PV TECH POWER

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BRIDGING SOLAR'S SKILLS GAP

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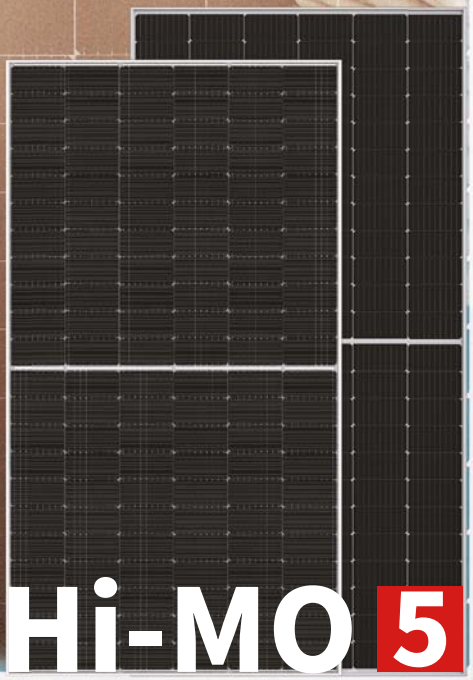

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Introduction

Welcome to volume 30 of PV Tech Power. As we were submitting this edition of the journal to press, events in Europe were escalating and what is unfolding in Ukraine are difficult to comprehend and, in truth, make the proceedings in these pages seem trivial. Our thoughts are with all those affected by the crisis.

The pages of PV Tech Power vol. 30 are this time littered with examples of the need to bridge the skills gap in solar PV. As megawatts have turned into gigawatts and gigawatts into terawatts, hundreds of thousands of skilled financiers, developers, systems designers, engineers and installers will be required to take solar modules, inverters and batteries – themselves the wares of an expansive workforce – and have them ready to generate clean, renewable power across the world.

As you'll read in our cover story (p.15), this is a task that's easier said than done and far from simply listing available roles and recruiting into them. Solar PV and other clean energy industries must get real on the need to start people onto solar as early as possible, establishing engagement programmes in schools and universities that can be followed through into internships and apprenticeships, ensuring a steady stream of would-be solar professionals.

A real world example of this can be found in Lightsource bp, which is chasing a target of bringing 25GW of solar PV to financial close by 2025. The developer speaks to PV Tech Power about how it is "building the machine" behind that target in our Financial, Legal and Professional section (p.62).

Deploying and maintaining a solar fleet that will soon surpass 1TW in generation capacity is, of course, no mean feat, and requires highly skilled professionals across the entire value chain. We're fortunate enough to have some of those write for us in this issue. To namecheck just a few, kWh Analytics' Sarath Srinivasan explores the reasons behind a noted underperformance of US assets against P50 estimates (p.38), 3E's Julien Deckx details the necessary strategies for early fault detection in our Plant Performance section (p.42) and Ryan Quint of North American Electric Reliability Corporation shares his experience of permitting renewables in the US, a key hurdle for solar and other renewables to surpass in the coming years.

In a technology-dominated industry as solar PV and energy storage, it's easy to become overawed by that technology, forgetful of the impact dedicated and highly-skilled professionals have on the sector. The pages of PV Tech Power vol. 30 are evidence enough of the sheer wealth of value that the people of this fantastic industry bring to it, and long may that continue.

Thank you for reading, and we hope you enjoy the journal.

Liam Stoker
Editor in chief
Solar Media

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EUROPE

Italy

Italy limiting profits of FIT-backed projects in response to energy crisis

Italy's government has started clawing back the profits of solar assets that have benefited from rising energy prices, a measure that has drawn stinging criticism from the country's renewables sector. Set to be in place until the end of this year, the policy applies to PV plants with a capacity above 20kW that receive feed-in tariffs through the Conto Energia scheme and are also able to sell electricity to the market or to Italy's energy management agency GSE. As much as 13GW of solar plants that receive feed-in tariffs through the scheme are affected, according to Stefano Cavriani, a board member of trade body Italia Solare. As of last year, Italy's installed solar fleet was just over 22GW. A group of industry associations, including SolarPower Europe, warned that the "complex and discriminatory measures" will jeopardise the European Union's climate plan and have "huge impacts" on renewables investments.

Credit: Eni

The measure applies to PV plants with a capacity above 20kW

Deployment

Annual EU solar PV deployment reaches new high of 25.9GW

The European Union's (EU) solar PV sector navigated a 2021 beset by supply chain disruptions and module prices hikes to post record levels of annual deployment, according to research from SolarPower Europe (SPE). Around 25.9GW of solar PV was added by the bloc's 27 member states in 2021, a 34% increase on 2020, the trade association said in its latest EU Market Outlook for Solar Power report. Taking the EU's total solar fleet up to 164.9GW, the latest figures come ten years after the previous record of 21.4GW of solar additions was set in 2011. The top five markets for EU solar deployment last year were Germany (which added 5.3GW), Spain (3.8GW), the Netherlands (3.3GW), Poland (3.2GW) and France (2.5GW).

New German coalition targets 200GW of installed solar by 2030

Germany's new coalition government has set the country a new target of reaching 200GW of installed solar capacity by 2030. The government has also brought forward the coal phase-out date from 2038 to 2030, by which time renewables are expected to account for 80% of electricity demand, thanks in part to the massive solar PV scale-up. While solar now produces around 10% of domestic electricity demand, trade association the Bundesverband Solarwirtschaft said barriers need to be "torn down" if the new target is to be reached, with an average of 15.6GW of solar needed to be installed annually from 2022 to 2030, a near-trebling of last year's figure.

Module prices

Solar modules set to benefit from reduced VAT rates in EU

Solar modules sold in the European Union (EU) could be subject to lower value-added tax (VAT) rates after an agreement was reached by finance ministers from across the bloc in December. The European Council agreed to update the rules on VAT rates to bring the tax's rules in line with EU priorities such as fighting the climate crisis, while also providing governments with more flexibility on the rates they can apply. Following consultations between EU member states, they have decided to widen the current list of goods and services that can benefit from reduced VAT rates to include, among other things, solar panels installed on private homes and public buildings.

PPA prices

Renewable PPA prices in Europe up 8% due to ongoing energy crisis

Renewable power purchase agreement (PPA) prices in Europe continue to climb, rising 7.8% quarter-on-quarter in response to the continent's deepening energy crisis, according to research from LevelTen Energy, a provider of renewable transaction infrastructure. Macroeconomic and regulatory challenges, including the energy crisis, have been compounded by supply chain constraints, inflation, rising commodity costs and government auctions culminating in reduced PPA supplies and rising prices, the company said in its Q4 2021 PPA Price Index report. As a result, Europe's P25 Index – an aggregation of the lowest 25% of solar and wind PPA offers – was €52.46/MWh (US$60.16/MWh), a 7.8% hike on Q3, which also saw an 8% jump in prices on the previous quarter.

Poland

EU approves extension of Polish auction scheme to support 9GW of renewables

The European Commission (EC) has approved an extension of Poland's auction scheme for renewable resources that is predicted to support the creation of 9GW of capacity after it passed European Union (EU) state aid rules. The scheme provides aid in the form of a variable premium on top of the market price, calculated as the difference between the bidding price and the wholesale electricity price. Initially approved in 2017, the auction has a budget of €9.4 billion (US$10.6 billion) and has now been extended until 2027.

M&A

ČEZ Group division Elevion targets European solar growth following Belectric deal

Elevion, the renewables arm of Czech conglomerate ČEZ Group, is targeting growth within Europe's PV market after closing the acquisition of Belectric's European assets. The deal will see Elevion acquire a 100% stake in Belectric GmbH as well as other European subsidiaries of the developer and PV services provider, including its operations in France, Italy, Israel and other European jurisdictions. German energy major RWE confirmed it was to divest parts of Belectric in mid-November. With Elevion having completed the deal, group CEO Jaroslav Macek said the significant growth of the European solar market presented "huge opportunities" for companies like Belectric.

AMERICAS

US Senate passes anti-forced labour act banning Xinjiang imports

In December, the US Senate unanimously passed the bipartisan Uyghur Forced Labor Prevention Act (UFLPA) that set bans on the import of products from China's Xinjiang region into the US unless importers can provide "clear and convincing evidence" they were not made with forced labour. The solar industry will need to begin providing evidence as to the origins of imported products from June. The final version of the Act retains the "guilty until proven innocent" rebuttable presumption clause that assumes all goods originating from the Xinjiang region are made with forced labour, and are therefore banned, unless an exemption is given.

Biden to split up Build Back Better bill as he priorities clean energy packages

President Joe Biden believes he can win support for the energy and environmental initiatives included in his Build Back Better (BBB) Act, saying he is confident of getting "big chunks" of the US$1.75 billion legislation signed into law. Businesses have claimed more than US$2 billion in economic activity is being lost every month the long-awaited bill is not passed. Featuring clean energy and climate investments totalling US$555 billion, BBB includes expanded and extended solar investment tax credits (ITC) and support for domestic PV manufacturers, among a host of other green initiatives.

Policy

Biden administrations confirms Section 201 extension, excludes bifacial modules

In February, Section 201 tariffs on solar imports to the US were extended by four years. However, bifacial panels continue to be exempt and the tariff rate quota for cell imports has doubled. The Biden administration confirmed the terms just two days before they were set to expire on 6 February. The President said he had concluded the safeguard action continued to be necessary given evidence that the domestic industry was "making a positive adjustment to import competition", and that an extension would provide greater economic and social benefits than costs. Increasing the tariff rate quota for cell imports to 5GW will enable double the amount of PV cells to enter the US without incurring the tariffs, paving the way for greater module assembly. But it is the continued exemption for bifacial panels which will prove the most significant boon for the US solar market, with the majority of module imports to the US in recent years being bifacial. The decision was welcomed by SEIA.

Credit: NREL

President Joe Biden during a visit to a National Renewable Energy Laboratory facility in Colorado in September 2020.

Regulation

Brazil publishes new net metering laws for distributed generation

In January, Brazil published its much-anticipated net metering laws that introduced a new framework for distributed generation in the country. Starting in January 2023, the new rules will see any solar PV systems below 5MW eligible for net metering tariffs until 2045. Analysts have noted how the new laws have caused a surge of new small-scale solar projects in the country as individuals and businesses scramble to access the more favourable incumbent policy structure. While the market is predicted to go into "overdrive" this year, the new regulations are still highly favourable to small-scale solar in Brazil. Small-scale solar far outstrips utility-scale solar in Brazil as a proportion of total generation.

CPUC indefinitely delays net metering vote amid uproar

The California Public Utilities Commission (CPUC) has decided to indefinitely delay its decision on controversial changes to the state's net metering laws. Dubbed NEM 3.0, the new scheme would have slashed solar export credits by about 80% and added a US$57 per month fixed charge for the average residential system that is partially offset by a US$15 per month credit for ten years. Research organisation Wood Mackenzie warned the changes, proposed by the CPUC in December 2021, would severely reduce residential PV's value proposition in California, cutting its solar market in half by 2024.

Investments

US DOE launches US$20bn initiative for grid upgrades

The US DOE has launched a "Building a Better Grid" initiative to catalyse the development of high-capacity electric transmission lines across the US. The programme seeks to identify national transmission needs and support the buildout of long-distance, high voltage transmission. It will support the development of nationally significant transmission projects and grid upgrades by engaging and collaborating early with key stakeholders, enhancing transmission planning, streamlining permitting processes and performing transmission-related R&D.

PPAs

Record 31GW of green corporate PPAs signed in 2021

A record 31.1GW of clean energy was bought by corporations through power purchase agreements (PPAs) last year, with technology companies once again the largest buyers, according to research firm BloombergNEF (BNEF). Representing a 24% jump on the previous year's record of 25.1GW, 2021's clean energy PPA figures were underpinned by a rise in activity from the largest tech companies, which collectively signed more than half of the deals. Amazon was the biggest buyer globally for the second year in a row, announcing 44 offsite PPAs in nine countries, totalling 6.2GW.

MIDDLE EAST & AFRICA

Mining

South African mining industry to build 3.9GW of renewables, eases pressure on public utility Eskom

The South African mining industry is planning to build 3.9GW of renewable projects and storage that would see the sector make strides towards meeting its 2050 net zero target and relieve pressure on South African public utility Eskom, which has called on the industry to supplement its energy supply. The projects, worth an estimated R60 billion (US$3.77 billion), include solar, wind and battery energy storage system projects which could provide Eskom with some of that supplemental capacity, said Roger Baxter, CEO of Minerals Council of South Africa, which represents the country's mining industry. In November 2021, Eskom CEO Andre De Ruyter told a South African Parliamentary Portfolio Committee that the utility needs to add an additional 4GW-6GW of capacity to conduct a reliability maintenance programme while not disrupting national electricity supply.

Credit: Pixabay

The mining industry in South Africa is increasingly turning to solar to supplement its energy supply.

Total Eren, Chariot land 40MW PV deal for South African mine as the industry continues shift to solar

South African mining company Tharisa has signed an agreement with renewables developer Total Eren and African energy company Chariot to build a 40MW solar PV project to power its mining operations as more of the country's heavy industries turn to solar. The Memorandum of Understanding plans for Total Eren and Chariot to develop, finance, construct, own, operate and maintain the plant that will supply power to Tharisa's eponymous metals mine in northern South Africa. It is a precursor to the signing of a long-term power purchase agreement for the supply of electricity on a take-or-pay basis, Tharisa said in a statement, adding that demand was expected to increase over the 50-year lifespan of the mine.

Investments

TotalEnergies lands 500MW Libyan solar PV project alongside US$2bn oil and gas investments

French energy giant TotalEnergies has won new contracts in Libya that include the development of a 500MW solar PV project, although it will also see the company pour US$2 billion into crude oil production and invest in gas extraction. Among the signed agreements is a Memorandum of Understanding between TotalEnergies and the General Electricity Company of Libya for the development a 500MW solar park that will supply electricity to the national grid. The solar park deal was dwarfed by TotalEnergies' additional investments in oil and gas announced at the same event.

Siemens, Desert Technologies eye 1GW PV portfolio in MENA and Asia via new JV

Siemens and sustainability investor Desert Technologies have created a new joint venture to invest and develop in solar and smart infrastructure in the Middle East, Africa and Asia, with investments earmarked for a portfolio of projects exceeding 1GW. The new venture, dubbed Capton Energy, intends to invest in existing and greenfield solar projects ranging between 20-100MW in size. Capton Energy will be led by Umer Ahmad, and the new CEO and chief investment officer said: "Capton Energy is already advanced in assembling a pipeline of solar-themed investments and is in progressive discussions to launch the inaugural fund raising."

Policy

Israel, Jordan sign deal to swap solar power for water

Israel and Jordan are set to swap solar power for desalinated water after the two countries signed a declaration of intent. The agreement will see Jordan build solar PV plants with a total capacity of 600MW that will export output to neighbouring Israel, with feasibility studies due to start in 2022. Israel, meanwhile, will provide up to 200 million cubic meters of desalinated water to Jordan, which is the second most water-scarce country in the world, according to the UN.

Tenders

Algeria launches tender process for 1GW of solar

Algeria has launched a tender process to support the deployment of solar PV projects in the country with a total capacity of 1GW. Called 'Solar 1000 MW', the programme will see developers bid to set up solar projects in lots of between 50MWp and 300MWp, with winning bidders securing a 25-year power purchase agreement, according to the country's Ministry of Energy Transition and Renewable Energies.

Floating solar

Singapore's G8 to install 65MW floating solar project in Ghana

Singapore-based renewables developer and engineering company G8 Subsea has secured a deal to install a 65MW floating PV (FPV) plant at a dam in Ghana. G8 said it has been awarded a letter of intent by Ghanaian utility Bui Power Authority to construct the FPV installation at the 404MW Bui Generating Station hydroelectric plant. Occupying 350,000m2 of water space at the Black Volta River, the GPM-65 Solar-Hydro System will feature G8's mooring and flotation technology to cater for variations in water depth throughout the year.

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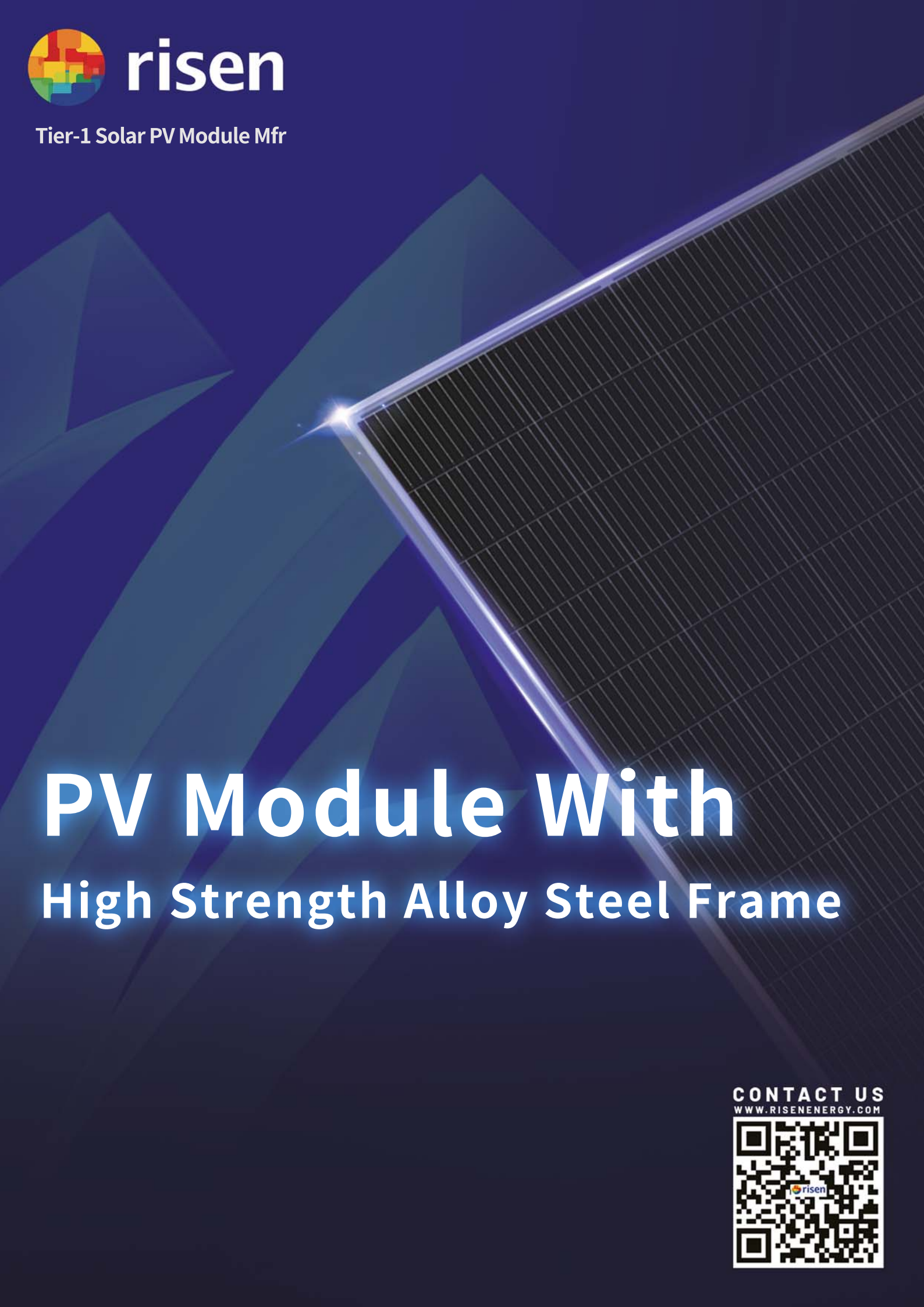

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Australia

Australia breaks renewable records but steep fossil fuel costs cause higher wholesale electricity prices

Solar PV and other renewables accounted for a record share of electricity generation in Australia's National Energy Market (NEM) in Q4 2021 at 34.9%, while average wholesale prices rose with the higher cost of fossil fuels despite their share of the energy mix shrinking. The trend was revealed in the Australian Energy Market Operator's (AEMO) Q4 2021 energy dynamics report on 28 January 2022, which also showed zero or negative spot prices during the middle of the day thanks in part to rooftop and utility-scale solar. Clean energy in the NEM accounted for an average of 34.9% of generation across Q4, up from 31.6% in Q3, with a peak supply of 61.8% on 15 November, beating the previous record of 61.4% set in Q3 2021.

Credit: Foresight Solar Fund

Solar PV and other renewables accounted for 34.9% of electricity generation share in Q4 2021. Image: Foresight Solar Fund.

India

ReNew sees 25% revenue jump but net losses soar due to NASDAQ listing

Indian independent power producer (IPP) ReNew Power posted a 25.6% jump in revenue for the first nine months of the fiscal year 2022 (FY22) compared with the same period in the 2021 fiscal year, while its net losses soared as a result of its August IPO on the NASDAQ. ReNew's total revenue for the first nine months of FY22 was INR51,581 million (US$693 million), an increase of 25.6% on the same period in the FY21. The company said the growth was down to an increase in generation capacity and higher wind Plant Load Factor (PLF) as a result of improved wind resources. The PLF for its solar assets remained much the same as last year (22% vs 22.3%). The company's net loss for the first nine months of FY22 increased substantially, however, as a result of its NASDAQ listing in August 2021. Net losses reached INR12,573 million (US$169 million) compared with INR4,093 million (US$55 million) in FY21.

Azure Power hails 'substantial savings' after refinancing 600MW PV project

Indian IPP Azure Power has refinanced a 600MW PV project in India, the company's largest to date. The 600MW interstate transmission system-connected project, located in Bikaner, Rajasthan, was allocated by Solar Energy Corporation of India (SECI) and commissioned in December 2021. Azure Power has refinanced its existing project finance facility, securing INR23.5 billion (US$313 million) of funding at an interest rate of 7.2% per annum, which is fixed for 42 months.

Indian hydropower company looking to deploy 10GW of solar over next 5 years in deal worth US$6.7bn

Indian state-run hydropower company SJVN is planning to deploy 10GW of solar PV in Rajasthan over the next five years through a INR50,000 crore (US$6.7 billion) investment. Confirmed during a signing ceremony in August 2021 but announced on 8 February 2022, the plans will see the solar projects built on land supplied by the Rajasthan Renewable Energy Corporation after state authorities accepted the proposal. Electricity generated from the projects will be distributed via Power Purchase Agreements (PPAs), taking advantage of "competitive tariff-based opportunities available in the market", said SJVN chairman and managing director Nand Lal Sharma.

Australia

New South Wales receives 40GW of applications for new renewable energy zone, representing a US$72bn investment

The Australian state of New South Wales (NSW) has received applications for nearly 40GW of renewable generation and storage projects for its planned Hunter-Central Coast Renewable Energy Zone (REZ) amid huge interest in clean energy resources in the state. Commercial interest equating to AU$100 billion (US$71.7 billion) has been registered in 24 solar energy projects, 35 large-scale battery energy storage systems (BESS), eight pumped hydro projects and 20 wind farms, according to a statement by the NSW government.

Australia's Fortescue plans renewables hub featuring 3.3GW of solar

Australian metals company Fortescue has unveiled plans for a vast renewables hub including up to 3,333MW of solar to power its mining operations in Western Australia. Fortescue Metals Group has submitted its Uaroo Renewable Energy Hub proposal to the Environmental Protection Authority of Western Australia. According to documents hosted on the Authority's site, the project, in the mineral rich Pilbara region, would consist of up to 340 wind turbines and a solar farm, which between them would have a maximum energy generating capacity of 5.4GW.

APAC expansion

EDP Renewables unveils US$7.4bn APAC investment plan after closing Sunseap deal

EDP Renewables (EDPR) plans to invest S$10 billion (US$7.39 billion) in renewables in the Asia Pacific (APAC) region by 2030 after closing its S$1.1 billion (US$813 million) acquisition of Singaporean developer Sunseap. The Portuguese utility said the investment was in line with its strategy for the APAC region, regarding it as the world's fastest growing renewables market with solar representing 65% growth in APAC for this decade. This will enable EDPR to ensure "a truly global reach" and diversifying its portfolio even further, the company said.

Lightsource bp expanding into Asian solar markets as 25GW plans progress

Lightsource bp is eyeing solar opportunities throughout Asian markets as it progresses towards its target of deploying 25GW of solar PV by 2025. Late in 2021 the developer, 50% owned by oil and gas major bp, increased its PV deployment target to 25GW by 2025 – a significant increase from the previous target of 10GW by 2023 – after securing a US$1.8 billion financing facility from 10 major banks.

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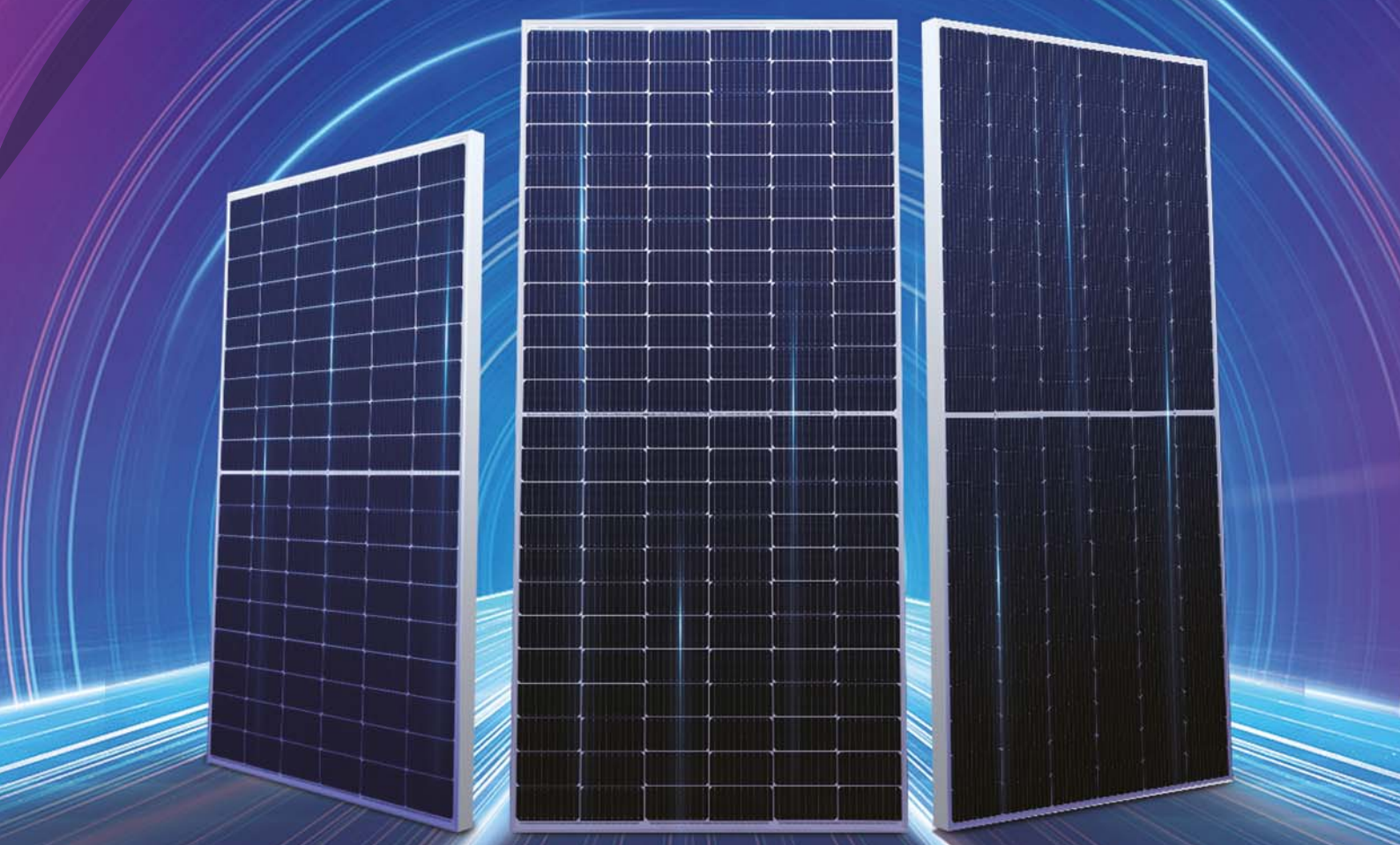

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MANUFACTURING

Manufacturing

LG Electronics to exit solar module business citing supply chain concerns

LG Electronics is to exit the solar module manufacturing business and shutter its assembly plant in Alabama, US. The decision, approved by the consumer electronics major's board in late February, followed what it described as a "comprehensive review" of the impact of soaring material and logistics costs on top of supply constraints on its solar business. LG said it would continue to lean on the renewable energy experience gathered by concentrating instead on sectors including energy storage and home energy management. Module production is to be wound down from this spring before ending in Q2 2022, affecting around 160 employees and a further 60 contract workers at the company's assembly plant in Alabama.

Europe

European solar developers seek 20GW of manufacturing capacity by 2030

Credit: Pixabay

The letter cited concerns over supply chain constraints globally.

Major European solar developers have called on the European Union (EU) to develop a PV supply chain strategy to avoid cost increases and disruption to projects, with the group calling for 20GW of manufacturing capacity by 2030. In a letter to European Commission (EC) President Ursula von der Leyen, other senior EC leaders and European heads of states, the letter said developing a "European strategy for the solar PV value chain" was necessary to "achieve the objectives of the European Green Deal set by the EC." It said that "if the right actions are taken in a timely manner" the EU could see a 20GW manufacturing capacity by 2030, adding that "industrial interest is there", with 2GW of cell manufacturing, financed mostly from the private sector, already redeveloped in Europe. The signatories – BayWa r.e., EDF Renewables, Enel Green Power, ENGIE, Iberdrola Renewables, Amarenco, Akuo Energy and Vattenfall Solar – lamented European divestment from "most strategic steps of the solar PV value chain." "Most of the EU project developers rely on a limited number of suppliers, with significant concentration in a limited number of countries outside Europe," said the letter.

India

India's PLI scheme to add 40GW of cell and module capacity

India's Production Linked Incentive (PLI) scheme is expected to add up to 40GW of additional cell and module manufacturing capacity in the country as it operates in tandem with the country's upcoming Basic Customs Duty (BCD), according to Indian rating agency ICRA, a Moody's Investors Service company. The scheme was awarded an extra US$2.6 billion in funding following high demand from manufacturers and ICRA said this, coupled with the impact of the BCD, was "expected to support the setting up of additional cell and module manufacturing capacity of up to 40GW."

Reliance Industries includes PV manufacturing in US$80bn Gujarat green plan

Reliance Industries has signed a Memorandum of Understanding (MoU) with the government of Gujarat for a total investment of INR5.955 lakh crore (US$80 billion) over 10-15 years to establish 100GW of renewables and set up green technology manufacturing facilities in the state. India's largest privately traded company will invest the vast sum in setting up solar PV module manufacturing (including polysilicon, wafer and cell manufacturing), electrolysers used in green hydrogen production, battery energy storage system (BESS) technology and fuel cells.

India and Australia to collaborate on solar manufacturing

Australia and India have agreed to collaborate on solar manufacturing and deployment, aiming to reduce the cost of solar PV, battery energy storage systems (BESS) and new clean technologies in both countries. A letter of intent (LOI) was signed between the two countries with the stated aim of scaling-up domestic manufacturing and deployment levels in both regions as well as supporting the development of clean hydrogen and other renewables technologies.

Capacity expansion

JA Solar confirms new US$552m investment in fresh round of capacity expansions

Solar Module Super League (SMSL) member JA Solar is again aggressively expanding its manufacturing capacity, unveiling a new RMB3.5 billion (US$552 million) investment programme for new facilities. JA Solar said it intends to expand the company's integrated capacity. New projects include 2.5GW of silicon wafer production capacity in Vietnam, 1.3GW of high-efficiency cell production capacity in Ningjin, Hebei province, China and 10GW of module auxiliary material production in Yiwu, China. The investment programme, which also includes the construction of a 200MW energy storage facility in Tuquan, China, is to cost a total of RMB3.455 billion.

