PV TECH POWER

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THE THIRD PILLAR

How floating solar can take the mantle of solar PV's third key sub-sector p.20

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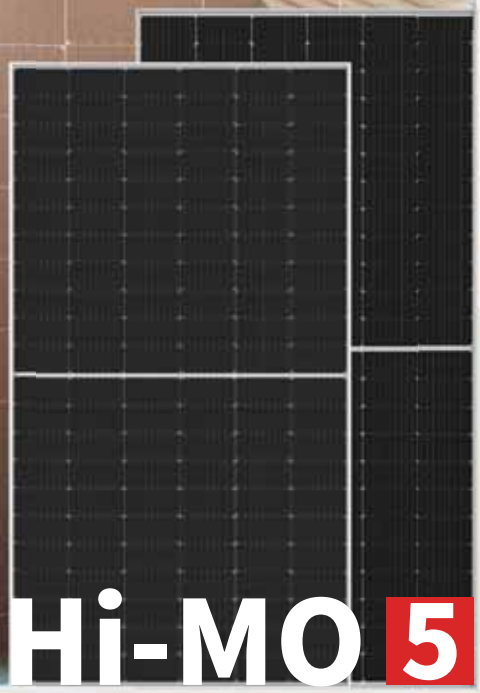

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Introduction

As the year draws to a close, it is perhaps easy to reflect on the feats and achievements, trials and tribulations the past 12 months have posed. 2020 has been amongst the most difficult of years for many and most of us will be pleased to see the back of it. While we have indulged in some reflection of sorts in this edition of *PV Tech Power* (p.14), we have, at the very least, attempted to cover the efforts and initiatives of those moving forward.

Our cover feature looks to explore what many in the sector have come to perceive as the 'Third Pillar' of solar; floating PV, and why the deployment method has yet to truly fulfil its potential. As you'll read (p.20), the obstacles are nothing structural or particularly insurmountable, but rather issues that are already being addressed. 2021 could really be the year that *floatovoltaics* hits the mainstream.

Elsewhere in this issue we also assess the market potential for green hydrogen – a sector which has gathered significant pace in the past 12 months – and profile a handful of the world's hottest markets for H2. With Europe's green hydrogen strategy aiming for as much as 80GW of electrolysers installed, half of which inside the continent and another half in nearby nations, powered by hundreds of gigawatts of renewables, the green hydrogen economy could prove yet another boon for utility-scale solar in the coming years. Of course, Europe is just one continent with hydrogen ambitions and, as you'll read (p.29), solar+hydrogen looks set to be the new solar+storage across the world.

We also hear how engineering, procurement and construction firm Mytilineos kept development at a site in Chile's Atacama Desert on track despite national protests in the country and, of course, a global pandemic (p.60), hear from Solarcentury's Chris West what solar system designers need to consider when exploring the use of high-power, large-area modules (p.54) and, in our Storage & Smart Power Section, hear from experts in battery fire safety how the industry can ensure its own safety moving forward (p.73).

In essence, this is a normal edition of PVTP, littered with articles charting the future direction of the downstream solar sector. But in a year that has been anything but normal, perhaps this is what's most required. This journal can provide context to the International Energy Agency's claim that solar is the 'new king of electricity markets', reasoning to Lazard's latest LCOE projections and, perhaps above all, clarification that in a difficult year, your work in the sector has contributed towards significant progress.

Thanks for reading and for all of your support and readership throughout 2020, and we look forward to hearing from as many of you as possible in the new year. From all of us at Solar Media, we wish you a prosperous new year.

Liam Stoker
Editor in chief
Solar Media

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EUROPE

Manufacturing

20GW European solar manufacturing base could support 100,000 jobs

Regulators in Europe should throw their support behind re-establishing a solar manufacturing base in the continent that could reach a capacity of 20GW and support more than 100,000 jobs, Meyer Burger and SMA have said. A white paper published by the companies in early December argues that solar is approaching a turning point in its innovation comparable to the transition from 4G to 5G in mobile communications. But unlike in other sectors, the duo argue, most modern PV technology and intellectual property is still 'Made in Europe'. Gunter Erfurt, chief executive at Meyer Burger, said: "In the context of this development, there is an opportunity in Germany and Europe to use the boom in solar energy and to set the pace for this central key technology of renewable energies. For this we need a holistic industrial strategy that thinks the generation of electricity and the production of the necessary technologies together. We need short-term supportive measures that improve the framework conditions."

Credit: Meyer Burger

Heterojunction modules were described as the solar equivalent of 5G technology by Meyer Burger.

Auctions

Floating PV and land beside motorways to be included in Portugal's next solar auction

Lots for PV projects on dams and beside motorways are set to be included in Portugal's third solar tender, the country's state secretary for energy, João Galamba, has said. Speaking at the *Large Scale Solar Europe Virtual Summit,* organised by *PV Tech Power* publisher Solar Media, Galamba announced that the Portuguese government is preparing an auction for "non-conventional" surfaces next year as the country looks to ramp up its installed PV capacity to reach 9GW by 2030. Studies are underway to assess the potential capacity and area for installing floating solar parks at reservoirs beside dams, while the government is meeting with Portuguese motorway companies to explore the addition of projects alongside highways.

