry experience.



Camila Ramos
Camila Ramos has 13 years of experience in the Latin American renewable energy sector. She is the founder and managing director of CELA, which supports clients in developing investment projects, including policy and legal framework analysis.

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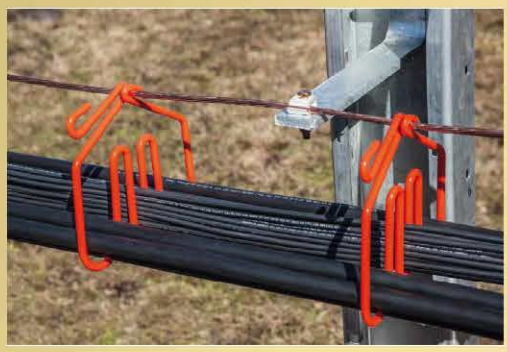
tions and maintenance. At a project's end of life, the CAB solution can assist with decommissioning by offering a simple solution that keeps cables easily accessible to technicians.



At its manufacturing base in Pennsylvania, United States, the system is produced by people with blindness and other disabilities, aiming to foster independence for disabled people in the community while also producing a range of high-quality products for the solar industry and others. The management system impressed the jury with its simplicity and ease of deployment, and high potential for labor saving impacts in the large-scale solar segment.

Jury comments:

Lida Jauregui-Rivera: For large-scale utility projects I see tangible results and gains with this product, during both construction and operation. There are some questions with grass cutting etc, but these are likely manageable.



Camila Ramos: Solutions like this are valuable in both installation and operations. And the way it is manufactured is a real bonus.

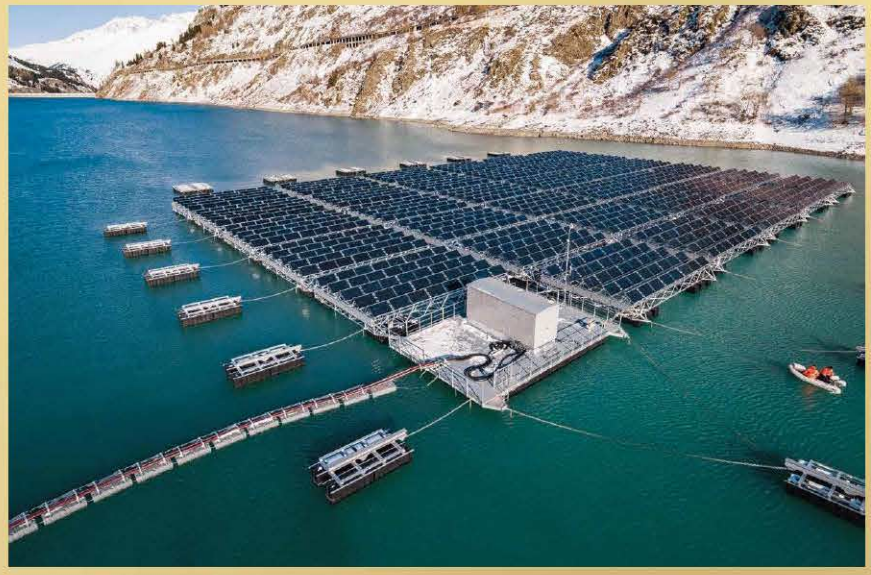
Highly commended

Studer Cables: Betaflam solar 125 flex WR 1500, DC cable for floating PV

Studer offers the first standardized DC cable designed specifically for floating PV applications. The cable employs a special cross-linked compound for multilayer isolation, promising moisture repellence and long-term protection against water ingress.

The company says it is the first solar cable to pass new specifications created by TÜV Rheinland. These include examination of the cable's physical and electrical characteristics during and after immersion in water (including saltwater) as well damp heat and extreme cold. In addition to the floating-specific additional tests, the cable meets all requirements outlined in IEC standards for forceful impacts, dynamic penetration, fire, and exposure to ozone and UV irradiation.

The cable is rated for 1,500V DC applications and tested to have a lifetime of more than 25 years in the field. As well as floating PV, Studer recommends the cable for other applications where moisture and cable durability might be of particular concern, including high altitude locations with snowfall and low temperatures, as well as coastal or even ocean-based systems.



Jury comments:

Nicolas Chouleur: It's the right move in terms of quality, and when you mix high voltage DC and water, you need an extremely reliable solution. It's good that someone is taking the initiative to say 'OK, at some point we're going to have put these cables underwater.

Lida Jauregui-Rivera: There are a lot of challenges when it comes to DC cabling in floating PV, and this is an innovative and thoroughly tested solution that will allow owners/investors to realize reductions in O&M and system cost.

2021 BOS finalists

- Axial Structural – Blocking System
- ampere.cloud – monitoring solution
- CAB Solar – Integrated grounding messenger wire cable management system
- Erthos – Earth mount racking
- ETH Zurich – Adaptive solar facade
- Fracsun – Soiling loss management
- GIZ – PV Port and Store
- Studer Cables – Betaflam solar 125 flex WR 1500, DC cable for floating PV
- QC Solar – High current connector

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Manufacturing: Lightweight PV gets into gear

The manufacturing category honors the latest and greatest developments in PV's upstream segment, from the raw materials and components that go into PV modules, batteries and other devices, to the processes and machinery used to bring them all together. While cost will always be king in the upstream segment, this year's winner represents both a new technology and an emerging market – reflecting the importance being placed on applications for PV beyond the usual power plants and rooftop installations.

PV manufacturing has had a rough year in 2021, with rising material prices and shortages of both electricity and shipping containers impacting availability. But manufacturers have pressed on with bringing larger formats and n-type technologies to large-scale production, both expected to help lower energy costs in the longer term. And the winner gives a nod to encouraging moves toward integrating solar generation in new applications and environments. Among this year's award entries in all categories we have seen exciting new products introduced for agrivoltaics as well as floating and building integrated PV, and in this case, an innovative and practical process to integrate solar power into vehicles.

Winner

Sono Motors: Vehicle integrated PV solution

Integrating solar power directly into other industries and aspects of our lives is sure to be an important strategy in future decarbonization and electrification efforts, and there is already plenty of buzz surrounding the possibility of vehicle-integrated photovoltaics. Sono Motors impressed our jury with its practical process that integrates solar into the vehicle manufacturing process.

The single-step process embeds solar cells into a polymer during the actual molding of the panels making up the vehicle body. This allows for solar cells to be integrated across the vehicle's entire surface including over complex curved surfaces. Vehicle body panels integrated with PV cells do not weigh significantly more



The Jury



Alex Barrows
Alex Barrows is the research director at Exawatt. He focuses on when and how new technologies will influence the solar PV market, and oversees PV market data analysis for the company. He obtained his PhD in the physics of perovskite-based solar cells from the University of Sheffield.



Alison Ciesla
Alison Ciesla is a Scientia Research Fellow at the University of New South Wales, Sydney. Through collaboration with industry, she specializes in understanding defects and hydrogen in commercial solar PV cells, especially regarding the degradation and reliability of PV modules.



Jonathan Govaerts
Jonathan Govaerts earned his PhD from Ghent University in 2009, with a focus on packaging and interconnection technology for flexible electronics. He has since worked with the solar cell group at imec, where he focuses on cell-module integration of silicon PV cells.

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than standard sheet metal panels, and are blended into the vehicle exterior, making them almost invisible.

Sono works with monocrystalline, interdigitated back contact cells integrated into a polymer matrix that serves as both front glass and backsheet. Since these materials are already in use in both the PV and automotive industries, the company says it can achieve a 95% recycling rate. The company estimates that a mid-sized electric vehicle, such as the Sion it produces in house, can be fitted with more than 1kWp of PV capacity using this solution. Based on the climate in Munich, where the company is based, Sono estimates its VIPV solution can achieve an LCOE of €0.12, and generate enough charge to travel 112 km per week on average.

Jury comments:

Alison Ciesla: VIPV is not a new concept, but this is the first I have seen that is integrated quite aesthetically well. And the range they say can be achieved, even on wintry days, is impressive. The fact that it is also recyclable is excellent.

Jonathan Govaerts: Technologies like this will only grow in importance, and their approach with lightweight materials will hopefully reflect onto other markets beyond vehicle integrated PV.

Alex Barrows: This points to the direction that the electric vehicle industry will likely take in years to come. Buying a car is about much more than LCOE, and tagging solar onto an already high ticket price item in order to enhance its functionality and appeal offers a whole new market to add to the usual rooftop and utility systems, which have a quite different set of considerations.

Highly commended

Coveme: Dymat High Barrier Backsheet and DuPont Teijin Films: Mylar based backsheet



The jurors also found two manufacturers worthy of a special mention for their innovations and focus on sustainability in backsheet manufacturing. Both Coveme and DuPont Teijin Films (DTF) have been able to integrate recycled materials into their backsheet products. DTF is recognized for its LuxCR process, which allows it to convert waste polyethylene terephthalate into a material that it can use in new backsheet films. The company is already offering backsheet films with 33% recycled PET, which it says have properties indistinguishable from those made with new material.

Coveme has also integrated up to 40% recycled PET into its dyMat range of high barrier backsheets, which come in black, white and transparent, and says its has plans to increase this percentage in the future. And Coveme stresses that its backsheet is completely PET based, not containing aluminum, which is more common for backsheets requiring very low water vapor transmission rates.

Jury comments:

Alison Ciesla: Being able to recycle modules and use recycled materials is a very important approach and I am not aware of anyone else doing it in the backsheet space. And there is potentially a huge impact, because with the transparent option as well it can reach virtually all types of module.

Jonathan Govaerts: The sustainability aspect here is very convincing.