LONGi 4GW Taizhou cell project set to start operations in August

Leading solar manufacturer LONGi is to add another 4GW of cell manufacturing capacity later this year, diverting funds previously earmarked for a separate cell production plant. LONGi confirmed it is to redirect around RMB1.2 billion (US$160 million) of capital initially raised in 2018 to finance a 3GW cell project in Ningxia, China, with just over RMB1 billion of that financing now set to fund the development of a 4GW cell project in Taizhou, which will come onstream in August 2022.

Bridging the solar skills gap

Workforce | As demand for solar grows, so too must its international workforce. But there are concerns that a shortage of skilled workers could stymie deployment just as it's needed to accelerate. Jules Scully assesses where the solar skills gap is looming and industry efforts to ease it.

Credit: Solar Energy International.

Trainees at Solar Energy International's lab facility in Colorado.

When Rick Naranjo in 2015 realised his executive role in the mining sector was at risk, he decided to take action and follow his interest in renewables by contacting a solar firm he had previously been a customer of. Fortuitously, that company – Pennsylvania-based commercial and residential PV installer Paradise Energy Solutions – was at the time looking for someone with his skillset to help run the business.

Seven years later, Naranjo is now the firm's vice president of operations, drawing on his knowledge of areas such as automation from previous roles. "I've always felt that the skills that you learn in one vocation can oftentimes be applied to a new vocation," he says.

Naranjo's move from mining to solar is a story being played out globally, with soaring PV deployment leading to a war over talent as solar firms seek candidates with the right skillset as the energy transition accelerates.

Global solar PV employment increased to 4 million workers in 2020, according to the International Renewable Energy Agency (IRENA), with the segment employing a third of the total renewables workforce. Under IRENA's pathway for the world to achieve the Paris Agreement goals and limit global temperature rise to 1.5°C, solar employment could reach 20 million by 2050.

Despite positive recent developments, skills gaps and shortages are increasing and will likely be widespread globally unless proactive measures are taken, IRENA said.

In 2019, 83% of solar employers in the US reported it was either "very difficult" or "somewhat difficult" to find qualified applicants, with installation and project development firms having the most challenges hiring, according to the 2020 National Solar Jobs Census report. A lack of experience, training or technical skills were the most significant reasons for their challenges when hiring, followed by a competitive job market and small applicant pool.

Solar developers spoken to by PV Tech Power say that recruiting, training and retaining workers is among the key priorities that the sector needs to address. There's currently a lack of qualified candidates compared to demand, says Nikos Papapetrou, general manager of Greek industrial group Mytilineos's renewables and storage development business, adding that issue is compounded by the so-called Great Resignation, during which workers have quit their jobs at historic rates.

Papapetrou says that with the industry growing, more specialisation is needed among workers, while PV plants continuously increasing in size means that developers require more people with large-scale project management skills.

This is a trend also noted by renewables recruitment consultancy Taylor Hopkinson, whose clients are now requiring talent with large utility-scale solar experience, including special planning experience, a track record in managing multi-landowner negotiations or a history in constructing these projects.

Jamie Taylor, the company's managing director of onshore renewables, says there is an influx of demand for talent in the UK solar developer space, with companies expanding or setting up teams and all looking for the same skillset – someone with a track record in originating and developing utility-scale solar PV farms. "This poses its own challenges as demand outstrips supply and the talent pool is stretched, with salaries for this skillset becoming inflated and companies vying for the same candidates," he says.

Among the challenges that solar companies face when sourcing suitable candidates, Taylor says, include budget expectations not being aligned with market rates and inflexibility on candidate location and working patterns. He says companies that are unwilling to offer flexible working – a perk that is often top of candidates' wish lists – may need to pay a premium to secure the right talent.

While increased homeworking due to COVID-19 has meant some employers are now more receptive to office-based staff working remotely, this is obviously not possible for many manufacturing, development and construction roles.

One company that has benefited

from its location in Nashville, Tennessee, is independent power producer Silicon Ranch. "Nashville's a good draw for talent. We've recruited and brought people from across the country and around the world," says the company's chief commercial officer, Matt Beasley.

Silicon Ranch earlier this year raised US$775 million in new equity capital to support the construction of its solar pipeline and potentially enter new markets. Beasley says the equity raise shows that capital is not the constraint for the solar industry, it's instead "finding the people, making sure that we are continuing to expand the workforce who is trained and ready to participate in the energy transition".

Projections by job type

In terms of employment by segment of the US solar sector, installation and construction-related jobs were the vast majority in 2020, representing more than two-thirds (67%) of the total, the country's National Solar Jobs Census revealed.

Manufacturing jobs, meanwhile, were 14% of all solar industry employment, while sales and distribution and O&M represented 11% and 4%, respectively. The 'other' category, comprised of workers in fields such as finance, legal, research, advocacy and communications, made up 4%.

The jobs census found that without significant policy shifts, the US solar industry is on track to employ 400,000 workers in 2030, representing a 73% increase on 2020's figures. However, achieving President Joe Biden's goals of decarbonising the grid and expanding domestic manufacturing will require more than 900,000 solar workers across the US supply chain by 2035.

The number of installation and development jobs might be expected to rise roughly in proportion to increasing annual installations, according to the US Department of Energy (DOE), which estimates that the clean energy transition could drive job growth in more than 100 occupations to support the emerging solar industry.

While the DOE predicts gains in module efficiency and efforts to streamline installations would increase labour productivity and thus result in smaller job gains, such efficiency advancements may be offset by combining solar with storage and blurring the line between solar, roofing and new home construction that could all affect solar labour intensity.

Increases in US solar O&M jobs will likely be smaller, the DOE said, owing to developments that could improve labour productivity such as longer inverter lifespans, improved monitoring systems and anti-soiling coatings.

In the European Union (EU), the vast majority (80%) of solar jobs in 2020 were associated with deployment, followed by O&M (10%), manufacturing (6%) and decommissioning and recycling (4%), figures from trade body SolarPower Europe (SPE) reveal.

Driven by competitive costs and facilitated by the easing of administrative and permitting procedures, the utility-scale segment's contribution to total EU solar jobs is set to surge from 19% in 2020 to 38% by 2025, according to SPE, with several countries – France, Greece and Italy – getting close to a 50-50 split between rooftop and utility-scale positions.

The growing fleet of PV projects across the EU will see the bloc's solar O&M workforce grow 82% between 2020 and 2025, says Sien Van de Wiele, project and communications officer at SPE. "These workers will need to be regularly retrained to be able to install rapidly developing technologies like batteries or new digital technologies such as energy management systems."

By the end of the decade, new EU plans to raise the share of renewable energy to 40% of final consumption by 2030 will see solar jobs across the bloc more than double compared to current levels, reaching 742,000 full-time equivalent jobs. SPE said this will lead to the share of deployment roles falling to 61%, while manufacturing (18%), O&M (14%) and decommissioning and recycling (8%) will all raise their shares.

Despite utility-scale solar jobs increasing their portion of the EU total, projections from EuropeOn, the European association of electrical contractors, suggest that reaching the EU's renewables target for 2030 means hiring an extra 225,000 professionals this decade to install and maintain rooftop solar systems.

There are two ways to look at it, says Julie Beaufils, EuropeOn secretary-general: "Either the green transition can trigger the creation of 225,000 jobs in this segment, or the solar market will be slowed down because of a huge gap between the available and needed workforce."

Such an expansion could see companies in the sector double down on workplace learning to support trainees. IRENA analysis on 35 key occupations in the global solar PV sector shows that only 16 of these jobs require a university degree, with the remainder of skills built through either on-the-job training, vocational training or apprenticeships.

Workforce training

For solar companies looking to achieve their workforce development targets, the US National Solar Jobs Census suggests options including tapping into local workforce development resources – such as training providers and community colleges – and expanding work-based training programmes that allow entry-level employees to learn on the job.

One organisation that has benefited from an uptick in demand for its programmes is Solar Energy International (SEI), which provides a raft of PV workshops and online courses. "We've seen hockey stick growth in the number of students that are enrolling in our courses worldwide, especially last year," says Chris Turek, SEI director of marketing and communications.

Carrying out training from the entry level, such as onboarding new installers, to courses for advanced O&M technicians, SEI tends to see a 50-50 split in its programmes among students that are new to the sector and those that already have jobs and want to upskill.

Turek says there has also been a rise in the number of people with transferable skills enrolling on courses that are aiming to use their existing knowledge from

2020 US solar employment by labour category	
Installation and developers	154,610
Manufacturing	31,050
Sales and distribution	25,663
Operations and maintenance	10,077
Other	10,073
TOTAL	**231,474**

2020 US solar installation and developers employment by market segment	
Residential	84,946
Non-residential	27,971
Community solar	11,677
Utility-scale	30,017
TOTAL	**154,610**

Source: National Solar Jobs Census 2020

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Credit: Nextracker.

Workers at Nextracker's PowerworX training programme.

previous jobs in areas such as the electrical trades or construction industry.

With solar companies looking to continuously update their teams' knowledge of new technology and components, SEI is ramping up its partnerships with PV manufacturers this year, allowing them to offer their training through its online platform.

To keep up with demand and the growth of the solar industry, Turek says "there's going to have to be a full commitment from the training providers, the students and the employers to create that 360-degree continuous training cycle".

Among the solar manufacturers that have partnered with SEI is tracker manufacturer Nextracker, which last year announced an initiative to support more women in joining the solar workforce. That programme is in addition to the company's PowerworX training programme, providing participants with instruction on the design, installation, commissioning, software and O&M of its PV systems.

Nextracker will ask engineering, procurement and construction (EPCs) contractors that are installing its equipment if they want their teams to take a course on-site or at one of the company's training facilities in the US, Brazil, Spain and Australia. "We're firm believers in supporting any programme that has skills transfer, whether you're a coal worker and you're coming into the solar field or an oil and gas veteran and you want to join the solar workforce," says Kristan Kirsh, Nextracker vice president of global marketing.

Graduates of the PowerworX programme receive credits from the North American Board of Certified Energy Practitioners, with the certification organisation reviewing the curriculum each year.

According to the 2019 US Solar Jobs Census, 14.5% of solar employers reported that insufficient qualifications (certification or education) was the most significant reason for their difficulty hiring. The Interstate Renewable Energy Council (IREC), which publishes the jobs census and accredits clean energy education programmes, is working to ensure that training providers and employers themselves can more effectively train workers.

> "There is a need to make this sector more attractive, by showing its many perks"

The renewables industry is still catching up with other sectors in terms of employers requiring certification when hiring, says Laure-Jeanne Davignon, vice president for workforce programmes at IREC. Employers "need to know whether someone was adequately trained, by knowing what training programme they attended or by their performance on a certification exam", she says.

As part of IREC's efforts to grow an inclusive renewables workforce, it recently launched a cross-sector initiative called the National Clean Energy Workforce Alliance. Aiming to promote more effective recruitment, training, credentialing and employer placements, the alliance brings together four main stakeholders: employers, training providers, community-based organisations and policymakers.

Davignon says it is essential that these four cohorts are actively communicating and have effective processes in place to move workers and learners through the training and employment pipeline.

But one of the biggest issues the sector faces, she says, goes beyond those four, and centres around connecting with the public. "Not a lot of people know about these jobs," she says. "We think that youth, especially, will care a lot about these occupations, but we need to do a better job of getting the word out."

Marketing and policy

To showcase the diverse range of careers in the solar sector and connect potential workers with training programmes, trade body SPE recently partnered with Google to launch the #SolarWorks campaign.

A video series tells the story of PV workers from across Europe, as they share their experiences and advice on kickstarting a solar career, while an online platform provides details of solar training programmes in markets such as France, Germany, the Netherlands, Poland and Spain.

"We need to communicate on the needs of the solar industry and ensure existing training is as accessible as possible," says SPE's Sien Van de Wiele.

Alongside the trade body and Google, partners on the #SolarWorks campaign include renewables developer BayWa r.e., independent power producer Sonnedix, module manufacturer Meyer Burger and EuropeOn, among others.

EuropeOn's Julie Beaufils says that while the solar industry has launched many marketing campaigns in recent years, public authorities and the education sector should look to encourage a change of mindset among young people so that they enter technical studies.

"There is a need to make this sector more attractive, by showing its many perks," she says, adding: "Governments must promote technical education and make it a positive alternative to university."

And with a higher volume of students, Beaufils believes it will be necessary to progressively update existing training

programmes and set up new facilities across Europe.

IRENA calls for financial support to be provided to technical and vocational education and training (TVET) institutions to ensure that programmes can meet the workforce needs of a continuously evolving renewable energy sector.

Many countries globally also need to build local professional capacity to develop, manage and execute renewable energy projects, IRENA said in a report last year, with the building of such capacity requiring close partnerships between universities, governments and the private sector to prepare students in careers such as energy engineering, management and policy.

"Training and workforce development programmes need to expand and be a key part of the solar industry's future," says Jen Bristol, senior director of communications at trade body the Solar Energy Industries Association (SEIA).

Given that the US solar sector is already affected by widespread shortages of skilled trades workers and that it typically takes an electrical apprentice four to five years to become a licensed electrician, Bristol believes this shortage could continue unless there is adequate investment in the workforce today.

She says the US needs more technical training programmes, such as apprenticeships, community college programmes and community-based workforce training initiatives, adding: "We also need to introduce solar curriculum at the elementary, middle school, and high school levels in diverse communities across the country."

While some employers in the solar sector are already struggling with recruiting workers with the right skills ahead of a projected surge in PV deployment globally, IRENA research suggests that almost two-thirds (64%) of the PV workforce needs minimal formal training.

Individuals with degrees in fields such as science, technology, engineering and mathematics (STEM) make up around 31% of PV workers, according to IRENA, while highly qualified, non-STEM professionals – such as lawyers, logistics experts, marketing professionals or experts in regulation and standardisation – account for roughly 4%. Administrative personnel make up the final 1%.

"Solar building and installation work is not unskilled, but it is not rocket science either and people can train to do the work if the economics are in place," says Jenny Chase, head of solar analysis at research organisation BloombergNEF. She says the best thing that governments can do is offer sustained demand for solar, not a rapid boom and bust, so that firms invest in training and workers gain experience in the field.

Having taken SEI courses to further his knowledge of the solar sector, Rick Naranjo of Paradise Energy is now also an SEI contract instructor. As part of the company's strategy of onboarding new workers, they are required to carry out on-the-job training while also studying for a six-week SEI course on solar electric design and installation, allowing them to deploy what have learned in the field.

According to Naranjo, finding employees is "extremely difficult" for Paradise Energy Solutions, meaning the company looks for people that have the right aptitude that can be trained.

For those that do take the leap into the sector as he did, Naranjo says it gives workers a front-row seat to a fundamental shift in how society uses electricity. "The next ten years are going to be very exciting… So if you like change and you want to be part of change, then solar is good for you." ■

War over talent sees solar graduates in high demand

With the energy transition picking up pace and record solar capacity being installed globally, universities are seeing heightened demand for their graduates among employers looking to secure the brightest talent.

In Australia, The University of New South Wales (UNSW) has revised its courses to have a greater emphasis on large-scale solar and wind, energy storage and grid integration, while also offering courses on rooftop PV and demand-side energy efficiency as they remain strong areas of employment, according to Professor Alistair Sproul, head of the university's School of Photovoltaic & Renewable Energy Engineering.

"The boom of large-scale solar and wind energy systems, as well as continued strength of rooftop systems and energy efficiency in Australia, has meant strong demand for our graduates," he says.

With positive messages regarding the renewable energy sector appearing in the media from companies repositioning themselves and from governments globally committing to tackle climate change, Sproul says UNSW is seeing a lot of interest in its courses from existing engineers in other sectors wanting to retrain so they can be involved in the energy transition.

In the UK, meanwhile, more young people are taking higher education courses in science, technology, engineering and maths (STEM) subjects at university than ever before, statistics from the country's Universities and Colleges Admissions Service (UCAS) reveal.

Offering a master's degree in solar cell technology, which is designed to train physical science and engineering graduates in the development of new PV devices, The University of Sheffield has seen graduates from the programme go on to get secure jobs with Chinese solar companies, while others have gone into areas such as supply chain consultancy and energy forecasting.

"We do incorporate case studies and company use cases within the degree," says Alastair Buckley, a professor of organic electronics at the university. Currently, he says, there is an especially high demand for graduates with data science skills, who are able to quickly find well-paid positions.

For the solar sector to overcome a potential skills gap, Sproul says the industry needs to get the message out to young people at school that "there are huge opportunities right here, right now in the renewable energy engineering sector and this will continue for decades to come".

Hands-on classes at The University of New South Wales.

Levelling the field: How solar is tackling gender diversity

Credit: Nextracker

Efforts are afoot to encourage more women to take up positions in the renewables sector.

Equality | Women still make up just 32% of the renewables workforce worldwide, but initiatives are emerging with the aim of improving gender diversity at all levels. Molly Lempriere takes a look at the current state of play, and how companies are looking to attract a more gender diverse workforce.

The benefits of gender diversity are well documented, and throughout the solar sector companies are increasingly looking to capitalise on these. Initiatives that highlight the opportunities within the renewables sector to school and university pupils, mentorship programs and diversity recognition initiatives are emerging, but what else can companies do to attract – and keep – women in the solar sector?

In the renewable energy sector globally, those identifying as a woman make up around 32% of the workforce according to a 2019 report from the International Renewable Energy Agency (IRENA). While this is higher than the energy sector at large – where it sits at 22% – there remain a number of key discrepancies. The share of women in science, technology, engineering, and mathematics (STEM) related positions sits at just 28%, for example, while they make up 45% of administrative positions.

For the solar sector more specifically, the same gap rings true. In the US, women represented just 26% of the solar workforce in 2019, according to research from the Solar Energy Industries Association (SEIA). This discrepancy is even worse at the top of organisations, with just 28% of that figure holding manager, director, or president-level positions. This has ramifications in a number of ways. Economically, women make 74 cents on the dollar compared to men in the solar sector in the US. For women of colour, the disparity is even starker.

32%

the percentage of the renewable energy workforce identifying as a woman according to a 2019 IRENA study

The barriers to entry

There are barriers to both entry and progression for women in the solar sector, with one of the first stumbling blocks being a lack of women and girls entering STEM subjects. This is a global trend, for example in New Zealand, in health related studies women make up 80% of graduates, but less than 30% of engineering, IRENA said.

"There's still the perception that all energy sector jobs are very technical," says Christine Lins, co-founder and executive director of Global Women's Network for the Energy Transition (GWNET).

"On the one hand, I think we need to work on attracting more women and girls to STEM subjects. But we also really put an emphasis on the fact that this sector does not only have technical jobs, but also needs political scientists, marketing people, all different kinds of professions. It's a very versatile subject."

When women do start working in the sector, they often find it hard to progress, held back by a number of factors including the work culture and a lack of role models. In a series of interviews conducted by GWNET for its report *'Women for Sustainable Energy: Strategies to Foster Women's Talent for Transformational Change',* the existence of a "boys club" culture – often brought from the conventional energy sector into the renewables sector – was described as creating unfavourable conditions for women as employees.

A survey by the Brazilian Women's Network in Solar Energy in 2019 found that 62% of women surveyed had heard sexist comments in a predominantly male work environment, while around half of the 130 respondents said that they had suffered some kind of gender discrimination within the solar sector.

However, awareness of the problem – or lack thereof – is also a barrier. IRENA found that only 40% of men perceive the existence of gender related barriers, in comparison with 75% of women. Similarly, 60% of men believe that genders are paid equally in comparison to just 29% of women. If the gap is not perceived it cannot be tackled, particularly if men still dominate the decision making positions.

CREDIT: GWNET

CREDIT: GWNET

GWNET hosts events throughout the year designed to advance gender equality in the renewables sector.

Tackling gender inequality at the root: improving STEM

Greater equality in STEM subjects at school and university must be one of the first targets for initiatives to increase gender diversity. Companies in the solar sector can support this by reaching out and working with schools and universities.

Additionally, companies should work to "showcase the full range of opportunities that a career in solar can provide", says Rachel Hayes, policy analyst at trade association Solar Energy UK.

"I have also found it interesting to break down the perception barrier that to work in the renewables industry you have to be 'clever'. I think the word clever can take many forms, but in the engagement I have had, this has often been raised with young women who may have learning difficulties or find academia challenging… As someone with dyslexia myself, I can relate to this. [But] a career in solar has no set pathway, there are both vocational and academic routes into the industry – roles for everyone!"

Beyond this, companies can support greater gender diversity by establishing paid internship programs, scholarships and training and apprenticeship programs, which can attract new people to the industry.

> "A career in solar has no set pathway, there are both vocational and academic routes into the industry"

"It's really important to offer the access opportunities to under-represented groups; by offering the first step, the first role, we are giving people a chance to develop they otherwise might not have had and are equipping them to go forwards in their careers from a foundation of meaningful work experience. It is important to widen the 'access' funnel as early as possible, to address gender balance in a sustainable way," says Axel Thiemann, CEO of Sonnedix.

Following on from providing these first steps, companies should examine every step of their talent acquisition process, from training hiring managers, to using software to check the language used in job adverts, having gender-balanced shortlists and a diverse interview process.

Setting gender diversity targets and quotas like the Equal by 30 Campaign, which calls on companies to commit to equal pay, equal leadership and equal opportunities for women by 2030, can also help foster progress.

Providing clear, supported pathways to progress

Policy and regulation can also be utilised to support women once they are working in the sector. This includes focusing on creating an inclusive work environment, retaining such staff members and setting out clear career pathways, says Jen Bristol, senior director of communications at SEIA.

"In addition, recognition and mentorship can be powerful tools and help women, people of colour, and other represented groups excel," she says.

Putting in place strong anti-discrimination policies, bringing a gender perspective into the decision making process, enforcing equal pay and adequate paid parental leave policies, can all help improve a company's culture. Mentorship programs are becoming an increasingly common way to retain and support women in the solar sector. "Women sometimes lack a bit of confidence, we can really see the benefits of providing the motivation to climb the career ladder, one step further, through mentorship," says Lins.

According to the *Women in the Workplace* study from McKinsey in 2018, women made up 48% of the entry-level workforce in the US, but just 23% of those at C-suite level, a proportion which decreases at each level. For women of colour, this disparity is even more stark, making up 17% of the entry-level workforce but just 4% of leadership positions.

Implementing clear pathways for progression and supporting women to take them through mentorship and strong cultural policies can help tackle this gap. To help recognise the efforts of companies in the solar sector that are introducing such policies, and therefore encourage further best practice, SEIA launched its Diversity Equity Inclusion and Justice (DEIJ) Certification Program in October 2021.

"Many companies are looking to improve their diversity business practices but didn't have the resources to implement practices on their own," says Bristol. "Through the diversity certification program, companies now have a clear path to make tangible improvements to their business practices," she says, indicating that more than two dozen companies have enrolled in the programme to date.

> "In addition, recognition and mentorship can be powerful tools and help women, people of colour, and other represented groups excel"

While undoubtedly progress is being made, the gender gap in the solar sector remains pronounced. Companies should look to best practice guides and success stories to begin working towards gender balance in their organisations now, but with the highest discrepancy remaining at the C-suite level, it will undoubtedly be a work in progress for years to come. ■

INTERSOLAR EUROPE 2022: where the international solar industry meets

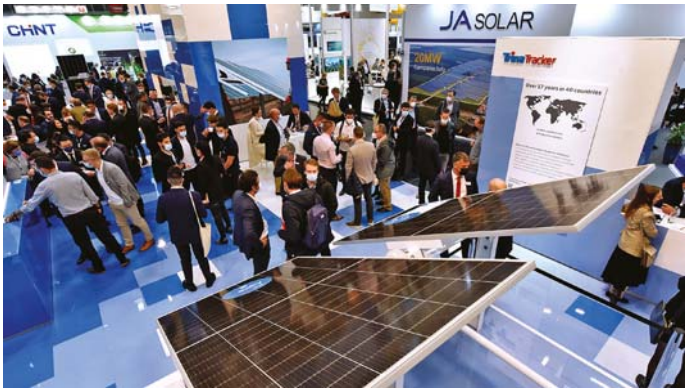
The European photovoltaics market is booming, demand is surging. The political framework is changing, and new players, products and business models are capturing the market. According to SolarPower Europe, installations with a power output of 25.9 gigawatts (GW) were installed last year – 34 percent more than in the previous year. This makes 2021 the most successful year in European solar history, with further strong growth anticipated for the next few years.

Unleashing photovoltaics in Germany:

The new German government has upped the speed of the energy system transformation. To achieve this, it plans to revise the German Renewable Energy Sources Act (EEG) and to launch a solar industry acceleration package. By increasing tender volumes, accessing new roof surfaces and making it mandatory to install solar panels on roofs, the government aims to rapidly increase installed PV capacity from 59 GW in 2021 to around 200 GW by 2030. The plan is to generate 80 percent of electricity from renewable sources of energy by 2030 and to decarbonize the entire electricity sector by 2035. These measures will strengthen Germany's position as the most important photovoltaics market in Europe.

Advancing tenant power models and mandatory PV installations for new buildings

The measures also include improvements to tenant power. In 2017, a study conducted by the German Federal Ministry for Economic Affairs and Climate Action concluded that there is great potential to be tapped into with solar installations on tenement apartment buildings. According to this study, up to 370,000 buildings in Germany would be candidates for tenant power models. The government also aims to review mandatory tender processes for large rooftop installations, which represent a considerable obstacle when it comes to increasing the number of commercial roof-mounted photovoltaic systems. While photovoltaic installations are to become mandatory for all new commercial buildings, the aim is to also use all suitable roof surfaces on private new builds for solar installations.



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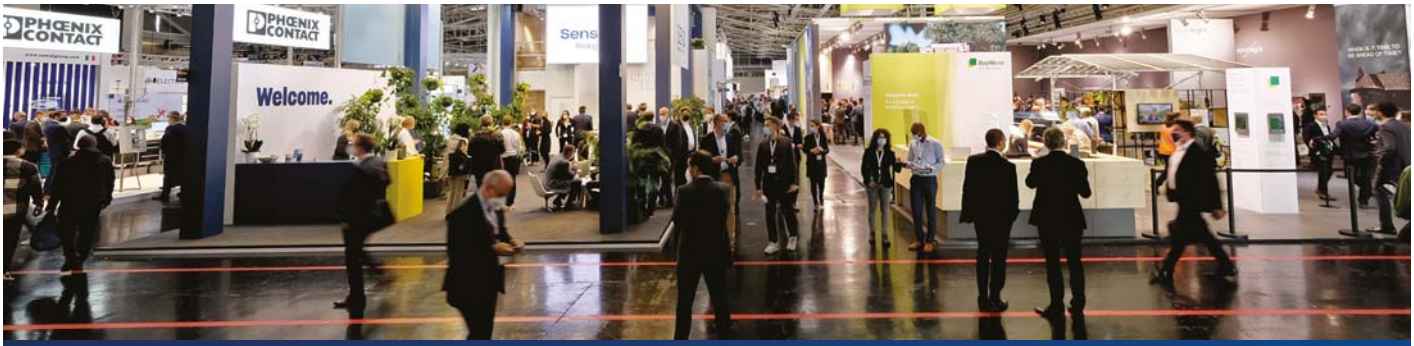
Promoting sector coupling

In addition, the new German government plans to lower electricity prices to create a framework for more renewable power at competitive prices. This aims to make heat pumps and e-mobility more attractive and to promote sector coupling. Another ambitious project of the new government is revising the national hydrogen strategy in 2022 to double the production of hydrogen generated from renewable sources of energy compared to previous plans.

The international solar industry meets in May 2022 at Intersolar Europe

In May 2022, Intersolar Europe will take to the stage right on cue: "The new German government is ambitious when it comes to climate and environmental protection. That means that the solar industry and the entire new energy world are getting the attention they deserve," says Horst Dufner, Head of The smarter E Europe. As the world's leading exhibition for the solar industry, Intersolar Europe forms part of The smarter E Europe, the continent's largest platform for the energy industry. The innovation hub brings together four exhibitions covering all aspects of the new energy world.



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Into overdrive: why Brazil's sector is about to take off

Brazil | After years of not living up to its solar potential, Brazil is on the cusp of a solar boom. A confluence of factors has led to rapid investment and deployment in the country, but a few hurdles still need to be overcome, writes Sean Rai-Roche

Credit: Scatec Solar

Brazil has some of the best solar irradiation in the world, with the average solar PV system generating twice as much electricity as the same one in Germany. And yet, Brazil tails the European country when it comes to installed solar capacity by more than 40GW. While it's the biggest market in Latin America, there is a sense of underachievement in the Brazilian solar sector so far. Things are, however, changing and optimism abounds the future of Brazilian solar.

Historically, Brazil has been dominated with hydropower and wind, but now the solar market is booming fast. Since 2017, when solar started to be included in the country's power auctions, the nation has climbed 12 places on the world rankings of installed solar PV and now sits at 14th, according to Latin American solar trade body ABSOLAR. And it shows no sign of slowing down. In fact, deployment in the country is expected to accelerate as Brazil is forecast to add 8GW of solar this year, far outstripping wind power at 2.5GW, according to BloombergNEF (BNEF).

The reasons for this are myriad and will be examined in detail below, but it is important to note that the main driver for solar PV is not via utility-scale projects, as is the case in most markets, but instead through small-scale distributed generation systems. That's not to say it's all plain sailing as barriers to greater deployment, such as access to project finance and grid constraints, do exist.

While utility-scale solar has achieved success in Brazil, distributed PV remains the country's hottest market.

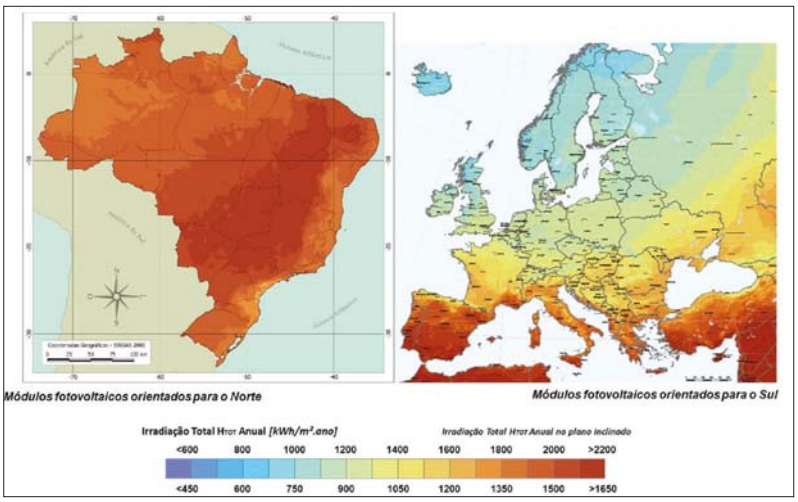
PV Tech spoke with analysts, companies, trade bodies and banks in the country to examine the key drivers for Brazil's solar market moving forward, discuss its potential and assess what obstacles need to be addressed for the country to capitalise on its environmental advantage.

The future is small-scale

It is crucial to note that small-scale solar is, and will continue to be, the main driver of PV deployment in Brazil. This year, the country is expected to add 8GW of solar, of which 5.5GW will be from small-scale sites, according to BNEF. Last year, the split was 4.6GW of small-scale solar to just 1.6GW of utility-scale. The reason for this is Brazil's very attractive net metering laws for systems up to 5MW that have been in place since 2015. The impact of the laws only started in earnest in 2017 – the first-year small-scale capacity additions exceeded 1GW (they were just 100MW in 2016) – and have caused a distributed solar boom in the country. The appetite for small-scale systems is growing further still, with research from ABSOLAR showing "90% of Brazilians want to produce [their] own renewable electricity at home".

The net metering laws do not tax generators who put electricity back onto the national grid, allow for 'remote generation' whereby electricity generated need not be consumed on site and can be shipped across the utility region easily and are loosely regulated, with a streamlined application process.