UK government confirms solar participation in forthcoming 12GW renewables auction

The UK government has confirmed solar's ability to participate in the country's next renewables auction, which is expected to contract for up to 12GW of new capacity. Solar will continue to compete as a so-called 'Pot One' technology, an auction pot which includes more established renewables generation classes, which will see the asset class compete against onshore wind for contract support. The country's energy department anticipates that the next auction round will contract for up to 12GW of new renewables capacity, more than double the previous round – which was conducted in September last year – which contracted for 5.8GW of capacity, mainly offshore wind. Specific budget allocations and capacity caps for each pot are to be determined close to the opening of the round, the department said.

Grids

Dutch network operators strike solar agreement to accelerate grid connections

Network operators in the Netherlands have struck an agreement with the country's solar sector to speed-up grid connections for solar projects. Under the terms of the deal, enshrined within a legal covenant, solar operators will agree to solar export limits of 70% of any given project's peak generation capacity, a measure which grid operators said would allow for grid connection times to be slashed. Trade body Holland Solar said the agreement would allow for solar to generate more efficiently and more affordably on the Dutch grid, adding that an influx of large solar projects in the Netherlands in recent years had resulted in various costly network upgrades to be required. Network operators have too agreed to provide more insight into particular areas of the grid which are more constrained, identifying where bottlenecks may be arising.

France

French solar sector warns of 'economic catastrophe' if proposed subsidy cuts go ahead

French solar developers, financiers and utilities have said government plans to cut subsidies for PV project owners would lead to an "economic catastrophe" that could threaten the country's energy transition. A joint statement signed by executives from industry players including Voltalia, First Solar and Enphase Energy said the early termination of contracts would result in defaulted payments, job losses and the tightening of financial conditions that would slow the development of future PV projects. The announcement was made after France's National Assembly endorsed a government amendment to revise subsidies on the largest PV contracts signed between 2006 and 2010, as it aims to save billions of euros by 2030.

Deployment

Repsol targets 15GW of renewables capacity by 2030

Repsol will ramp up investment in solar PV and wind in the next five years as looks to reach 15GW of renewable energy capacity by 2030. The Spanish oil major will spend €5.5 billion (US$6.6 billion) between 2021 and 2025 on low carbon technologies to help it develop more than 500MW of green energy projects annually. Then, from 2025 to 2030, the firm is targeting the addition of more than 1GW of installed renewables capacity each year. Having entered the PV market in 2018, Repsol currently has just 390MW of solar projects under construction, both in Spain. These are slated for completion in the first half of next year. However, the company currently has 4,305MW of solar projects under development and negotiations.

Iberdrola aims for 16GW of installed solar in five years

Iberdrola is set to double its renewables capacity by 2025 through a €75 billion (US$88.9 billion) investment package that sees the Spanish utility seek to take advantage of the "global energy revolution" and reach carbon neutrality in ten years. The company forecasts that its largest-ever funding plan will enable it to increase renewables capacity from its 32GW level last year

to 60GW in 2025, with solar PV set to more than double to 16GW. With renewable energy project pipeline of 70.5GW, including 30.7GW of solar, Iberdrola said it is in a "unique position to tackle the global energy revolution", focusing on countries with ambitious climate and energy targets.

Finance

BayWa r.e. pockets US$642m in Energy Infrastructure Partners equity sale

Renewables developer BayWa r.e. has received a major capital injection of €530 million (US$642.3 million) through the sale of a 49% stake in the outfit to Energy Infrastructure Partners (EIP).The deal values the renewables division of agricultural group BayWa AG at more than €1 billion (US$1.2 billion), and will see it pivot towards an independent power producer model, the company said. BayWa AG, the renewable energy division's parent company, will remain the group's majority shareholder with a 51% stake.

Amarenco targets 3GW of PV by 2023 after closing funding deal

Independent power producer (IPP) Amarenco Group has secured €150 million (US$176.8 million) in funding as it looks to ramp up solar project development in Europe and Asia. The capital raise, which saw asset management firm Tikehau Capital "contribute significantly", will see Ireland-headquartered Amarenco move forward with plans to convert its merger and acquisition deals as well as project pipeline into "value-generating assets". The money raised combines a share capital increase and an equity line totalling €150 million. According to Amarenco's co-founders, the funding will contribute to the company's ambition to have more than 1GW of projects under construction in the coming months and 3GW by 2023 in Europe, Asia Pacific and the Middle East.

M&A

Statkraft to acquire Solarcentury, adding 6GW to global solar portfolio

Norwegian renewables giant Statkraft is to acquire UK-headquartered solar developer Solarcentury, taking on a 6GW global portfolio in doing so. The deal, struck at a purchase price of £117.7 million, will see Statkraft take on a pipeline of utility-scale solar projects in markets including Spain, Chile, Italy, Greece, France, the Netherlands and the UK. Statkraft has maintained a target of developing at least 8GW of wind and solar by 2025, and the company said the acquisition – which also marked the renewables giant's "renewed commitment to solar power" – will also play a major role in reaching that target. Furthermore, Statkraft said the deal would make the company a leading developer within Europe's solar market, with the potential to become world-leading.

AMERICAS

M&A

Iberdrola bolsters US renewables position with US$8.3bn PNM transaction

Iberdrola has cemented its status in the US renewables market by acquiring regulated utilities arm PNM Resources in a deal worth US$8.3 billion. PNM Resources, which holds Texas- and New Mexico-facing utilities PNM and TNMP, will be merged into Iberdrola's existing US utility Avangrid, which already operates in some 24 states. PNM also holds 2.8GW of generation capacity, which will add to Avangrid's 8.1GW. PNM shareholders are to receive US$4.3 billion in cash, with net debt and other adjustments with a value of US$4 billion factored into the overall enterprise value of the transaction.