Other finalists

- Teknisolar – Robostak Laminator
- Coolback – Combined frame & backsheet solution

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BESS: Smart systems expand reach

As the commercial case for batteries grows on the back of falling prices, technology advances continue to improve market position and services. Our jurors argued that there remains a lack of knowledge on what battery assets can do, but that pv magazine's award entrants are working to change this. The winner shows how software can ensure efficient integration of batteries into electricity markets and systems – enabling more projects.

The Jury



Adrien Amigues
Adrien completed his PhD on the discovery of new electrode materials for Li-ion and Na-ion batteries at the University of Cambridge in 2016. He then worked as research scientist and head of intellectual property at OXIS Energy (UK), specializing on lithium-sulfur and solid-state battery technologies. Adrien joined The Faraday Institution In 2021 and works as a battery technology and commercialization analyst.



Anna Darmani
Anna is a lead analyst on the gobal energy storage team at Wood Mackenzie Power & Renewables, where she focuses on the Europe, Middle East and Africa storage markets. Earlier in her career, she worked at EIT InnoEnergy, developing innovation and technology roadmaps and contributing to several EU research and advisory projects. She was one of the founding members of the European Battery Alliance. Damiani has over seven years of experience in the energy industry and a previous career as senior project control and planner.



Alison Lennon
Alison Lennon is a research and teaching academic in the School of Photovoltaic and Renewable Energy Engineering and an ARC Future Fellow at UNSW, Sydney. Her research focuses on the areas of silicon solar cell metallization and interconnection, optical modelling for photovoltaics and more recently high-power lithium-ion storage and autonomous solar energy harvesting devices.

Winner

Fluence: IQ Bidding Application
Fluence's bidding software for grid-scale energy storage and renewable assets uses artificial intelligence, advanced price forecasting, portfolio optimization, and market bidding automation in an attempt to ensure storage systems and renewable assets are responding optimally to market and reliability needs. The company says that by providing asset and portfolio managers with updated price forecasts and optimized bids every hour, utilities, IPPs and operators can maximize the value of these assets, improve grid reliability and efficiency, and support the transition to a more sustainable and resilient electric grid.

Fluence argues that conventional bidding approaches for energy storage and renewable assets simply can't keep up with the volatility and complexity of rapidly changing wholesale markets without the aid of digital intelligence. The solution supports energy storage and renewable technologies from any provider and is configured to meet the unique warranty constraints and operating parameters of each asset.

According to Fluence, the platform, which is currently used to optimize a variety of energy resources in California's CAISO market and in the Australian National Electricity Market, can increase revenue and operational efficiency for battery-based energy storage by 40% to 50% and revenue for standalone renewable energy assets by more than 10%.

Jury comments:
Anna Darmani: Many people are not sure what to do with their batteries and Fluence is delivering a solution that can inform them better.
Alison Lennon: What I liked about this solution is that it is integrated into the battery management system – understanding how a battery is degrading and accommodating its bidding according to that. Many other energy trading systems are not as sophisticated.
Adrien Amigues: The solution seems compatible with any type of battery and renewable energy on the market, which if accurate, makes it very appealing. It could really drive investments towards batteries and renewables.



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Highly commended

Home Power Solutions: picea

All-in-one residential seasonal storage solution, picea, promises no more costs for household electricity. In addition to lead batteries, fuel cells and an electrolyzer, a prototype installation includes a 10kWp PV system with an annual yield of about 10,000kWh. On sunny days, picea stores solar energy that is not needed for direct use in the form of hydrogen. With a storage capacity of up to 3,000kWh, the solution can supply single and two-family homes with green energy all year round. Additionally, heat produced by the fuel cell is harnessed in the home, reducing costs and emissions. Picea achieves an overall utilization rate of around 90%, that is, around 6,000kWh of electrical energy and 3,000kWh of thermal energy.

Jury comments:

Anna Darmani: What they are coming up with is unique and really innovative, but I'm struggling to see a market for them. In particular segments, though, they could solve a bigger problem for the industry, such as in the off-grid markets.

Alison Lennon: I was really impressed by the engineering and innovation in this product. But in terms of efficacy, I'm not 100% sure that the best approach is to have all in one piece of equipment.

Adrien Amigues: A very appealing, unique residential energy storage system. However, I question the cost of the installation of the solution and the technology readiness level of fuel cells.





Highly commended

Amphenol: REDTR Robust Thermal Runaway Detection for Lithium-ion Stationary Storage

Amphenol has developed a gas sensor platform that can detect initial flammable gas venting from cell failure within BESS. The Robust Early Detection of Thermal Runaway (REDTR) uses a combination of infrared spectroscopy and thermal conductivity sensors that will not suffer drift, poisoning, or nuisance alarms. It can detect first vent gas release within seconds of single cell failure without the need to customize for electrochemistry, cell size, or enclosure volume. Amphenol's sensors require no replacement or recalibration maintenance across their 20-year lifespan. The company has the advantage of large-scale manufacturing of this technology, bringing the price point for hazard detection to well under $100 for ESS applications.

Jury comments:

Anna Darmani: Even though the risk is low, fire safety is still a big deal for some customers. I thought they had a good product that can add value and bring something to the market. I think if they get to the market, they will have a huge impact by reducing fire risk and costs at the same time.

Alison Lennon: Their strength is in combining a number of different, already existing sensing technologies into a composite sensing device. I think they thought about that quite well.

Adrien Amigues: Interesting technology to detect safety issues at pack level. The reason why I scored down the "Market impact" section is because the technology provides a warning before any incident occurs rather than resolving safety issues per se.

Other BESS finalists

- Axsol – ARVEY E-Series
- BYD – Battery-Box Premium
- Discover Battery – LYNK Communication Gateway
- Enphase – Encharge 3T / Encharge 10T
- NOVUM engineering – NOVUM AI and deep analytics
- Sungrow – Liquid Cooled Energy Storage System ST2752UX
- Voltfang – Voltfang second-life batteries

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Publisher's Pick 2021: On a mission to deliver '24 hours of sun'

The energy transition away from fossil fuels to renewables has come to the fore during the ongoing Covid-19 pandemic, as if it required this heinous virus to finally make us recognize the ill state of our climate and planet. But our Publisher's Pick for 2021 was working on this energy transition decades before it became a global priority, investing very early in efficient and smart inverters and concepts to make PV electricity available even when the sun was not shining.

Winner

Fronius International

Eckhart K. Gouras, the publisher of **pv magazine**, has selected the PV manufacturer Fronius International as the winner of the 2021 Publisher's Pick award. The Austrian company celebrates the 30th anniversary of the Business Unit Solar Energy this year, and in these 30 years Fronius has moved ever closer to its vision of a future in which 100% of the world's energy needs are covered by renewable sources such as solar PV.

In the summer of 2020, **pv magazine** partnered with the Austrian inverter manufacturer to showcase its new GEN24 Plus hybrid inverter in a webinar. Leonhard Peböck, product marketing at Fronius International, opened the webinar with a story: His parents run an ice cream shop in Upper Austria that is very popular on summer weekends. Their shop has a garden and on one summer weekend, a sudden change in weather forced many customers to seek refuge inside the shop. The heavy storm caused a power outage, leaving the ice cream in the store to melt, and leaving customers, who had hoped to enjoy delicious ice cream, disappointed to find merely cream. Peböck advised his father that a PV system coupled with backup power could have prevented this mishap.

Peböck's father heeded his son's advice and ordered an 8kWp photovoltaic system together with the GEN24 Plus hybrid inverter with the full backup option. Should another blackout happen, the GEN24 Plus inverter will automatically island the shop, keeping the ice cream chilled and customers happy.



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Peböck's story not only vividly describes the benefits of the GEN24 Plus inverter, but also points to the manufacturer's mission "to achieve 24 hours of sun." This year Fronius is celebrating 30 years as a solar PV manufacturer, a long time in this still young industry. The company has been around even longer than that, but embraced solar in 1992 as PV feed-in tariffs emerged in Europe to boost the fledgling industry. In addition to PV, the manufacturer with headquarters in Pettenbach, Austria, is active in the fields of welding technology and battery charging technology. It has 5,660 employees globally and exports 92% of its products. Thirty-six subsidiaries around the world and a network of partners and representatives in over 60 countries power the company's global growth.

What is remarkable about Fronius is not only its pioneering role in solar, but its holistic approach in making PV the cornerstone of a round-the-clock distributed energy system, whether for residential, commercial or industrial users. Its trailblazing work on this front is one very important reason for making Fronius this year's Publisher's Pick. It deserves this award for its relentless pursuit of a new energy paradigm built on solar and sustainable practices.

One way to get to "24 hours of sun" is to integrate batteries, as Fronius has done by combining its GEN24 Plus with modular lithium-ion batteries. Another option, one that is not yet as mature and cost effective as lithium-ion batteries, is to store the solar energy as 100% green hydrogen. While green hydrogen has recently emerged as a key enabler of the energy transition, especially in hard-to-decarbonize industrial sectors, Fronius was already developing PV and hydrogen solutions in 2018, when **pv magazine** showcased the company's Solhub fueling station in a podcast on our German trade media platform. At the time, Austria had only five such facilities and the one developed by Fronius was the first in Austria to use solar to power the electrolyzer and not carbon-based fuels.

But the global energy transition is not only about replacing fossil fuels with clean renewables. The other big shift is moving to distributed energy and not relying mainly on large power plants and the extensive transmission and distribution grids that accompany the traditional top-down model. Fronius is dedicated also to this historic shift and its early move into green hydrogen is a good example. The Solhub plant showcased in our German podcast is a distributed energy resource (DER) that directly provides fuel cell vehicles with green hydrogen, avoiding the need to transport the clean gas via trucks or pipelines.