At the start of the year, however, Brazil



Source: ABSOLAR

Brazil's solar resources in Kwh/m^2 per year compared with Europe's shows the environmental advantage the country has.

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announced long-awaited changes to its net metering system, with profound consequences for the solar industry. While the new laws remain "highly favourable" to small-scale solar deployment, less generous payments in the future are turning what is already a "red-hot" market into one "going into overdrive" as generators scramble to access the existing, more lucrative scheme, according to James Ellis, head of Latin American research at BNEF.

Under the new rules, which come into effect in January 2023, any solar PV systems below 5MW will be eligible for net metering tariffs until 2045 but will have to start paying tariffs on the power generated for the first time. "According to the new tariff system, between 2023 and 2029, there will be a gradual increase of the amount to be paid with respect to the distribution tariff and, starting in 2029, the full amount of the distribution tariff will apply," explains Camila Ramos, managing director of Clean Energy Latin America (CELA).

"The prospect of major revisions to Brazil's net metering policy has already been a key ingredient driving a distributed solar boom that has seen small-scale capacity jump from zero in 2015 to 11GWdc [today] – double [the country's] total utility-scale solar capacity," Ellis says.

When it comes to the "bigger picture", Ellis says "the new law provides much-needed legal certainty to the sector – consumers, developers, investors and distributors – and will put Brazilian behind-the-meter solar on a more sustainable growth path beyond the current frenzy."

Expect 2022 to be a boom year for distributed generation in Brazil. After this, deployment levels should start to fall but will remain strong as the policy environment continues to be favourable. Small-scale solar will continue to drive PV deployment in the country (see figure 1), although utility-scale projects will have their part to play.

A role to play for utility-scale

Although utility-scale capacity additions are set to remain below small-scale generation as distributed generation takes centre stage, the contributions large projects make will still be important to Brazil's energy mix. Crucial to this is the growth of the free market in Brazil as developers increasingly trade power from solar PV directly on the free market via bilateral agreements.

Once solar became included in national auctions in 2017, about 1GW of utility-scale solar was added every year from 2017 to 2020, although this was far surpassed by utility-scale wind. In 2021, however, more utility-scale solar was commissioned than wind, with the trend set to continue over the next few years. BNEF expects roughly 2.5GW to be commissioned this year, compared with 2.4GW for wind, with this remaining above 2GW for the next few years. Utility-scale solar has been the most competitive power source in Brazil's latest reverse auctions, says Ramos.

When it comes to utility-scale projects in Brazil, developers enjoy certain financial benefits too, including an exemption from import tax and ICMS, which is the equivalent to state VAT in Brazil. ICMS Agreement No 101/1997 exempts certain equipment of solar and wind project from state VAT and runs until 2028.

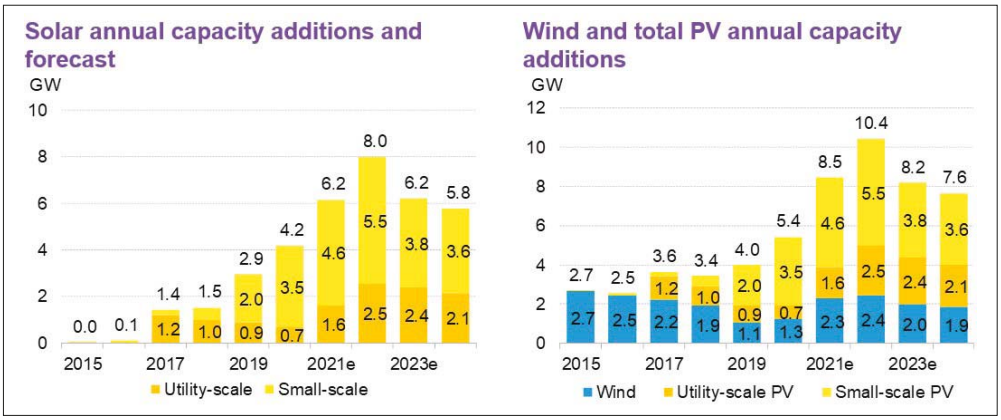
In addition, a Federal Government programme called Special Regime of Tax Exemption for Infrastructure Development suspends federal taxes on the import and sale of equipment, machines and services for infrastructure projects, including solar.

These financial factors in combination have led to levelised cost of energy (LCOE) for solar in Brazil being on par with wind, where it is a world leader, and among the likes of China and the US, at a low of US$33/MWh, according to BNEF (see figure 3).

"Brazil has fantastic solar resource and natural conditions to reach one of the lowest LCOE in the world," says Luis Barros, head of operations and maintenance for EDP Renewables.

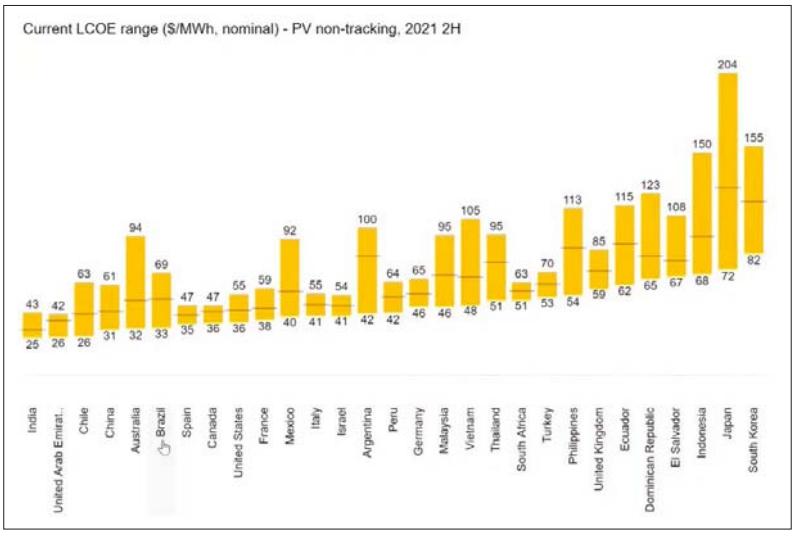
Importantly, the Brazilian power sector is comprised of two different markets – the regulated market and the free market. Brazilian agency ANEEL oversees the regulated market and determines the commercial relationship between consumers and providers through auctions, while in the free market generators can strike bilateral agreements with parties able to negotiate on price and volume. This free market is growing significantly, says Ramos.

"Corporate PPAs are becoming a very important source of solar PV," says Ramos. And the free market is also becoming an option for smaller consumers as the threshold for accessing it drops, with smaller consumers increasingly able to trade on it. There is even a schedule in place to



Source: BNEF and ANNEL.

Annual solar capacity additions in Brazil, actual and forecast.



Source: BNEF.

Brazil's LCOE is among the lowest in the world and had dropped considerably in recently years.

allow residential consumers to access the free market, she explains, "so this is a very important development for utility scale projects."

Financing constraints and currency considerations

Companies looking to invest in the Brazilian market should be aware of two financial issues – access to project finance and currency risk if trading in Brazilian real. Heavy competition for project finance from either state development banks or private lenders can be an issue, while much financing in the country still takes place in local currency, rather than US dollars, which is more volatile, causing risks to bankability.

There are a couple of hurdles to project financing in Brazil, says Axel Holmberg, senior vice president of business development in Latin America for Scatec, which sees Brazil as a key market given its size, solar resources and industrial activity.

First, there is access to financing from government funded development banks. These banks have the most competitive rate but limited budgets, says Holmberg. Second, utility-scale solar in Brazil is a crowded market and private finance sources are also in high demand, meaning stiff competition between developers.

When it comes to development banks, there are a few different options. Some cover specific regions – such as BDMG that provides finance solely for the state of Minas Gerais or BNB in the Northeast of Brazil – while others like BNDES cover the whole country. "But their budget is coming from the government on annual basis, and it cannot finance all the demand in the market," says Holmberg.

There are also long lead times for development bank financing and the disbursement never happens before construction starts, says Ramos, meaning developers will need a bridge loan or existing capital to break ground.

Moreover, development banks cannot finance imported equipment, so only local components of a project will get support. This mean that developers will often opt for dual financing – development banks for local components and commercial banks for any imported aspects of the project.

A BNDES spokesperson told PV Tech Power it funded roughly 700MW of solar projects last year, up from 663MW in 2020. "BNDES can leverage up to 80% of a project that applies for financing" and assesses "environmental permits, regulator authorisation, equipment and construction contracts, and energy commercialisation strategy" when making decisions, it says.

The average size of PV projects in its portfolio is around 190MW, although BNDES also finances smaller and distributed generation projects through partner financial institutions.

Meanwhile, commercial banks are a source of finance for both small and utility-scale solar. Recognising Brazil's distributed generation boom, more commercial banks are offering financing for small-scale solar systems. "It's getting easier and easier to finance a distributed generation PV system," says Ramos.

For utility-scale financing from commercial banks, competition is fierce, and the market is dominated by large-scale power producers, meaning it can be hard to access capital, says Martin Vogt, CEO of MPC Energy Solutions, an independent power producer (IPP) with projects across Latin America. MPC is not active in Brazil in part because of "massive competition", preferring to focus on other Latin American markets.

> "It's getting easier and easier to finance a distributed generation PV system"

Another financial factor to be aware of when it comes to project financing in Brazil is whether agreements are made in US dollars or Brazilian real. Signing agreements in real can open companies up to risk through fluctuations and regulatory uncertainly, with the dollar being a much more stable bet, say Vogt and Holmberg.

PPAs in the regulated market are always in real, but while a portion of PPAs are brokered on the free market in dollars, a recent piece of legislation has formalised the practice, with Ramos expecting increasing numbers of private PPAs to be signed in dollars moving forward.

Grid constrains an issue, but not a huge one

While challenges certainly exist and improvements need to be made, the transmission and distribution network in Brazil is much better than most other countries in Latin America. That said, transmission queues are growing, and a lack of capacity can lead to curtailment in some regions.

Brazil has an almost completely connected national grid system that covers all the major demand and supply centres unlike other major Latin American markets, says Ellis. For example, Argentina has been unable to hold any renewable auctions since 2016-17 because of a lack of grid capacity, stymieing its transition to renewables.

"The overall transmission picture is less worrying than we see in some other markets. But that's not to say that this isn't an area of concern where you see huge amounts of renewable capacity being commissioned," says Ellis.

What's more, Brazil is to pare back discounts on the rate for using the electricity transmission system (TUST) or the electricity distribution system (TUSD) from March this year, which renewable projects in the country have enjoyed for some time. While this is more detrimental to wind, it will also impact solar power producers.

"Congestion on the transmission lines and rising costs associated with that is an area of concern for both wind and solar, but particularly for wind," Ellis notes.

"The generation potential in Brazil is greater than its transmission capacity," says EDPR's Barros. "This has led to a 'race' among companies seeking to build new renewable energy plants to qualify for the 50% discount on the rate of use of the transmission system."

Another issue is the length of connection queues. "There is a huge competition for connection," says Ramos, with this varying by region. The state of Minas Gerais just north of Rio de Janeiro – a solar hotspot in the country – has much longer queues than other, less solar heavy regions, she explains.

One way to resolve this is to build out the transmission capacity and Brazil's Energy Research Corporation (EPE) is "trying to work with associations and companies in the sector to reduce the levels of uncertainty regarding the planning process of these new transmission lines," says Barros.

The Brazilian solar market has a lot of things going for it. A solar rich environment with lucrative distributed generation opportunities and a growing utility-scale scene have converged to spur deployment in the country, which has historically been slow on solar. While financing and grid constraint issues do exist, these are likely to be addressed through a combination of public and private activity alongside infrastructure upgrades. After years of languishing down the bottom of the solar league tables, Brazil is on the up-and-up and is on the way to realising its true solar potential. ■

How solar is helping tackle South Africa's power crisis

Credit: Scatec

South Africa | Alice Grundy explores the success of South Africa's renewables auctions and the challenges that still remain for the development of PV in the country.

Faced with connecting to a constrained grid suffering from frequent scheduled blackouts, known as load shedding, utility-scale solar PV in South Africa has had to have a degree of resiliency to it. Its most prominent route to market, the Renewable Energy Independent Power Procurement Programme (REIPPP), continues to be fruitful and has recently seen 25 new contracts announced for wind and solar, with its next bid window soon to be released.

A series of auctions offering independent power producers (IPPs) power purchase agreements (PPAs) with state utility Eskom, the REIPPP has been heralded by some as responsible for kickstarting the market for renewables in South Africa, although some concerns remain over previous stalling of projects and contracts.

"It has been extremely integral to the rollout of renewable energy in South Africa, and it continues to be," says Niveshen Govender, COO of the South African Photovoltaic Industry Association (SAPVIA).

Around 2.3GW of utility-scale solar PV has been installed in South Africa since the REIPPP began ten years ago, according to SAPVIA. The fifth bid window of the REIPPP – results of which were announced in October 2021 - saw around 1GW of solar PV awarded contracts at an average weighted price of R429/MWh (US$28.1/MWh).

Of these projects, some are under development by IPP Scatec, which has been successful in all but one round of the REIPPP. Scatec has won a total of 12 projects across the auction rounds, including the Upington Solar Complex consisting of Dyason's Klip 1, Dyason's Klip 2 and Sirius, which have a combined capacity of 258MW. But the IPP's review of the scheme is mixed.

Scatec's Upington Solar Complex, consisting of three PV plants which have a combined capacity of 258MW, has previously been successful in the REIPPP

"In our experience, REIPPP is one of the most onerous tender processes we've participated in globally but clear and fair, requiring sufficient upfront preparation and good quality advisors," Jan Jurie Fourie, general manager for Sub-Saharan Africa at Scatec, says.

It's also a fiercely competitive auction, with most of the serious global competitors present. Fourie says this is because the tender process has a track record of deals being closed and projects built, while South Africa's Integrated Resource Plan (IRP) provides developers and inves-

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tors with a long-term view of what the market holds.

The IRP – last updated in 2019 – is an electricity infrastructure development plan based on least-cost electricity supply and demand balance. It included plans to pursue a diversified energy mix, describing the huge potential of renewable energy for the creation of new industries, job creation and localisation across the value chain.

"In our experience, REIPPP is one of the most onerous tender processes we've participated in globally but clear and fair"

For some, however, the REIPPP has led to headaches beyond the auction process. SOLA Group has also been part of the procurement programme since it began, but has had several projects cancelled by the government. As a result, SOLA converted one of its projects that was in the REIPPP process to the private sector, which "gave us a sense of where the future is going", Chris Haw, chairperson of the SOLA Group, says.

"We now spend pretty much all of our time providing energy to clients in the private sector rather than involved in government procurement programmes."

Indeed, 27 PPAs worth R56 billion (US$4.7 billion) with successful IPPs from the 3.5, 4 and 4.5 REIPPP bid windows were delayed around 2016. At the time, Eskom told sister publication PV Tech that the issue was not with renewables themselves, but with the destabilising effect on South Africa's strained grid.

The signing of the contracts finally took place in April 2018, with the National Energy Regulator of South Africa (NERSA) launching an investigation into Eskom's refusal to sign the PPAs in 2017.

Now, however, Scatec says that all of its preferred bidder projects in the REIPPP and RMIPPP – a technology agnostic emergency tender set to support the grid amid heavy load shedding – are progressing well and will likely reach financial close in the first half of 2022. "As what is typical with large infrastructure projects there has been some delays due to delays in government approvals for RMIPPP," Fourie says.

Future auctions

Much like bid window five, bid window six of the REIPPP is to also include 1GW of solar PV and 1.6GW of wind. "It would again be fiercely competitive with the grid likely having the last say when it comes to project selection for Preferred Bidders," Fourie says.

However, Govender says it's difficult to determine how competitive the sixth bid window will be because solar PV tariffs worldwide are not currently stable. "You're seeing prices of PV modules increasing currently, instead of decreasing, you're also seeing the logistic issue of South Africa where we are unable to get our components shipped to South Africa on time and being more costly."

Macri, however, says the price is likely to decrease based on the trend in prices seen in previous REIPPP rounds. "On the other hand, limited grid capacity in high-resource areas could lead to the selection of projects with relatively higher tariffs as it happened in R5, and highlight further the need to increasingly consider battery storage to facilitate the integration of larger renewables capacities."

With there being an oversubscription of bids in the fifth window - only 25 out of 102 projects were selected - there is certainly no shortage of interest in the market. "However, the possibility of further extensions to grid-connection and financial close deadlines are likely as this has repeatedly been seen in earlier rounds," Macri says.

Bid window five recorded the lowest tariff since the inception of the REIPPP, with the tariff declining by 43% (in real terms) compared to the previous round, and by 84% (in real terms) compared to round one. Shaunagh Moodie, research analyst, Clean Energy Technology at IHS Markit says that round five's record-low tariff could have been lower still if grid capacity constraints had not resulted in some cheaper projects from being rejected.

"Prices have fallen steeply since inception of the programme due to a number of factors including increased competition, lower input cost, lower returns accepted by investors and efficiencies on the advisory and construction side. There is however currently upward pressures on local interest rates, FX rates, logistics, modules and metal pricing which could signal a stabilisation of tariffs or slight increase in tariffs for the time being," Fourie says.

Looking ahead, Fourie says that REIPPP auctions will continue as the country needs all the power it can get in order to replace old decommissioned capacity and service the growth of the economy. He adds that the sizes of projects are also likely to be amended, while having an element of dispatchability to projects will become increasingly important.

SOLA Group's Haw says that while SOLA is still registering for the REIPPP, whether or not they participate in bid window six is not yet a given. "We're not doubting that they might be able to get the programme back up and running and that'd be good for South Africa, but we just had a tricky experience here. We don't want to have our fingers burned again until we've got some real evidence that the programme is back on track. And we haven't actually seen that yet.

"The difference between the procurement and the building is where the big question mark lies at the moment," Haw says.

Competitive pricing

Overall, solar PV is becoming increasingly cost competitive due to the persistent increases in Eskom electricity tariffs, according to Moodie. In 2021, NERSA approved the highest tariff increase over the past decade of 15.63%, amounting to ZAR133.64/kWh for FY 2021/22.

Recently, Eskom announced intentions of a further increase of 20.5% for FY2022/23 to ZAR161.04/kWh. "This, in addition to persistent load shedding resulted in South Africa's distributed PV segment maintaining a healthy demand for solar PV systems despite other global markets being harder hit by solar PV price increases due to global supply chain challenges and component shortages," Moodie says.

Eskom has been facing financial difficulties for some time, with a gross outstanding debt of R392.1 billion as of September 2021. Last year, the utility put forward a US$10 billion strategy to close the majority of its coal-fired power plants by 2050 and instead support renewables. A spokesperson for Eskom says the utility has existing relationships with various development finance institutions and multilateral development banks, and is in continual engagement with these entities to fund its pipeline of projects, which includes ~8GW of clean generation options.

"As Eskom is shutting down coal-fired plant in line with the Integrated Resource Plan of 2019, and at the same time is

driving the development of new renewables and gas capacity, funding/financing is therefore required for the transition and significant investment in new generation, transmission and distribution capacity," the spokesperson says.

However, questions over Eskom's role in enabling renewables, in particular its role in generation, remain for some operating in the industry.

"It's a difficult place for Eskom to be competitive because there's a lot of fast moving technology and companies that have got a head start actually in building large scale generation facilities with renewables," Haw says.

This is echoed by Fourie, who says that in his view, Eskom shouldn't be involved in the renewable energy generation side. "The private sector can do it better, cheaper and faster," he says. "Eskom's most important role is an enabling role by ensuring the grid is strengthened and expanded and that the grid connection process is quick and seamless."

Grid a familiar foe

South Africa's grid has been under strain for some time, with both load shedding and constraints key characteristics. The lack of available grid capacity in certain areas of South Africa is a roadblock being navigated by solar developers, with these often being the best areas for both wind and solar from a resource perspective. This in turn is creating a major bottleneck that, according to research firm IHS Markit, is holding back the market from realizing its full potential.

> "The private sector can do [renewable energy] better, cheaper and faster"

Load shedding, meanwhile, was first implemented in 2008 due to Eskom experiencing supply constraints as a result of aged infrastructure and excess demand. Despite capacity investments since then which have led to oversupply and high reserve margin, capacity availability still remains low as a result of unscheduled shutdowns and maintenance issues. Indeed, Eskom has previously stated that South Africa has a shortage of new generation capacity estimated at 4,000MW - 6,000MW.

The Eskom spokesperson says that what the utility can and is doing is conduct reliability maintenance in order to catch up with the maintenance of its ageing plant, to bring it to acceptable levels of performance and reliability. "Meeting the capacity gap, both in generation and transmission capacity, must continue to be a priority for the country," the spokesperson added.

Meanwhile, IHS Markit's Silvia Macri, principal research manager, Africa and Middle East Power & Renewables - Climate and Sustainability, says: "New capacity additions going beyond IRP 2019 plans and better energy planning with transmission investments would help solve the problem in the long term."

The country's Council for Scientific and Industrial Research found that 2020 was South Africa's worst ever year for load shedding, with 859 hours recording - nearly 10% of the year. But the practice is throwing more focus onto solar-plus-storage for the commercial and industrial sector.

"I think it's only giving a stronger business case to renewable energy, solar PV particularly," Govender says. "With more load shedding and with more power cuts, you have a lot more private entities going with solar PV and battery storage to cater to some of the load."

Indeed, while these hybrid systems are generally more costly, increased finance availability has made it a more affordable and accessible option for many residential, commercial and retail customers who have had their working hours impacted by load shedding. In particular, the mining and solar sectors are becoming increasingly intertwined. "Mining companies need reliable power for their activities, and investing in self-generation is a priority considering the frequent power interruptions on the grid," Macri says.

Late last year, the South African mining industry announced it is planning to build 3.9GW of renewable projects and storage, with this supporting the sector's 2050 net zero target while helping relieve pressure on Eskom, which has previously called on the industry to supplement its energy supply.

Meanwhile, so-called energy 'wheeling' projects – where a business signs a PPA with a renewable asset and the power is transported, or wheeled, through the transmission infrastructure – are beginning to take off in South Africa. Last year, the SOLA Group completed what it claims to be the first large-scale solar wheeling project in South Africa.

Global retailer Amazon signed a PPA for the project, with SOLA now having similar projects in the pipeline. However, it's taken a while to get to the point where solar wheeling is viable, with the economics previously making it hard for large energy users to see there was a benefit. However, with the economics having improved over the time, it's now an attractive offering.

Additionally, the legislative framework has also made wheeling tricky, having prevented private companies from getting generation licenses for projects over 1MW in size, SOLA says. However, when the IRP was updated in 2019, this too was updated, allowing companies like SOLA to get a licence for this type of project. Further changes have meant that projects up to 100MW can now be licensed. "That's the reason why it suddenly become a commercially viable thing to do and legally viable thing to do," Haw says.

However, even if a 100MW project is built offsite and the power wheeled, if a blackout occurs on the grid, the business is still left without, once again highlighting the need to solve the load shedding on South Africa's grid.

One of the major initiatives that SAPVIA has going forward is to work with Eskom to strengthen the grid, looking at innovative ways to connect more renewable energy.

Alongside this, SAPVIA is also working on the localisation of manufacturing. While a local supply chain for components is starting to be built in the country, "we're still struggling a bit with the modules and inverters", Govender says.

"We are, however, working together with the African government on a localisation master plan for renewable energy components to see what can be localised, what can be locally manufactured, and how to ramp that up over the next coming years to meet the demands of the industry."

Overall, one thing's for sure; 2022 is set to be an interesting year for solar development in South Africa. Sure, there's much to be solved between tightening grid capacity, load shedding and the development of local manufacturing. But there's also much to be excited about. The sixth bid window of the REIPPP holds great potential, and when coupled with the rise in interest in PV in the C&I sector, it sets this year up to be an exciting one indeed. ■

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Challenges and experiences of floating PV and BOS components

Floating solar | Floating solar applications continue to grow both in terms of project size and geographical reach, however there remains some uncertainty around the demands placed on balance of system components away from the module, such as floats, clamps, cabling and other electrical equipment. TÜV Rheinland's Jörg Althaus details the factors that may influence purchasing decisions when it comes to FPV projects.

Credit: Sembcorp Industries

Careful consideration is required on the selection of BOS components based on the conditions the system is likely to experience.

Floating Photovoltaics (FPV), sometimes also called floatovoltaics, are solar panels on a floating body on water, mostly reservoirs or lakes, but sometimes also offshore on salt water. The technology opens new opportunities in particularly in densely populated countries with high cost of land.

The market for this technology has grown rapidly in the last 5+ years. Most experience has been collected in Asia, but in recent years many systems are starting to get deployed across Europe as well. Some countries have also started to provide special funding for FPV projects or product development, one example being Germany's Federal Network Agency's support programme announced in October 2021.

As with any new technology there is some uncertainty regarding reliability and code compliance which may impact the bankability for some projects. As holistic standards for FPV have not been developed yet and "field" experience is limited, compared to ground mounted PV, it is essential to look at the potential additional technical risks and take measures to mitigate those.

The various environmental factors influencing FPV reliability are partly additional stresses compared to ground mounted systems. Stresses caused by wind and waves are of main concern here, but the reflection of sunlight from the water surface needs to be considered as well. On the one hand it increases the energy yield of a FPV system, but on the other hand it also increases the potential for UV-related degradation mechanisms.

Further snow and ice loads may need to be taken into account when dimensioning the floats. Cases have been reported where the load bearing was under dimensioned and the systems were loaded such that the modules actually touched the water line, a scenario for which the modules or other system components are not designed.

Finally, vegetation and fauna cannot be neglected. Sea birds see a good place to rest and may leave plenty of dirt behind on their departure, while barnacles and ferns can find a new home on FPV systems.

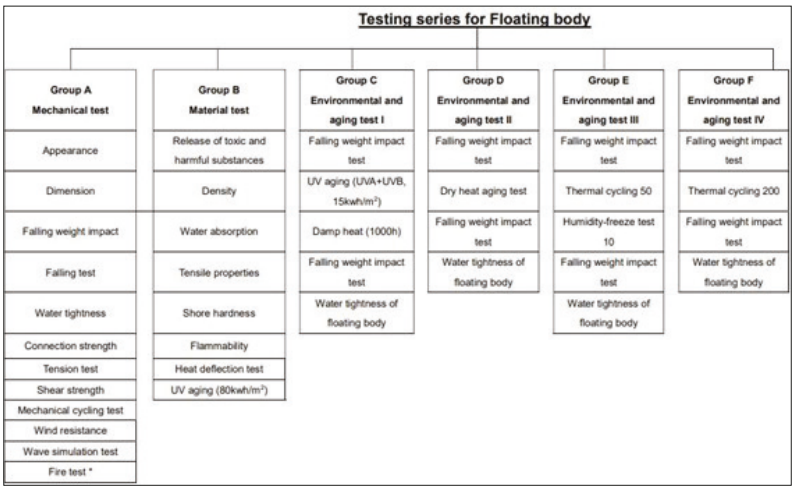
Component selection

The system components of FPV are different or include additional parts than conventional PV systems. Two main design concepts have come to dominate to date: floats made from high-density polyethylene (HDPE) or of reinforced hydro-elastic membranes. Both variants can offer advantages depending on the specific project conditions and design. However, given the challenge of both coping with and protecting the surrounding environments, correct dimensioning and design is crucial. In the absence of an international standard for floating bodies, TÜV Rheinland has put together a test specification to address the various stresses the bodies need to withstand.

TÜV Rheinland's in-house standard - 2 PfG 2731/02.20 Requirements for materials used in and construction of floating bodies - provides a list of test methods to allow the assessment of various designs. Included are a number of mechanical tests looking at the load baring capacity, tensile strength and elongation under heat.

Further environmental tests like UV resistivity, temperature resistivity, water tightness and buoyancy tests also form part of the assessment. Finally, demo systems are taken to a wave laboratory to assess reaction to wind and wave exposure. The first tranche of floating bodies have undergone the extended testing procedure, while more are currently being tested.

On top of the floating bodies, the main system components are fixed - the main being the PV module itself. Here, several points need to be considered when choosing the right module for a system.



Credit: TÜV Rheinland

The test programme for floating bodies from TÜV Rheinland 2PfG 2731

Since some bodies are smaller than the modules that get installed on them, the mounting situation needs to be carefully checked. The typical spread of mounting clamps at a 2/3 position of the module length may not be applicable to all designs. Should the mounting instruction of the module maker not be applicable, it is important to test the mechanical strength of the modules under real installation situations. As dynamic loads through wave and wind are to be expected, it is recommended to request for a Dynamic Mechanical Load Test in accordance with IEC 62782.

The permanent exposure of the modules to moisture may limit the product choice to modules with increased resistivity to moisture ingress. Glass/glass module designs may be a good choice, however some designs with polymeric backsheets also include added moisture barriers, e.g. by aluminum sheets within the multilayer backsheet.

If the system is designed for sea water environments, a Salt Mist Corrosion Test following IEC 61701 is applicable to all critical components.

Due to some reported issues with insulation resistance in FPV systems and the general risk of long-term exposure of electrical components to water TÜV Rheinland has further taken a step ahead in introducing its 2 PfG 2750/09.20: Requirements for cables with improved water resistance for installation in PV Systems. While standard DC cables for PV installations are typically qualified against IEC 62930, respectively EN 50618, such cables are not designed for longer-term submersion in water and may hence have issues in permanently moist environments.

The new standard allows PV cables to be qualified for improved water resistance. A main added requirement here is that the conductor within the cable has to be of Class 5 in accordance with IEC 60228: Fine stranded copper conductors for single and multi-core cables and wires. A requirement for capacitance change after water submersion is also included in this standard, and similar standards are currently under development for other floating system components, such as connectors and wiring compartments.

Combiner boxes and inverters, if installed on the floating bodies as well, certainly also need to be built such that they withstand the higher humidity and dynamic load associated with floating PV proejcts. While these components are typically designed as fixed/non-moving parts, the permanent movement on a floating system may require reinforced containment of the sensitive electronic parts.

The issue of safe and cost-effective anchoring and mooring concepts are also garnering increased attention. Strong wind events or high wave activity as well as long-term fatigue and corrosion are real threats to the anchoring and mooring systems and hence the right choice of components and dimensioning is essential.

System requirements for water reservoirs, where water levels may vary by more than 10 meters, are very different than for an inland lake with only small wave action and rather stable water levels, and a completely different challenge presents itself in the mooring and anchorage for an offshore system.

In all cases the station keeping system shall allow a certain offset, but keep the system in proximity to an anchor point. Mooring systems are no new thing and have been used in the oil and gas industry for years, but statistics do show that on average a mooring system (assessment in period 1980-2001) fails every nine years, with fatigue failure being the biggest worry (Noble Denton Phase 1 Mooring Integrity JIP - Brown, et al., 2005; Noble Denton Europe, 2006). For a 25-year project plan, this suggests close monitoring and potentially integration of failure detection instruments is in place.

Besides the criteria for choosing the right components, O&M practices need to be adjusted to the onsite conditions. Preventive actions against flora and fauna influencing FPV systems performances as well as inspection cycles and content of such inspections deviate from standard on-shore practices. Beside the components above the water line also those below require maintenance.

A point that is still under investigation is the bio compatibility of some of the materials used in FPV systems. It is important for the industry to work together and share the learnings from real installations to make full use of this additional potential for solar energy use. ■

PV Modules	Dynamic Mechanical Load Test (IEC 62782); Salt Mist Corrosion Test (IEC 61701)
Junction Boxes	Development of an amendment to IEC 62790
Connectors	Development of an amendment to IEC 62852 containing an annex with supplement requirements for connectors intended to be installed in a FPV system
Wiring Harness	Project team for creation of a NWIP was founded. A complete new standard is under development
Cables	TÜV Rheinland 2 PfG 2750/09.20: Requirements for cables with improved water resistance for installation in PV Systems
Floating Bodies	TÜV Rheinland 2 PfG 2731/02.20: Specification for technical requirements of floating bodies used in PV Power Plants

Table 1: Status of standardisation for various FPV system components

Authors

Dipl.-Ing. Jörg Althaus is segment manager for photovoltaic power plant services at TÜV Rheinland. As a long-standing technical expert in the field of solar energy, he represents TÜV Rheinland in industry associations, speaks at technical forums and has contributed to many international industry standards.