AES to merge US development arm with sPower, creating 12GW US clean energy pipeline

AES Corporation is to merge its US-facing clean energy development business with independent power producer sPower, creating a platform with a 12GW project pipeline in the country. AES and Alberta Investment Management Corporation (AIMCo), which collaborated to acquire sPower in 2017, said the merger will bring together capabilities in solar, wind and storage to accelerate the transition to cleaner energy solutions across the US. Future projects from the combined 12GW development pipeline will be owned 75% by AES and 25% by AIMCo. Although there is no change in ownership of operating assets and backlog, the new platform will manage the 2.5GW of operating assets and the existing 2.6GW contracted backlog.

Policy

Bifacial exemption from US Section 201 tariffs is repealed

The exemption for bifacial solar panels from Section 201 tariffs in the US has been repealed, meaning bifacial panels imported into the US are now subject to tariffs of 20%. In October, prior to the US election, President Donald Trump issued a presidential proclamation that included, amongst other measures, a movement to repeal the exemption for bifacial panels within Section 201 trade tariffs. But that bid was initially thwarted, with

Record breaker

Invenergy unveils 1.3GW solar project, set to be US' largest

Google and Honda will be among the offtakers of a 1,310MW PV project to be constructed by Invenergy that is set to be the largest solar generation facility in the US when complete. Currently under development in northeast Texas, the Samson Solar Energy Center represents a US$1.6 billion capital investment and will support up to 600 jobs over the course of its 36-month construction period, according to Invenergy. The announcement sees Samson take the title of largest planned US solar project from the Gemini facility, a 690MW development under construction in Nevada that will also feature 380MW / 1,400MWh of battery energy storage.

Credit: Invenergy

Invenergy's Grand Ridge Solar facility in Illinois

Judge Katzmann of the US Court of International Trade issuing a temporary restraining order that prevented the exemption from being repealed while further motions were considered. A ruling on 19 November heard that the temporary restraining order had been lifted, with both parties – the Solar Energy Industries Alliance and others acting as the plaintiff, and the US government as defendants – invited to seek further recourse by filing separate actions.

Auctions

Colombia plans 2021 renewables auction to become 'leader in Latin America's energy transition'

The government of Colombia has announced plans to hold a renewable energy auction in the first quarter of 2021 that it says could represent an investment of more than US$6 billion in the country. Speaking at the inauguration of a new solar farm in the city of Cartagena, President Iván Duque said the auction will make the country a "leader in Latin America's energy transition". The renewables auction, which will be Colombia's third, will be for projects that are set to be operational by December 2022.

Residential and C&I solar

Scaling distributed solar and storage is lowest-cost path for US to reach clean electric grid

Deploying at least 247GW of rooftop and community solar and 160GW of local energy storage is the most cost-effective way for the US to transition to a clean energy system by 2050, a new report has found. Those additions would be enough to power more than 25% of US homes, while also saving consumers up to US$473 billion on electricity, the joint study from Sunrun, Vote Solar and the Coalition for Community Solar Access (CCSA) says.

Corporations 'walking the walk' with clean energy as US C&I solar capacity soars

Led by tech firms and retailers, corporations installed 1,286MW of new solar capacity in the US in 2019, the second highest amount on record, a new report from the Solar Energy Industries Association (SEIA) has revealed. Over 8,350MW of commercial solar capacity has now been developed across more than 38,000 US systems. Topping the list are Apple and Amazon, followed by Walmart, which installed the most solar among corporations in 2019 and increased its use by 35%. Last year also saw more onsite commercial solar installed than ever before, reaching 845MW.

Subhead: Distributed generation

LG Chem recalls some home batteries in US following reports of fires

LG Chem has voluntarily recalled some of its residential battery products in the US amid concerns surrounding fire safety. The impacted systems were sold by distributors from January 2017 until March 2019. Sunrun, the residential solar installer that originally teamed up with LG Chem in 2016 to offer PV-plus-storage solutions in the US, said the recall has affected approximately 5% of its Brightbox rechargeable solar battery system installations. "We have already started proactively replacing batteries impacted by the recall and have credited customers for the brief downtime," Sunrun said in a statement.

Policy

Victory for Illinois campaigners after 'unlawful' net metering policy rejected

Solar power campaigners in Illinois have declared victory after an attempt to block full net metering for new solar customers was overruled. The Illinois Commerce Commission (ICC) voted down power company Ameren Illinois' calculation of the number of solar energy customers within its territory. This means full retail net metering has been reopened, and new solar customers can gain credit for the excess energy they produce once it is dispatched to the grid. A spokesperson for Ameren told sister publication PV Tech that it is not clear whether the company will attempt to appeal the decision, but that Ameren Illinois' tariff was based on "an express reading of the statute.""We continue to agree with the underlying policy embedded in the law with respect to the 5% solar penetration threshold," the spokesperson said.

Auctions

Chile unveils auction for 2,310GWh of energy and storage

Chilean authorities have announced plans to carry out an auction next year, looking to procure 2,310GWh of renewable power from generation and storage. Preliminary bidding terms published the country's National Energy Commission (CNE) say selected projects must start delivering power from 2026 and sign up to 15-year power purchase agreements. The final bidding terms will be published this December, with the auction set to take place in May 2021. CNE had planned to hold the auction this year, but it was postponed because of the impact of COVID-19.