At **pv magazine** we created the UP initiative in May 2019 to shine a light on sustainability in the global PV and energy storage markets. Sustainability is also one of our five core values next to quality, innovation, commitment and respect. So as we surveyed these markets to select the Publisher's Pick for 2021, Fronius' track record and commitment in this area stood out. The "24 hours of sun" concept is no longer science fiction, but companies like Fronius are developing the building blocks to make this a competitive reality around the world. The company's holistic embrace of this concept, its innovation and attention to detail, and commitment to sustainability make Fronius the perfect candidate for this latest Publisher's Pick award.



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Indium: sustainability,

The supply of indium, both for layers in silicon solar cells and some thin-film PV technologies, is increasingly seen as a future potential bottleneck that solar and other industries relying on the material will have to manage. Resolving indium supply concerns may be a case of rethinking mining waste and recycling, reports Ian Morse.

When phones and computers became more widespread around the turn of the century, scientists and industry professionals began to worry about the supply of the 49th element on the periodic table: indium. Indium plays an important role in both LCD and OLED displays. By weight, it's almost three-quarters of a layer of transparent conductive oxide, called tin-doped indium oxide (ITO), used to translate electrical signals into light.

Indium's centrality contrasts its level of consumption. Markets consume infinitesimal amounts of the element each year amounting to roughly 800 tons. However, total recorded reserves only amount to roughly 15,000 tons, according to the U.S. Geological Survey, before it stopped counting reserves. Even if the rate of consumption was level, manufacturers worry that those known reserves could disappear in just 20 years. The fear of scarcity led to skyrocketing indium prices in the early part of this century.

Solar need

The solar industry currently comprises just 9% of demand for indium, but it's vital for heterojunction (HJT) PV, which presents a promising route to surpassing the current crystalline silicon cell efficiency ceiling. Some thin-film PV materials also contain indium or make use of ITO layers. The World Bank predicted last year that trends in solar development would mean that by 2050, PV technology alone would account for more than double current indium demand.

As a result, the rapid expansion of solar manufacturing capacity is raising renewed worries that delicate supply chains will be strained by the push to transition from fossil fuels to zero-emission energy.

But the supply chain for indium is more nuanced than that, said Tim Werner, a research fellow at the University of Melbourne. "It's not a question of scarcity. It's a question of sustainability," he told **pv magazine**. Until recently, there was little understanding about where indium came from, and what pressures its supply experienced. There is likely much more indium available than is recorded, he said.

Indium's role

Major developments in solar technology depend on indium's conductivity while remaining flexible and thin. For HJT cells and other PV technologies, projected demand is likely to make the costs of ITO weigh heavily on uptake. Recognizing that solar uptake would likely put pressures on materials, scientists have long sought less material-intensive options for production.

In HJT cells, researchers are exploring various routes to working with thinner ITO layers while maintaining cell performance. In a recent paper in *EPJ Photovoltaics*, scientists at Germany's Fraunhofer Institute for Solar Energy Systems found that reducing the ITO layer to 90 nanometers could reduce the solar industry's demand for indium by almost 50%

Thin-film options also achieve lower material use, if they can overcome the economic barriers that have so far constrained them to a small fraction of the market. In copper-indium-gallium-diselenide, or CIGS, indium acts as the photon-absorbing layer that kicks off the electricity production. "Indium, as far as CIGS cells are concerned, is extremely important. You wouldn't have the same material if you didn't have indium. It wouldn't perform as well," said Lorelle Mansfield, a material scientist at the US National Renewable Energy Laboratory in Colorado.

Recognizing the pressures on CIGS, scientists in the Swiss Federal Laboratories for Materials Science and Technology (Empa) have encouraged others to shrink the proportion of indium in cells to facilitate large-scale adoption. Currently, indium in CIGS comprises just 3.7 grams per square meter of the panel, according to Mansfield.

The US Department of Energy has funded several CIGS research projects, but companies that aimed to sell CIGS have largely succumbed to silicon-based rivals

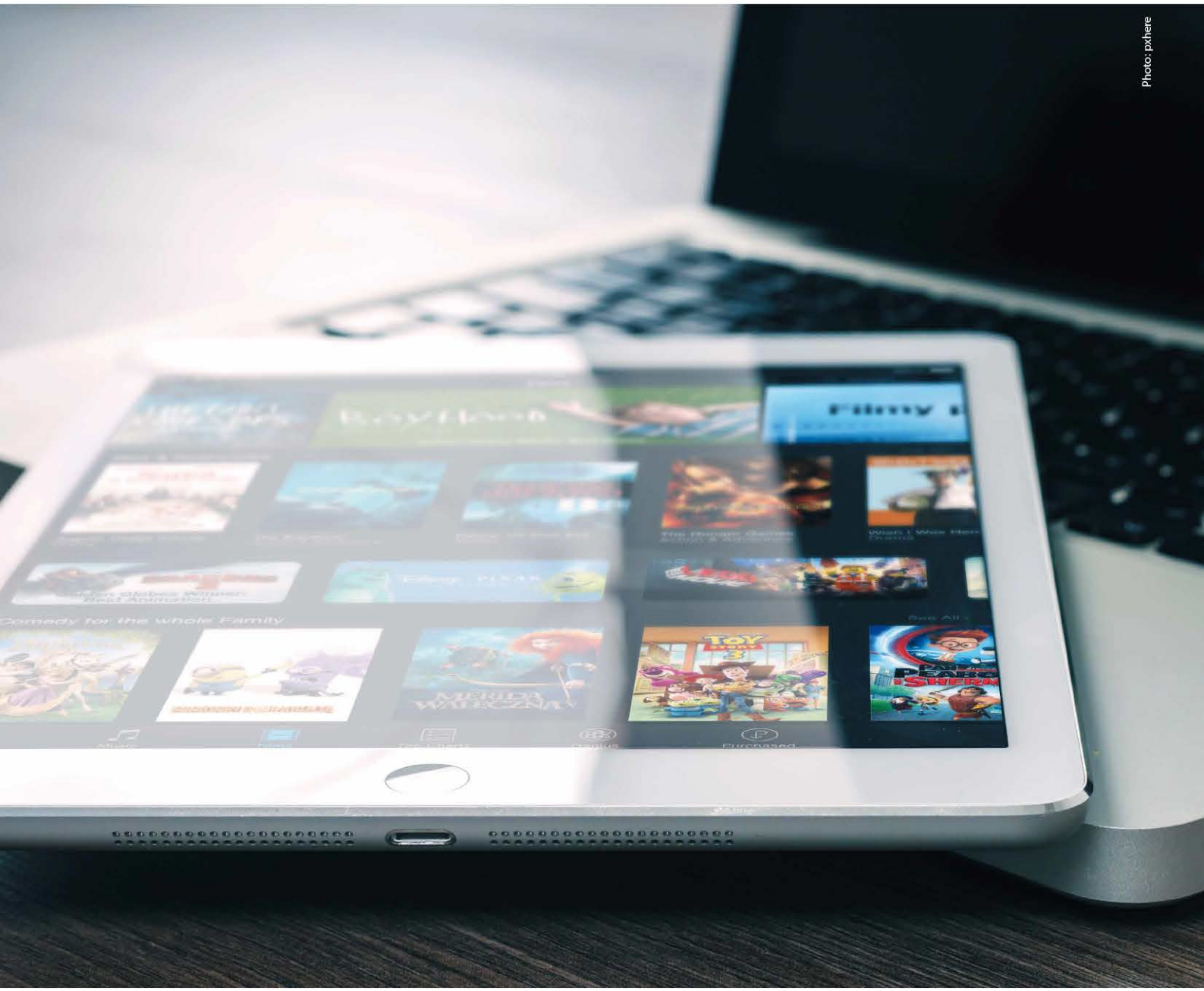


Swedish company Midsummer produces solar roof tiles based on CIGS thin film. Concerns have been raised over growing demand for indium in this and other solar cell technologies, but improvements in processes to extract the material from mixed ores could take the pressure off the supply chain.

Photo: Midsummer

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not supply



Indium is vital in the production of touchscreens and LCD displays. The solar industry currently represents just 9% of global demand for the element, but a recent World Bank report warns that based on current trends, this could soon skyrocket.

that were able to benefit from achieving superior scale. Mansfield believes CIGS will still have a niche especially in flexible, transparent, and lower-price markets. "We're going to need all of these technologies to meet the goal that we want to meet with reducing emissions," Mansfield said.

There have also been attempts to replace indium in the module entirely. Recent research has proposed swapping some of the ITO layers with silicon-based materials. Aluminum-doped zinc oxide has been used in the lab, although it's more susceptible to corrosion.

Murky supply

Indium appears on the list of critical minerals of the United States, Canada, the European Union, and Australia – for which it ranks third-most critical. However, there are no "indium mines" in operation.

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Researchers estimate that between 2000 and 2019, companies lost

19,000 tons

of indium to production losses and scrap

Instead, indium supply comes as a byproduct mainly from zinc sphalerite mines, where it appears in almost invisible concentrations of 0.01% or less. Often zinc mines and refineries may not pay attention to the indium in the concentrates they sell. Zinc products tend to be sold, sometimes across borders, without factoring indium into the price. And zinc mines don't report the concentrations of indium in their deposits, unless it can play a large enough role in their businesses.

Indium is mostly found in low concentrations in zinc ores like this sphalerite ore mined in the United States. Mines and refineries often pay little attention to indium when buying and processing these ores, making the material's supply chain difficult to track.