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What you need to know about green hydrogen and its integration with solar PV

Green Hydrogen | While still nascent, green hydrogen can take off as a fuel source and energy storage system if it is afforded the support, regulatory environment and financial backing it deserves, Hive Energy's Shirvine Zhang tells Sean Rai-Roche.

Credit: Toshiba

Green hydrogen has long been touted as a key means for economies achieving net zero status given its importance to heavy industry and potential as a source of energy storage. The last few years have seen an increasing number of large-scale projects announced as companies and governments attempt to be early movers into the nascent industry.

Despite recurring fervour around its potential, however, the technology has failed to take off in the same way as other renewable technologies. But things are slowly changing, driven in part by the falling cost of renewable power, which is crucial to the consistent production of green hydrogen. Key here, is the role of solar PV, although its nature as a variable source of power does pose some challenges.

PV Tech Power sat down with Shirvine Zhang, head of hydrogen and hybrid energy at UK renewables company Hive Energy, who has worked in the green hydrogen space since 2016. Zhang discussed the potential of green hydrogen, project financing, the ins and outs of electrolyser technologies and what support the industry needs to realise its potential.

Solar-to-hydrogen projects have thus far been limited to a handful of smaller pilots, however that looks set to change.

PV Tech Power: What role do you see for the green hydrogen in five years' time?

Shirvine Zhang: There were a lot of discussions prior to 2019 [about the potential of green hydrogen] but that didn't seem to build up the momentum somehow. And then suddenly it happened, and people realised it's going to play an important role in the decarbonisation journey, particularly

in the transport, industrial and those hard to abate sectors.

Over the last few months, we have seen quite a few gigawatts of green ammonia production being announced or coming online. So, certainly the market has started developing quite quickly and I hope we can see some major developments on offtaker side as well as the financing side.

How important is it to have guaranteed offtakers when developing a green hydrogen project?

I think for small scale projects from a couple of megawatts to 100MW, it's very important to have domestic offtakers. It would be more economic to have an offtaker in reasonably close distance.

There are some pilots in the UK and Europe where they have access to a private gas grid, so they could deliver the hydrogen through the pipeline. That's the cheapest option for long distance. Transportation costs are high but also because hydrogen is low density, compressed hydrogen needs to be transported in gas cylinders or gas tubes with pressure between 200-500 bar at the temperature of -253 degrees Celsius at least.

From a solar company's perspective, what are some of the key things that they need to know about integrating a green hydrogen electrolyser with a PV plant?

So that will depend on your power supply solution, so whether you would just rely entirely on solar or if you would have a combination of solar and power from the grid, which could include power generated using fossil fuels. The choice of electrolyser technology is dependent on the power supply. The Polymer Electrolyte Membrane (PEM) electrolysis and alkaline electrolysis (AE) are two of the most dominant in the market today. In general, PEM works better with variable power generation, while alkaline would work more efficiently with a constant power supply. There are some projects using other technologies, for example solid oxides.

Is the cost of electrolysers coming down and what does it mean for the market?

We expect a substantial reduction in the capex cost for the electrolyser. It's still considered expensive. Similarly to PV, batteries and offshore wind, where the capex substantially reduced overtime, we expect the cost of the electrolyser technology to come down.

To produce cost competitive green hydrogen or green ammonia, the capex needs to be reduced and the power price needs to be competitive. It doesn't make sense to use expensive electricity to produce green hydrogen, so I think renewable generation development is very important.

How can solar and storage help lower the cost of production of green hydrogen?

We want to extend the electrolyser operating hours as long as we can to reduce the cost of production of green hydrogen. The power curve as well as the power price are the key elements we will have to think about when developing such projects.

And obviously with the massive expansion of renewables comes more options when it comes to that green hydrogen production. We're looking at both solar and wind, hydropower or geothermal potentially in some of the markets. You need to secure dedicated renewable generation for green hydrogen if you want to consider gigawatts of production. We target markets with very good renewable resources and relatively cheap electricity.

Then there is also storage. Battery storage system is still considerably expensive for this type of project. We'd include battery energy storage system, but that's more for smoothing the power curve. It's not really considered as a major source of power for the electrolyser.

How do financing structures need to change to accelerate green hydrogen development?

The pricing model is still unclear for green hydrogen production, and it is difficult to secure debt financing for green hydrogen projects at the moment. Initially, some of these early projects will probably be financed using balance sheets.

But to scale up and to actually accelerate the supply of green hydrogen, commercial banks are expected to play a bigger role in this.

If you look at the offshore wind sector [in the UK], government support was key, and we had the contracts for difference (CfD) structure to help the offshore wind market and to give investors and banks confidence to finance the projects. The bankability of green hydrogen projects is still a major concern, especially as the offtake market is still nascent. A similar mechanism to the CfD will be required to support the development of a green hydrogen market.

And so that's something that needs to have a collective effort by all the players in the markets.

What are some of the barriers to greater green hydrogen production?

Regulation is still not very clear, especially on the guarantee of origin. We've been looking at a blending option to the gas network but at the moment it's unclear how that solution can be commercialised. And so, we're waiting for regulations from the European Union and also, similar to offshore wind and solar PV, we need government support on policy and subsidies for the early round of projects.

Green hydrogen projects will need government support in terms of both policy and financial support to help the market develop quickly. We also need to look at the options including technology we can improve to reduce the cost of production.

For the first round of the projects there will be a lot of collaboration with offtakers, suppliers as well as developers, particularly the integration between the renewable generation to the electrolyser and integration from hydrogen production with the offtaker.

When do you see green hydrogen becoming commercially viable and challenging the likes of blue hydrogen?

You need to consider other elements into this equation. So, not just the cost of production but also renewable generation, which is key for green hydrogen. I think blue hydrogen will be an interim fuel in the transition period between grey to green, because blue hydrogen still has quite a lot of cost of vantage compared to green.

It depends on the carbon price or carbon tax [set by government] as well as zero carbon commitments. It also depends on the value chain and how value chain develops. But these types of projects are still quite complicated to develop. We are aiming to achieve one or two projects and reach commercial operation date around 2025 or 2026.

But I think once more projects come online, especially utility scale projects, it will help accelerate the standardisation of the supply chain and value chain development and the whole game would change. ■

Solar asset underperformance and the impact on equity investors

Performance v P50 estimates | Last year analysis by renewables performance aggregator and insurance provider kWh Analytics highlighted the extent of solar asset underperformance against P50 estimates in the US. Here, the company's Sarath Srinivasan details some of the reasons behind that underperformance.

Credit: Spower/Nextracker.

The solar industry has seen tremendous growth in the last decade. From an installed fleet of only 7GW in 2012, today the total amount of solar generation installed in the US has grown to over 114GW. The industry is expected to continue growing at an accelerated pace over the next decade with the installed base of solar expected to quadruple to approximately 400GW.

This growth is supported by a large pool of capital that is being redeployed from traditional energy and infrastructure investments into the energy transition, including solar projects. Most of the capital flowing into renewables comes from the infrastructure investment vehicles mandated to invest in de-risked, stable projects with predictable long-term cash flows. For the industry to mature and deliver on these expectations from investors, it is important to use data to both ensure that the return expectations are appropriate and aligned with observations from the data and also to identify opportunities for improvement where clear gaps emerge.

kWh Analytics, an independent aggregator of renewable energy performance data and the leading provider of insurance for our climate, collaborated with 15 of the 20 largest US asset owners to publish the Solar Generation Index report in 2021. The report is the industry's most comprehensive solar energy validation study; it compares estimated average production, or P50s, against actual production with the goal of understanding project performance.

Solar assets across the US have underperformed against aggressive P50 estimates in recent years.

In the 2021 report, kWh Analytics found that solar PV projects chronically underperformed their average (P50) production estimates by 5 - 13% from 2011 - 2020, with the performance worsening over time, particularly in the last five years. Between 2011-2015 some regions were still performing in line with their P50 estimates, but in recent years the performance has been uniformly poor across all regions. The underperformance across different geographic regions and throughout the industry indicates a clear gap between long-term investor expectations and actual performance.

When an equity investment in a solar project is underwritten, the baseline inves-

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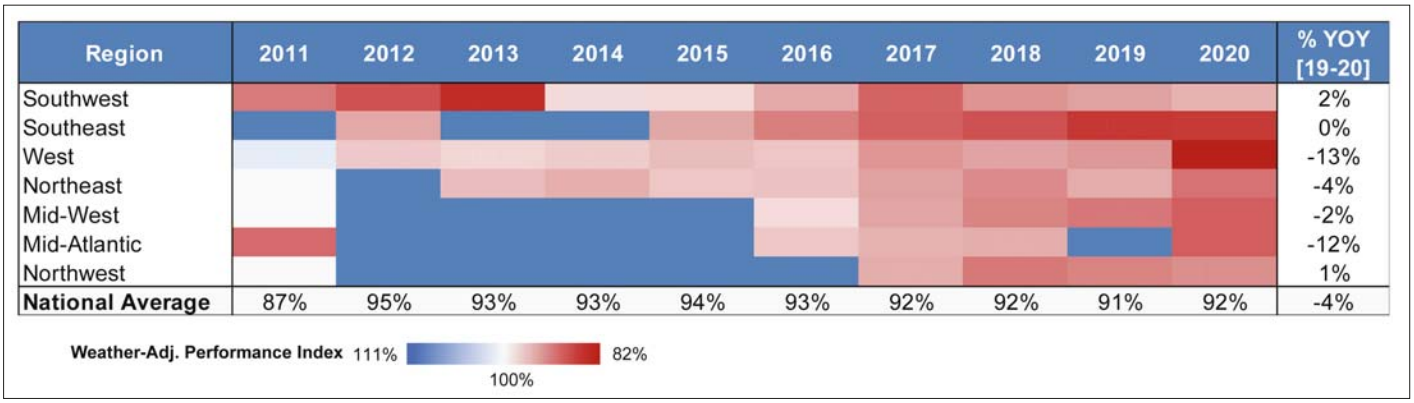


Credit: kWh Analytics Solar Generation Index: Quantitative Insights from Leading Asset Owners, 2021 Volume

tor return expectation (approximately 7-8% levered return) is that a project will produce at 100% of the P50 level on average over the life of the asset. But over the last five years, the national average has been stable at around 92% and is expected to continue, barring significant additional investments in the assets to rectify the situation. With the typical financing structure of a solar project, the implications of a long-term trend of solar assets in the US performing at a 92% average is likely to have a devastating impact on equity returns.

"These lower realised cash yields relative to expected cash yields based on aggressive P50 estimates eventually causes investors to recalibrate their expectations, generating uncertainty and volatility in the investment cycle"

For example, kWh Analytics looked at a hypothetical 100MW solar project in California with a US$35/MWh PPA. When a solar project performs at 92% of P50 on average over a 10-year period, this results in 8% lower revenue for the project compared to initial estimates. Given the equity investors' position in the capital structure, the cash flow to equity will be 60% lower in this example, significantly impairing the equity value of these investments. These lower realised cash yields relative to expected cash yields based on aggressive P50 estimates eventually causes investors to recalibrate their expectations, generating uncertainty and volatility in the investment cycle.

This paper examines the underlying causes for the underperformance and looks at a few examples of practical data-driven approaches to risk management for improving solar asset performance. Using data-driven insurance products like the Solar Revenue Put, which now protects over US$3 billion in solar assets, enables investors to benefit from the positive feedback loop of using data driven risk management.

Table 1

Causes of solar asset underperformance

Every year, kWh Analytics works with leading industry contributors to publish the Solar Risk Assessment. In 2021, contributing firms included independent engineer DNV, renewable asset manager Radian Generation, global renewable operations and maintenance provider Novasource, irradiance forecaster Clean Power Research and tracker manufacturer Nextracker. The report identified several factors contributing to solar asset underperformance including overly optimistic irradiance assumptions, higher-than-expected degradation, terrain and soiling mis-modeling, poor modeling of sub-hourly inverter clipping, higher-than expected equipment downtime and bankrupt manufacturers.

One of the key inputs to estimating a project's performance over its lifetime is the annual degradation. The industry today uses a 0.5% degradation assumption based on a 2016 study. However, recent research from the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory and kWh Analytics shows that the 2016 assumption is outdated and actually underestimates degradation by up to 0.5% annually in some cases.

According to DNV, "Uneven terrain often causes losses for north-south aligned single-axis trackers on east-west slopes and/or rolling terrain due to uneven row-to-row shading and electrical mismatch. Even the most sophisticated slope-aware backtracking cannot recover all of these losses. Furthermore, trackers installed on south- or north-facing slopes may see small gains or losses, respectively." DNV estimated terrain losses of over 6% in locations with increasing sloped land with the median loss being 2.1%.

In the 2020 Solar Risk Assessment, NextEra Analytics examined energy estimate errors resulting from the outdated method of using hourly temporal resolution for solar energy production modeling despite the known variation of the solar resource at intra-hour time scales due to

Degradation Research (2016 - 2021)

Authors & Date	Analysis Type	Site Type	Measurement Point*	Yearly Degradation
Current Industry Assumption				
NREL (Jordan et al.) 2016	Meta-analysis (200 studies)	C&I, Resi, and Utility	25% System 75% Module	Median: -0.5%
Latest Research				
NREL (Deceglie et al.) 2018	RdTools	C&I and Resi	System	Median: -1.0% non-resi -1.2% resi
LBL (Bolinger et al.) 2020	Fixed effects regression	Utility	System	Mean: -1.1% Sigma: +/-0.2%
NREL (Deline et al.) 2020	RdTools	C&I and Utility	Inverter	Median: -0.72%
kWh Analytics 2021	RdTools	C&I, Resi, and Utility	System	Median: -1.09% resi - 0.80% non-resi

**Note: Module degradation focuses on solar panels, while inverter and system degradation focuses on the system as a whole (inverters, transformers...etc.)*

Table 2

Credit: kWh Analytics Solar Risk Assessment: 2021, Quantitative Insights from the Industry Experts

"Even the most sophisticated slope-aware backtracking cannot recover all of these [terrain] losses"

intermittent cloud cover. NextEra Analytics concluded that: "Results showed that hourly-resolution energy predictions were biased high compared to minute-resolution runs on the order of approximately 1-4%. In addition to location, site configuration (e.g., DC:AC ratio, AC size) also significantly influenced the hourly bias."

In a paper titled "PV Fleet Performance Data Initiative: Performance Index–Based Analysis", the NREL identified inverter downtime as one of the factors contributing to solar asset underperformance. The report noted that "The overall availability in this data set is 97.7%, excluding the first year", referring specifically to inverter availability. According to Novasource, a key contributor to this trend is the use of equipment from discontinued manufacturers. In the 2021 Solar Risk Assessment, Novasource concluded, "The inverters from a discontinued manufacturer generated a Technical / Gross availability of approximately 85%, meaning that on average the devices were unable to produce power for 15% of the year. When comparing that to the Technical Availability of the active manufacturers – 92% for Manufacturer 1 and 95% for Manufacturer 2 – it's clear that the portion of the fleet comprised of the defunct manufacturer's equipment significantly underperformed that of the fleet with OEM support. What accounted for the additional downtime for the unsupported inverters? The disparity is almost entirely due to two factors: 1) the inability to get effective technical support and 2) the delay in locating and procuring replacement parts. The average interruption was seven days for Manufacturer 2, 20 days for Manufacturer 1, and over 60 days for the discontinued inverter manufacturer." Meanwhile Radian Generation concluded that "An analysis of nearly 2GW of utility and commercial solar plants in 2020 shows that 80% of performance-related plant tickets are caused by inverter outages," indicating that inverters continue to remain the main source of availability losses in solar projects.

Leveraging data to deliver superior risk-adjusted returns to solar asset investors

The insurance markets have led the way in enabling innovation through the use of data in every major asset class – except solar, up until now. The path to maturation of the solar investment asset class and continued access to a lower cost of capital, lies in leveraging data-driven insurance solutions to improve the risk profile. This strategy enables investors to rely on data to generate superior risk-adjusted returns by placing an effective floor on equity cash flows and reducing the volatility and tail risk of solar asset returns. By using data across the lifecycle of a project, investors can develop more certainty in their production forecasts, and better manage operations and maintenance.

Production insurance

Data and data-driven insurance products can, over time, help bridge the gap between actual and expected solar asset performance. In project finance, whenever a counterparty that's best positioned to take on a risk is able to do so, the project returns improve for all counterparties on a risk-adjusted basis. A specific counterparty might be best positioned to take on a risk either due to the ability to directly mitigate the impact of the risk factor or due to having superior data to enable better pricing of the risk.

When investors rely on historical data and use insurable production estimates in calculating their return expectations, the quality of investment decisions improves, resulting in improved risk adjusted returns. For example, if an investor tries to insure a project with aggressive P50 estimates, the high price of the insurance creates a feedback mechanism for the market that allows investors to adjust their views. Alternatively, the presence or absence of production insurance could be used by investors to discern the risk inherent in accepting the P50 estimates of the project.

Currently, equity investors are exposed to the risk of aggressive P50s on most solar projects, but they are not always best positioned to take on the risk. When it comes to solar asset performance, insurance products like kWh Analytics' Solar Revenue Put are best positioned to take on the tail risk of chronic asset underperformance. This is driven by insurers' ability to take on weather risk, aggregate the performance risk across a large volume of insured projects and access to high quality data. For a single asset, underperformance could lead to catastrophic impairment of equity value. However, when aggregated across the solar fleet, the cost of insuring against this risk becomes manageable and creates the ability to improve risk-adjusted returns.

Using data to improve operations and maintenance

Wood Mackenzie, an energy research and consultancy firm, noted in the Solar Risk Assessment: 2021 that, "Digital technology has become an established tool of plant asset management for renewables operations, however solar lags behind wind in fully deploying these tools."

In addition, Fracsun also noted in the report that onsite measurements of soiling compared to original IE estimates of soiling have a mean relative error of 99.5%. Using onsite soiling data and documenting the trends over time would help asset managers mitigate soiling losses by optimizing how and when to clean the plant. Similarly, tracking vegetation conditions and growth accurately over time will help improve decision making on vegetation management scheduling, which can be based on local growth cycles as opposed to one-size-fits-all bi-annual or quarterly mowing. Proactive soiling management strategies triggered by monitoring data trends associated with local irregular events such as winds and regional wildfires could also help alleviate abnormal soiling losses.

Conclusion

Turning a blind eye to chronic solar asset underperformance damages the industry's credibility with investors. This weakens the very foundations of the industry and threatens continued access to an ever-decreasing cost of capital that has been crucial for the growth of the industry. To start the next chapter of growth on a firmer footing, the solar industry must adopt data-driven risk management approaches to enable the delivery of stable long-term returns to investors and financing counterparties. ■

Author

Sarath Srinivasan is the head of risk transfer products at kWh Analytics, a leader in climate insurance that's insured over US$3 billion of solar assets to date. With over a decade of experience in renewable energy project finance closing over US$5 billion in transactions. Previously, Sarath managed the solar business unit at Gardner Capital, helping acquire, develop and finance over 120MW of solar projects in the southeast and midwest, was instrumental in financing over a 100MW of C&I solar projects at SunEdison and was also a part of the Power and Utilities investment banking team at Barclays.

Strategies for early fault detection

O&M | With solar operations and maintenance experiencing significant price pressure, adequate fault detection that occurs as quickly as possible has become increasingly important for asset operators. Here, 3E's Julien Deckx explores early fault detection strategies for solar PV plants.

Utility-scale solar PV O&M costs came down a staggering 85% between 2005 and 2017 (numbers for Europe) [1]. This steep descent is an indication of the immense price pressure that O&M service providers are under. Since manpower is a large part of the cost, the managed capacity per operator is continuously increasing. The growth and consolidation of the market means that portfolios become larger and more geographically spread out.

One of the ways that O&M service providers have been able to cope with this pressure is digitalisation. Smart monitoring platforms allow to identify issues remotely, with less need for plant inspections. However, the evolution to larger, more diverse portfolios with less on-site presence makes it challenging to keep the operation of PV plants at an optimal level. With tight margins in a post-subsidy era, asset owners can no longer afford to lose revenue from avoidable losses.

To get a sense of the potential gains in plant performance, the plants connected to the 3E Asset Operations solution (part of the SynaptiQ digital platform) were analysed. For sampled plants, the average Energy Performance Index, which is computed as defined in IEC-TS 61724-3 [2] was calculated. This method compares the measured energy to the expected energy based on a detailed simulation of a plant, given the measured meteorological data. Energy Performance Index was divided by availability to filter out losses from plant and inverter unavailability. After removal of outliers, average plant performance was estimated at around 97%. At current PPA prices in Europe, around €60/MWh, a 3% loss comes down to about €2,200/MWp/year (figuring a specific yield of 1200 kWh/kWp). This revenue loss is the equivalent of approximately 24% of the total Opex of a utility-scale plant, estimated at US$10,000/MW/year (€9,000/MW/year) [1].

The numbers above suggest that there is still significant progress to be made to improve the performance of solar plants. While digital tools have helped to make the operation and maintenance of PV plants exponentially more efficient and effective, the reduced on-site presence also means that some production losses are left undiscovered for larger periods of time.

Luckily, digital tools are further evolving. A new generation of AI-driven advanced analytics is capable of automatically and continuously providing a detailed breakdown of the root causes of production losses. Based on detailed monitoring data, such system can detect issues in a very early stage. This prevents PV plants from underperforming for large periods of time and increases overall profits.

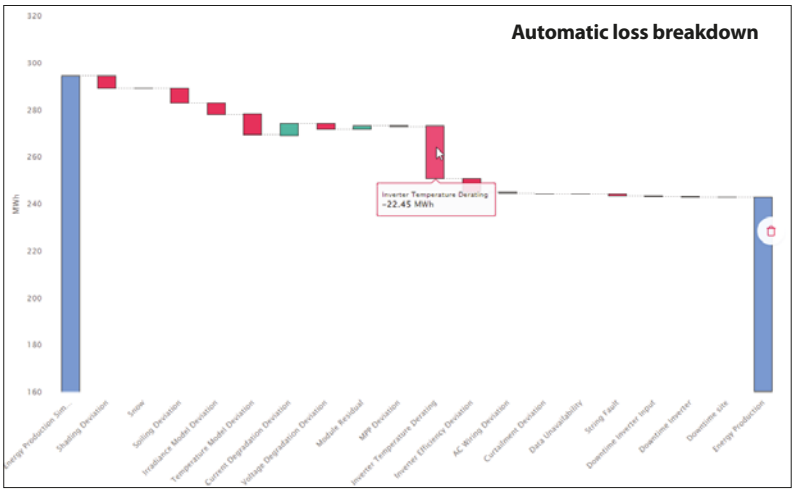
Case study: inverter temperature derating

A 1MW rooftop plant with known issues was analysed retrospectively. In spring of 2020, PR values suddenly dropped about 10% compared to the year before. After many hours of manual analysis, it was discovered that this problem was due to derating of the inverters because of overheating.

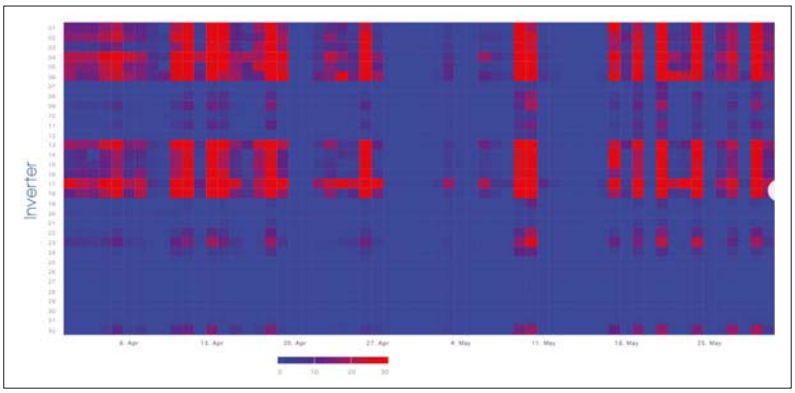
An automated loss breakdown for the period of April-May 2020, generated in 3E Solar Analytics (part of the SynaptiQ digital platform), is shown in Figure 1. The inverter temperature derating is identified by the automatic analysis and is quantified to be about 7.5% of the expected production. Additionally, an exceptionally dry month of April caused a soiling loss, which accounts for another 2% loss over the two months.

Plotting the derating loss per day and per inverter (Figure 2) reveals that the problem occurred for a subset of the inverters. Indeed, the devices with overheating issues were those at the highest, and thus hottest point in the inverter room.

How would this analysis have helped



Credit: 3E Solar Analytics



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Heatmap of temperature derating losses [%] per day and per inverter

Credit: 3E Solar Analytics

Temperature derating losses at plant level per month

early detection of the problem? Figure 3 shows the inverter temperature derating loss per month for the plant. Temperature derating issues were detected as early as May of 2019, when they caused a 0.43% loss. With 3E Solar Analytics, the plant operator is notified through an alarm. The system warns that inverter losses of up to 20% occurred on certain days. Based on this alarm, the plant operator investigates the issue and improves the ventilation in the inverter room. As a result, the problem is fixed a year before it becomes apparent in the performance metrics, thus avoiding thousands of euros of lost revenue.

Setting a reliable baseline

The early detection of losses, as shown in the example above, requires a reliable baseline. The expected production of the plant should be simulated, including a detailed modelling of inverters and string sets. This is typically done by creating a digital twin, which serves as a model to simulate energy output as a function of meteorological conditions. The reliability of the simulation is dependent on the type of digital twin that is being used:

- Physics-based (aka white-box) modelling: the digital twin is based on the expected physical response of the devices in the plant, derived from the parameters in the datasheets
- Data-driven (aka black-box) modelling: the digital twin is trained to replicate the behaviour of the plant based on historical data, with little to no domain knowledge

The data-driven approach may be better at predicting the actual performance of a plant, but it will inherit performance losses that occur in the training data. The physics-based approach provides a more deterministic baseline, but some model parameters may not be fully accurate. A hybrid grey-box approach provides the best of both worlds (Figure 4). The physics-based digital twin is used both to simulate business plan yield based on a typical meteorological year, and to recalculate expected yield based on measured meteorological data. The comparison between those two simulations allows to assess resource losses. Machine learning is then used to break down the gap between expected and measured yield into different loss categories, as well as to formulate recommendations to recover lost production.

This approach results in a more detailed and more reliable analysis than a black-box method. An accurate physics-based digital twin includes the datasheets of all devices, as well as the full string configuration. The temporal resolution of the simulation should be 15 minutes or less. Indeed, inverter clipping may occur in sub-hourly intervals - this would be missed if the resolution is too low, leading to an overestimate of the expected performance of the plant.

Unexpected losses consist of model corrections, performance losses and availability losses. The grey-box method gives flexibility in terms of which unexpected losses are fed back to the digital twin to correct the simulation model. This flexible method allows to serve the multiple purposes of simulation:

- Contractual performance assessment: how does the plant perform compared to the initial simulation model (e.g. for EPI calculation)? The digital twin is not altered.
- Technical performance assessment: how does the plant perform compared to the corrected simulation model? Only model corrections are applied.
- Energy forecasting: what energy output is expected from this plant, including performance losses? Both model corrections and performance loss deviations are fed back to the digital twin.

Classification and quantification of performance losses

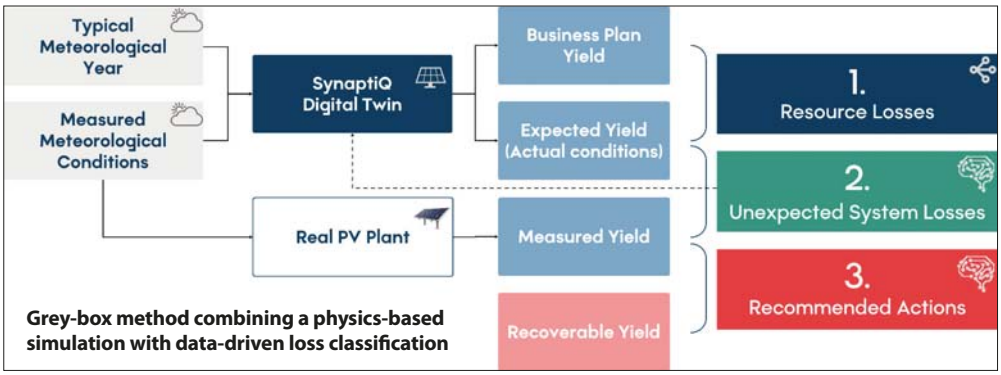
Performance at plant level, or even at inverter level, is the result of many confounding factors. Issues in one level can thus remain masked by overperformance in other levels. The key to identifying problems early on is to have a sufficiently detailed simulation, combined with equally detailed monitoring data. Concretely, it's necessary to monitor current and voltage at MPPT level and compare those to simulated current and voltage. This comparison allows to separate MPP tracking issues from other losses at the DC side. Assessing voltage and current degradation separately gives a more in-depth understanding of underperformance at module level.

A few examples of relevant performance losses are given below:

Tracker losses can be identified when monitoring tracker angle and comparing it to the simulation. This type of loss can go undetected for a long time because it can be a very localised failure that doesn't immediately impact the KPIs on plant level.

Shading losses can be detected as drops in DC current with consistent patterns according to the time of day and the time of the year. New constructions may arise in the vicinity of the plant. It's important to identify this in time in order to adjust business plans if needed.

Degradation losses can be identified by analysing consistent deviations between MPP current and voltage on the one hand and measured current and voltage on the other hand. Having a



Grey-box method combining a physics-based simulation with data-driven loss classification

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split-up between current degradation and voltage degradation is indispensable in order to reach detailed conclusions. For instance, light-induced degradation (LID) and normal annual degradation typically manifest themselves as current degradation. On the other hand, potential-induced degradation (PID) is characterised by voltage degradation combined with current degradation and mismatch losses.

Soiling losses look very similar to current degradation but evolve faster and are characterised by the presence of cleaning events. Indeed, sudden jumps in performance, whether caused by rainfall or by manual cleaning, can be detected automatically. Based on those events, soiling can be separated from the more long-term effects of degradation. Note that some types of soiling may be permanent, especially in the absence of manual cleaning, and, as a result, can no longer be distinguished from current degradation. Known examples include bird droppings and dirt from surrounding trees. Soiling losses may also be quantified by using on-site sensors. In the absence of sensors, and particularly in climates with frequent rainfall, soiling losses may not be apparent in overall performance KPIs. Nearby activity may lead to hidden performance losses. Automatic detection of soiling losses from monitoring data addresses this issue.

Maximum power point (MPP) losses are caused by imperfect tracking of the MPP by the inverter. Losses due to MPP tracking should be carefully separated from specific causes, like inverter temperature derating.

Inverter temperature derating is identified when MPP losses are associated with high inverter temperatures. As seen in the case study above, inverter temperature derating can manifest itself as a marginal problem before significantly affecting the performance of a plant.

String faults can be detected, even without string monitoring, as long as the number of strings per monitored string set is limited. Smart detection of string faults uses the knowledge of the number of connected strings to identify whether a drop of power is caused by the failure of one or more strings. Further intelligence is built in to avoid false positives, e.g. in the presence of shading. Especially in utility-scale plants, string faults can easily go unnoticed. When identified, they are relatively easy to fix, especially if a site visit is scheduled for other maintenance work. Indeed, remediating string faults provides a sure and quick return on the maintenance cost, if and when detected automatically and reliably.