MIDDLE EAST & AFRICA

Finance

Robotic solar cleaning specialist Ecoppia lands US$82.5m in IPO

Israel-headquartered O&M solutions provider Ecoppia has launched an initial public offering (IPO) after securing more than US$82.5 million through a public tender phase. The tender secured US$82.5 million from institutional investors, valuing the company at US$300 million. The tender was oversubscribed, with Ecoppia receiving expressions of interest totalling US$144.75 million received from institutional investors. Public demand within the tender phase was also oversubscribed with US$76.74 million of interest recorded despite just US$1.5 million of allocated shares. Ecoppia is now to list on the Tel Aviv Stock Exchange. While no specific details were provided as to how the proceeds of the offering are to be spent, Ecoppia states that it has more than 16GW of signed agreements for its cloud-based cleaning solution, which uses robotics to clean solar panels without the use of water or manpower. According to the company, its solutions clean 10 million operational solar panels each night, helping to minimise ongoing operations and maintenance costs for asset owners and operators.

Saudi Arabia's PIF increases stake in ACWA Power

Saudi Arabia's Public Investment Fund (PIF) has raised its shareholding in renewable energy developer ACWA Power. The

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South Africa

Solar sector hails South Africa's move to procure 6.8GW of renewables

South Africa's solar industry has welcomed government plans to purchase 6.8GW of additional renewables from independent power producers as of 2022, but warned that an "urgent response" is needed to tackle the country's energy crisis. Energy minister Gwede Mantashe announced that the country is looking to buy a total 11,813MW of new generation capacity by 2027, the majority solar and wind, with all electricity to be purchased by state utility Eskom following a tendering process. The procurement programme will target connection to the grid for new generation capacity "as soon as reasonably possible", he said. With South Africa faced with rolling blackouts in recent months, it is hoped the procurement will help secure a more sustainable energy future for the country. "The move to more energy capacity is much needed, given our current energy crisis," said Nivesh Govender, COO of the South African Photovoltaic Industry Association. "Our current abnormal circumstances require an urgent response, which is why there is a need for government to harness renewables now to counter the threat to South Africa's energy security." According to the South African Renewable Energy Council, the determination allocates a capacity of 2GW to solar and 4.8GW to wind, while an additional 513MW will come from storage. Despite the gains for renewables, the plan also calls for 3GW of gas generation and 1.5GW of coal-fired capacity.

Credit: juwi.

The 86MW Waterloo solar park in South Africa was developed by juwi and connected to the grid in November.

sovereign wealth fund has taken its stake from 33.36% to 50% to ensure the Riyadh-based power company plays "an integral role" in developing the state-owned wealth fund's renewable energy interests, it said. In a statement, PIF said the increased stake would help to drive and diversify economic growth in Saudi Arabia. The deal also comes several months after China's Silk Road Fund completed the acquisition of a minority 49% stake in ACWA's renewables arm, ACWA Power RenewCo. ACWA currently has 58 power facilities in operation or under construction, with operational capacity of around 37.7GW. Around three quarters (74%) of ACWA's assets under construction are dedicated to low carbon technology. The two entities have worked together since 2013, when a subsidiary of PIF, Sanabil Direct Investments Company, bought a minority stake in ACWA. PIF made a direct investment in the group five years later. Mohammad Abunayyan, chairman of ACWA, called PIF's investment a "vote of confidence" in the group's ability to expand its operations "without compromising environmental stewardship".

ASIA-PACIFIC

China

China's path to carbon neutrality could see country reach 4.2TW of solar by 2050 – BloombergNEF

A massive renewables scale up by China to help it achieve its recently announced carbon neutrality pledge could see the country reach 4.2TW of solar capacity by 2050, a new study from BloombergNEF claims. The research organisation predicts that solar and wind could account for as much as 74% of China's generation capacity, requiring an investment of US$6.4 trillion over the next 30 years. The more ambitious scenario included in the report – called 'China's Accelerated Decarbonization' and produced alongside Bloomberg Philanthropies – sees electricity accounting for 53% of final energy consumption by 2050, some 92% of which is delivered by zero-carbon power sources such as solar and wind, with hydrogen-fuelled gas turbines providing balancing needs.

TBEA New Energy debuts flexible mounting structure at solar project on former open-pit mine

Chinese EPC TBEA New Energy has debuted a new flexible mounting structure designed for use in rugged terrains at a 300MW project on a former open-pit coal mine in China. The structure, which sees modules affixed to mounts that slope according to the terrain's elevation, has allowed for three-times the generation that would have ordinarily been possible, the company said. TBEA New Energy completed the 300MW grid-parity solar project in Jiaokou County, Shanxi Province, in November 2020, connecting it to the region's grid. It is expected to produce around 408GWh of electricity each year.

Trina adds to supply deal run with three-year Daqo polysilicon contract

Trina Solar has signed another upstream manufacturing supply agreement, penning a long-term high purity polysilicon supply deal with Daqo New Energy. Under the terms of the deal Daqo will supply Trina with between 30,000 – 37,600 tons of polysilicon between November 2020 and December 2023. Prices will be negotiated on a monthly basis according to market conditions, with Trina making an advance payment to Daqo.