Photo: Ivar Leidus/Wikimedia

Australia, for instance, sends much of its zinc concentrate to be refined in China, which also dominates the industries in display screens and solar PV. While Australia has no listed indium production, its zinc products likely contain indium. China produces roughly 50% of the world's indium, but its materials are largely imported in the form of other concentrates. In its critical minerals report, the Australian government lists five exploration projects that may produce indium. Some of these companies don't list indium in shareholder reports.

That makes tracking down the sources of indium difficult. Estimating the sources of the mines that send indium to the world's technology manufacturers requires making inferences about the trajectory of zinc purchases.

"We do know where the world's zinc is being mined and where concentrates are going, and refined indium is coming from those countries that buy the zinc," Werner said. With that approach, he estimated that indium reserves are closer to 300,000 tons, 20 times higher than previous estimates.

"So, then the question is not really 'are we going to run out of indium?'" Werner said. "It's 'where is it going to come from?' and 'what are going to be the impacts or risks associated with different indium supply chains?'"

Adaptability and expansion

Researchers in Germany and China estimated that indium experienced the highest supply pressure, second only to tellurium, in the forecasted expansion of solar technologies to 2050. Projected demand will outstrip China's projected supply, they wrote, unless significant changes in reuse and processing were made.

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Other metals crucial to solar panels are also produced as byproducts. Gallium, for example, is derived from mining bauxite, a mineral used to extract alumina. The demand for some of these minor metals may drive companies to oversupply other primary metals. "You're more inflexible to changes in demand, because you always need there to be zinc in order to get the indium," Werner said.

Indium refineries regularly only recover a fraction of the available indium. Technological improvements in processing may also be able to increase production without having to mine more land. Researchers from Germany and Portugal recently outlined a methodology in the journal Mineralium Deposita to extract roughly a fifth of the world's supply from a copper-zinc deposit in Portugal, where scientists have long noted the high concentrations of indium.

Companies continually mine indium ore, but it often goes to refineries that cannot extract the indium. Instead, it's sent elsewhere to be separated. Given that zinc refiners already have access to indium ore, adding an additional processing circuit could extract indium without necessitating large capital expenditures. Otherwise, the indium ends up in waste.

At one project in Tasmania, Australia, a decades-old waste pile left by a lead-zinc mine contains indium and may be recoverable. "If there can be some innovation in recovering mine waste, we would open up an enormous reservoir," said Werner.



Photo: University of Melbourne

Tim Werner, a research fellow at the University of Melbourne, estimates that global indium reserves could amount to around 300,000 tons. He warns that shortages of the material are caused further down the supply chain.

Indium recycling

Considering indium's scarcity, recovery and reuse of ITO layers and other solar components could boost the viability of the solar panels. ITOs are regularly recycled, and Japan and South Korea dominate the recovery of these metals. Places with fewer zinc mines, such as the European Union, have devoted research funding to investigating whether their recycling industry can help fill forecast demand.

The small amount of indium in a solar panel or display screen makes it difficult to build a business case for recycling. Recovering all the indium in use by Australia's citizens, Werner said, would only produce as much indium as is contained in one deposit of mine waste. "So purely from a mass perspective, recycling does not seem that viable to me. From a strategic perspective, some countries might think it's more important," Werner said.

Material recovery can also target materials that are typically lost before the products reach consumers. Researchers in China recently wrote in the journal *Sustainability* that scrap and waste from the country's bustling manufacturing sector could be important feedstock for recycling industries. They estimate that between 2000 and 2019, companies lost 19,000 tons of indium to production losses and scrap.

Werner hopes that the understanding of indium's supply chain will lead to greater scrutiny about a critical material whose demand is likely to jump significantly. "Particularly with a lot of these climate change discussions right now, people who research mining are trying to highlight that, yes, we are going to need a lot more mining to meet demand for critical metals, to build the renewable energy capacity to meet these climate targets, but it matters where that mining takes place."

Ian Morse

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HJT for high performance

With PV cells the next focus for boosting power output, heterojunction is seeing production capacity increases. Its advantages are numerous, not least its favorable temperature co-efficient, says Recom Technologies CEO Hamlet Tunyan.

We've seen the impact of more severe weather events become more widely discussed within the PV industry. High temperature has been acknowledged as a factor in terms of cell performance and reliability. The issue is compounded by climate change and increasingly hot summer temperatures. How does Recom address heat as a performance issue?

This is indeed becoming an increasingly pressing issue, as we are witnessing the warming of the planet. The issue, of course, has had the attention of the solar industry since its inception as one of the many complications associated with conversion of solar energy to electricity.

At Recom we pay special attention to this and strive to attain the lowest temperature coefficient possible for the panels we produce. We have a large presence in the Gulf region, where we sell panels and develop projects ourselves, and the high temperatures in the region are a major concern. Until recently we have kept step with the existing technology, continuously adopting it into our module manufacturing process. I must say that the technology has performed relatively well. However, we can claim that with the introduction of Recom's heterojunction Lion series we have moved a step ahead in



Photo: RECOM Technologies

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attaining a lower temperature coefficient of -0.24% and securing better performance. At very high operating temperatures, more than 50 C, HJT power loss is less than 6.5% compared to higher than 9% for mono PERC. I believe we will continue to see further improvements on this matter in the coming years.

What are the main barriers that need to be addressed to promote further growth in the US solar roof market?

As a PV module manufacturer based in Europe and utility-scale solar projects developer globally, we were not much attuned to the US rooftop market developments. Recently, however, we have begun to make some inroads into this segment.

Clearly, the commercial and residential rooftop market is growing rapidly and is driven in large part by ambitious state-level renewable energy targets, as well as clean energy tax credits and other supportive policies adopted at the state and federal levels. The solar Investment Tax Credit (ITC) provides a 26% tax credit for solar systems on residential and commercial properties, one of the most important federal policy mechanisms to support the growth of solar energy in the United States.

However, this incentive having been phased down over the years may be eliminated altogether in early 2022. Now that more and more states are committing to getting 100% of their electricity from carbon-free sources such as wind and solar power by 2030, I believe that first, the federal tax credits that have helped fuel the growth of clean energy should be extended and expanded. Secondly, the utility regulations should support the growth of renewable energy, including through policies like net metering that compensate owners of renewable energy systems fairly for the energy they supply to the grid.

Without these measures at state and federal levels, I am afraid, residential solar may fall victim to government complacency fed by solar's past success.

Going more deeply into the US marketplace, supply chain transparency has been a growing issue for US solar companies. What are Recom's traceability protocols and what changes, if any, have been made to enhance supply chain transparency?

This is an issue that Recom has no problem with and I would even say that those strict criteria put us in an advantageous position. As a European manufacturer, we are bound with strict EU laws and regulations. Low-carbon footprint certificate for panels is a requirement in France for public tenders for projects above 100kW.

The certificates we acquire for our different panels, all provide detailed description of the materials used, their origins and their production carbon footprint. Additionally, each material used in our production has its serial number and barcode, through which their formation can be tracked and traced at every step of production.

HJT power loss at 50 C is less than

6.5 %

You mentioned your HJT products – is Recom developing the technology? What is the outlook you see for it in the near future?

Along with our own manufacturing facility in France and local R&D team, we invest in, and work with leading global research institutions and manufacturers to innovate, develop, share and commercialize the latest technological advances in solar module manufacturing. Our primary R&D partner in the area of solar panels is a leading French research center, the National Institute for Solar Energy – CEA/INES. One of the topics we were pursuing with them over the past several years was HJT technology.

HJT will remain with us to at least the next decade. We may see variations of cell configuration, as has been the case for PERC, where from one cell we moved to half cut then to tri-cut and shingled, thus enhancing efficiency. We will see similar evolution in HJT until we leap to the next technological innovation such as perovskite technology in conjunction with HJT.

Interview by pv magazine

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Expansions in n-type

The past 12 months have been a turbulent time for PV manufacturing. Rapid and impressive developments in technology have been accompanied by price increases up and down the supply chain, and energy shortages weighed on production in the second half of the year. Chinese n-type module manufacturer Jolywood is now pressing ahead with ambitious expansion plans despite the disruption. pv magazine publisher Eckhart K. Gouras and editor Mark Hutchins recently caught up with Cathy Huang, European sales director at Jolywood, to discuss the company's plans to bring n-type TOPCon technology into mainstream production.

How do you see the market for n-type technologies today?

We see demand growing already. Today, PERC is still the mainstream technology in PV, but it is approaching its limits in terms of efficiency. In n-type, there is still a lot of room for improvement, and it is beginning to attract big attention.

Thanks to improvements in the key equipment for n-type cell and module production, the cost of investment for TOPCon technology is getting lower, and we can reach large-scale production very quickly. In PERC technology, the investment per gigawatt is around CNY 150 million ($23.5 million), and now for TOPCon it is about CNY 200 million. So it is already quite close, and we have a roadmap to bring it even closer in the near future.

For TOPCon, you can upgrade from an existing PERC line as well, so there is plenty of interest from a lot of established players. And as the scale gets larger, the costs will drop even lower. We think that TOPCon technology is the most cost efficient in the market today, and it will be the next-generation mainstream technology.

You mention improvements on the equipment side – is this largely down to Jolywood's POPAID (plasma oxidation and plasma assisted in-situ doping) deposition, which reduces the number of process steps?

Yes, our first generation of TOPCon modules required 12 steps in processing, and we have now reduced this to nine, which is the same as PERC. All of our production lines are now operating with this 'TOPCon 2.0' technology, and we are working on the third generation, which will require even fewer steps. We hope by the end of next year we will be ready to bring this third generation into mass production.

This year, PV manufacturing has been hit with rising prices and supply chain disruption – how has Jolywood been affected?