Data verification

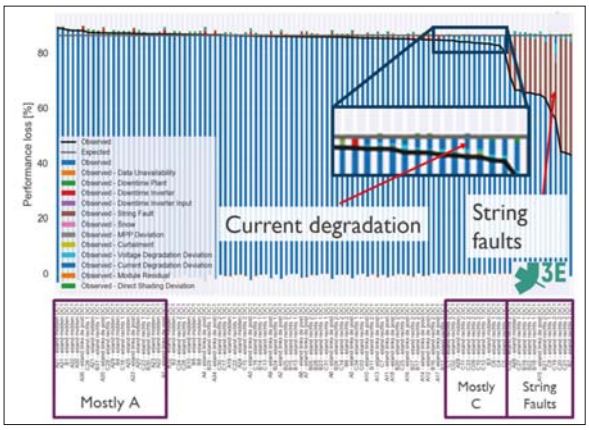
An important condition for the accurate identification of performance losses is a thorough assessment of the data being used. The analysis of plant performance is based on three important pillars: the digital twin of the plant, measured production data and the measured meteorological data (irradiation in particular). Automated analysis of the combination of this data allows to identify common errors like incorrect scaling factors, missing DC inputs, incorrect string configuration and time shifts. The irradiation data specifically, if coming from sensors, must be analysed continuously. Advanced comparison of sensor data with satellite data allows to identify issues like offsets, non-linearity, incorrect orientation, and shading. Appropriate actions should be recommended to remediate.

Validation

Incorrect conclusions from automatic production loss classification can lead to unnecessary costs related to onsite inspections and further examinations. Furthermore, in the context of warranty claims, it is crucial to show that losses have been quantified correctly. It is therefore indispensable to validate the correct functioning of such advanced analytics.

The difficulty that arises when conducting a validation of production loss analysis, is to find a suitable ground truth. In absence of performance losses that are known with 100% certainty, comparison with other methods is a suitable second choice. This is especially true when the other methods provide the diagnosis based on a fully separate set of input data. This is the case for drone inspections, which combine thermal and visual imaging to detect issues in a plant.

Figure 5 shows a comparison of the automatic loss analysis of a 1.4 MWp rooftop plant with a drone inspection. A total of 16 string faults were discovered by the automated loss analysis, which is 1 more than detected by the drone. In addition, current degradation was detected in those areas where a large number of hotspots was found by the drone. These hotspots are mostly caused by bird droppings, as the site is located in a port area with seagulls. There is a strong correlation between the number of hotspots



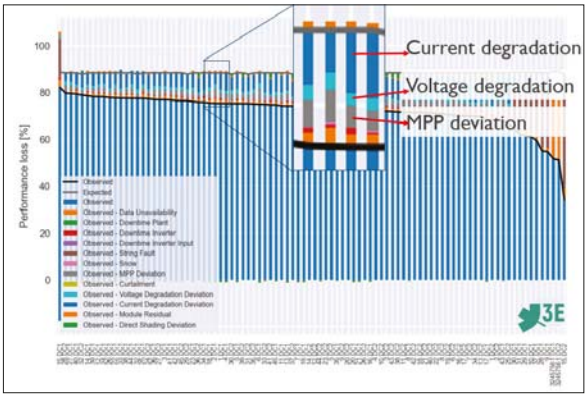
Credit: 3E Solar Analytics

Credit: Sitemark

Automatic loss classification per inverter; analysis from drone inspection

detected by the drone and the energy loss estimated by the automated loss analysis.

The automatic loss analysis of a 1MW ground-mounted plant was compared with a drone inspection report (Figure 6). The analysis from monitoring data detected a combination of current degradation, voltage degradation and MPP deviation. The smart recommendation engine recognises this combination of losses, where the



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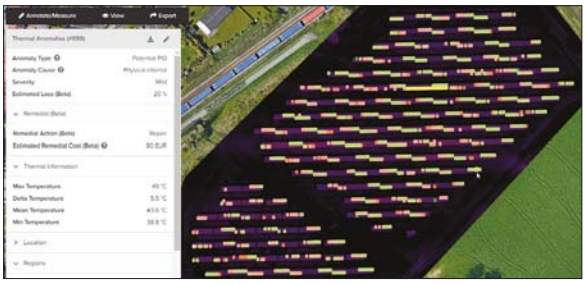

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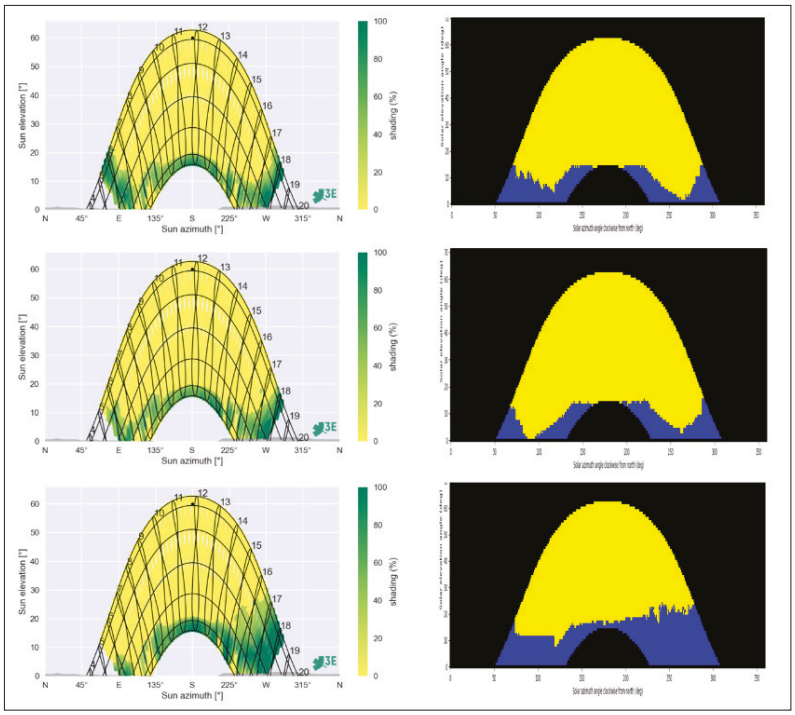
Automatic loss classification per inverter; analysis from drone inspection



Credit: 3E Solar Analytics

Shading maps from 3 locations on a plant as calculated from monitoring data by 3E Solar Analytics (left) and derived from a 3D drone scan (left)

MPP deviation in fact points to a module mismatch, as potential-induced degradation (PID). The drone inspection confirms this same issue, with a similar estimated performance loss of around 20%.

In order to validate the detection of unexpected shading from monitoring data, the digital twin of the plant was altered to remove known shading. As a ground truth, the shading profile of selected locations in the plant was calculated from a 3D drone scan of the plant and surroundings. The shading maps calculated by the advanced analytics were then compared to those derived from the 3D image. The results from both methods were found to be in good agreement (Figure 7). ■

Acknowledgements

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Where sun meets water: the rise of floating solar

Floating solar | Floating solar has grown at a slower pace than its land-based counterpart but technological developments, efficiency gains and land constraints are making it an increasingly appealing option for developers. Shauna Ng, content executive at Sunseap, examines the technology, its benefits and where the sector is headed.

Given its clean, renewable nature as a source of energy, it is undeniable that solar PV power is essential in global efforts to address climate change. As well as ground-mounted and rooftop solar installations, thanks to advancements in technology, solar panels can now also be deployed on water bodies.

Below, we explore floating solar energy systems, detailing the advantages of a floating solar PV plant to upcoming technological innovations.

Examining the floating solar PV sector

Floating solar PV (FPV) systems are a relatively new concept – the first patent for this type of solar technology was registered in 2008. Since then, floating solar panels have predominately been installed in countries like China, Japan as well as the UK.

As global efforts towards carbon neutrality accelerate, the demand for floating solar capacity is growing quickly. A 2019 report by global research firm Wood Mackenzie estimates that global demand for floating solar power is expected to grow by 22% year-over-year on average from 2019 through 2024. With this rising demand, opportunities for green loans have also risen for the financing of these sustainable projects, stimulating the global economy in its reach towards carbon neutrality.

In 2021, the biggest operational FPV system was in China – a 320MW facility in Dezhou, Shandong province. It deployed the floating array on a reservoir near Huaneng Power's Dezhou thermal power station.

Photo of one of the world's largest floating solar farms on seawater in the Straits of Johor, completed by Sunseap Group in March 2021.

Sunseap has a hand in the installation of FPV systems – in March 2021, Sunseap announced the completion of an FPV system along the Straits of Johor, Singapore with a capacity of 5MWp. While the system may seemingly pale in comparison to the 320MW facility in Dezhou, Sunseap's solar farm is actually one of the world's largest offshore floating photovoltaic system (OFPV). This means that the system is deployed on seawater, instead of on freshwater bodies.

Singapore's spatial constraints led Sunseap to look offshore, to the open seas, as a viable alternative for renewable energy, ultimately deploying the PV system in coastal waters. In doing so,

It is hoped that the successful building of the 5MWp OFPV system will lead to more OFPV projects in the region as land-scarce countries tap offshore solar as part of their renewables strategy.

Photo of one Sunseap's personnel inspecting the floating solar farm in the Straits of Johor.

Sunseap also achieved another milestone: constructing an undersea cable system connecting the floating platform to the mainland, creating a 22 KV electrical distribution network.

OFPV systems carry similar benefits as their freshwater counterparts, albeit with the challenges of sea conditions and associated costs. Unlike inland water bodies, the open sea is subject to a range of conditions and is prone to change, from fluctuations in temperature and rough swells to the corrosive nature of saltwater. Such unfavourable conditions, combined with the biofouling commonly found in warm tropical waters — where microorganisms, plants, algae, and small animals accumulate on surfaces — can potentially accelerate the degradation of PV system components, such as inverters.

With these challenges in mind, Sunseap's OFPV system was designed with a robust constant tension mooring system that is able to withstand changing weather conditions, keeping the platform and all of the operational equipment on board steady. In addition, the system also utilises Huawei's field-proven, smart string inverters to make the floating solar farm more efficient, safer, and more reliable.

The components of the OFPV system, such as the inverters, have also undergone a series of tests for salt corrosion and heat dissipation, demonstrating their resilience to harsh environments and temperatures. By deploying such technology, Sunseap has been able to streamline the operations and maintenance (O&M) process of the floating platform, as well as prevent rust and general material wear and tear.

Comprising 13,312 panels, 40 inverters and more than 30,000 floats, the energy generated yearly from this seawater-based installation can potentially offset an estimated 4,258 tons of carbon dioxide.

It is hoped that the successful building of the 5MWp OFPV system will lead to more OFPV projects in the region as land-scarce countries tap offshore solar as part of their renewables strategy.

The benefits of floating solar

It is interesting to note that despite how FPVs are more challenging and costly to build and operate as compared with land-based systems, demand for FPV systems is evidently still on the rise. So, what is driving this demand and the growing popularity of floating solar farms?

1. Space, or the lack thereof

One of the biggest advantages of FPVs is that these solar panel installations do not require any land space. Most of these deployments can take place on unused space on bodies of water, such as hydro-electric dam reservoirs, wastewater treatment ponds, or drinking water reservoirs. They are places that are unobscured from the sun and with low risks of vandalism or theft.

This will allow landowners to better capitalise on land area that would otherwise be occupied with the solar installations. In addition, installing solar panels out on open water reduces the need for

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Photo of the Memorandum of Understanding signing ceremony between Sunseap Group and the local municipal authority of Indonesia's Batam Island.

tree removal and forest clearing, which is a practice that is used in the case of ground-mounted, utility-scale solar panel installations.

FPV systems thus offer exciting opportunities, especially for land-scarce and densely populated cities, to tap into solar energy.

2. Performance and conservation

Another benefit of FPV systems would be improved module performance. Bodies of water have a cooling effect, and this can boost how efficiently these systems generate electricity by as much as 12.5%. Over time, this translates into significant cost savings. Solar modules perform better when they are cooler, meaning that a floating solar array will outperform a land-based solar array of comparable size owing to the cooling effects of the water.

"Bodies of water have a cooling effect, and this can boost how efficiently these systems generate electricity by as much as 12.5%"

Besides the water having a cooling effect on the solar-powered systems, it works the other way as well. The floating solar panel installation provides shade to the body of water and reduces the evaporation from these ponds, reservoirs, and lakes. This is a particularly useful environmental benefit in areas that are more susceptible to droughts.

The shade from the FPVs can also reduce the presence of algae that blooms in the freshwater, which is not only dangerous for consumption (if they occur in a source of drinking water) but can also lead to the death of marine life in the water.

3. Infrastructure, resources and costs

Floating solar often requires less in terms of both labour and materials than a land-based project of similar size. Additionally, less maintenance may be required as floating panels are generally located away from potential debris sources and shipping routes.

FPV installations are much quicker to build than fossil-fuelled power stations and can be ready in a matter of months, while the latter can take several years to construct. As more countries in Asia-Pacific commit to competitive solar and overall renewable energy targets, FPV installations will be key to meeting these goals.

The future of floating solar – technological advancements under way

In July 2021, Sunseap signed a Memorandum of Understanding (MOU) with the local municipal authority of Indonesia's Batam Island to build and develop an FPV system on Duriangkang Reservoir in the south of the island.

The FPV is projected to have a capacity of 2,200MWp and span around 1,600 hectares. This will make it the largest FPV in the world to date.

This hyper-scale FPV farm is expected to generate more than 2,600GWh of electricity per annum, potentially offsetting more than 1.8 million metric tons of carbon annually. This is equivalent to taking more than 400,000 cars off the road each year. Construction of the Duriangkang project is slated to begin in 2022 and is expected to be completed in 2024.

On top of the FPV system, the project will also include the development of an Energy Storage System (ESS). The ESS is also slated to be the largest in the world to date with a storage capacity of more than 4,000MWh.

The rapid growth in the solar industry has magnified the key limitation of solar energy – its dependence on the weather. To reap the full benefits of solar energy, we must store some of the energy when it is generated and use it during peak demand – this is where ESS systems step in as a solution, standing as the key to success in our carbon-constrained world. With ESS, electricity can be saved for later, when and where it is most needed. This enables the optimal use of FPV systems while ensuring an uninterrupted supply of electricity.

Sunseap's announcement regarding this project in Duriangkang reservoir might herald a new era for emerging markets such as Malaysia, Thailand, Vietnam and of course, Indonesia as the race to zero gathers momentum with FPVs and ESSs featuring prominently in decisions that will be made in the decade ahead.

Other rising technological advancements in the solar industry include weather forecasting technology such as skycam devices and algorithms that improve energy efficiency. Skycam devices can view clouds and gauge their altitude, density, direction and speed, and predict at what point the clouds will move over a solar farm. This tool helps anticipate momentary losses of solar power due to clouds, giving more time for other power generation units to plug the gaps.

A researcher from the University of Sydney has also found the key to the next renewable evolution. The focus of the research is a class of crystalline compounds called perovskite, a photoactive crystalline substance. Compared to silicon, a material traditionally used in the construction of solar panels, perovskite is much more time efficient in assembling. It is also bendable in a way that rigid silicon is not. Being used at a thickness of up to 500 times less than silicon, it is also very light and can be semi-transparent. This means that it can be applied to all sorts of surfaces like phones and windows.

The research is investigating the layering of both silicon and perovskite onto the same photovoltaic cell, to give a higher voltage than either could give on its own. The numbers so far are impressive: a single layer could be 33% efficient as compared to the 18%-22% efficiency of traditional silicon photovoltaic cells. These sorts of figures, if they can be realised commercially, would revolutionise renewable energy. ■

Grid and design consequences of the latest PV technology

System design | Jan Vedde, senior project manager for European Energy, takes a look at the key technological trends in the solar PV market, from changes to silicon cell manufacturing to the benefits of bifaciality.

Today it seems generally accepted that solar PV can provide competitively-priced electricity in many markets around the world, a condition recently acknowledged by International Energy Agency (IEA) with the statement: "In most markets, solar PV or wind now represents the cheapest available source of new electricity generation," given in its World Energy Outlook 2021

Energy professionals will know that the reason for the competitiveness is related to a dramatic reduction in installation costs, as highlighted by the International Renewable Energy Agency (IRENA) in its *Renewable Power Generation Costs in 2019* report, which says: "costs for electricity from utility-scale solar photovoltaics (PV) fell 82% between 2010 and 2019."

While these cost reductions have been driven mainly by economies of scale, mass production, collaboration between module manufactures and suppliers, support schemes and competition in mainly the Chinese PV industry, this paper will discuss the nature of the technology advances and the impact of these upgrades on the utility-scale system designs and associated requirements for development such as grid connection, finance, divestment and management of assets.

This development in PV technology has been achieved by both thin film modules based on cadmium telluride cells as manufactured by First Solar, which takes up around 5% of the overall market, as well as for silicon-based PV modules.

Svinningegaarden, a 33.9MWp project on Zeeland (pictured), was one of the first projects in Europe to deploy new large-format 540Wp bifacial modules from LONGi.

In this paper the technical developments related to silicon-based high-power modules will be discussed, covering: increased diameter of Czochralski monocrystals, replacement of wire saw cutting abrasive from silicon carbide to diamonds, opening of the cell backside to enable bifacial modules, replacing backsheets with glass in bifacial applica-

tions, stepping up quality assurance through third party inspection at module factories, introducing inverters with higher current carrying capability per maximum power point tracking (MPPT) and ensuring compliance to very elaborate power quality requirements at the point of grid connection.

Silicon based solar cells

When it comes to the solar cell, the most significant technical advances relate to the silicon substrate, which is a key factor for most the solar market, i.e., the market covered silicon based solar cell.

For years both casted multicrystalline and Czochralski (CZ) grown monocrystalline ingots have been cut into wafers by use of slurry-based wire saws and used as substrates for the cells processing.

Within a very short period of a few years, the casting method has been abandoned and all new PV products are now based on monocrystalline wafers – and they are cut with by diamond coated wires, which ensure less material loss than previous slurry-based wire saws. More importantly, the diameter of the monocrystal has also increased significantly, from previous cells typically 200-223mm, while today either 250 or 300mm dominates, corresponding to full square wafers with side lengths of either 182mm or 210mm.

Since the current generation under illumination of a solar cell is proportional to the area of the cell, these two wafer sizes impact the current rating of the solar module, which is an important design criterion when the electrical design is made. At least when the mainstream p-type PERC cell architecture is considered, the cell current for a 210mm cell will be around 1.3 times higher than that of a corresponding 182mm cell.

Large-format PV modules

The size of a standard module mostly depends on the quantity of full cells encapsulated into the laminate, which often is chosen to be either 72 or 78. The number of cell units might be doubled by using half-cells to reduce the internal resistive losses, but two typical large-format modules sizes would be the 182mm wafer based 540Wp series with dimensions 2256 x 1133mm^2 (LONGi version) or the 210mm wafer based 600Wp series from Trina, Risen and others, which measures 2172 x 1303mm^2.

While the 540Wp product will generate a module current close to 13A, the 600Wp module will generate more than 17A. Correspondingly to the large current, the voltage of these modules also differ such that the highest power modules have the lowest voltage – around 41V – whereas the 540Wp module will provide a maximum power point (mpp) voltage close to 50V. Both the large physical size and module current have implications when assessing the system designs for these new products.

Bifaciality and glass-glass module versions

A very important feature within these new large-format modules is the option to open the backside of both the cell and laminate for light penetration into the cell semiconductor junction. For p-type modules the efficiency of light conversion received on the back will be around 70% whereas n-type modules might see 85% or higher backside efficiency relative to the front. In most cases the energy gain from bifacial modules exceeds the limited extra price to be paid for this feature, but the financial value of this gain depends on how well the modelling of this extra gain has been verified and validated in the scientific community, since the bankability of this gain highly depends on this status.

> "Today it's common to also conduct third party audits at the factory sites, not only prior to supplier selection but also during the manufacturing campaign and after the actual production in a pre-shipment inspection"

Transparency of the backside of the module can be obtained by both transparent backsheets and glass. Whereas the backsheet can ensure an overall lower weight of the module – which may be of importance to certain roof projects – the glass-glass laminate panels benefit from a stronger and stiffer module with better protection of the cells from moisture ingress and mechanical stress.

Module quality assurance

Utility scale projects tend to assign up to 40% of the total Capex on PV modules and it's of high importance that the quality, durability and performance of this key component can be guaranteed towards the financing bank and ultimate asset owner. Only a few years ago, it was sufficient to ensure that the product was type-certified against IEC 61215 and other relevant standards, that the supplier bankability could be confirmed based on its ranking on the Bloomberg listing of Tier 1 suppliers, and that the warranty terms did cover both replacement and shipping costs and a warranty re-assurance was in place.

Today it's common to also conduct third party audits at the factory sites, not only prior to supplier selection but also during the manufacturing campaign and after the actual production in a pre-shipment inspection. In order to ensure that such inspections provide value to the buyer, it's necessary to include the detailed inspection scope, acceptance criteria and inspector mandate into the contract. This part of the contract is also where technical concerns related to the new large-format modules must be addressed by defining inspection procedures dedicated a mitigation of uncertainty in quality and performance, which a first-mover needs to address for any new product that cannot provide long-term field testing and where yet unknown failure modes cannot be excluded since this new product is based on several underlying process changes from crystal growth to encapsulation as described above.

Substructure solutions

Bifacial modules do request new substructure design, to ensure the shading from the structure on the backside of the module is kept to an acceptably low level. Larger panels may also lead to larger areas per fixed tilt table or tracker, which translates into renewed focus on statics. Whereas the design criteria will be mostly unchanged, recent incidents with torsional galloping – where panels under high wind loads have blown modules off trackers – will need to be considered. For this reason, technical advisors (TA) will have an increased awareness of the static calculations, to ensure that they are fully updated with respect to the new format.

At the inverter level

The capability requirements of the inverter for conversion of dc-power to ac will be more demanding when a 1,500V string (typical maximum voltage

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criterion) is equipped with the new large-format modules that may carry up to either 33 modules at of 600Wp format or 27 modules of 540Wp per string, at typical string lengths. Not only does the overall dc/ac power ratio impose design restrictions to the electrical design, but also the fact that the maximum power point tracker, which needs to manage power from several input strings, often has a maximum current capability per MPPT close to 25A, which invalidates the option to have two high current strings (each of 17A excluding the bifacial uplift) managed by a single MPPT. In order to load the inverter with a reasonable dc capacity above the inverter rated power, often new inverter models are required that are capable of managing more than one high-current string per MPPT.

Not only have the new PV panel specifications introduced new and more demanding inverter features and upgrades, new requirements for generators have also recently been implemented within the European Union, which will place more focus on the inverter and the inverter manufacturers expertise in the area of grid-compliance.

Grid connection regulation

For many years, the typical residential or commercial PV system could be connected to the electrical grid with few formalities and grid compliance documentation in the form of type-test certification of the inverters. Such systems demonstrated limited capability to deliver grid support on request and often it was only possible to offer remote control in terms of an 'ON' and 'OFF' status requested by the utility. Today the technical requirements for generators have increased significantly, and in some countries like Denmark and Ireland the transmission system operator (TSO) takes action to ensure conformance to these requirements, not only based on type-testing certificates but through detailed analysis and verification of the provided grid-simulation models they cover. This is provided using, for example, PSCAD (power systems computer-aided design), which defines the component characteristics in the electrical system, and RMS (transient analysis) modelling.

Since the national implementation of the European regulation (2016/631) on Requirements for Generators is still fairly new, the electrical design based on the new large-format modules is also new. And since new inverter models have just been introduced to allow for more current to be managed per MPPTs, it's obvious that this process of grid-simulation model compliance validation is not only time-consuming but also represents a high risk of delays. So even if it may be possible to obtain an Energisation Operational Notification, or EON, whereby the new PV park can start to test the electrical equipment installed, the more interesting Interim Operational Notification (ION) status that allows the project to feed energy into the grid for the first couple of years, cannot be received before these grid-simulation models have been approved.

Credit: Siemens Gamesa

Hybrid renewables projects featuring battery energy storage facilities are increasingly common to ease grid concerns.

Since the exact and detailed requirements to the inverter sub-model documentation may not be published and available by the TSO, but still may exceed the requirements given in the commonly referenced VDE AR-N 4110/4120/4130 and EN 50549-2 certificates, it can be quite troublesome to ensure timely compliance to these grid connection conditions.

Grid-access and energy storage

Many utility-scale projects are being connected to the grid these days and the pipeline of potential projects are booming. Once a municipality has accepted the plans for a project and a final investment decision has been made, it's much faster for the project developer to execute the detailed engineering, procurement and construction of the project, than for the utility to ensure availability of sufficient grid connection capacity, including necessary enforcement of the shallow and deep grid.

For the utility or TSO, the decisions on grid maintenance/upgrade and strategic enforcement must relate to (mandatory) long-term grid plans covering a five to ten-year development horizon, and it's often difficult to adapt such plans to capacity requests that may be developed from a green-field screening into ready-to-build status in just a few years.

For projects where full connection capacity may not be available until several years after the PV project can be realised, it may be an option to grid-connect with export capacity that is permanently or temporarily limited. This might also reduce the connection costs in case the connection charges are high and structured as a capacity-based connection charge.

In such a situation it will be relevant to consider establishment of a battery or other energy storage system to capture the otherwise curtailed energy. Similar considerations may evolve from grid connection agreement requirements addressing allowed export capacity ramp-rates and other minimum export capability requirements. Whereas it may not be too difficult to analyse the energy storage business case related to curtailment, and even a revenue stream related to down-regulation and arbitrage provided that the future baseload electricity price and volatility can be assessed in the specific bidding zone, it's much more difficult to assess the amount and duration of revenues that may be collected in the ancillary service market.

Grid connection and energy storage decisions are becoming more demanding and critical, but this may relate more to the changed operational conditions for the grid-owner when more intermittent energy sources and higher demands are being connected to the grid, rather than the latest technology developments directly within the PV field. ■

Author

Dr. Vedde is PV expert at European Energy where he is responsible for assessment and selection of technologies for utility scale PV projects. He's professional career includes positions as R&D manager and CTO within manufacturing of silicon feedstock, monocrystalline growth and wafering, manufacturing of PV modules and solar glass, PV project development, EPC, risk assessment and regulatory affairs.

Balancing the speed of interconnection and the reliability of the power system

Permitting | Ryan D. Quint, senior manager at North American Electric Reliability Corporation take a look at the key considerations – and difficult balance – of managing grid connection from a transmission operators point of view.

The electric power system is an ecosystem of millions of interconnected components – breakers, relays, transformers, inverters and so on – but it is also an ecosystem of entities that work together to ensure reliable and secure delivery of electricity to end-use consumers. As clean energy policies around the world are rapidly accelerating the interconnection of wind, solar photovoltaic (PV), battery energy storage systems (BESS) and hybrid plants, it is important for us to remember that each entity has a role to play in ensuring the effective transition towards very high penetrations of inverter-based resources. The energy transition is a shared experience – we must work together to keep the lights on while undergoing rapid technological change.

We hear time and again that the renewables development community faces a rigid, inflexible interconnection process. With over 800GW of resources "stuck" in the interconnection queues in the US, the development community is frustrated at the challenges they face when seeking to interconnect new resources to the bulk power system[1]. We most commonly hear that the greatest barrier to interconnecting more clean energy resources (and updating existing ones) is the "broken" generator interconnection process, and difficulty meeting interconnection requirements and study processes that are prerequisite for commercial operation.

Some of the challenges we most commonly hear from the development community include:

- Inconsistent interconnection processes across regions
- Unpredictable, ever-changing and complex modeling, performance and commissioning requirements
- Opaque or unfair interpretation of rules

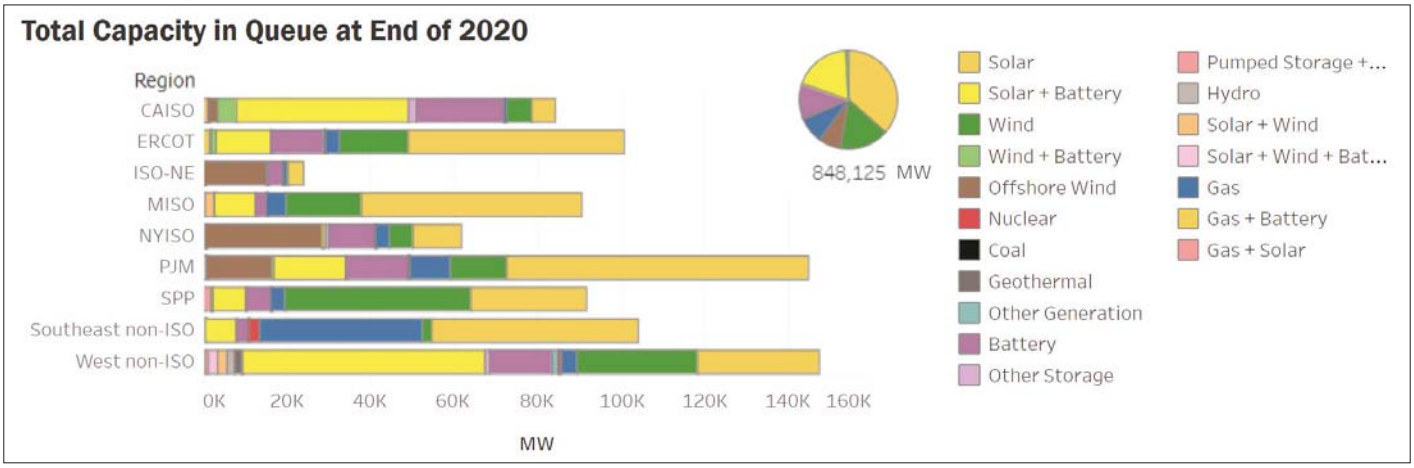
On the flipside, we hear a number of related complaints from transmission planners and operators, such as:

- Rapidly evolving technologies (e.g. grid forming inverters, batteries, hybrid plants) require new modelling, studies and processes
- Little trust in submitted study models, incorrect or poorly parameterised models, and lack of supporting materials to validate the models
- Gaming the interconnection queue with multiple requests for the same project, leading to unnecessary re-studies and a high dropout rate
- Unreliable real-time performance of existing resources yet no clear corrections to models or equipment to address known reliability issues (e.g. findings from NERC reports)

Both sides present valid frustrations and underline a clear need for improvements to the interconnection process. We should not consider this issue an "us versus them" situation; both sides generally want safe, secure, reliable, streamlined and economical interconnection of new clean resources – and to avoid the next major blackout. The repercussions and backlash from that bad day are just too great a burden to bear.

The need for reform

The need for an improved generator interconnection process has been identified in multiple NERC reports, most recently the *Odessa Disturbance Report* analysing the widespread loss of solar PV resources in the Texas Interconnection[2]. In addition, NERC has also strongly recommended all transmission service providers modernise and improve their interconnection processes and requirements to support increasing levels of inverter-based resources[3]. A long-term solution – in the form of a modernised and improved regulatory process that unifies and simplifies the connection process without compromising the sufficiency of analyses – will inevitably take time; however, we cannot wait to make changes to requirements and existing processes to manage the interconnection queues of today.



Credit: Lawrence Berkeley National Laboratory.

US interconnection queues by asset class.

We are beginning to see movement across multiple regions regarding interconnection process reforms. The Connections Reform Initiative is addressing concerns with delays and complexity connecting to the Australian National Electricity Market[4]. The Federal Energy Regulatory Commission (FERC) recently released an Advanced Notice of Proposed Rulemaking (ANOPR) seeking to reform, streamline and modernise the generator interconnection process[5]. The Global Power System Transformation (GPST) Consortium is also seeking to develop technology to improve system reliability and streamline the interconnection process under an accelerated energy transition[6].

Finding balance

Under high penetrations of inverter-based resources, ensuring reliable operation of the bulk power system and rapidly interconnecting new generating resources are somewhat conflicting concepts that must be delicately balanced. The balancing act between these two perspectives is absolutely critical.

In a perfect world, transmission service providers would have clearly outlined interconnection process and requirements, and be able to conduct very fast and accurate reliability studies. In reality, the models submitted to the transmission planner do not represent the planned or installed equipment, or are just entirely unusable for performing studies. Model quality checks have not been properly conducted by the interconnecting customer or by the transmission planner. Or the planner has identified the need for detailed electromagnetic transient (EMT) studies due to the complexities of a high penetration inverter-based world. These add significantly more complexity, time and study work to the process. Can we simply ignore these issues? Can we avoid running studies? Can we live with modelling errors? Absolutely not! Not if we intend to keep the lights on...