Vietnam

Vietnam's 'robust' renewables expansion backed by rising investor interest

Vietnam is set to expand its solar and wind capacity as a supportive regulatory environment and growing investor confidence spur on new project development. That's according to a report from consultancy Fitch Solutions, whose "robust forecast" for the country foresees more than 17GW of non-hydro renewables capacity added between the end of 2020 and 2029, reaching a total of 25GW by the end of the decade.

Vietnam's 'largest' solar park completes following LONGi module supply

The first phase of what is claimed to be Vietnam's largest utility-scale solar project was completed in November 2020, using LONGi's Hi-MO 4 Series modules. The 273MW first phase of the Xuan Thien Ea Sup project, located in Dak Lak, Vietnam, was energised earlier this month. Once fully complete, the Xuan

Credit: LONGi

The first phase of the Xuan Thien Ea Sup project, located in Dak Lak, Vietnam was completed in November.

Thien Group-commissioned project will have a total operating capacity of 600MWac/831MWp. The overall project has a total investment value of VND20,000 billion (US$862 million), and the first phase has been commissioned some five months ahead of schedule. Work started in April 2020 and module supply agreement was signed with 'Solar Module Super League' member LONGi a month later.

India

Modi teases new support as India doubles down on domestic solar manufacturing efforts

India will provide additional support for domestic solar equipment manufacturers to help meet the country's soaring renewable energy generation capacity, Prime Minister Narendra Modi has said. With demand for domestically manufactured solar cells and modules expected to be around 36GW over next three years, Modi said the government will offer production-linked incentives for high-efficiency solar modules as it aims to make India "a global manufacturing hub" in the renewables sector. Speaking at the RE-Invest 2020 conference in November 2020, Modi announced that India's green energy capacity will rise to 220GW by 2022, far higher than its 175GW target. Currently, renewables account for 36% of the country's total capacity, at 136GW.

Indian solar tariffs fall to record low following SECI auction

Solar tariffs in India hit a record low of INR2/kWh (US$0.0270/kWh) following an auction this week for 1,070MW of PV projects that are set to be developed in the state of Rajasthan. The Indian unit of Singapore's Sembcorp Industries and Saudi Arabia-based Aljomaih Energy and Water Company posted the record bids in the auction carried out by the Solar Energy Corporation of India (SECI). The prices represent a 15% reduction on previous lowest bid for solar power in India from another auction held by SECI in early 2020. Sembcorp's Green Infra Wind Energy and Aljomaih Energy and Water Company won 400MW and 200MW respectively. The remaining 470MW of capacity was secured by NTPC, India's largest power company, following its bid of INR2.01/kWh. Most offers submitted by the 14 companies participating in the auction were also below India's previous record bid, with the tender oversubscribed by 3,280MW.

Manufacturing

Seraphim constructing 750MW highly-automated module assembly plant in Vietnam

China-headquartered module manufacturer Seraphim is building a 750MW module assembly factory in Vietnam to expand its global production footprint and better serve the growing US market. The assembly plant will be used to produce Seraphim's S3 and S4 series half-cell modules. Initially, 500MW of annual nameplate capacity will be allocated to the S3 modules series with the latest S4 modules accounting for 250MW of annual capacity at the new facility, its first in Vietnam. Jun Zhuge, Seraphim's executive vice president, said the latest construction project will increase the company's share of the global module manufacturing market and "enhance our competitiveness in the US".

Japan

'Very good news': Solar's role in achieving Japan's 2050 carbon neutrality goals

Solar will likely play a major role in achieving Japan's policy goal of reducing greenhouse gas (GHG) emissions to zero by 2050 and could reach 130GW to 160GW in cumulative deployments by the 2030 financial year. This is according to Tokyo-headquartered analysis firm RTS Corporation, which hosted a webinar on the carbon neutral pledge made by Prime Minister Yoshihide Suga just before the end of October 2020.

Credit: Ciel & Terre.

The Hyoshiga Ike 2.7 MW floating solar site in Japan.

Australia

Record year forecast for corporate renewable PPAs in Australia

Corporate renewable power purchase agreements (PPAs) in Australia are set to reach record levels in 2020, with governments and business investing AUD$2.4 billion (US$1.78 billion) and buying more than 1GW of green energy. That is according to a new report from Business Renewables Centre Australia (BRC-A), an organisation that aims to simplify the purchasing of large-scale renewable energy, which says that there still remains a "significant pipeline" of deals under development. Among the top solar corporate PPAs recorded by BRC-A during the 2019-20 financial year were Amazon's deal for the 146MW Gunnedah facility, Shell's agreement for the 120MW Wandoan project and mining company Molycop's contract for the 120MW Bomen farm.

2020 in retrospect: A year in solar

2020 review | While COVID-19 may have dominated headlines internationally this year, 2020 has been a year of considerable progress for the global solar supply chain. Here, the PV Tech editorial team re-cap some of the biggest and most impactful stories of the year.

Credit: Array Technologies

Solar has continued to march onwards in 2020, despite the year's challenges

Q1: Manufacturing ramp-ups, O&G firms eye solar capacity, pandemic impacts

Setting the tone for a year that has seen large-scale manufacturing capacity expansions and new size wafers and modules, **LONGi** announced plans to construct a new 20GW wafer plant in Yunnan province, China, with an ambition to grow the facility to 40GW in the future. The company then went on to secure two separate three-year wafer supply deals that together are purported to be worth more than US$3.3 billion.