This has caused us a lot of headaches this year, it's true. Due to control of energy consumption policies in China, we have had to cut down on production. And we have had other difficulties along the value chain. For example, one of our suppliers sent us a notification that they would have to cease production for four whole days. It is difficult to secure materials for our production, and many suppliers are in a similar situation.

Silicon prices have also increased dramatically, and with this energy control policy, silicon manufacturers are unable to expand their capacity – so this could be an ongoing problem into next year.

> *"We hope by the end of next year we will be ready to bring this third generation into mass production"*

And how has this year's PV price increase impacted the cost gap between PERC and TOPCon?

Now the difference is about $0.02 per watt. The increase in prices has not affected only silicon – virtually all component suppliers have raised prices. Encapsulant film, for example: We use two layers of POE film in our modules, and the price for this has increased by 40%. With glass there has been a shortage and the price has increased by more than 25%. Aluminum frames and the junction box have gone up significantly as well. On top of this, shipping costs have gone up dramatically, and we don't see any possibility for them to fall again in the near future.

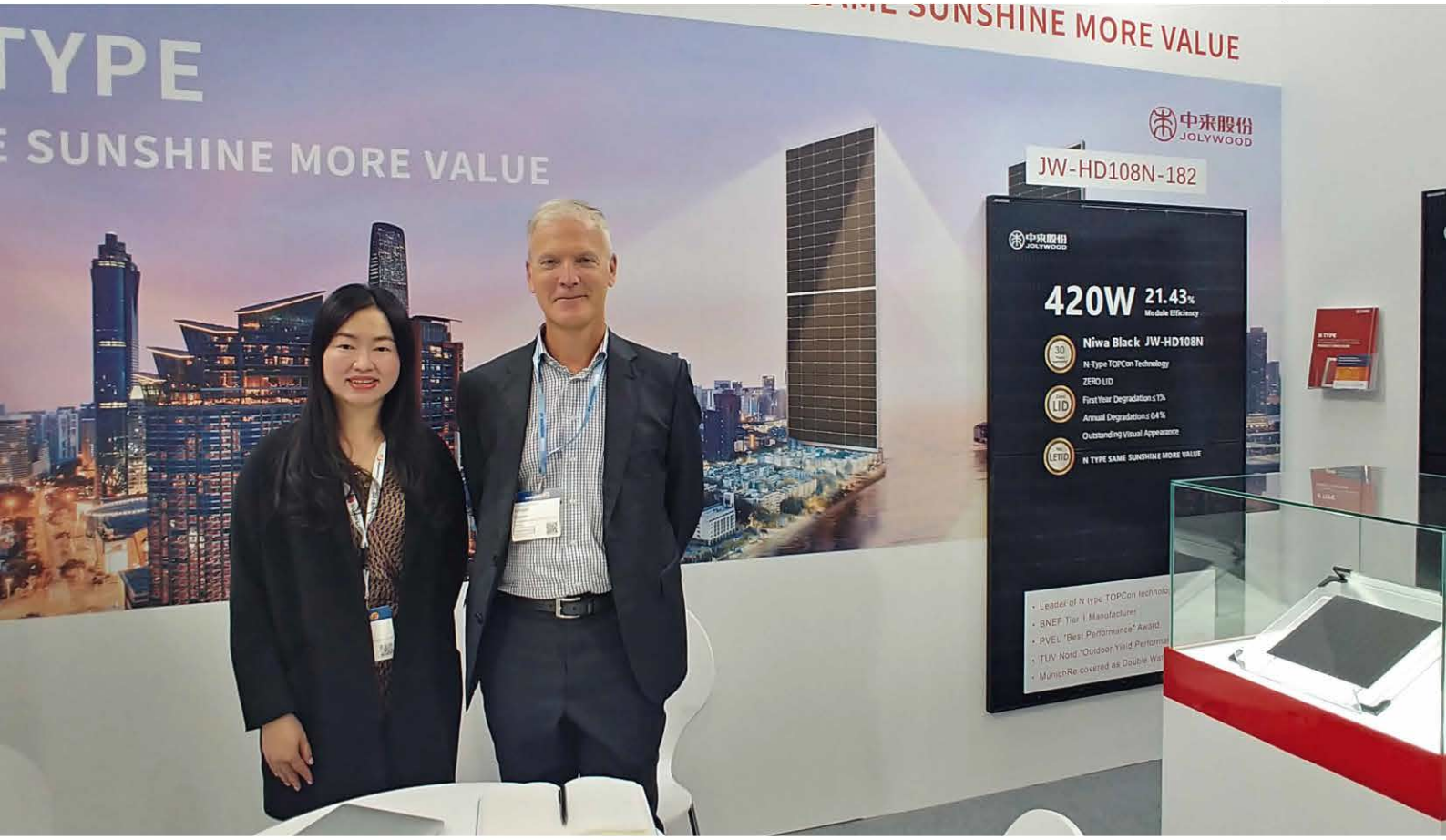
So it has been quite challenging for us. But what we can do is keep close communication with our suppliers and our customers, and try to find a balance to reduce losses both for us and our customers.

Are your customers already delaying orders further into 2022, in the hope of lower prices?

Not really. Many had already postponed orders from the first half of the year to the second half, and now they don't have any time left. Many have tight deadlines for delivery, so there is strong pressure on manufacturers, but a shortage in materials and energy limitations at the same time. For 2021, we think only the upstream industry will be able to achieve profits, while returns will be very low for module manufacturers.

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Photo: pv magazine



Cathy Huang, European sales director at Jolywood, is pictured with **pv magazine** *publisher Eckhart K. Gouras at the Intersolar Europe exhibition in October 2020.*

And what can you tell me about Jolywood's expansion plans?

We are building out a factory in Indonesia, this has been slowed due to Covid restrictions – our engineers have been unable to travel without lengthy quarantine periods. But we hope to bring this factory online early in 2022. The factory is primarily being built to serve local markets, we have an agreement for a big project in Indonesia, which includes local content requirement for the modules. Longer term, we will also be targeting the U.S. market with products from this factory as well.

We are also building a new factory in Shanxi province, China, for high efficiency n-type cells, and it is targeting 16GW capacity, to be completed in two 8GW phases.

And all Jolywood modules are produced in house, is that correct?

We have some OEM contracts, but for module assembly only. The solar cells are always ours – it's not possible for us to buy other n-type cells. We also supply some cells to other manufacturers.

Which size wafers are you currently using?

We have both M6 (166 mm) and M10 (182 mm) in production, and the M10 size is mainstream for us. This year we will also be introducing G12 (210 mm) to production. And we will still produce some products with M6, particularly for residential markets. But for most of our orders today, the mainstream is M10.

And Jolywood has partnered with Munich Re to offer a 'double warranty' – could you tell us what's behind this?

With our n-type technology we offer a 30-year performance warranty, and n-type has a very low degradation rate – the warranty covers 0.4% annual degradation. Additionally, we also have reinsurance with Munich Re, so customers are doubly protected. And with support from an insurance company, even in the event of a warranty claim, we can handle things more easily. There won't be problems for us with cash flow, or anything along those lines.

Interview by Eckhart K. Gouras and Mark Hutchins

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pv magazine test: Introduction to LETID testing

Together with our test partners, we have decided to add LETID testing to our set of benchmarking tests for PV modules, as the industry has improved its knowledge about the risks and mitigation of this relatively new mode of PV module degradation. George Touloupas, senior director of solar and storage at CEA, provides an update.

> *"Overall, there can be severe energy yield loss, even if the modules eventually fully recover after many years"*

LETID (light and elevated temperature-induced degradation) is a mode of degradation of crystalline silicon PV cells that was identified and researched a few years ago. The initial research was spearheaded by Q Cells, which also coined the term LETID in 2015, with Australia's University of New South Wales contributing important work on the root causes and mechanism. Compared to boron-oxygen LID (light-induced degradation), that develops in a period of a few weeks of operation, LETID can take years to develop and happens faster in sunnier and warmer locations. After reaching a maximum power loss, modules affected by LETID will regenerate and regain power, but this process can be very slow and is, again, dependent on local climate conditions. Overall, there can be severe energy yield loss, even if the modules eventually fully recover after many years.

Although the initial focus of LETID research was on multicrystalline PERC cells, it was soon discovered that mono PERC cells can suffer from severe LETID. In fact, other cell types, such as Al BSF and even n-type cells, can have LETID susceptibility, but to a lesser degree than PERC, in general. It has been found that metal contamination, hydrogen content and process parameters have a strong impact on LETID. Good material and process control need to address these factors to mitigate LETID.

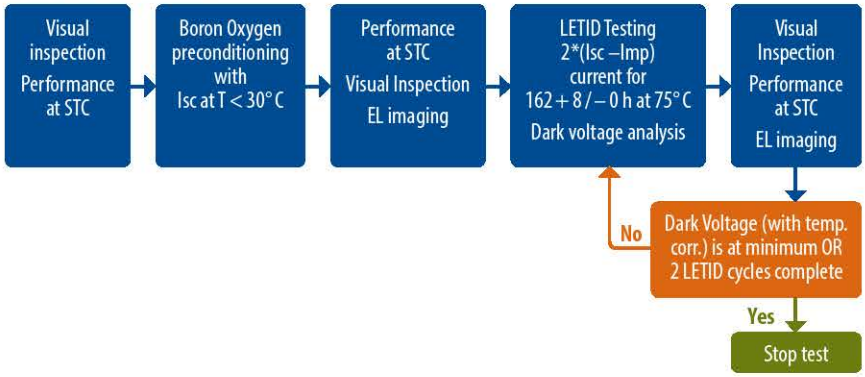
Batch testing

In recent years, many major manufacturers have developed mitigation processes and have managed to control LETID and avoid having the originally feared severe losses. However, the need to screen products for LETID sensitivity by using an efficient testing procedure remains relevant. CEA introduced LETID testing in 2019, as part of the product requirements definition, which is done on behalf of buyers at the procurement stage, as well as a part of CEA's batch testing protocol, which is used to decide if a large production batch, typically between 5MW and 20MW, is susceptible to a particular failure or degradation mode.