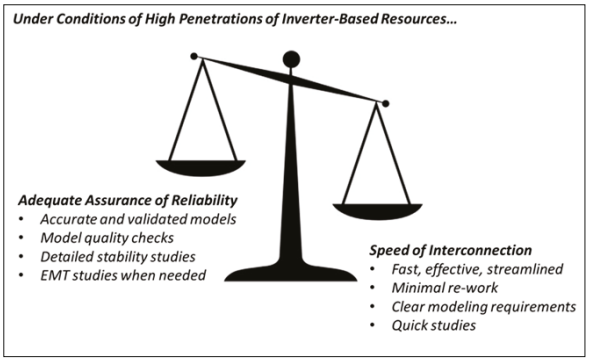


Figure 2

Actionable recommendations

We need to *stop admiring the problem* and instead get actively involved in developing solutions to address these challenges. Emerging technologies being deployed on the grid present exciting opportunities but require effective policies, suitable requirements, accurate models and adequate studies. In an effort to provide useful guidance that we can act on now, I offer the following recommendations to the development community to help support our rapid energy transition:

- **Understand the complexities of the interconnection process:** Today's interconnection queues are dramatically more complex than in the past when only a handful of large synchronous generators were seeking interconnection with 5–10+ year construction timelines. Today we see vastly different resources being interconnected on significantly expedited timelines. Existing processes are stressed by adequately studying these complex resources, let alone on such a quick timeline. However, transmission service providers must uphold their responsibility to identify reliability issues and develop mitigating measures. Inverter-based technologies present new and complex issues that need to be addressed. Examples include controls interactions, low short-circuit strength issues, oscillations, power quality issues, ride-through performance issues and possibly the need for grid forming inverters. These challenges are intensified and widespread as we connect more power electronic-interfaced generation to the grid. Ultimately, there is no way around it in today's modern world; however, these reliability issues can be addressed with detailed modeling and studies that *must* be performed during the interconnection process.
- **Prepare to meet interconnection requirements:** Interconnecting customers should prepare for the requirements established to ensure reliable operation of the bulk power system. In addition to NERC and FERC requirements, transmission service providers have their own unique requirements. NERC released a reliability guideline[7] strongly recommending these entities comprehensively update their interconnection requirements to be clear, consistent and appropriate for inverter-based technologies. Transmission planners will have detailed modelling, validation and study requirements throughout the process. The market operator, where applicable, will also have interconnection requirements, business practices manuals, operating guides, etc. All these requirements serve a vital role and must be adhered to at all times. As the technology landscape rapidly evolves, developers should expect that requirements will evolve at a similar pace to keep up with changing grid reliability needs. Coordinate with your transmission service provider and other applicable entities to address issues early.
- **Ensure model quality and accuracy during interconnection studies:** This point cannot be stressed enough. Model accuracy and model quality matters, and is one of the biggest challenges with the interconnection process today. NERC in its analysis of widespread solar PV loss events has highlighted that the unreliable performance of solar PV resources across multiple large disturbances stem from inaccurate modeling and studies during the interconnection process. In many cases, models provided to the planner were inaccurate , were not validated, or were not checked adequately by the transmission planner; therefore, the resource operated in an unstudied state. This problem needs to be fixed as quickly as possible. Providing a model is necessary but not sufficient – that model must match installed equipment. NERC has strongly emphasised the need for transmission planners to develop comprehensive model quality checks pre- and post-commissioning to ensure the model matches actual equipment and settings. If a discrepancy is identified, mitigating measures should be implemented immediately. Prior to commercial operation, this may include re-study or additional documentation from the developer. After commissioning, this may require curtailment or other consequences until a solution is implemented. Developers should expect that transmission planners across North America, and likely around the world, will put significantly more emphasis on ensuring model quality prior to conducting studies. This will require more assurance in the form of oneline diagrams, attesta-

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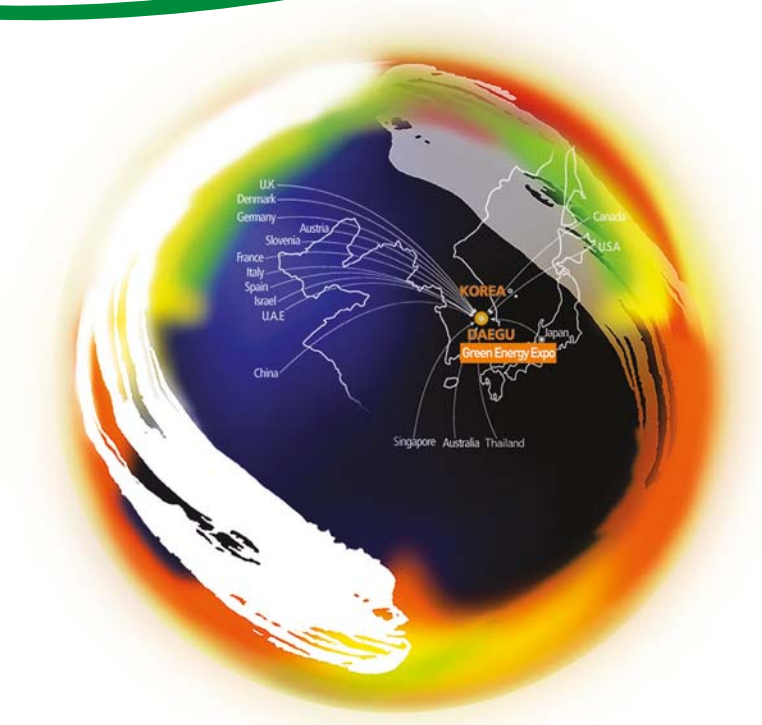

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tions from OEMs, specification sheets and factory test reports. Identifying these issues late in the interconnection process will delay it. Refrain from using models of generic equipment to "get through the queue"; this will only be flagged later and void all studies.

- **Understand material modification and pick equipment early:** Equipment needs to be locked in as early as possible. The later specific equipment is selected, the longer the interconnection process will require. Planners must study the actual equipment being installed. Using a model of generic equipment greatly increases the chances of requiring a re-study once parameters are finalised. This is a significant pain point for developers but planners absolutely need to study the performance of the expected *actual* equipment being installed. Interconnection requests with speculative data should expect that the interconnection process could be delayed until appropriate decisions can be made regarding equipment, control modes, settings and other aspects of the facility. In an iterative selection process, expect re-study work and expect delays. The term "material modification" has added confusion in this area because it means too many things. There are activities underway to address these issues in North America; however, the main message is that developers should coordinate with the transmission service provider and transmission planner ahead of any modifications that will affect the electrical output or response of the facility during normal or abnormal conditions. Selecting equipment and settings early and minimising equipment modifications will significantly help expedite the interconnection process.
- **Establish strong relationships and contractual language with OEMs:** Developers and plant owner/operators should develop strong working relationships with the OEMs but should also ensure that their contractual language is updated to reflect requirements imposed by the transmission entities. Requirements imposed on the developer, particularly modeling requirements, are often pushed to the OEM. Consider OEMs that offer transparency, willingness and ability to provide clear documentation and post-commissioning support. For example, the industry is moving toward use of "real-code" models generated from source code from the actual installed equipment. Planners may require EMT models that include this type of code and the OEMs will need to provide this information during the interconnection process and during the lifetime of the project. OEMs should be diligent and support addressing reliability initiatives identified by utilities. Simply relying on a third-party consultant to make selections and develop models may be insufficient for meeting interconnection requirements in the future.
- **Eliminate queue gaming:** Many transmission service providers highlight that the same project is submitted as multiple interconnection requests. The identical projects are then withdrawn at different phases of the process as the transmission entities conduct feasibility and system impact studies. As the projects drop out of the queue (commonly due to limited transmission capacity and the need for expensive transmission infrastructure costs), this requires a significant amount of extra work involving writing updated contingency files, revising oneline diagrams, updating models and base cases, re-running reliability studies and then re-determining appropriate mitigations for reliability issues. This all adds unnecessary delay in the interconnection process. One possible solution to this issue is to raise the bar (that is presently very low) for customers to enter the interconnection queue. If only projects serious about connecting (land permitted, equipment selected, design complete, construction ready, etc.) entered the queue with a higher "down payment", then we would see less redundancy and less delay. Last minute decisions regarding proceeding or withdrawing at every stage of the queue only lengthens the process for everyone.
- **Hire reputable, highly-referenced consultants and engineering, procurement, and construction (EPC) contractors:** While the developer has the responsibility of meeting the requirements of the interconnection process, the support team of consultants and EPC contractors used throughout the process are often the entities performing the work to demonstrate compliance with those requirements. The area of primary concern presently is the consulting work conducted to develop and validate the models used for studies. Again, a significant amount of re-work is needed due to errors in the models developed by the consultants hired by the development community. For example, a consultant scopes model development with a set number of hours (cost) and timeline for delivery (date). However, the consultant then finds out that the plant has mixed inverter types with one OEM providing site master control. Digging into the user-defined models and developing appropriate plant models will require significantly more time and money than expected. Therefore, the developer and consultant decide to use generic models that do not reflect the actual equipment. As stated above, NERC is calling on transmission entities to better screen for these types of errors and demand validation materials to prove the model matches reality. Developers should expect these issues to be flagged. The solution is to allocate sufficient resources and hire reputable consultants that can deliver on the results needed to meet the requirements of the interconnection queue.
- **Have technical staff on-site:** Investment firms should ensure that developers have technical staff on-site and available throughout the lifecycle of the project. The staff should understand the engineering, design, modeling, study work and other aspects of the facility needed to effectively meet each milestone of the interconnection process. Excluding external factors like necessary transmission upgrades, the ability to address identified issues throughout the process directly correlates with the speed in which the resource can connect. Confusion or misinterpretation of results, requirements or questions can lead to significant delays in project completion or the inability to meet technical requirements. Transmission entities will also need to ensure they are staffed with engineering staff able to model, study and analyse the response of these new resource types.
- **Future IEEE 2800 Standard coming:** A large body of industry experts is currently wrapping up *IEEE Draft Standard for Interconnection and Interoperability of Inverter-Based Resources interconnecting with Associated Transmission Electric Power Systems*,[8] which is

specifying uniform minimum technical requirements for the capability and performance of BPS-connected inverter-based resources. The standard will cover an array of topics from modeling and studies to power quality and ride-through performance. The project was initiated to address challenges with the interconnection process and gaps in reliable operation of inverter-based resources on the BPS, of which one of the key drivers were the ongoing widespread loss of solar PV disturbances in North America. The standard was recently approved by the IEEE Standards Association RevCom[9] and received very high balloting approval from industry. Note that IEEE standards are voluntary until an authority governing interconnection requirements enforces them. In the case of P2800, industry is expected to fully and comprehensively adopt the future IEEE 2800 standard and its complementary 2800.2 testing and verification standard[10]. The OEMs and development community should be aware of this future standard's use, and prepare to meet all requirements and recommendations outlined in the standard as they will very likely be put into effect soon.

It is incumbent for us to recognise the gravity of the work we are doing. In the U.S. alone, nearly 400 million people depend on reliable and secure delivery of electric energy to fuel every facet of modern society. We cannot let the balancing act of ensuring reliability and interconnecting new resources quickly lean too far in either direction. Focusing too much on reliability aspects will hinder interconnection of low-cost and clean energy resources; however, leaning too far towards quickly interconnecting resources without enough due diligence will be extremely costly for all parties involved particularly when the next widespread outage affecting millions is linked to the unreliable operation of the renewable resource fleet. We can do our best to ensure this does not happen – but recognise that providing that assurance takes time during the generator interconnection process. ■

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Author

Ryan Quint is the senior manager of BPS Security and Grid Transformation at the North American Electric Reliability Corporation. His primary focus areas include grid transformation, enabling emerging technologies, security integration, and integration of inverter-based technologies and distributed energy resources. Prior to joining NERC in 2015, Dr. Quint worked at Dominion Virginia Power and the Bonneville Power Administration. Dr. Quint received his PhD from Virginia Tech and is a registered professional engineer.

25GW by 2025: How Lightsource bp is 'building the machine' to lead a global solar charge

Business | In September 2021 Lightsource bp set itself the target of reaching financial close on 25GW of solar by the end of 2025. Liam Stoker spoke to the developer's leadership team to discover how it is expanding into new markets, securing financing deals and assembling a workforce capable of reaching that target.

Credit: Lightsource bp

Lightsource bp – the solar developer co-owned, as the name suggests, by energy major bp – is in a race to ramp up its solar deployment. The race isn't against any perceived challenger or obstacle, but to meet the developer's own lofty ambition.

In September 2021, the company drastically increased its previous deployment targets, setting itself the aim of bringing 25GW of solar PV to financial close by 2025. Having in 2018 (the year after bp acquired a 43% stake in the business) set itself the target of bringing 10GW to close by 2023, it constituted quite the uptick in ambition.

Speaking to *PV Tech Power,* Lightsource bp CEO Nick Boyle says the increased target was set in stone after it became apparent that the initial aim would quickly be outdone, something he described as being "typical Lightsource". Instead of resetting the 2023 goal, because of the development time necessary for certain projects it made more sense to set a more aggressive target for two years down the line.

But setting that target and announcing it to the market was a dangerous move reputationally, Boyle says, despite the company having the upmost confidence in it being met. "It just constitutes doing more of the same which, yes, means we've got to bring on a significant number of additional people. But these are additional people in additional countries to do the same as we've historically done, rather than anything new," he says.

The US accounts for around 40% of Lightsource bp's development activity.

With a new target on the horizon, the developer has since set about placing all of its ducks in a row in terms of financing, development opportunities and the manpower to get the job done.

New horizons

When bp acquired its 43% stake in Lightsource – the company has since increased its stake to 50% - the solar developer had not long since broken out of its home market of the UK and was pursuing opportunities in five markets. That list now stands at 16, and grows every year, Boyle says.

The US, where Lightsource bp is pursuing opportunities from New York to California, constitutes around 40% of the company's operational activities. Western Europe remains a core market for the firm, while a presence is also held in the solar hotspots of Australia, India and Brazil. This is now being followed up with a concerted move into a number of Asian markets as the company heads further east than it has before. A Southeast Asian hub in Singapore has recently been opened, with eyes on Taiwan, Vietnam and Korea. The company's first projects in Taiwan are set to be announced in March 2022 which will see the developer complete arrays above fisheries in the country. An additional team on the ground in China is tasked with various support roles, such as equipment QA.

"What we're not trying to do is move into every single market in parallel. That's not doable"

The key to juggling so many markets at once, Boyle says, is to basically not do them all at once. "What we're not trying to do is move into every single market in parallel. That's not doable," he says. That said, group COO Ann Davies notes that the company will indeed double the number of projects it has in construction this year, with a doubling in the number of deals concluded also set to help increase its activity.

With just under four years to go, Lightsource bp is already in hot pursuit of that 25GW figure. "We've got a significant percentage of them [projects] already in the bag," Boyle says. "But that doesn't mean that we're not continuing to look for new greenfield assets, and indeed, continuing to buy early or even middle stage, pre-developed assets."

Identifying the right markets can, however, be a little trickier, with Lightsource bp looking for the right mix of ample development opportunities, supportive domestic attitudes to solar and a grid that's conducive to distributed generation.

Rather than having specific policy or subsidies in place, Lightsource bp wants to work with national governments, rather than against them. "There's no point pushing against someone if there are countries that have a positive attitude towards solar. There are countries where development is more challenging, [and] we would avoid those because of the fact there are countries where those restrictions don't exist," Boyle says.

But outside of the political sphere, one of the biggest hurdles remains the grid. "I think the grid is a massive differentiator. In some countries the issue is that the existing grid is under pressure and therefore needs upgrading, but in some newer countries maybe the grid just doesn't exist. Those challenges in a distributed generation business such as ours are extremely important," Boyle adds.

Scaling up

This is exacerbated by the scale at which Lightsource bp looks to operate. "Scale is important to us, and if we are going to enter a new market, we want to be leading it and scaling within that market. If all the above allow us to build scale - and it could be within the next couple of years or longer term - those are factors we consider," Davies says.

"If we are going to enter a new market, we want to be leading it and scaling within that market"

Boyle says the "two letters at the end of our name" indicate the value it places on volume. "From our perspective, to go into a country we need to a couple hundred megawatts there, but ultimately that market needs to be gigawatt-plus, otherwise it's simply not worthwhile for us," he adds.

That scale has repercussions elsewhere. Davies says Lightsource bp is a more attractive customer for both services and equipment, with the developer forging partnerships with its suppliers that "only become available" at that kind of scale. "And I think that helps us weather some of the storms on the supply chain by working together," she says.

That much was perhaps evident in November 2021 when Lightsource bp signed a 5.4GW module supply deal with thin film specialist First Solar, a deal which secured 'Made in America' modules for its US portfolio – important against the backdrop of heightening trade tensions between the US and China – and, as Davies notes, diversified its module supply away from polysilicon-based modules that have risen so dramatically in price over the past 12 months. The benefits are mutual, however, with both Davies and Boyle stressing the certainty the contract gives First Solar in its capacity roadmap.

Supply chain volatility has dented project economics almost universally in the past 12 months. A 20%+ increase in module costs has triggered project pushbacks, but not, in the case of Lightsource bp, any firm decision on whether or not a market works for them. "That's more deciding when we go, rather than necessarily if we go," Boyle says.

But an unavoidable consequence of delivering gigawatts of solar in such a constrained timeframe is the need for financing to ramp up in tandem. For that target to be achievable, Lightsource bp would have to mobilise financing unlike anything the developer had done previously.

Upping the game, upping the volume

"We needed to up the game and the volume, and that is exactly what that represents," Boyle says, when drawn onto conversation around the US$1.8 billion credit facility it closed with 10 major banks and financing institutions in September last year. High street banks such as Natwest and Santander were joined by major financial services firms such as Wells Fargo and Mitsui Sumitomo. The company cast its financing net farther than it had done previously, too, bringing in financiers it had yet to work with.

In truth, Lightsource bp could have struck a similarly-scaled financing package with a smaller number of banks,

and that would of course had been easier to conclude. But the strategic importance of forging relationships with larger banks now moving into the renewables space – and doing so in volume – was not lost on Lightsource bp. The company now fully intends to go back to these financiers in the not-too-distant future. "By illustrating, here's what we've done in a safe and controlled environment, we're able to then say to them: let's go again and increase the funding," Boyle says.

With new names entering solar and broader renewables financing, Boyle says conversations with potential lenders are easier than ever before even despite the aforementioned supply chain volatility and increased scale at which the PV industry operates at. "After pressure from shareholders and boards to invest in renewables - solar is right in that sweet spot," Boyle says, adding: "The low carbon economy represents a massive potential area of growth for banks."

It's a symbiotic relationship, of course. Without that scale of lending, Lightsource bp could simply not achieve what it needs to.

Fortunately, in power purchase agreements the solar industry has an instrument that banks are now entirely au fait with. Prior to bp's involvement in what was then Lightsource, the developer was a champion of corporate PPAs and, perhaps, ahead of its time. Uptake in 2015 and 2016 was low initially, but now the industry has demonstrable success and a replicable template, the market is taking off. "The ability to say 'here's one we made earlier' is hugely positive. Back in 2015 or 2016, it was a short list of companies looking to sell PPAs and an even shorter list of companies looking to buy," Boyle says.

PPAs are also music to the ears of investors, offering bankability and certainty to revenue streams that, in an environment dogged by power price volatility, can calm the pulse of even the most risk averse financier. Davies says matching the tenure of financing to the tenure of the PPA creates a mechanism in which the bank is essentially lending money for a period of time when they know exactly how much the project is going to be generating, changing the financing entirely.

There is, however, potential upside in leaving some revenue streams open to that volatility though, with merchant-based revenues enjoying periods of spiking power prices across Europe in particular. In Europe, Lightsource bp is aiming for a contracted versus merchant revenue split of 70:30, a ratio the company says allows some exposure to that potential upside, but ensure revenue stability at the same time.

With financing in the bag and a long list of projects to be worked on, Lightsource bp is now casting its eyes internally and readying itself for what looks certain to be a frenetic three years.

Building the machine

Establishing a target, identifying the right markets and projects and arranging the requisite financing is, of course, a considerable way towards achieving your business aims. But without the necessary people to make it happen, those projects will only ever exist on paper. It's for this reason that Lightsource bp committed to creating some 500 new permanent roles at the business when the 25GW target was set in stone.

Around 400 vacancies are to be filled this year, Boyle says, spread across various job functions. Engineers, financiers, developers, HR professionals and those who work in communications have either joined the business already or will join in the months ahead as Lightsource bp looks to make another leap in scale.

Boyle and Davies both state that the recruitment across the company into different job functions is about "building the machine" that supports the entire business in its aim. "We need to build the machine where the machine is one that can develop across 16 countries safely, sustainably and with quality engineering. We need to get that right," Boyle says.

But is that easier said than done? As this volume of PV Tech Power illustrates (p.15), there are concerns about a looming skills gap in solar PV. Boyle says that while indeed Lightsource bp is attracting a quality of individuals that is "going through the roof", it needs more. "There's never been a more exciting time to be in energy, and I don't think it's ever been more challenging," he adds.

Recruiting in more technical areas is especially challenging, Davies says, compounding the general sense within some solar circles that there just aren't enough skilled engineers to go around. This becomes even more prevalent in high voltage areas, where competition for the labour force is especially fierce.

"It forces us to become attractive employer, look in different pools and think creatively about the type of experience and individual we need," Davies says, highlighting one recent apprentice in particular that has joined from a previous role as a musical director, but is tapping into a digital skillset to work on digitalising Lightsource bp's solar assets.

There's something of a saying in UK solar circles that Lightsource bp - or simply Lightsource, as it was formerly known - has contributed towards the careers of so many PV professionals in the country that it'd be more appropriately referred to as the University of Lightsource. Boyle compounds this by noting that during a recent round of discussions with six companies in the space, each had an ex-Lightsource staffer near the top of the organisation.

"The unfortunate thing about having the University of Lightsource is that we had to pay to train them and now someone else is milking the benefit," Boyle says, stressing how his company's position in the market and talent of those it recruits and brings through makes it a target. "As the number of new players increases, obviously they're going to go to Lightsource to potentially attract those players."

The importance is therefore on maintaining talent, and not just attracting it. Something as simple as paying individuals appropriately and ensuring the environment is right in terms of career path can go a long way, Boyle says. "We treat them with respect and make sure that we create the right environment to make sure they're thriving in their careers. It's the right thing to do because it means there's a greater stickiness to us as an employer," Boyle says.

Recent research published by BloombergNEF revealed that in 2021, Lightsource bp topped the list of global buyers of development assets. Enel was second, with a multi-gigawatt gap separating the two. "It's not only that we were the biggest, which is amazing, but it's the margin by which we were the largest… it's really great to be up there with some of the market leaders," Boyle says. With three years to go and just over 20GW to close on to reach its stated aim, Lightsource bp is primed to lead the charge on solar PV throughout this decade. ■

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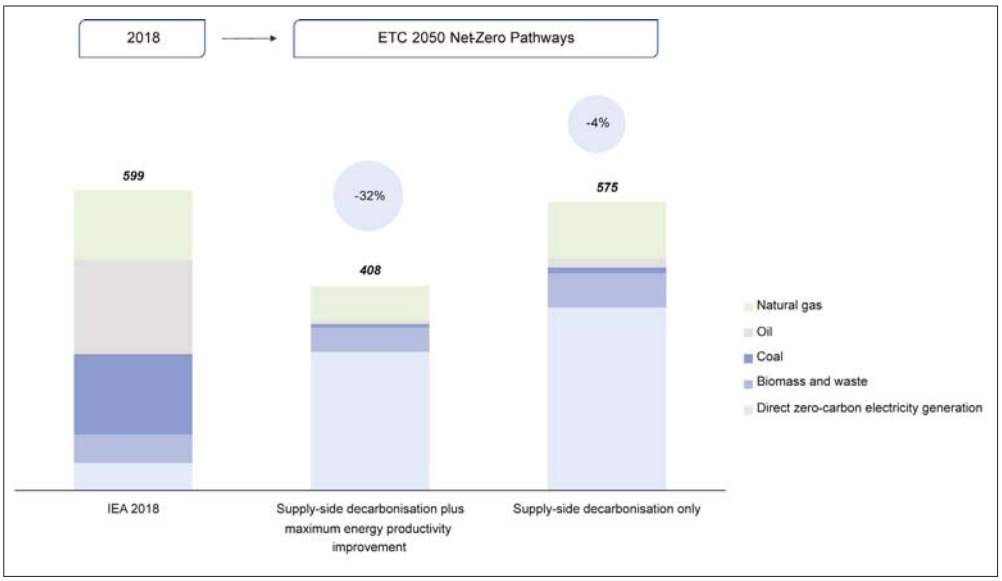
Flexibility is central to our low carbon future, and a major economic opportunity

Economics | As energy systems the world over embrace renewables en masse, flexibility is quickly outpacing generation as the most valuable provision an asset has. Alexa Capital CEO Bruce Huber examines the rise of flexibility and the major economic opportunity it poses for the energy sector.



Source: International Energy Agency, Alexa Capital

Primary energy demand (EJ/year)

You wouldn't use fossil fuels if you wanted to build a low carbon energy system from scratch. Apart from producing emissions, fossil fuel-powered generators are inefficient and prone to breakdowns. Take a car, for instance: a petrol or diesel internal combustion engine has around a 30% efficiency, while electric engines are more than 90% efficient. The energy required for one internal combustion engine could drive three electric vehicles.

Thus, with the technologies we have today, it makes far more sense to convert limitless renewable energy straight to electricity and use that to power as much of our society as possible. This is why electrification is a key theme for net zero emissions pathways published by authorities such as the International Energy Agency — and why clean energy is such an important growth opportunity for investors today. But electrification is not without its challenges.

As the need for electricity increases, and with it the amount of variable renewable generation feeding into the grid, it gets harder to match supply and demand. If demand goes up on a fossil fuel-powered grid, you can deal with it by putting more coal or gas into your thermal plants. But if demand goes up on a clean energy-based grid, you cannot get the wind to blow harder or the sun to shine more. Instead, you need to find new ways of keeping supply and demand in lockstep. If not, you risk spiralling energy costs whenever demand exceeds supply.

You also risk frequent blackouts, since the massive rotating masses of today's fossil fuel-powered turbines act as metronomes to keep the alternating current on the grid pulsing with a constant frequency. Without it, the grid crashes. Overcoming the need to accurately balance demand, supply and frequency in tomorrow's electrified energy systems is one of today's most significant economic opportunities.

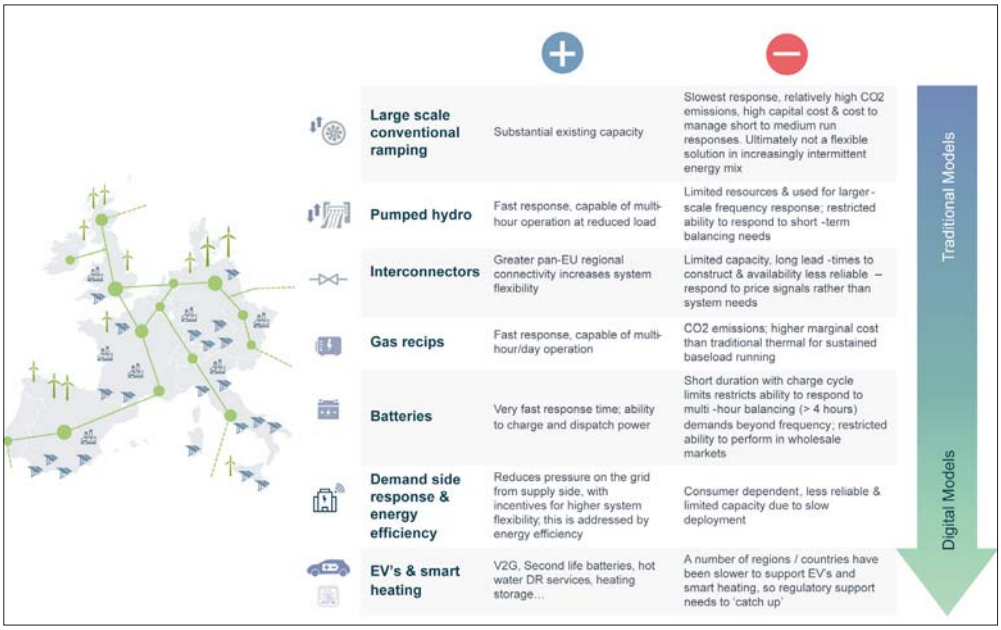
The key is flexibility, a concept which includes an array of conventional and emerging technologies and business models to support the transition to a low-carbon society.

Flexibility and the electrification challenge

There are multiple ways to make a grid flexible enough for demand to meet variable levels of supply. Conventionally, this is done by drawing on assets such as efficient, responsive combined-cycle and open-cycle gas turbines, pumped hydro reservoirs and grid interconnectors linking high-voltage distribution networks. But with changing power markets and a shift to more distributed generation, there is a growing requirement for more dynamic, digitally enabled and distributed options to address bottlenecks in electricity distribution networks. In more and more markets, we are seeing the introduction of grid-scale energy storage, mainly in the form of lithium-ion batteries, and gas peakers, with the former addressing the short-term (typically under four-hour) system volatility and the latter handling longer-duration requirements. At the same time, capital is being drawn to digital models of operation because these are better able to mitigate growing power market risks.

Emergence of new flexibility business models

We are now seeing the emergence of technology-enabled service models that pay customers to address supply-demand imbalances in increasingly decarbonised



Credit: Alexa Capital

power markets. Using smart meters and industrial control devices, electricity users such as supermarkets and food distribution groups can be rewarded for turning down freezer units during periods of peak system demand. Water utilities can turn off wastewater processing pumps. Greenhouse growers can turn up combined heat and power (CHP) units to export electricity to the grid. Data centres can do the same with backup generation. Electric vehicle fleet operators and charging networks can shift when to charge loads. And there are many more industrial examples.

These demand-side flexibility programmes can work with large energy consumers such as aluminium smelters or by aggregating smaller load centres such as households and multi-dwelling

Conventional and emerging sources of grid flexibility

housing units equipped with smart heating systems and appliances. In addition, commercial and industrial (C&I) electricity users are reducing their energy bills through a combination of efficiency investments and the digitisation of their processes, supported by an array of fast-growing service providers. Meanwhile, grid system operators can procure extra generation capacity that is kept on hand specifically to deal with peaks in demand.

Electric vehicle charging is an obvious target for flexibility services. Electric car batteries connected to the grid could deliver part of their charge back to the electricity network at times of high demand—in return for appropriate compensation, of course. There is a similar outlook for other areas of transportation that could become electrified over time, such as ferries and heavy-duty road transport. Another emerging flexibility opportunity is in what is called sector coupling, where energy use is integrated with supply sectors.

One example of this is likely to be in the production of hydrogen from electrolysis. This so-called green hydrogen is free from carbon emissions and could ultimately replace fossil fuels in a wide range of applications. But for it to be cost competitive, it requires very low-price electricity. Hence, some models predict that green hydrogen could be produced in Europe whenever there is an excess of wind power. Nowadays this power is simply curtailed but in future, with sector coupling, it could be diverted to power electrolysis at near-zero cost.

Investors wake up to the potential of flexibility

Above and beyond these options, the need for grid operators to juggle different forms of flexibility —discharging a battery here, dialling down a heating system there — requires a new generation of sophisticated digital control platforms, providing yet another tier of investment opportunity. The importance and value of flexibility is growing as the level of variable clean energy on the grid increases.