But LONGi was not finished there. After expanding its business overseas through the acquisition of Vietnamese PV cell and module manufacturer **Vina Solar**, the firm then started production at a new 5GW module assembly plant to produce its Hi-MO series modules using large area 166mm x 166mm (M6) wafers. The company said at the time that output at the facility would be "at the forefront of the industry".

Q1 also saw a significant module manufacturing development from **Trina Solar**, which launched its Duomax V bifacial double-glass modules based on 210mm silicon wafers and mono-PERC cells, a landmark that the company said would see it embrace a "new era" of solar. Compared to more conventional 410W bifacial double-glass modules, the Duomax V can reduce balance-of-system costs by between 6 – 8% and the LCOE of projects by 3 – 4%, according to Trina.

In terms of polysilicon manufacturing, **Daqo New Energy** was said to have taken the average total production cost of primarily monocrystalline-grade polysilicon to a record low, while **Tongwei** announced it would significantly increase high-purity polysilicon production and high-efficiency solar cell production over the next five years.

China's dominance in solar manufacturing had a knock-on effect elsewhere, however, as **Wacker's** polysilicon division revealed it had slumped to a loss in 2019, with CEO Rudolf Staudigl noting that underlying conditions for solar-grade polysilicon "remained unsatisfactory", with prices falling "amid high overcapacity built up by state-subsidised competitors in China". Meanwhile, South Korea's **Hanwha Solutions** said it would close its solar-grade polysilicon production business by the end of 2020. Polysilicon pricing would remain turbulent throughout the year

The effects of COVID-19 on the manufacturing sector were noted early in the quarter, with component shortages and factory closures slowing production. Official data from China said solar exports from the country in January were around 35% lower than in the prior year period.

A recuring theme for the year has been oil and gas (O&G) majors announcing aggressive green energy capacity expansion targets alongside plans to reach net zero emissions. The "deep pockets" of the O&G industry could be crucial in accelerating the deployment of renewables, the **International Energy Agency** (IEA) said a report. After increasing its stake in PV project developer **Scatec Solar** in late 2019, Norway's **Equinor** pledged to achieve net zero greenhouse gas emissions at operations by mid-century, by which time its O&G production business is expected to have halved in size.

Taking a similar strategy was

Credit: Trina Solar

Trina Solar's Duomax V bifacial double-glass modules.

BP, which, having upped its stake in global solar developer **Lightsource BP** to 50% last year, announced it would aim to attain net zero status "by 2050 or earlier". The company's CEO Bernard Looney said at the time that the world needed a "rapid transition to net zero", adding that energy that is just reliable and affordable is "no longer enough". "It must also be cleaner. To deliver that, trillions of dollars will need to be invested in replumbing and rewiring the world's energy system. It will require nothing short of reimagining energy as we know it."

Before announcing its own net zero target later in the year, France's **Total** was especially acquisitive in the solar sector in Q1, taking a 50% stake in Indian conglomerate **Adani Group's** solar business for approximately US$510 million and purchasing a 1.2GW portfolio of projects from Spanish firm **Solarbay**. **Eni's** new emissions reductions plan, meanwhile, foresees the Italian company deploying 55GW of renewables by 2050, as it focuses on green energy developments mainly in OECD countries.

As well as the manufacturing-related disruptions, COVID-19 and the resulting lockdown measures began to impact PV project development, as **BloombergNEF** reduced its global solar demand forecast for 2020. The research organisation highlighted the possibility that the pandemic may have such an impact on demand that 2020 could mark the first time in several decades when annual demand falls below that of the previous year.

Meanwhile, the **IEA** called on countries to keep the clean energy transition "front of mind" as they prepared coronavirus stimulus packages.

The impacts from the pandemic must not be allowed to compromise the "inescapable challenge" of climate change and global emissions, **IEA** executive director Fatih Birol said. "The coronavirus crisis is already doing significant damage around the world. Rather than compounding the tragedy by allowing it to hinder clean energy transitions, we need to seize the opportunity to help accelerate them."

> "To deliver that, trillions of dollars will need to be invested in replumbing and rewiring the world's energy system."

Q2: COVID's looming shadow recovery prospects

There is an elephant in the room when it comes to the second quarter of 2020. Whilst this year has seen numerous milestones reached when it comes to the solar sector, it remains a simple fact that COVID-19 hit this quarter the hardest, resulting in slowdowns, shutdowns and various impacts on the supply chain.

Analysis from **Wood Mackenzie** in April found that as much as 2GW (dc) of utility-scale PV projects could suffer various delays over the year due to COVID-19, with some in the sector suggesting the plummeting power prices seen in Europe as a result of the lockdowns could dampen investor enthusiasm for subsidy-free solar. Prices of €20/MWh were seen in Spain, as well as €32/MWh in Italy as Q1 came to an end in March, throwing uncertainty over project finance. Alessio Cipullo, head of European Affairs and Studies at Italian association **Elettricità Futura**, pointed to how there were questions over what "merchant investments and grid parity investments will look like with such weak prices".

Away from COVID-19, there were other concerns to contend with. The quarter was one in which research was released by **Dupont Photovoltaic Solutions** that identified a rapid increase of cracking in PVDF (Polyvinylidene Fluoride) backsheets. This was notable in the overall outer layer cracking rate of PVDF backsheets, which had increased four-fold (from 5 to 23%) in module arrays in the field for between four and nine years, according to Dupont.