The chart to the upper right shows LETID batch testing results from CEA's projects since 2019, based on more than 140 tests performed on various products from multiple suppliers. When testing started in 2019, very few suppliers were ready or willing to accept testing, so 2020 was the year that batch testing

LETID test flowchart

Source: CEA



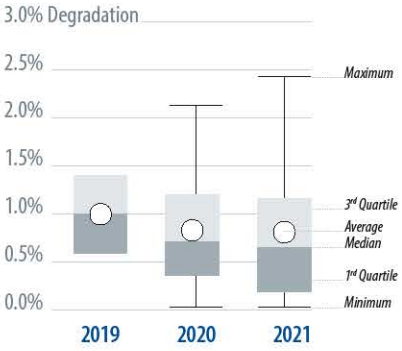
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About the author



***George Touloupas** is the director of technology and quality for solar and storage at Clean Energy Associates. He leads projects centered on developing CEA's internal quality standards, researching new production technologies, and developing new services. He has an extensive background in PV manufacturing, as well as downstream experience. Prior to joining CEA, he worked as the chief operating and technical officer at Philadelphia Solar in Jordan and technical and operations director at Recom.*

CEA's LETID batch test results 2019–2021 Source: CEA



for LETID picked up volume. One can see a big spread of results in both 2020 and 2021, with average degradation being about 0.80%, but reaching as high as 2.5%, highlighting the need to control LETID of production batches.

LETID tests

Q Cells and others developed tests that need months to complete, and this is not practical for a fast-moving industry. TÜV Rheinland developed an internal 2PfG series standard for LETID testing back in 2019, with the objective to accelerate LETID testing without compromising the detection of the maximum degradation. A new draft IEC technical specification for LETID detection testing is in progress and is expected to be published in 2023, and will be based to a large extent on TÜV Rheinland's internal LETID testing standard.

We have therefore chosen to base our LETID testing of new product samples on the draft IEC technical specification. Chart (below left) shows the test flow, described at a high level.

Similar to the existing grades for the other indoor tests, we developed grades for LETID testing results based on general industry knowledge and our experience from batch testing data, where values range from 0% to as high as 2.4%. The LETID degradation is calculated based on power after BO preconditioning, to separate LID degradation from LETID degradation (see table below).

The reason we adopted strict criteria is that the industry keeps improving, and that 50% of CEA's LETID batch testing results in 2021 are below 0.70% (the median value).

Three samples were tested in this first lot: Longi's LR5-72HBD-535M, JA Solar's JAM72S30-540MR and Trina's TSM-505DE18M. Among these three samples, LR5-72HBD-535M was submitted by Longi and the other two were purchased from the market.

Both Longi and Trina modules showed negative LETID (which is a gain), achieving a grade of 100. This can be explained by some small measurement uncertainty. Overall, the results are within expectation, as CEA has observed values close to zero or slightly negative in our batch testing results. On the other hand, the LETID of JA Solar's product was close to CEA's average for 2021 batch testing results. *George Touloupas*

> *"One can see a big spread of results in both 2020 and 2021, with average degradation being about 0.80%, but reaching as high as 2.5%, highlighting the need to control LETID"*

pv magazine test: LETID Results

Product Code	LR5-72HBD-535M	JAM72S30-540MR	TSM-505DE18M
Module Type	Bifacial PERC	Monofacial PERC	Monofacial PERC
Front side LETID	-0.36%	0.79%	-0.02%
Grade	100	74	100

CEA LETID Grading

Grade range	100	90	80	70	60	50	40	30	20	10	0
LETID	≤0.00%	0.30%	0.60%	0.90%	1.20%	1.50%	1.80%	2.10%	2.40%	2.70%	≥ 3.00%

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pv magazine test

November 2021 results

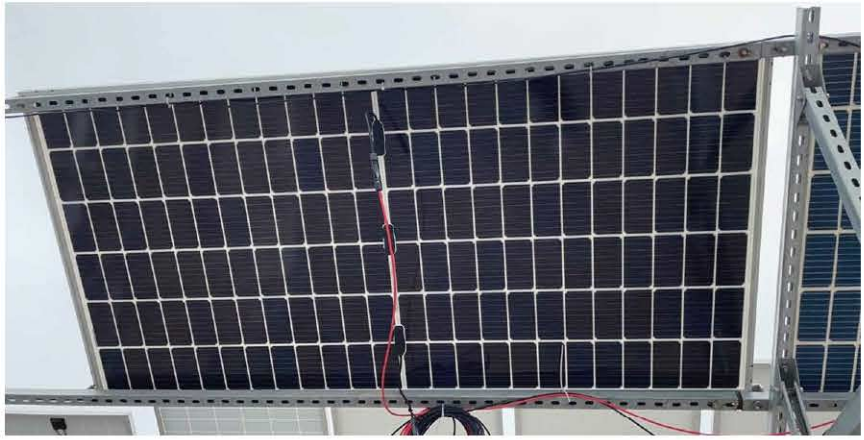
The November 2021 results have arrived from the pv magazine test field in Xi'an, China, alongside analysis from George Touloupas, senior director for solar and energy storage at CEA.

In the last issue, we discussed our challenges with high-current modules and the need to both increase the DC cable cross sections and apply corrections to the power values derived from the meters, in order to account for the higher cable losses of high current modules. During November, our partners at Gsola replaced the DC cables with bigger 4 mm² ones, and also modified the microinverters so that the starting time for all product types is the same and we do not have discrepancies from early- or late-day power clipping. In parallel, the CEA team modified the database so that every few minutes a temperature-corrected resistive loss correction would be applied for each PV module, based on the value of its current (I^2*R(T) losses).

Due to the time spent doing these modifications, data collection started on Nov. 20, with an additional three-day gap, due to mandatory power cuts at Gsola's facility. After a few days of operation, due to the low sun angle at this time of the year, and the fact that the test field underwent an extensive replanning last April, shading was detected on the test field, compromising the energy yield data of these samples. The affected modules were repositioned afterwards, but the November data was already impacted. Fortunately, the section of the field with the bifacial modules was not affected by shading, therefore, in this issue we will present the energy yield results only for the bifacial products. As a result, the bifacial boost will not be listed, as the baseline value of the monofacial module yield is not available.

The chart to the top right shows the meteo station data (irradiance and ambient temperature) for November 2021.

George Touloupas



The mounting structure had to be reconfigured to accommodate large-size modules, without shading of the rear side. M10 (182 mm) products can be seen in this picture.

Notes on the energy yield measurements:

- 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 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.

Average values

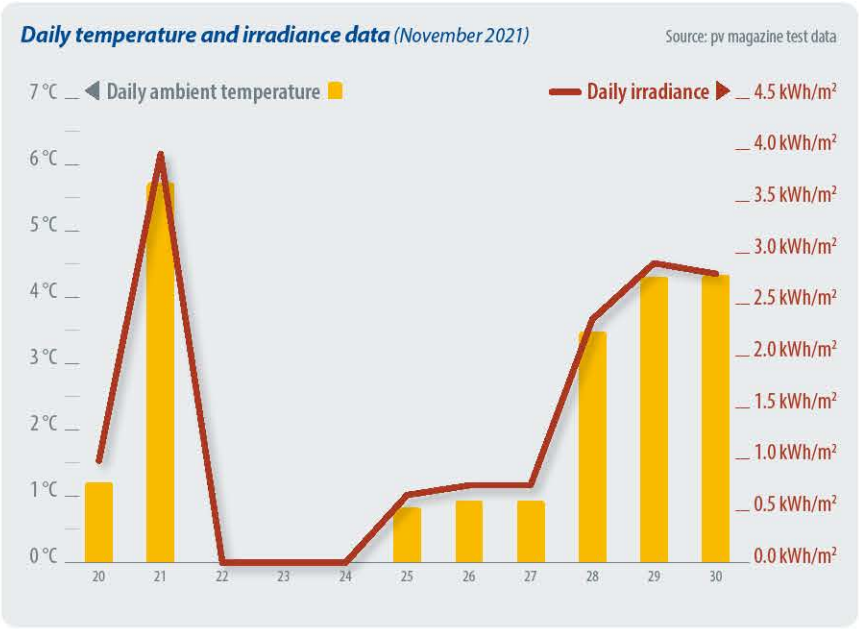
	Total Nov 2021 Wh/Wp
Average monthly yield	36.43
Operation days	8
Average daily yield	4.55