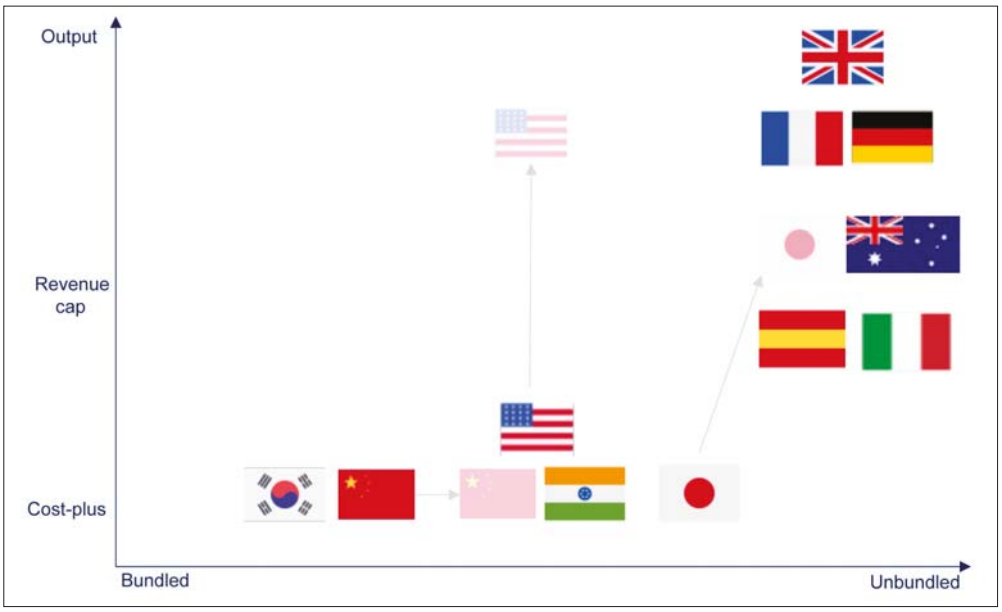
In the US, for example, Stem Inc installs energy storage in commercial properties and manages these so customers reduce energy consumption, benefit from flexible tariffs and get more reliable electricity supplies. Stem's customers include Fortune 500 companies, project developers, utilities and independent

Landmark Acquisitions and Strategic Investments in Flexibility & Grid-Scale Storage

Year	Quarter	Target	Country	Valuation ($m)	Solution	Acquirer/Investors
2020	Q3	Advanced Microgrid Solutions LLC	US	N/A	*Energy Storage Integrator*	Fluence Energy Inc
	Q3	**Anesco Ltd***	UK	N/A	*Grid-scale Energy Storage*	Gridserve Holdings Ltd
	Q4	**Anesco Ltd***	UK	N/A	*Grid-scale Energy Storage*	Gore Street Energy Storage Fund plc
	Q4	Fluence Inc	US	N/A	*Energy Storage Integrator*	Qatar Investment Authority
	Q4	Next Kraftwerke GmbH	Germany	N/A	*Renewables Aggregator*	Royal Dutch Shell plc
2021	Q2	STEM Inc	US	1,350	*Energy Storage Integrator*	Star Peak Energy Transition Corp.
	Q2	Voltus Inc	US	N/A	*Demand Side Response*	Activate Capital
	Q2	Origami Energy Ltd	UK	N/A	*Demand Side Response*	Barclays plc
	Q3	**Aggreko plc***	UK	3,000	*Flexible Stand-By Power*	Isquared Capital Advisors US LLC, TDR Capital LLP
	Q3	**Anesco Ltd***	UK	N/A	*Energy Storage EPC*	Aksiom Group Ltd, Ara Partners Group
	Q3	Open Energi Ltd	UK	N/A	*Demand Side Response*	BP plc
	Q4	Leap Inc	US	N/A	*Demand Side Response*	Park West Asset Management, Sillicon Valley Bank
	Q4	GridX GmbH	Germany	N/A	*Demand Side Response*	E. ON SE
	Q4	**Habitat Energy Ltd***	UK	N/A	*Grid-scale Storage Aggregator*	Quinbrook Infrastructure Partners LLC
	Q4	Getec Gmbh	Germany	3,000	*Energy services Aggregator*	JP Morgan Asset Management Inc
	Q4	Voltus Inc	US	1,300	*Demand Side Response*	Broadscale Acquisition Corp
	Q4	Opus One Solutions Energy Corp	US	N/A	*Demand Side Response*	General Electric Co
	Q4	Voltagrid LLC	US	N/A	*Demand Side Response*	CPPIB

Credit: Alexa Capital

Acquisitions and investments in flexibility and grid-scale energy storage companies have grown in recent quarters (*Transactions advised by Alexa Capital)



Credit: Alexa Capital

As the power sector becomes unbundled, regulators adapt incentive mechanisms for flexibility

power producers, and its Athena software helps solve renewable intermittency across the world's largest network of distributed energy storage systems.

Two other examples are Tesla, which provides flexibility services through battery storage, and Fortum, which fills supply gaps with hydro power in the Nordics and gas-fired power generation in Central Europe. There are many other growth companies emerging in flexibility markets—and they are catching the attention of strategic corporate and institutional investors (see table 1).

Also, institutional investors are accelerating investments into companies that provide flexibility. Qatar Investment Authority invested US$125 million into energy storage solutions company Fluence Energy in the first quarter of 2021. Fluence subsequently raised nearly $900 million in a Q4 2021 public listing. And Voltus, Inc. completed a US$1.3 billion special purpose acquisition company listing, supported by Broadscale Acquisition Corp, in the same quarter.

Where to find the new technology-based business models?

It is no mistake that Open Energi, Limejump, Flexitricity, Habitat Energy and Next Kraftwerke all hailed from Europe. And the companies leading the provision of flexibility services in North America, including Stem, Fluence, Advanced Microgrid Solutions and Voltus, cut their teeth in California. That's because the largest opportunity for flexibility services has been in markets that are highly deregulated and where there is an increasing dominance of variable clean energy on the grid. Having grid constraints and high power pricing, at least at certain volatile peak periods, creates an environment where economic incentives force technology and markets to deliver new solutions.

Because of this, we see flexibility services taking off first and foremost in markets such as Germany, Italy and the UK. Outside Europe, Australia is a big market for flexibility services, particularly in states such as South Australia where clean energy is beginning to dominate the generation mix. The US, meanwhile, is somewhat lagging in flexibility innovation because of the less deregulated nature of its electricity networks – however, flexibility services are beginning to take off rapidly in states such as California and Texas. And the outlook for flexibility is on the up.

We anticipate more regions will transition toward unbundled regulation in order to attract the vast pools of institutional capital to fund renewable infrastructure. With this shift, these more deregulated markets must embrace flexibility solutions to deliver low carbon energy system stability. And we expect more cross-border capital flows into these deregulating markets – from both strategic corporates as well as institutional and 'infrastructure plus' investors which bring expertise and

Case Study: Quinbrook Infrastructure Partners

Quinbrook Infrastructure Partners has a long history of investing in flexibility, supported by a management team that has been on the leading edge of power market investing for many years.

Quinbrook recently launched an aggressive investment programme around flexibility, firstly through Velox Power, a UK business managing grid-supporting clean and renewable gas generation, including high-efficiency, low capacity-factor gas generation plus grid-scale energy storage. In September 2020, Quinbrook expanded its flexible services capabilities with the acquisition of Flexitricity, one of the first companies to offer digitally-controlled demand-side flexibility services to industrial & commercial customers. Flexitricity had developed a virtual power plant (VPP) platform over the past 15 years and has developed a portfolio of nearly 1,000 megawatts of aggregated flexibility across the UK managed through its algorithmic AI control centre based in Edinburgh, Scotland.

In November 2021, Quinbrook further expanded its flexibility portfolio with the acquisition of Habitat Energy. Habitat Energy, based in Oxford, UK, has developed a leading battery storage optimisation and trading platform which enables performance management and revenue optimisation for grid-scale energy storage. These acquisitions have helped Quinbrook develop a portfolio of flexibility services that it is now using to target electricity markets in multiple geographies, including Australia and the USA, where it is focusing on clean energy intensive grids such as those operated by the Electric Reliability Council of Texas (ERCOT).

Ultimately, Quinbrook plans to provide an end-to-end suite of dynamic flexibility offerings stretching from generation grid assets to customer-based demand centres. The company is addressing what co-founder David Scaysbrook defines as 'covariance risk': where growing levels of renewable capacity leads to zero or negative energy pricing as the wind turbines or solar panels in a region produce simultaneously at times of high renewable resource.

"The market is quickly moving away from vanilla wind and solar development and shifting to favour those [projects] that are multi-technology," Scaysbrook says. "What the market wants is a carbon-free, round-the-clock product. Flexitricity was compelling because it's one of the leading demand-side response enterprises in the UK. [The] Habitat [deal] was driven by a belief in the proliferation of

battery storage. Those enabling technologies exist on their own. Our role is to synthesise them into a workable whole."

experience as well as capital. As the chart above shows, alongside continued investment into the UK, Australia, Texas and California, we anticipate a greater focus on markets such as Spain, Italy, Ireland, Germany, Holland and, in due course, Japan – all of which have aggressive renewable generation development targets.

The growing opportunity for capital flows

In fact, it is not a stretch to say that flexibility is likely to be one of the greatest investment opportunities of the energy transition. It is a prerequisite to being able to operate grids in the absence of fossil fuels. This alone should set apart flexibility as a major investment class, but in addition flexible service operators are rapidly developing new value-added offerings.

> "It is not a stretch to say that flexibility is likely to be one of the greatest investment opportunities of the energy transition"

And their sphere of action is expanding from the grid to encompass other sectors, from households and C&I companies to electric vehicle charging and carbon offsetting. This is leading to growing opportunities for flexibility-related digital integration and engineering services. The flexibility providers of the future will likely offer a broad range of value-added services, from energy management, asset optimisation and resiliency of supply to clean power provision and net-zero pathway development.

The potential for players to participate in the emerging flexibility landscape is so vast that it is hard to predict where future winners will lie. Sectors as varied as software, automotive and Big Tech are all seeing the importance of electrification and looking for ways to add value. We are moving to a world where all sources of electric supply and demand, from the solar panel on your roof and the immersion heater in your hot water tank to the kettle in your kitchen are connected by digital networks and interact with each other to keep the grid stable.

In this world, next-generation utilities will build on flexibility to offer products such as heat-as-a-service (HaaS) or decarbonisation-on-demand. There is a good chance that traditional utilities will not survive the transition. But before then, regulation needs to catch up with technology. As was evident from the wild swings in energy prices worldwide in 2021, the way power markets are regulated today does not support the way flexibility needs to work tomorrow. ■

Author

Bruce is CEO of Alexa Capital. Throughout his career, he has advised on hundreds of capital markets and M&A transactions, including IPOs, follow-ons, convertible & debt, energy project financing, as well as corporate finance, including public and private M&A. Before establishing Alexa Capital, Bruce was previously Global Head of Cleantech Investment Banking for Jefferies & Co. where he led the industry group operating across offices in Frankfurt, London, New York, San Francisco, Mumbai and Shanghai.

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Introduction

Welcome to the latest edition of 'Storage and Smart Power,' brought to you by Energy-Storage.news.

Last year was one of phenomenal growth for the energy storage industry, but of course, if you're reading this, you probably already know that.

You probably also realise that the trend needs to continue. That growth needs to accelerate and extend into more corners of the globe, if the industry is to reach the scale needed to modernise and decarbonise the world's energy sector.

Recent figures from the American Clean Power Association point to 2.6GW/10.8GWh of utility-scale battery storage deployments in 2021, with over 1GW brought online in Q4 2021 alone.

At Energy-Storage.news we've reported throughout the year on many of the projects in that deployment base in the US. We've also written about and discussed some of the other leading markets, like the UK, Australia and China.

However, opportunities have also opened up — or are beginning to open up — in various European countries like Belgium, Germany, Italy, the Netherlands and France. Some of Africa's first large-scale battery storage projects are underway, key markets in Latin America like Chile and Mexico are starting to see deployments and in Asia, the Philippines, Taiwan and India are among regional markets picking up pace too.

It's been tremendously exciting to report on many of those developments and we're hoping 2022 will bring many more.

But with supply chains still disrupted by the COVID-10 pandemic, international politics on an unsteady footing and the power of petrodollar lobbying being brandished, we all know nothing comes easy.

We're committed to bringing you the best in news, analysis and commentary so that as a publisher, we can play our small part in helping this exciting industry and we look forward to hearing from many of you throughout the year.

In this edition, we look at the supply chain issue and a number of other key upstream factors impacting the growth of a European battery storage industry, in a contributed article from Emad Zand, president and Northvolt Systems.

Northvolt is building out dozens of gigawatt-hours of battery manufacturing in Europe and while its main off-takers will be the automotive industry, subsidiary Northvolt Systems is strongly committed to the stationary energy storage space, Emad writes.

We have a special energy storage entry in the popular PV Tech Power regular 'Project Briefing' series: Energy-Storage.news writer Cameron Murray takes a close look at Energy Superhub Oxford in the UK, which features the world's biggest lithium-vanadium hybrid battery storage plant.

Last but not least, Charley Grimston, co-founder of specialist data-driven battery insurance technology company Altelium, writes about the importance of insurance in underpinning, and indeed underwriting, the success of the battery industry, with a mix of big picture dynamics and a focused look at his company's work.

As always, thanks for your attention and we hope you enjoy this edition of Storage & Smart Power.

Andy Colthorpe
Solar Media

Expansion plan to take world's biggest battery storage project to 3GWh

Plans to nearly double the output and capacity of the world's biggest battery energy storage system (BESS) project to date have been announced.

Owner Vistra Energy wants to add another 350MW/1,400MWh BESS to the Moss Landing Energy Storage Facility in California's Monterey Bay. The existing facility is 400MW/1,600MWh and was brought online in two phases.

A 15-year Resource Adequacy agreement has already been signed with California investor-owned utility (IOU) Pacific Gas & Electric (PG&E) for the new capacity and submitted to the regulatory body California Public Utilities Commission (CPUC) for approval.

Vistra has said the site and its interconnection allow for it to eventually bring Moss Landing Energy Storage Facility to 1,500MW/6,000MWh, if market conditions allow it to meet demand.

Credit: LG Energy Solution.

Battery racks inside Moss Landing Energy Storage Facility in Monterrey, California.

Batteries not cause of overheating or smoke that forced Moss Landing project offline

In related news, Vistra Energy expects the 300MW/1,200MWh Phase I of Moss Landing Energy Storage Facility to come back online during the first half of this year. After an incident on 4 September 2021, where overheating was reportedly detected in battery modules, Phase I was taken offline and remains out of action. Phase II (100MW/400MWh) is still operational.

The incident caused "limited battery damage" to about 7% of Phase I's battery modules, while "other facility systems" were also damaged. It appears that rather than battery modules overheating and causing the incident, it was actually a sprinkler system's response to smoke coming from an air handling unit, in which a bearing had failed.

It appears the Very Early Smoke Detection Apparatus (VESDA) onsite triggered the spray of water at a threshold of smoke detection below what should have been required. This was likely due to a programming error in the VESDA, Vistra said.

QuantumScape signs up Fluence as first non-automotive partner for solid-state battery tech

Fluence has entered a collaboration with solid-state lithium-metal battery startup QuantumScape, with the pair working together to develop stationary energy storage solutions using the new technology. Solid-state technology offers the potential to increase energy density, charging time and safety of operation of lithium batteries, replacing the liquid electrolyte with solid material. Designing solid-state batteries that last a large number of cycles at scale and at low cost however has proven difficult so far. QuantumScape claims to have made key breakthroughs in the technology. Its partners include automaker Volkswagen, which has invested US$300 million into it the company to date.

Energy storage technology and services provider Fluence is the first non-automotive company to sign agreements with the startup.

Eight-hour lithium-ion project selected in California long-duration procurement

An eight-hour duration lithium-ion battery project has become the first long-duration energy storage resource selected by members of California Community Power (CC Power), a Joint Powers Agency representing non-profit energy suppliers.

Seven member organisations voted to enter into an energy storage service agreement for the project with its developer, REV Renewables, a subsidiary of LS Power.

The project, called Tumbleweed, will have 69MW output and 552MWh capacity and is expected to come online in 2026, connected to the California Independent System Operator (CAISO) grid.

It comes as a result of the regulatory California Public Utilities Commission (CPUC) ruling that energy suppliers in the state must bring online 11.5GW of energy resources — nearly all of which have to be low or zero-emissions — within five years to ensure what it defined as 'Mid-Term Reliability'.

Honeywell signs 19GWh 'next-gen' battery deal with startup FREYR Battery

A major supply deal and exchange of energy storage system (ESS) technologies and components has been agreed between Honeywell and Norwegian lithium-ion battery manufacturing startup FREYR Battery.

FREYR is building out gigafactories in Europe, with an emphasis on sustainably sourced materials and low-carbon production, beginning with its first 2GWh plant currently under construction in Mo i Rana, Norway and targeting up to 83GWh of annual production capacity by 2028.

FREYR will leverage Honeywell's various relevant technology offerings, such as industrial software, integrated automation, field instrumentation and security integration solutions into its manufacturing processes, subject to viability.

Honeywell meanwhile will purchase 19GWh of FREYR's battery cells between 2023 and 2030.

Flow batteries to be installed at Alberta solar-plus-storage projects

An eight-hour duration Lockheed Martin flow battery energy storage system will be deployed at a 102.5MW solar PV project in Canada. Lockheed Martin is investing US$9 million towards Saddlebrook Solar + Storage Project, in Alberta, Canada, which is under development by energy infrastructure company TC Energy.

A 6.5MW / 52MWh Lockheed Martin GridStar Flow battery energy storage system (BESS) will be integrated with the project's bifacial solar modules, storing solar energy so it can be dispatched to the Alberta electricity network at peak times.

It marks the first large-scale pilot for the technology which Lockheed Martin, best known for its aerospace and defence tech solutions, has been developing for some time.

At another Alberta project, Chappice Lake Solar + Storage, Invinity Energy Systems will supply a 2.8MW/8.4MWh vanadium flow battery system to be DC-coupled with 21MWp of solar PV. Both projects are being supported by Emissions Reduction Alberta.

Data-driven insurance for batteries: An unsung hero of the green energy transition

Insurance | Insurance is a cornerstone of de-risking financing and investment into energy storage. Data and analytics-driven decision making is not only for the operation and optimisation of batteries, it's also vital for peace of mind and cementing the long-term success of the industry, Charley Grimston, co-founder of specialist insurer Altelium writes.

Credit: Altelium.

Insurance has always been a building block of market growth. The possession of insurance or, in the case of lithium-ion battery products, an insured warranty, is a sign that the product is supported, understood, evaluated and assessed against risk.

The warranty will last beyond the life of the original manufacturer and gives the product quality assurance and bankability, enabling the market to grow and mature. It therefore plays a vital role in the development of the battery energy storage market.

In addition to this role in helping to secure finance, or in taking risk and financial liability off a business's balance sheet, insurance can play a key part in helping to meet Environmental Social and Governance (ESG) targets. In doing this, it also helps address and overcome some of the key challenges of the sector, namely confidence in battery lifecycles and fire safety risks.

Insurance impacts on nearly every aspect of creating a successful market for energy storage.

This is because the information and techniques required to secure insurance, such as due diligence of risk and risk mitigation, are also required by new climate change regulations.

The process can also play a meaningful part in establishing best practice procedures relating to site planning, design and operation to mitigate fire risk, particularly in the context of securing Operational All Risk (OAR) insurance for energy storage sites.

The global standard for corporate climate-related financial reporting is the framework of The Task Force on Climate-related Financial Disclosures (TCFD). Endorsed by the G7 and G20, more than 2,200 organisations have officially supported reporting in alignment with the TCFD.

Countries like the UK and New Zealand have introduced mandatory reporting requirements aligned with the TCFD's recommendations, and US president Joe Biden is quoted as saying that his administration's policy is to promote "consistent, clear, intelligible, comparable, and accurate disclosure of climate-related financial risk" and to "act to mitigate that risk and its drivers".

The demand from investors for meaningful information on how companies are preparing for the climate transition is directly relevant to anyone operating in the energy storage market.

While this top-down pressure is being applied, there is also pressure from the bottom up, as consumer rights are strengthened. For example, the Danish consumer ombudsman recently confirmed that scientific documentation such as life cycle analysis must be provided to back up green claims, with sizeable fines for any company found guilty of 'greenwashing'.

Similarly, in the UK the Competition and Markets Authority (CMA) has begun its review of industries where there are consumer concerns about misleading 'green claims'.

Credit: Flickr user Phil Roeder

President Biden has emphasised the importance of disclosing climate-related financial risk.

Claims of 'green wash' will be judged against the six principles that are based on existing consumer law:

- Claims must be truthful and accurate
- Claims must be clear and unambiguous
- Claims must not omit or hide important relevant information
- Comparisons must be fair and meaningful
- Claims must consider the full life cycle of the product or service
- Claims must be substantiated

It's easy to see how these six principles could be applied to insurance, or the provision of information as part of the insurance process.

Understand risk to reap rewards

In the same way that life cycle analysis of carbon emissions has to be calculated at every stage in the product's development, from first to end of life to give a realistic calculation of carbon output (or reduction) so too risk has to be understood and quantified at every stage; from understanding manufacturing systems and internal battery chemistry, to knowledge about best practice operating plans and procedures in energy storage systems.

This is why insurers who specialise specifically in batteries are so important to the future of the energy storage market, because few have the ability to understand the chemistry and technology involved, or the ability to process and apply the battery data required to understand, mitigate and price the risk to offer realistically valued premiums and meaningful terms.

While energy storage companies will want to ensure good ESG ratings for their stakeholders, investors and customers, the metrics and processes involved can play an important part in securing insurance, reducing risk, improving operational safety and increasing profitability.

An example of how this will work in practice is provided by the Moss Landing Energy Storage Facility, at 400MW/1,600MWh currently the world's largest battery energy storage system (BESS) project. Its 300MW/1,200MWh Phase 1 shut down last September following "a high temperature event". It will come back online in the first half of this year.

It has been reported that rather than battery modules overheating and causing the incident, it was actually a sprinkler system's response to smoke coming from an air handling unit. A bearing unit failed, which caused the heat detection system to trigger automatic flooding.

There had initially been no battery failure although the automatic drenching caused damage to 7% of the installed battery modules.

Future energy storage sites will now take such a circumstance into account and the likelihood of it happening again will be planned out though different sensors and systems.

Reviewing design plans, including heating and ventilation, fire detection systems such as gas detection and infrared thermal cameras, plus water management, spacing of units and blast walls, will all be part of good risk mitigation and planning.

Work together with your insurer

There is, of course, mutual interest between lenders and borrowers in ensuring projects are appropriately protected against relevant risk exposures. The more well designed and operated the storage system, the more favourable the insurance terms will be and it stands to reason, the more sustainable and higher ranking on any ESG framework that asset will perform.

Insurers are the keepers of extensive applied battery knowledge and experience, and by forming a good working relationship and sharing knowledge with them, the energy storage market will benefit from this expertise through improved premiums and services.

There are two layers to the process used by insurers to assess risk. Firstly the reference data of the batteries involved is examined, to understand the battery chemistry and the electrical architecture within the BESS. The second layer is to look at the operational data from the site to understand how the asset has been designed and built and how it is being managed - the system of checks and maintenance in place.

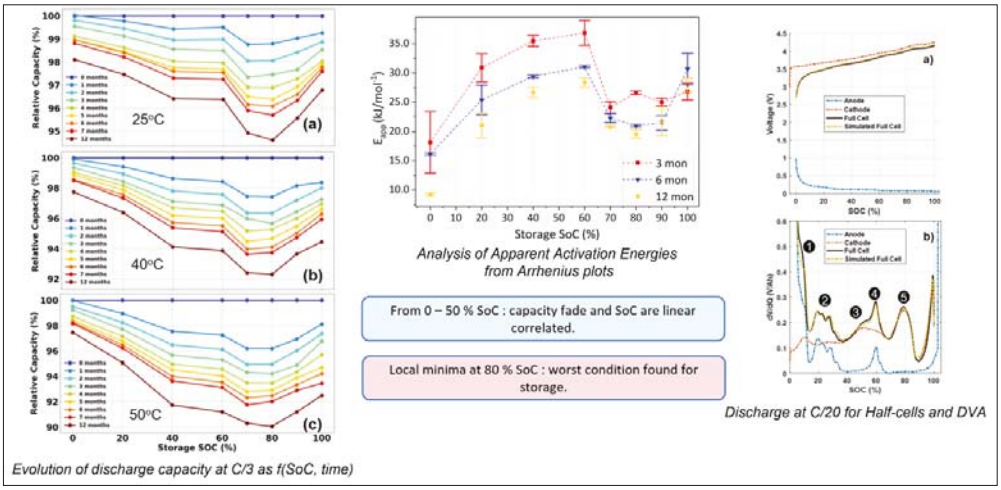
AI and advanced science replaces historical reference points. Altelium for example works with Lancaster and Newcastle Universities in the UK, each specialists in different areas of lithium-ion chemistry, and our co-founder Professor Harry Hoster is Scientific Director of ZBT, Centre for Hydrogen and Fuel Cell Technology at Duisburg-Essen University, Germany.

How battery data is gathered and used

Battery chemistry and health is obviously the predictor of future health and safety. Knowing the internal resistance of a battery cell gives an indication of lithium plating which affects both degradation and likelihood of short circuits occurring.

The data on different chemistries and performance against charging cycles and operating conditions is gained through enhancing real life battery data from telematics and connected devices with AI, and testing batteries in laboratory conditions to both gather raw data and test the AI modelling outcomes.

Lithium ion battery degradation slide Dr Alana Zülke.png



Credit: Dr Alana Zülke / Altelium

Up to 150 battery cells can be simultaneously tested, ageing batches of batteries under different, well defined conditions of current, voltage and temperature. This speeds up a process that normally takes a year to a matter of weeks.

We can determine from the data what the gradient of degradation is and match that against the mean data we have for that chemistry, and also determine other factors inside the battery.

The chart below is taken from a presentation given at the 2021 Altelium Industry Day where Dr Alana Zülke presented the results of a four year research project between five universities, coordinated from the Lancaster Energy Bat Lab, to test the affect of calendar and cyclic ageing on batteries.

This has proven that battery degradation is highly dependent on the charge level at which the battery is left and on the ambient temperature, factors which are at play in all BESS facilities. The research allows optimised life prediction models to be developed and informs better use strategies to extend the durability of batteries.

This informs due diligence, where we assess the design and manufacturing process to consider all the electrical and electro mechanical systems within the BESS to identify the failure rate of different parts and their optimal operating condition.

Running data monitors the performance of the asset for compliance against insurance terms and allows us to feed back data to the operator so that they can optimise the asset lifetime and output.

On the fire risk and explosion side, the design of the battery is explored but also the design of the system within the container, and the overall site layout, what we describe as the second layer of assessment.

Looking at the site, it is vital for example that there is proper separation of units one from another, with fire walls between each; proper types of fail-safe systems must be in place so that the system can be shut down by a bystander or emergency responder.

From a sustainability and risk perspective this is clearly a symbiotic relationship. While we are looking for good design from factors such as chemistry and cooling systems, and good husbandry from asset management and maintenance, site owners are looking to protect their assets and investment and optimise their returns through the same processes.

Connected Energy's 1.2MW/720kWh BESS project assembled using Renault second-life EV batteries at an industrial site in Belgium, Europe.

Credit: Connected Energy

Learning from the UK's biggest BESS made with repurposed EV batteries

This process has just been under been undertaken at Cranfield University, a British postgrad research university. It has installed a BESS to allow the site to balance its energy behind the grid, accommodate a newly enlarged solar farm and an air source heat pump on the district heating to reduce reliance on the gas-combined heat and power system (CHP).

While Cranfield's system is dwarfed by sites such as Moss Landing, what is significant about it is that it's the biggest second-life battery storage system to date in the UK.

The three containers supplied by Connected Energy each hold 24 second-life Renault Kangoo car batteries. One will take excess solar generation at the weekends and deliver this back to the campus on Monday. Two others will connect the battery storage system directly into two of the site's 40 transformers. This scale of application is exactly what many organisations across the world will need to switch to green energy solutions, reduce their reliance on fossil fuel-based energy and meet net zero targets.

Perhaps even more importantly, Cranfield is a blueprint for the EV industry, where batteries are given a second life.

This second life must be facilitated to reduce waste and maximise the use of the embedded carbon locked in vehicle batteries, and in this respect having the ability to diagnose healthy batteries is absolutely crucial.

Strong ESG ratings can mean lower capital costs

Mitigation through risk transfer to the insurance market through organisations such as Altelium is one of the most cost-effective, tried and tested ways of obtaining such protection for insurable risks. Plus as mentioned, it can provide key metrics for ESG targets or climate-related financial disclosures.

What those metrics should be is still open to discussion. There are several agencies specifically established to provide ESG ratings, such as MSCI, Vigeo Eiris which is part of Moody's Investors Service, FTSE Russell from the London Stock Exchange Group and RobecoSAM.

All work on the basis of rules-based methodologies, for example Vigoe Eiris applies a score from 0 – 199 against up to 38 criteria developed for 40 different industries.

Because a good ESG rating can help attract a lower cost of capital there is a big incentive to scoring well on these measures, beyond the desire to do the right thing for the environment. A high ESG rating can also help to recruit and retain staff and customers, but gathering, collating and scoring the required data can be complex task. Using the data for insurance purposes adds value to the work involved.

The most important aspect to the metrics, from the point of view of ESG and the CAS principles, are that they are clear and meaningful and this is obviously applicable to the insurance and warranty application process too.

The key steps in supplying information for insurance assessment, ESG or climate disclosure are:

1. Share information & plans
2. Create a framework of questions and answers which can form KPIs and be easily updated
2. Provide regular feedback of any changes to plans

3. Share learning from across the market, as in the Moss Landing example to build on and share from experience.
4. Involve specialists such as fire experts or design engineers from your insurers team

At Altelium we have an online system or platform which provides a step-by-step guide through this process, and most insurers are moving to this type of model.

Adapting, learning and overcoming industry's challenges

Once an account or customer is accepted, an online 'wizard' prompts with question and responds intelligently with further questions and prompts to help capture all the information required to assess risk and provide insurance cover.

Platforms such as this are often called 'end-to-end' because the entire process from initial due diligence, data analysis, paperwork and payment, monitoring and management processes are all handled within one Cloud-based, secure system.

"With an active and engaged insurance market, the sector will be able to adapt, learn and overcome the challenges it faces"

With an active and engaged insurance market, the sector will be able to adapt, learn and overcome the challenges it faces, most notably in mitigating fire risk and also further down the line, trading in second life batteries and managing them at their end of life.

In December the EU published its Circular Economy Action plan outlining the mandatory requirements for all batteries (i.e. industrial, automotive, electric vehicle and portable) placed on the EU market. Requirements include use of responsibly sourced materials with restricted use of hazardous substances, minimum content of recycled materials, carbon footprint, performance and durability and labelling, as well as meeting collection and recycling targets.

With its emphasis on end of life and recycling this is another area where insurance will help to inspire the necessary finance to invest in recycling plants as well as develop protocols and procedures for the safe handling and transportation of used batteries.

When the system of disclosures and reporting is working well it will be the driver for the transition to green energy through battery storage systems operating under ever safer and more sustainable conditions, with insurance underpinning a lively and rewarding market. ■

Author

Charley Grimston is executive Chairman and co-founder of Altelium, an insurtech business offering insurance for batteries driven by real-time AI-powered data analytics. He has deep experience of the insurance industry and floated the first Lloyd's quoted investment trust underwriting vehicle on the London Stock Exchange, under the Hambro Conning Grimston flag (HCG Lloyd's Investment Trust plc). Charley was a founder member of Lloyd's Corporate Capital Association.
He remembers the excitement of first seeing a US wind turbine in 1976 being underwritten in the Lloyd's market and has been involved in the green energy industry ever since. Charley is a member of the British Standards Institution (BSI) committee which developed the UK standards for safe and environmentally conscious handling of battery packs and modules.

Building a battery industry for Europe

Manufacturing | By now, everyone's heard of Northvolt, the Sweden-headquartered startup founded by former Tesla exec Peter Carlsson, building 150GWh of lithium-ion battery factories in Europe. But while investments and off-take deals from the automotive industry have rightly been a major focus of attention, its stationary energy storage division Northvolt Systems has a story to tell too. By Emad Zand, president, Northvolt Systems.