However, Q2 was certainly not all doom and gloom for the solar sector. In May, investment bank **Roth Capital** suggested a V-shaped recovery was on the cards for the US residential solar market, and it was widely discussed – and strongly recommended – that renewables – solar PV included within this – could help drive a green recovery from the pandemic. In Europe in particular, this call started to gather steam in Q2, with **SolarPower Europe** joining nearly three dozen other associations in urging the EU to ensure recovery measures followed the principles of the European Green Deal.

US$30/MWH
Solar's LCOE in Q2 2020, according to BloombergNEF

The quarter also saw huge gains made when it comes to the costs of both solar and renewables. Research from **BloombergNEF** found that utility-scale solar and onshore wind new builds had become the cheapest option in countries home to two-thirds of the world's population, with solar's levelized cost of electricity (LCOE) being pushed below US$30/MWh. The LCOEs for storage batteries were also reported to have fallen to US$150/MWh, half the figure reported two years back.

Meanwhile, Abu Dhabi claimed the world's lowest tariff for solar for its 2GW Al Dhafra project, with the first-ranked bidder out of five tendered for the project setting their price at US$0.0135/kWh. This came in cheaper per kilowatt-hour than the previous solar record of US$0.0164/kWh, claimed by a bidder in Portugal's major solar tender in 2019.

Favourable policy decisions were also made in Q2. In the US, measures designed to support solar and other renewables in the US were proposed within a landmark US$1.5 trillion infrastructure investment Bill, tabled by House Democrats. Prospective measures outlined in that bill included a modernisation of energy

Credit: Total

Total is targeting 35GW of renewable generation capacity by 2025.

Credit: Meyer Burger

Heterojunction solar cell production.

infrastructure, including an investment of more than US$70 billion to help modify grids to accommodate more renewable energy sources, a commitment to "reinvigorate" the country's commitment to clean energy by building on existing tax incentives, and promoting green energy and energy efficiency projects that adopt high-road labour practices. The US' policy framework would draw into sharper focus later in the year, of course.

In June a 20% levy on imported solar modules, cells and inverters was proposed to come into effect from August in India, a move designed to help stimulate domestic manufacturing. However, this decision would be cited as a blow to Chinese inverter manufacturers which, according to research compiled by **JMK Research & Analytics**, had come to dominate India's rooftop solar inverter market.

Continuing on the finance theme, research from the **Solar Energy Research Institute of Singapore (SERIS)** found that combining bifacial solar modules with single-axis trackers remains the most cost-effective path for developers across much of the world. They modelled the performance of various solar designs based on NASA irradiation figures, with the results, which were checked against field data, showing that mixes of bifacial and single-axis trackers carried the lowest levelised cost of electricity (LCOE) across 93.1% of the areas under analysis.

Meanwhile. **Meyer Burger** announced plans to start exclusive heterojunction solar module manufacturing in the first half of 2021, with the intention of raising CHF165 million (US$173.4 million) to do so.

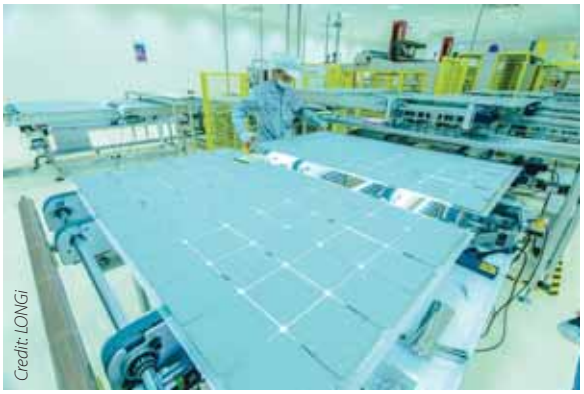
It is clear that whilst COVID-19 dominated the headlines during Q2, the quarter was also one of great progress. Low demand and sunny weather led to high levels of solar generation in many countries and the sector emerged from a quarter full of uncertainty and unprecedented barriers with a greater resilience than when it entered. Q2 laid the foundations for what was to follow in H2, with promises of green recoveries and project completions on the horizon.

Q3: Upstream pinches and a US residential solar shake-up

Throughout Q3 there were several key developments across solar's upstream sector, including **JinkoSolar** starting off the quarter by laying claim to a record large-area N-type monocrystalline silicon solar cell conversion efficiency of 24.79%. The cells have a practical size of 267.72cm2 and are made of high-quality CZ mono-Si substrate, helping them achieve the record levels independently confirmed by the **Institute for Solar Energy Research** in Hamelin, Germany.

Further progression was made by competitor **Trina Solar**, which announced in August that it was planning its first major solar cell manufacturing expansion for years due to its migration to large-area PV modules using the 210mm wafer size. This change will allow it to increase production of its high-performance mainstream 'Vertex' Series modules in 2021 onwards.

Modules featuring 210mm wafer sizes have been in the spotlight for much of 2020, in particular in China, where the production capacity of 210mm mono cells is set to reach an astonishing 120.5GW when combining capacity expansion and production lines of tier 1, 2, and 3 cell manufacturers and new investments, according to an industry survey from September 2020.



Credit: LONGi

Solar manufacturers are increasingly pushing for larger wafer sizes.