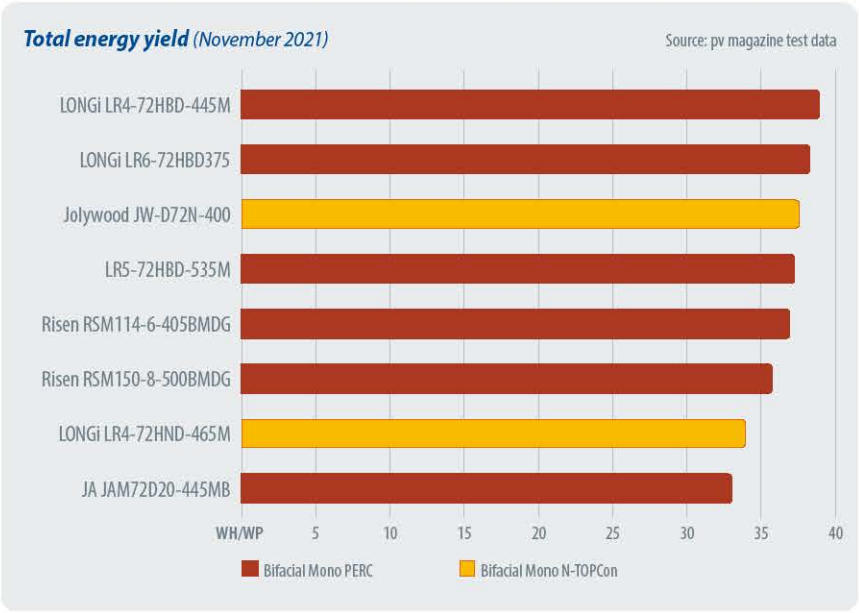
Energy yield ranking

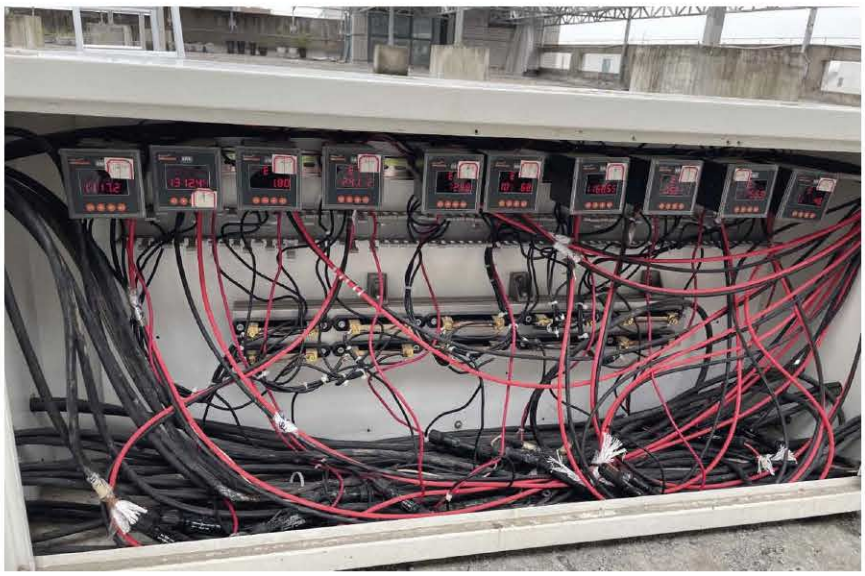
#	Installation Month	Product	Type	Total Nov 2021 Wh/Wp
37	2021/7/1	LONGi LR4-72HBD-445M	Bifacial Mono PERC	38.879
26	2019/8/28	LONGi LR6-72HBD375	Bifacial Mono PERC	38.247
27	2019/12/31	Jolywood JW-D72N-400	Bifacial Mono N-TOPCon	37.564
38	2021/11/20	LR5-72HBD-535M	Bifacial Mono PERC	37.225
28	2020/4/15	Risen RSM114-6-405BMDG	Bifacial Mono PERC	36.900
32	2121/7/1	Risen RSM150-8-500BMDG	Bifacial Mono PERC	35.706
39	2121/7/7	LONGi LR4-72HND-465M	Bifacial Mono N-TOPCon	33.937
34*	2121/7/1	JA JAM72D20-445MB	Bifacial Mono PERC	33.015

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

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Photos: CEA

Precision class 0.5 meters, taking current and voltage measurements every five seconds.

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

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The actual, real demand

Green hydrogen is being proposed for an ever-wider variety of uses. While some of these are still a way off, others make little sense. But there are sectors where demand for green hydrogen is a reality today, writes Christian Roselund.

Green hydrogen is the new cure-all of the energy transition; either a wonder drug or snake oil, depending on who you're speaking to, and the potential use. Green hydrogen is a prospective zero-carbon solution for a wide variety of applications, including iron and steelmaking, ground transport, long-duration dispatchable power, fertilizers, and more.

Cost, efficiency, and competing options for decarbonization are key considerations for these uses. In some applications, the market is more mature compared to others where hydrogen may ultimately be the best solution but may take time to play out. Additionally, there are geographical distinctions in the applications for hydrogen, driven in large part by the policy choices of nations.

Thankfully, this is no longer a theoretical conversation. Electrolyzers are being ordered and shipped, now.

Green steel

The application that has attracted the most attention in the last few years is steel.

Norwegian company Yara International plans to electrify and decarbonize ammonia production at this facility in Herøya, Norway, along with partners Aker Clean Hydrogen and Statkraft.



Photo: Yara International/Dag Frode Heiland

Inspired by the success of the Hybrit consortium's production of fossil-free iron in northern Sweden, a new "green steel" industry is rapidly emerging. The H2 Green Steel consortium and Iberdrola have announced plans for a €2.3 billion hydrogen-based iron plant in either Spain or Portugal.

Hybrit and other projects have shown that the process of using hydrogen as a "reducing" agent to separate the oxygen from iron in iron ore is eminently practical – if you have inexpensive renewable power and local ore. After all, demand is available, particularly among auto and truck makers. Mercedes Benz, Scania, and Volvo have all lined up to buy "green steel," despite its higher cost.

Another consideration is that there isn't another mature technology ready today to decarbonize primary steel production, and iron and steel making comprise 7% to 8% of global emissions. Boston Metals is championing the rival molten oxide electrolysis process, but it won't even get to "semi-industrial validation" until this year or next. A pilot plant is even further away, and if its process does successfully emerge, it will have catching up to do. "We see hydrogen as being the lowest-cost way to produce net-zero steel globally by 2050," explains Meredith Annex of BloombergNEF.

Annex says BloombergNEF is tracking 20 different green steel projects, including multiple phases. Many of these are pilot projects, however in the three full-scale commercial plants planned in Northern Sweden and the Iberian Peninsula, **pv magazine** has counted 2.4GW of electrolyzers.

Including these plants, 19 of the 20 green steel projects being tracked by BloombergNEF are in Europe. But Europe is not the ultimate prize, as the continent has fallen in recent years to less than 10% of global steel production. A more telling sign is that China's Hebei Iron and Steel is also building a hydrogen-based direct reduction project. "We do expect to see [green steel] projects in China," notes Annex.

There remains a big question about what will happen with the world's fleet of existing blast furnaces, which burn high

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for green hydrogen

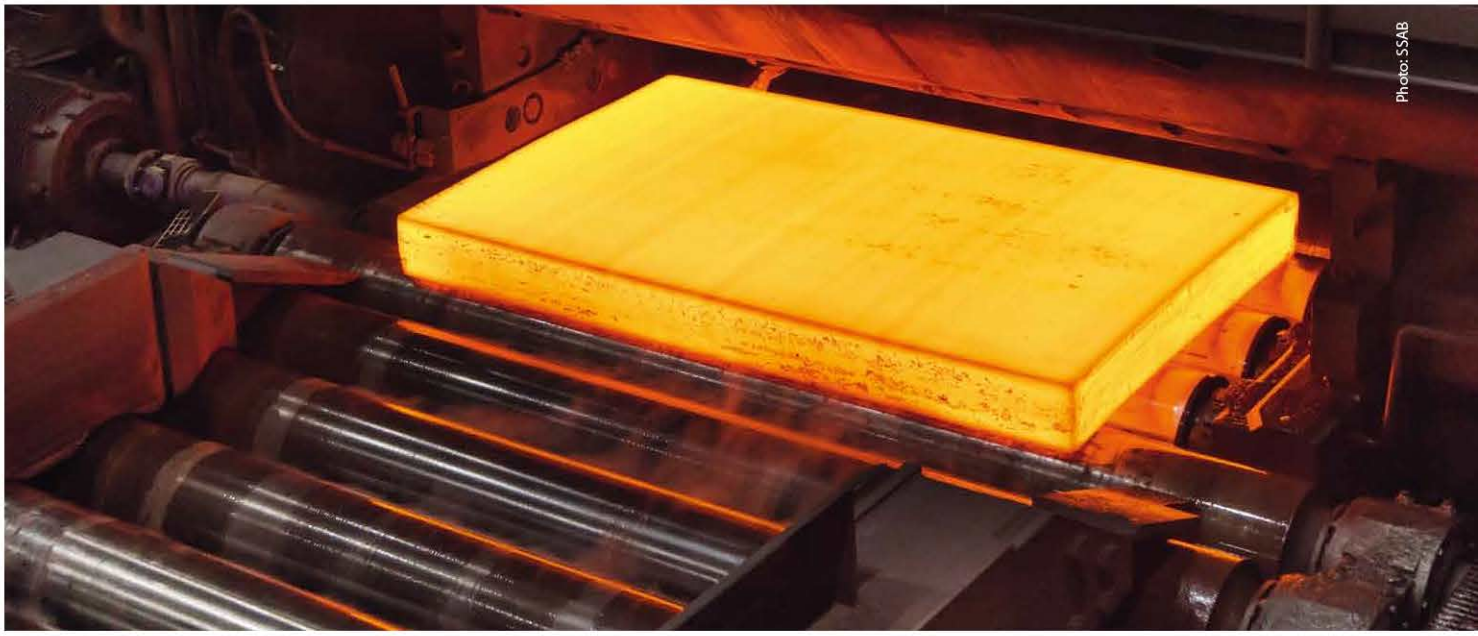


Photo: SSAB

In August 2021, Swedish company SSAB announced production and delivery of fossil-fuel-free steel, produced in Oxelösund, Sweden, with hydrogen, as part of the HYBRIT project involving partners SSAB, LKAB and Vattenfall.

purity coal to reduce the iron. Analysis by Agora Energiewende shows that 71% of global blast furnace capacity is scheduled for upgrades or replacement this century, and that this could be a good time for incumbents to move to hydrogen-based direct reduction.