Credit: Northvolt

At Northvolt Systems we're working for a clean energy future by contributing to the establishing of a new industrial base for lithium-ion battery solutions in Europe.

Just as we've seen with developing a renewable energy industry, fostering a domestic battery energy storage industry not only represents a significant economic opportunity for Europe, but security of supply for a technology that is a linchpin in the transition towards clean energy.

Establishing this new industry isn't straight-forward and there are certainly challenges in developing the necessary components for a world-leading, sustainable supply chain, but we're further along than people might think. From our perspective, Europe holds all the right ingredients to become a global leader in battery energy storage solutions and it has every reason to embrace this opportunity.

The evolving European landscape for ESS

It's fair to begin with acknowledging that while battery energy storage remains a young industry within Europe, it is one full of promise and potential.

The potential stems from the idea that Europe holds all the right competences to support a complete, globally competitive battery storage supply chain. By embracing the opportunities of this new industry and driving them to their full economic potential, Europe could very well become the leading global supplier of battery energy storage to a global market forecasted to attract some US$262 billion in investment out to 2030.

Many in the energy industry recall how 15 years ago Europe was tipped for leading the solar PV industry. But for reasons including lack of engagement from industry, as well as from governments and the EU to create favourable conditions,

Northvolt might be best known as a cell manufacturer for the automotive industry, but it's also a producer of whole battery systems for two distinct market segments: Industrial and Grid.

the opportunity was lost. It is precisely this which we must avoid with the battery industry.

To the promise, we need look no further than case studies of deployed energy storage systems (ESSs) for evidence of what the technology can do to quicken the adoption of clean energy and enable the transition away from fossil fuels. And indeed, there are even pioneering European ESS companies operating within this landscape – albeit with cells and batteries sourced from Asia, the long-standing home of the lithium-ion battery industry.

The relative immaturity of the ESS industry can be understood for two core reasons. First, since the region has historically lacked upstream cell production, it has not been in an ideal position to foster either battery competence or synergies in battery solutions.

Second, while theoretical need for energy storage has been recognised for

some time, the realisable market demand has lagged behind. Clear market structures and reliable revenue streams for the operation of ESS are a prerequisite for business-case viable projects, but they also serve to encourage investment in components of industry itself, including components suppliers and developers.

To both points – the location of cell manufacturing and the viability of ESS – we see change that leaves Europe not only well-positioned and motivated to mature its ESS supply chain, but to lead it.

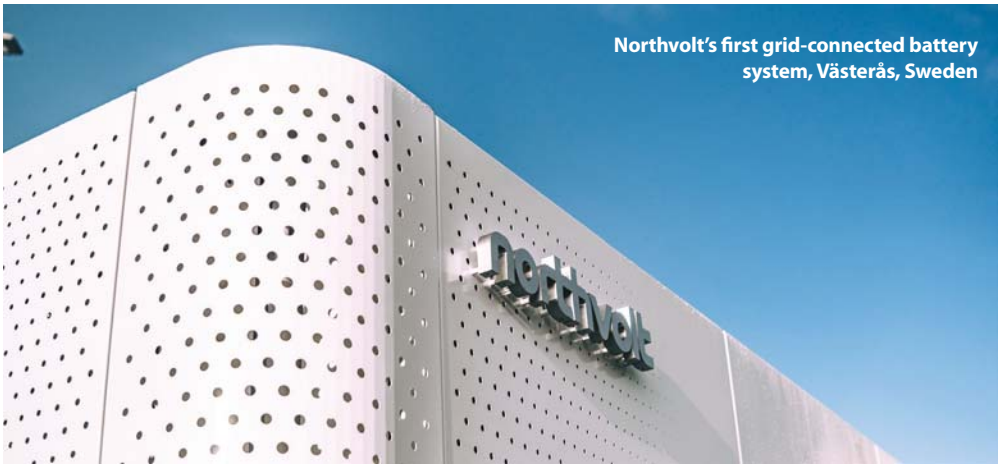
Europe is well underway in scaling up its cell production capacity: long-time champion of the European battery chain, European Commission Vice-President Maroš Šefčovič, has stated that by 2025 Europe will be the second largest producer of batteries in the world and supplying almost 90% of its domestic battery production needs.

In parallel, markets have become more favourable for energy storage deployments. To be sure, some markets are further ahead than others, certainly the UK and Germany can be highlighted in this respect; but broadly we have the right foundations which are strengthened by EU commitments to decarbonisation.

There are of course still challenges for the European supply chain, but above all there is opportunity. It is telling that in acknowledging the need for its own proactivity towards batteries, the US government has recognised the approach of Europe towards fostering a domestic battery supply chain. The acknowledgement is well-earned. The EU has a proven track-record for nurturing its battery industry – focussing on cell manufacturing, upstream materials preparation and recycling.

Embedded within the EU's approach is a particular focus on calls for sustainability within the battery industry. This is prudent – positioning the new industry to leverage what can become a differentiating factor for European products. On this front, new legislation currently under development in Brussels, namely the Battery Directive, is key.

The European Commission's Battery Directive proposals are well-aligned with what Northvolt strives towards. Notable highlights include mandating of carbon footprint labelling, new procedures to ensure ethical sourcing of raw materials and ambitions for battery recycling. Stakeholders to the emerging European battery landscape should embrace sustainability from the outset.



Northvolt's first grid-connected battery system, Västerås, Sweden

Credit: Northvolt

BloombergNEF forecasts installations in the order of 1TWh of energy storage by 2030, with much allocated for Europe. Beyond the value of directly enabling these European deployments, the real opportunity is for Europe to become home to leading ESS developers supplying the global market, much as we see with wind power and energy efficiency technology.

With the right approach, in time what we could come to see in the European battery energy storage industry is a textbook example of the environmental, societal and economic gains to be secured in repositioning industrial might in manner aligned with demands of a world facing a climate emergency.

Scaling for an energy revolution

When we set out to begin developing battery systems there were few European companies engaged in the grid-scale battery solutions ecosystem. The few players out there were invariably operating in high-end, niche fields, designing for small orders at high cost.

What we envisioned was quite different. At Northvolt, we're in business of accelerating the shift away from fossil fuels. As it is with developing cells for the automotive industry, building a successful ESS industry in Europe requires safe, high-performance products, scaling manufacturing and cutting costs. This philosophy has shaped our approach, both in terms of product design and developing manufacturing capacity.

At the same time, this thinking determined strategic positioning towards the supply chain itself. And we faced challenges here. Europe didn't have a supply chain full of players with proven track records in delivering to large-volume, battery systems development.

Accordingly, we've taken an unconventional approach to seek out competences rather than products. What that means in practical terms is that many of our suppliers are not traditionally battery component suppliers. Instead, we've aligned ourselves with groups possessing the right manufacturing and technical competence, together with an attitude for growth and adaptability that matched our own.

This approach has been successful for key components including mechanics, electronics, and thermal solutions. We've found great partners with the right competences, and with a few exceptions our supply base is European. And this shouldn't be surprising – Europe, after all, might not always be able to compete on cost against Asian manufacturing, but what it does have is high-end competence to build to specification, to certification, and build well.

And this is just what is required in a battery system. These are sophisticated products after all, which must be built according to rigorous safety and quality requirements.

In part, the strategy worked because of how we've scaled the team at Northvolt Systems. In keeping with Northvolt's tendency towards consolidating verticals of the cell supply chain within its own activities, Northvolt Systems has built up specialised competences for systems design, development, testing and production in-house, leaving dependency on outside suppliers only for select components.

Localising supply chains

Selecting for European suppliers is key to strengthening the supply chain in the region. First and foremost, it enables these companies to build up experience with battery systems products and enhance their competitiveness. Relatedly, supplier visibility on their role to play in contributing to the industry will encourage their

own investment in necessary equipment and dedicated facilities to support the industry and expand their capacities.

Additional benefits stem from localising the supply chain too. The alternative is a reliance on distant component suppliers. Aside from the increased environmental footprint associated with this, what the Covid-19 pandemic demonstrated was the very real risks associated with trans-continental supply chains. Given the opportunity we have in Europe to build up this new industry from scratch, it would be a mistake not to embed sustainability and resilience against supply chain disruption within it from the outset.

Again, we can highlight that EU policy and ESS markets are moving in the same direction as the EV market – with both OEMs and end-customers starting to look under the hood of the cell and whole battery system. All players in the ESS ecosystem have a role to play in ensuring sustainability and transparency of their products; and developing the local value chain is crucial to securing this.

Safety and sustainability

Within ESS, the cell is key. As mentioned, Europe has proven itself swift to establish a domestic cell supply and this continued focus provides a springboard to developing a robust ESS industry, which lies downstream of cell manufacturing but prospers from synergies arising when the two are geographically localised.

Northvolt Systems will source lithium-ion cells from Northvolt Ett, the battery gigafactory, located in northern Sweden. As a battery systems developer we have several requirements for cell supply. Low cost being a prerequisite, safety would be the next fundamental. The emerging European ESS supply chain cannot be relaxed towards this point – we've seen examples of what happens when battery systems fail.

Fortunately, this is an area where Europe can excel and set the global benchmark for safety in battery systems. Assurance on safety of battery systems is already a hygiene factor for customers, and rightfully so. It's worth noting that aside from physical design providing a route to safety, digital technologies provide a powerful toolbox to be leveraged in pursuit of safe systems.

Digitalisation is prioritised at Northvolt Systems, and we have a dedicated software team developing what we term Connected Battery digital architecture. We see that software not only enhances safety of systems but is vital to harnessing the full potential of batteries across the multiple applications they can serve for their full lifecycle. Connectivity enables optimisation of cell and module performance, reduces the need for reactive maintenance and is altogether the backbone to lowering total cost of ownership over the lifetime of the system.

Beyond safety, we prioritise sustainability, that's to say having both a cell that carries a low environmental footprint and transparency on its raw materials. As mentioned, European policy will begin demanding this. But so too will ESS customers. It's therefore critical for the battery systems supply chain to already today be planning for this future. Ultimately, like safety, sustainability can become a valuable differentiating factor for the European ESS industry and strengthen its competitiveness.

Build to cost, build to scale

For the European ESS industry to scale towards global leadership, it's critical to design both manufacturing and product technologies to enable competitive pricing. For this, one insight we've had is the importance of modularity. That is to say, designing a base module for integration into packs and systems that can easily be scaled with minimal additional design requirements or components.

The aim to design products for scalability extends to how we deliver new manufacturing capacity. Here too, we can be smart in how we establish factories. A balance must be found between CAPEX and OPEX. There is an unavoidable sizeable upfront cost to deliver assembly lines, but we can be smart in selecting machinery and tools, which when paired with well-designed products, is future-proofed for future battery systems products.

Especially on the mechanical and assembly sides, leveraging large-scale manufacturing techniques and methods – which Europe has considerable experience of from other sectors – is invariable rewarded with lower unit costs.

Reflecting what the European battery systems industry can and should become, we can highlight Northvolt Systems Dwa – the battery systems assembly facility under development in Gdansk, Poland. The facility will feature highly automated assembly lines for high-volume production of modules and module-to-pack integration. A port city with excellent road access to the continent, the facility is well-positioned for both inbound volumes of cells from Northvolt Ett and components and for outbound product flows.

Northvolt will invest US$200 million to build this new battery systems factory and it will become the largest of its kind in Europe. Development is already underway and production is scheduled to begin in 2022 with an initial annual capacity of 5GWh and a potential future capacity of 12GWh.

Batteries are rapidly becoming a cornerstone technology of energy, mobility and societal functioning at large. For Europe to transition effectively to net-zero, it requires battery systems of its own. But the opportunity is much greater. We missed our chance with solar PV, let's not make the same mistake with batteries. ■

Credit: Northvolt

Northvolt's Voltpack Mobile System providing temporary energy storage

Author

Emad Zand is the President of the Systems division at Northvolt. He joined the company in 2017 as part of the early team. Prior to joining Northvolt, Emad was active as an angel investor and board professional after leaving his role as CEO of a medical device company, where he completed a successful turnaround and sale. Emad has a Master's degree in Economics from Stockholm School of Economics and started his career at McKinsey & Co.

Project briefing

WORLD'S LARGEST LITHIUM-VANADIUM HYBRID BESS TRIALLED AT OXFORD

Project name: Energy Superhub Oxford
Location: Oxford, UK
Capacity: 55 MWh (50 MW/50MWh Lithium-ion, 2MW/5MWh Vanadium flow battery)
Energisation date: July 2021 (Lithium-ion), December 2021 (Vanadium flow)
Developer/asset owner: Pivot Power, part of EDF Renewables
Technology providers: Wärtsilä, Infinity Energy Systems
Optimiser and trader: Habitat Energy

Known globally for its university, Oxford is now making a name for itself as a testing ground for the largest hybrid battery energy storage system (BESS) of its kind anywhere in the world.

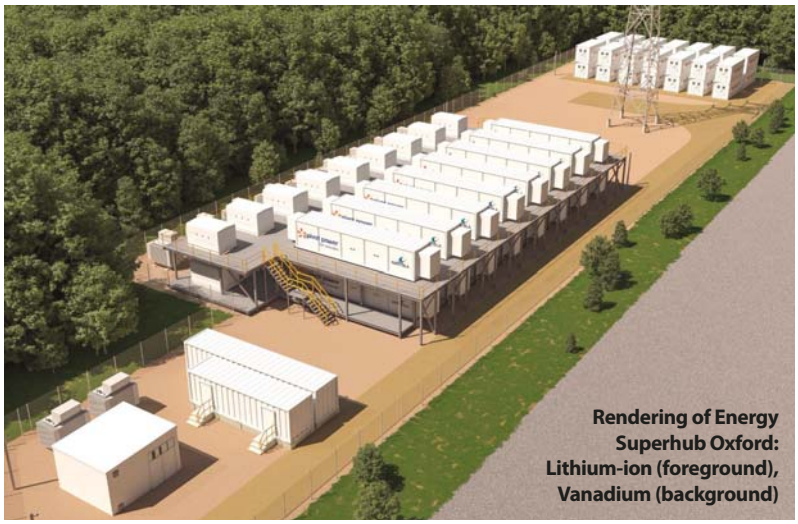
Energy Superhub Oxford (ESO), set to fully launch in the next few months, is the result of three years' work by a consortium of private sector organisations, the local council (local authority) and the University of Oxford, plus government body Innovate UK which funded a quarter of its £41 million (US$55.8 million) cost.

The engine room of the ESO is the largest lithium-vanadium hybrid BESS in the world, which combines the high-power of lithium-ion battery storage with heavy-cycling, non-degrading vanadium redox flow. Also part of the project are the UK's largest public electric vehicle (EV) charging park and 60 residential ground source heat pump retrofits. Vanadium batteries are at a much earlier stage of commercialisation than lithium, making the ESO fundamentally a demonstrator project with multiple, complementary aims.

Ask the council and it is likely to talk about reducing CO2 emissions by boosting EV take-up, demonstrating the smart heat pumps' potential for energy and cost-saving, and helping the grid's efforts to decarbonise.

Project developer Pivot Power's COO/CTO Mikey Clark — perhaps unsurprisingly given his engineering background — was keener to talk about the underlying unique hybrid battery technology's potential to capitalise on developments in the UK grid services market.

"We really want to test how a flow battery could be co-optimised into lithium-ion-type systems," he tells PV Tech Power about the reasoning behind the project.



Rendering of Energy Superhub Oxford: Lithium-ion (foreground), Vanadium (background)

Credit: Pivot Power / Energy Superhub Oxford

The BESS is already live and set to be fully operational and trading in the electricity markets in the coming weeks - the lithium-ion system is already - while the EV park will open to the public in Q2 2022. But even before any of that, the project has already delivered numerous firsts and superlatives.

The 55MWh BESS was the first grid-scale battery system with a tertiary connection to the UK grid's transmission system when it connected in July 2021. Tertiary connections provide a way of connecting directly to National Grid's high voltage transmission network, with each connection providing up to 57MW demand or generation capability.

As well as being the largest lithium-vanadium hybrid installed anywhere in the world, it has the largest vanadium flow battery system in the UK, and largest BESS optimised by an AI-enabled optimisation & trading engine (OTE) in the country to date, provided by optimisation specialist Habitat Energy.

The EV park will outnumber any other public one in the country for charging points when it opens in Q2 this year. It was also Finnish energy giant Wärtsilä's first BESS project in the UK and vanadium battery supplier Invinity Energy Systems' largest ever installed.

"We're really proud of how Energy Superhub Oxford has delivered on its promises and the feedback we have received from government bodies and Innovate UK. It's been a truly collaborative project and its success is down to the relationships we've cemented with our partners," Mikey Clark added.

The unique hybrid battery launch is noteworthy amidst a total reshaping of the market for providing services to National Grid, the UK's electricity grid operator. Increased volatility due to growing renewable intermittent generation, a saturation of the ancillary services market and new services for power producers and BESSs to bid for, means a myriad of potential ways its effectiveness can be demonstrated.

More locally, Oxford City Council is hoping Energy Superhub Oxford can reduce the city's annual CO2 emissions by 10,000 tonnes in year one and 25,000 tonnes by 2032 — equivalent to 3-4% of the city's total scope 1 emissions in 2019 — primarily through energy trading, providing a model for other cities looking to decarbonise their economies.

Launching the project and division of BESS responsibilities

ESO's story begins before the COVID-19 pandemic struck. It launched in April 2019 when planning and preparation processes kicked off. Construction on the BESS and heat pumps started a little over a year later while the EV station broke ground in the first quarter of last year.

The lithium and vanadium flow batteries were energised in July and December of 2021, respectively.

RENEWABLES HUB PILOT

"The lithium-ion battery is trading in the market. The flow battery is live but not yet trading in the market, but we expect it to be there in the next few weeks," Clark says.

The lithium battery is a 49.9MW one-hour system while the vanadium flow packs 2MW/5MWh and the system sits beside and connects to the Cowley National Grid substation on the southeast outskirts of the city. Project manager Tim Rose said in a webinar that the two battery systems will provide grid services separately for the first three to six months of them both being in the market.

A total £41m has been invested into delivering ESO of which £11.3m was a grant provided by Innovate UK to part-fund the activities of all consortium partners. Of the battery costs, 15% was for the vanadium flow with the remainder on the lithium system, site construction and grid connection, though Pivot wouldn't be more specific.

Wärtsilä delivered the lithium system and will also control the entire BESS through its GEMS software and energy management system (EMS) platform. It will process operational data at its expertise centre in Trieste, Italy, and is working on three other similar UK projects with Pivot Power.

The vanadium flow system was supplied by Invinity Energy Systems while Habitat Energy is playing the role of trader and optimiser, providing instructions to the GEMS about what services the BESS should do based on market demands, while also maximising the lifetime of the asset, all through its AI machine learning-enabled OTE platform.

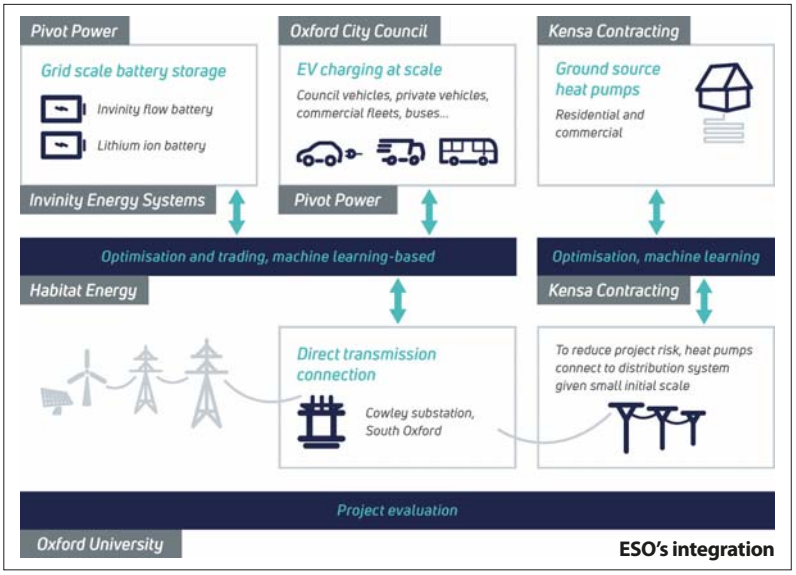
Habitat Energy's head of UK business development Ralph Johnson says machine learning (ML) has a lot to offer energy storage assets like ESO's which require the constant analysis of hundreds of different data points to get the most accurate forecasting of prices and market value.

"We have developed all our forecasting ML algorithms from the ground up. They take all that data and use it to forecast prices really effectively across different spaces. So day-ahead markets, intraday markets, the Balancing Mechanism, system price markets etc. And we then utilise those forecasts with our algorithmic dispatch platform or to inform our trading team," he tells PV Tech Power.

He adds that its platform has mainly focused on 1/1.5-hour systems, so he sees a real learning opportunity for Habitat with this project too. But recent shocks to the system in the UK market have highlighted the need to combine algorithms and the human element, adds Jon Doughty, Habitat's UK managing director.

Habitat and Invinity are both keen to emphasise their roles well before and well after the project's launch, respectively.

Habitat provided revenue forecasts and commercial implications of certain designs and worked with Wärtsilä early on to ensure the BESS could enter markets as soon as possible. Invinity will continue to track systems remotely and assess individual subcomponents combined with site visits, says Ed Porter, business development director.



ESO's integration

Credit: Pivot Power / Energy Superhub Oxford

Timeline	
Q2 2019:	Planning and preparation begins on BESS, EV network and heat network
Q1 2020:	EV procurement by council bodies begins
Q3 2020:	Construction begins on heat pump network
Q4 2020:	Construction begins on BESS
Q2 2021:	Construction begins on EV network; operation & evaluation starts on heat network
Q2 2021:	Lithium-ion energised and begins trading in market; operation and evaluation begins on BESS
Q3 2021:	Construction complete on vanadium flow battery
Q4 2021:	Vanadium flow battery energised
Q1 2022:	Vanadium flow starts trading in market
Q2 2022:	All heat pumps built; EV charging park to open to general public
Q2 2023:	ESO fully operational after ramp-up period with evaluation of all three parts complete

Adjacent technologies and challenges faced

As part of the project, Pivot also delivered the 8km private wire which connects the new Redbridge Park & Ride electric vehicle (EV) charging park to the National Grid substation. The park will have 38 fast-to-ultra-rapid chargers.

Pivot decided to have the EV network connect directly to the substation, rather than the BESS, so that EV charging was not reliant on the BESS being charged. However, the BESS has an island mode capability which ensures that it can continue to operate independently and power the EV charging network in the event of a grid-level blackout, Pivot tells PV Tech Power.

The private wire is also strategically routed to enable future connections to

Energy Superhub Oxford Invinity vanadium flow battery. Energised and expected to go into commercial operation very soon.

Credit: Invinity Energy Systems

other vehicle hubs en-route to support Oxford city's wider push to electrify its vehicles. ESO has helped fund an electric waste collection truck and made available grants to taxi drivers to switch to EVs as part of the project.

The charging park will be the responsibility of the City Council as well as charger supplier-operators Fastned, Tesla & Wenea, each of which has committed to sourcing power via renewable sources (Fastned has a solar roof at the park, for example). The flow of power to the park will go through Habitat's OTE platform.

Kensa Contracting delivered the 60 grid-connected ground source heat pumps providing homes with clean heating. They feature smart controls, dynamic pricing and load shifting to allow users to save money and increase the renewable mix of their heating's power sources. Tim Rose said that residents preferred a direct grid connection rather than the BESS.

Like any project of this scale, ESO faced several challenges and delays, including pushing back the project's completion date by a year to March 2023, which was blamed on the Covid-19 pandemic. Clark and Rose both talk about planning processes initially restricting the project's size but praise the council for its flexibility when helping get the project on its feet.

Wider regulatory changes also hit ESO's ambitions. For example, the removal of the UK government's Renewable Heat Incentive (RHI) in 2020 forced a scaling back of the number of heat pumps planned by 80% from 300 initially to just 60.

That said, some wider rule changes have been positive. Clark says there was no Connection and Use of System Code (CUSC) agreement written for energy storage when ESO launched in 2019, and Pivot has worked with National Grid to rectify this during the project's development.

PV Tech Power roughly estimates that a lithium-ion system of ESO's total size in MWh could generate £4.5-9m in revenue and £2.3-2.8m gross profit a year, based on industry benchmarking data from Habitat and UK energy market data firm Modo Energy. Pivot wouldn't comment on this nor discuss internal rate of return (IRR) forecasting.

Unique potential in the grid services and electricity trading market

All our interviewees agree that the hybrid battery system will give the ESO's BESS versatility when going out into the merchant and ancillary services markets. 'Merchant' means operating in the electricity trading market without long-term contracted revenues from National Grid for things like frequency response.

"We didn't want to rely on contracted revenues but instead want to go out to the market with a nearly 100% merchant model. That plays into getting the right tech into the stack in order to give us a lot of versatility," Clark says. "The majority of the hub's revenue will be from merchant as well as some ancillary services but, over time, a trend towards more and more merchant."

He gave a specific example of how the hybrid BESS could tackle frequency response services in the ancillary market: "As most of the deviations from 50hz happen within a two-megawatt tolerance, a lot of those cycles can go through the Invinity battery, that doesn't degrade like a lithium-ion one which can pick up anything big. This is one hypothesis that is really interesting to us and me as the CTO, given the number of cycles we could potentially take off," he says.

Clark and the other consortium partners are reluctant to provide more specific examples at this point.

"To say exactly what markets and what benefit we can achieve from the asset is probably difficult at this stage," says Johnson.

"Its ability to dispatch for longer durations, and to hold its state of charge with fewer concerns around asset degradation, gives us opportunities to potentially capture value across long periods of the day in the merchant space. So interestingly, periods where the market price shape is flatter (and less volatility exists) and you're actually looking to capture more lower margin spreads over longer durations of time. That's really an interesting opportunity where long-duration energy storage can add value," he says.

"Combining that approach with the strategy we would employ to capture the value you can achieve in volatile conditions, where those spreads can be larger, across multiple power markets (day ahead, intra-day, Balancing Mechanism), but over much short time periods (30 mins to 1 hour) with the 50MW one-hour lithium ion battery is a really interesting challenge. Being able to access both sets of value with the same asset is a real positive for this project and something we're really looking to investigate and explore."

New pre-fault, higher-output ancillary services like dynamic regulation (DR) and dynamic moderation (DM) will be accessible for the vanadium flow battery thanks to its longer duration, Johnson and Porter both say.

It should be noted that Pivot's more recent projects of similar power magnitude have two-hour lithium batteries. The business case has shifted towards two-hour systems since ESO was launched, Brent Iversen, Senior Business Development Manager at Wärtsilä Energy Business tells PV Tech Power.

"People in the UK market are still looking at between one and two-hour batteries and the business case debate is quite balanced, though I think the majority of developers are now starting to go for two-hour systems," he adds.

Wärtsilä and Invinity both say integrating the two battery systems into one GEMS went smoothly.

Iversen: "It required a lot of software programming and development to integrate the two batteries but essentially this is one of the features of the GEMs system, that we can integrate multiple

generators or assets into the GEMs to operate those assets in the best possible way."

Capitalising on an evolving market and decarbonising the sector

As alluded to before, the National Grid services and trading market is going through numerous changes which ESO can capitalise on.

Habitat's Ralph Johnson tells PV Tech Power the energy market is becoming increasingly volatile due to the closures of baseload power plants and increased intermittent renewable generation. Providing the flexible capacity to mitigate that is the bread-and-butter opportunity for energy storage.

He also expects a saturation of the market for frequency response ancillary services which will drive down price and push energy storage owners to move towards a merchant strategy, already seen in other ancillary areas. As Clark said earlier, having a flexible BESS like a hybrid makes ESO well-positioned for that.

US readers should be reminded that, as Iversen alluded to, a 2.5 hour battery is at the very long end in the UK market which still focuses on 1-2 hour systems. The big challenge for longer duration systems has always been the higher capex, Johnson says, and combining it with a lithium-ion system could mitigate some of that and improve its IRR from its standalone figure.

"There is still more value available for longer duration systems in contracts such as the capacity market agreement, but for longer duration storage to generate better IRR, we may need another ancillary service or another market opportunity or a change in the existing ones that adds value on that front," he says, though expects future changes in price shape could favour long-duration.

Pivot Power's Mikey Clark tells PV Tech Power that without the Innovate UK grant "...we wouldn't have moved as quickly with Invinity as we did."

In response to PV Tech Power's question about when Invinity would be able to sell vanadium batteries like this one without the benefit of a grant, Porter points out that all low-carbon and long-duration flexibility tech is subsidised right now. He expects emerging energy storage technologies to be partially reliant on grants for a while.

ESO promises to save 10,000 tonnes of CO2 a year once fully operational, increasing to 25,000 tonnes by 2032. Rose said the bulk of this would initially be related to the trading activity of the BESS as the EV impact would be relatively low at first.

The simplest example of that is buying energy from the grid when there is excess renewable generation and selling it back when it's needed. He indicates that the University of Oxford will have a role in measuring ESO's impact here and keep Pivot's "feet to the fire on that" alongside its assessment of the BESS' performance against a digital twin.

However, Johnson is rather tentative on this: "There is some argument that you are potentially reducing the need for higher carbon generation during those periods (of higher demand). To measure this you'd need to look at the generation mix at different times and National Grid are looking at doing this, looking at CO2-intensity for settlement periods," he says.

Clark touches on this point more broadly: "Storage is an enabler for renewable energy and reducing carbon emissions as part of the UK's energy transition. We have 60-70% of Europe's winds, we've got 16GW of solar and 15GW of wind and massive potential for interconnection. There is a lot going on in the market which requires flexible assets which can dispatch quickly."

Future

This project has come at an exciting time for the UK energy storage market. Data from Solar Media's UK Battery Storage Project Database Report shows that the UK has a BESS pipeline totalling 25GW, of which 99% is lithium-ion systems and just under half already has planning permission approved. Today, 1.6GW is operational.

ESO is the first of up to 40 similar projects that Pivot Power is targeting across the UK which could total 2GW of energy storage, or 50MW each, all grid-connected. Clark says that all will have a similar power magnitude to ESO's but it is the only one using a vanadium flow battery, for now, as "we are still waiting to see how the technology performs."

The company is looking at a range of technologies and industries that can combine with its BESS projects. This could be renewable generation or even industries that could be directly powered by its batteries. The most obvious one is EV charging but BESS has the potential to help power light railways, for example.

Doing this would also have the effect of demonstrating more tangible positive results of BESS installations, with grid balancing and renewable load shifting far from the average person's thought process.

The company's target of 2GW is certainly ambitious and commendable, and if achieved it would account for 5-10% of the 20-40GW of energy storage the UK needs by 2050, according to National Grid's modelling.

All involved will be hoping ESO delivers on all its promises, many of which it already has, and provides a model for other cities wanting to contribute to the decarbonisation of the UK's energy sector. ■

Credit: Pivot Power / Energy Superhub Oxford

Rendering of the project's Redbridge Park & Ride EV charging park

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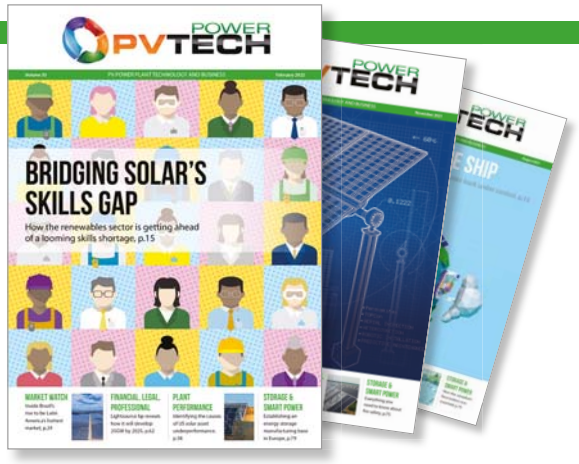

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