If they don't, others may take the opportunity. "Startups will push the incumbents towards this technology if they don't already do it," notes Abhinav Bhaskar, the product manager for hydrogen at consultancy Rystad Energy.

Power sector

Another area with significant demand for green hydrogen is the power sector, where it can provide the long-duration, dispatchable power needed in grids with high portions of renewable energy. "When it comes to long-duration storage, there really is no technology that could do the job better than hydrogen," argues Gniewomir Flis, hydrogen expert at Agora Energiewende.

Modeling done by Tim Grejtak, senior innovation analyst at US utility ConEdison, confirms this. While Grejtak finds that novel battery technologies may be more cost effective for use cases of 100 hours or less, for longer durations H2 is the clear winner. "It's going to come down to what the electricity markets favor," notes Grejtak.

So far, the preference has been for hydrogen. As of July, BloombergNEF reported 14.8GW of projects to burn hydrogen to power turbines for the power sector. 43% of this capacity is in the United States, with significant demand in Canada, the United Kingdom and Europe.

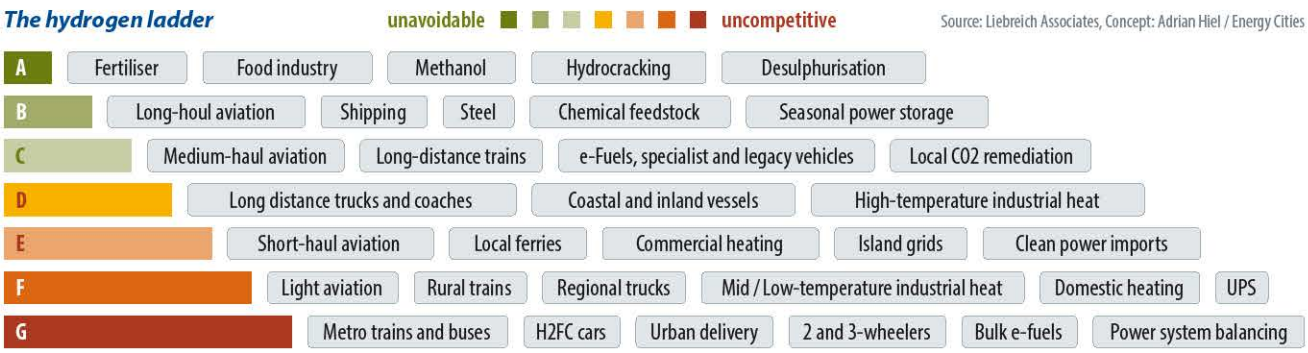
But while turbine makers, including GE, offer some turbines that can run on 100% hydrogen today – and others that can handle mixes above 80% – most of these will initially use blends. "A lot of them are still figuring out what their schedules are for blending," notes Annex. Additionally, it is not clear that this capacity will run on green hydrogen, as the US also plans to support "blue" hydrogen – hydrogen made from methane with carbon capture and storage – as well as "pink" hydrogen, made using electrolysis powered by nuclear energy.

And this solution may not be the best option in all cases. Both Grejtak and Flis note that conversion of existing gas plants to run on green hydrogen saves a lot of money compared to other long-duration storage options – if the circumstances are right.

"Making a gas asset H2 compatible is not just about replacing a burner in a turbine," explains Flis. He notes that if geological storage in salt caverns for hydrogen is available – as it is at the Intermountain

"Conversion of existing gas plants to run on green hydrogen saves a lot of money compared to other long-duration storage options – if the circumstances are right"

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Power Plant in Utah – then converting a gas plant to run on hydrogen makes sense. But it may not if you need to install special tanks to store enough hydrogen for continual operation.

Both the United States and Europe have a lot of these caverns. However, Flis notes other less fortunate regions may be forced to utilize different solutions for flexible power and long-duration storage.

Refining and ammonia

Beyond steel and electricity generation, there are several "no-regrets" applications where green hydrogen could replace existing hydrogen production, most of which is from the steam methane reforming process. In 2020, oil refining was the largest source of hydrogen demand globally – and the sector with the largest number of green hydrogen projects tracked by BloombergNEF, at 23.

BloombergNEF's Annex attributes much of this to corporate emissions reductions goals, with EU regulations anticipated under the REDII program. And while the United States is contemplating a tax credit in the Build Back Better legislation before the Senate, she sees slower progress in this market. "European players have stronger targets," explains Annex. "US players are still catching up."

Meanwhile, ammonia is the second-largest source of current demand for hydrogen and has the second-largest number of green hydrogen projects underway. This includes three massive projects that Norwegian fertilizer maker Yara is planning with partners in Norway, the Netherlands, and Australia.

And while fertilizer is currently the largest source of ammonia demand, there is the promise that ammonia can be a carrier for green hydrogen. Already Japan has begun importing ammonia made with "blue" hydrogen from Saudi Arabia to co-fire in coal power plants. The potential for demand from not only these uses but also as a fuel for shipping has led to large "green ammonia" projects to be announced in Australia, Chile, Ireland, Saudi Arabia, and Spain.

In fact, BNEF's Annex notes that most of the ammonia projects that are being announced are for export, not for on-site fertilizer production. She adds that green ammonia for export "is happening earlier than we thought it was going to."

Options, dead ends

There are multiple promising emerging applications for hydrogen. Notably, bat-

Intermountain Power Plant, a 1.9GW coal-fired power station in the US state of Utah, is set to be replaced in 2025 by a natural gas plant that is also designed to burn green hydrogen.



Photo: Doc Searls/Wikimedia

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Photo: BMW Group



US-based Boston Metal is developing a molten oxide electrolysis process to rival hydrogen in green steel production, and has picked up investments from major players, including BMW. However, industrial validation and pilot production for the process still appear at least several years away.

teries aren't practical for long-distance shipping and aviation. The net-zero pathways for the global shipping industry are focused on using either methanol or ammonia as fuel, either of which would be derived from carbon-free hydrogen production. In aviation, a recent deal between Alaska Airlines and ZeroAvia suggests that commercial hydrogen-powered aircraft could be transporting passengers as soon as 2024.

Other applications are more dubious. While gas utilities have widely promoted blending of H2 in their gas networks, heat pumps use energy inputs much more efficiently; a report by Energy Transitions Commission estimates a 5x efficiency gain.

Another more questionable application is personal vehicles. While makers of fuel cell electric vehicles (FCEV) promote the superior range and claim other technical advantages, they have clearly lost out to battery electric vehicles (BEV) in the market. Currently there are more than 100 BEVs on the road globally for every FCEV. As time goes on, the bar for FCEV to catch up gets higher and higher. There may be more potential for FCEV in heavy trucks and other long-distance road transport.

There are strong reasons for governments to take an active role in prioritizing specific uses of hydrogen in support programs. Electrolyzers will consume an enormous amount of power as the world decarbonizes steel, ammonia, shipping, and potentially portions of transport. Global economies may be hard pressed to put enough renewables online to both rapidly decarbonize and supply hydrogen.

Many analysts and advocates see this coming and are pushing for hydrogen to be used where it is most needed and most efficient, and not towards use cases where electricity can serve better.

However, as hydrogen is emerging as the new darling of the oil and gas industry, there is a real danger that these less useful applications will be prioritized. This is particularly a risk in nations where the oil and gas industry holds substantial political power, such as the United States. pv

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Final thought

Europe's path to 40GW

Gulnara Abdullina, Vice-President Europe, Longi Solar



Photo: Longi Solar

The European PV industry is experiencing a renaissance. Older markets are coming back in both utility and distributed generation, while newer markets are really blooming. If you look at the fundamentals of the European PV industry, it is very sunny situation.

However, the solar business in Europe is not without its challenges. We are facing issues in the supply chain and in logistics which are hampering the operations of many manufacturers – not only modules, but also balance-of-systems components. And that has an impact on project timelines and returns.

The growth drivers in the utility-scale sector will be the continuation of government PPA tenders, rise of corporate PPAs, and merchant projects. In addition to ground-mounted markets in Spain, Germany, France and the Netherlands, we expect Portugal, Italy, Greece and the United Kingdom to ramp up again.

The distributed-generation (DG) segment has dominated Europe in 2021, and in 2022, DG will take at least 50% of the market. Rising electricity prices make solar more economically viable and a handful of governments are stimulating PV adoption for homeowners as part of the Recovery stimulus. We also expect to see a nice rise in the C&I sector as more markets approach the GW-level club in 2020, notably Italy and Spain.

The application landscape in Europe is also becoming more diverse. At Longi, we have already provided our modules to around 45MW of floating PV projects in the Netherlands – and the modules are adapted to this type of installation. Agri-PV is also quite promising and with land constraints in Europe, it is the perfect way to integrate PV into the existing ecosystem.

I am very excited about the future in Europe. While growth has been hindered by supply chain and logistics disruptions in 2021, we've still enjoyed 30% growth, and the market is expected to grow to the mid-30GW level this year. I'm confident we will hit 40GW of annual installations by the end of 2023.

Preview of issue 02/2022



Photo: SMA

E-mobility beckons

The supply of EV chargers and the first steps of solar electric vehicles provide opportunities for PV.



Photo: Pixabay

Less silver for HJT

Efforts to reduce silver consumption in HJT cells are promising.



Photo: Ocean Sun

Seaward expansion

An update on efforts to expand floating PV's boundaries beyond the shoreline.

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