One area of the solar sector that has seen volatility through Q3 is the price of solar cells, in particular in China. In early August, **Tongwei** announced that its prices for poly cells had increased by anther US$0.06/W, while its 156.75mm, 158.75mm and 166mm mono cells rose by US$0.08/W, when compared to prices on 24 July. Following this **LONGi** announced wafer prices were jumping US$0.03/W and its cells by US$0.08/W, marking the beginning of what many referred to as a 'price war'.

Price volatility has been driven by polysilicon supply, with a number of incidents at facilities owned by **GCL-Poly** and previously **Daqo** putting pressure on module price control. For **Tongwei** this was also exacerbated by severe floods in southeastern China in August forcing it to shut its 20,000-tonne polysilicon plant in Leshan City, Sichuan, further impacting the supply chain.

US$0.0131/KWH
Portugal's new record-low solar tariff

Other factors played into the growing prices, with the cyclical, seasonal nature to polysilicon, wafer and cell prices impacted as production slowed early in the year due to COVID-19 but demand for solar remained high with strong installation predictions for the second half of 2020.

Manufacturers and developers urged caution in response to the rising prices, pointing to the jump as a reaction to events such as the floor rather than a long-term trend. Despite this, it has undoubtedly caused challenges for module companies that were forced to renegotiate supply prices.

In Europe, record low prices were recorded in Portugal's second solar auction closing with prices of €11.14/MWh (US$13.12), or US$0.0131/kW. This auction – with 700MW available, of which 670MW was awarded – beat the previous industry record tariff of US$0.0135/kWh set by in Abu Dhabi by the Al Dhafra project in April. Portugal awarded **Hanwha Q CELLS** half of the 12 lots in the auction, while other winners including **Tag Energy**, **Iberdrola** and **Enel**, with the majority of the bids including battery

European Energy's Apulia solar farm is particularly significant as it has not been supported by state subsidies.

Credit: European Energy

storage. The result was particularly significant as prices came in around 25% lower than in the previous year, when the lowest bid in the country's first auction was €14.76/MWh, itself a record at the time.

Elsewhere in the continent, **European Energy** forged on with Italy's largest solar farm. The 121.5MW Apulia triplet of sites, secured €96.5 million (US$113.59 million) in funding in August from French financial service firm Natixis. As well as the sheer scale of the project – which is comprised of three sections: a 63MW site that's been in operation since November 2019, a 40MW site in grid parity completed in June 2020 and a 18.5MW site in grid parity due to be completed later in 2020 – the Apulia solar farm are significant as it is thought to be the first Italian PV farm to be financed without having first been supported by state subsidies.

In the US, **Sunrun's** acquisition of rival **Vivint Solar** in July shook up the sector, creating a combined entity with a customer base of nearly 500,000 and 3GW of installs on its balance sheet. The sheer scale of the resultant company from the US$3.2 billion all-stock acquisition will allow it to "accelerate the adoption of solar" in the US residential market it said.

While Sunrun secured its top spot in the US, others have struggled more in 2020. In particular, Tesla announced that Q2 2020 was its worst quarter for deployment on record. Across the three months it installed just 27MW of rooftop solar, alarming watchers as it fell 7% year-on-year despite Q2 2019 setting its previous record low. Chief executive Elon Musk remained upbeat about the long-term prospects of the technology however, adding that he was "very excited about that business potential".

Q4: A bitter election campaign and the new king of power

As the year drew a close, all eyes narrowed in on what became a bitterly contested US election campaign, marked by accusation of vote rigging and election fraud. Nevertheless, Joe Biden was declared President-elect, and he will become the 46th President of the United States in January 2020. Upon entering the White House his in-tray will be dominated by pandemic measures, but the defeated Donald Trump did manage to throw one solar curveball by managing to force through the repeal of bifacial's exemption from Section 201 tariffs that he fought for throughout the year. Further measures to extend the tariffs and make them steeper at 18% were also included within a Presidential Proclamation issued in October, and more detail is expected to emerge in the coming weeks.

> "I see solar becoming the new king of the world's electricity markets"

Staying in the US, a study conducted by analytics firm **kWh Analytics** found what it deemed to be a "troubling reality" in October, revealing that swathes of completed solar farms in the country were underperforming against original projections. From a sample of projects assessed, kWh projected that more than 30% of solar farms had missed their productions targets by more than 10%, even accounting for weather fluctuations. The company had suggested that developers may have been too optimistic when taking into account technology evolution.

Moving upstream, material and component costs were again proving to be a particular point of contention. A consortium of major Chinese module manufacturers including **Canadian Solar**, **Risen Energy**, **JA Solar**, **JinkoSolar**, **LONGi** and **Trina Solar**, amongst others, issued a joint statement calling for government intervention regarding solar glass prices that they said had spiralled "out of control" in recent months, with prices in some instances more than double what they stood at even in Q3. The breathtaking pace of capacity expansions had, evidently, not spread throughout the chain.

Meanwhile, manufacturers to have thrown their weight behind the 210mm class of large-area modules issued a further plea for industry standardisation, issuing a range of ideal formats and specifications that, they said, would allow the entire solar industry to deliver "the best possible scale" if they were adhered to.

But, after what has been an altogether difficult and at times troubling year for many, it is imperative that the solar industry reflect and acknowledge a year littered with sterling achievements and considerable progress. Capacity expansions galore and cheaper-than-ever solar tenders are just the start of a decade of progress that other power industries can only dream of replicating.

That much is evident from the slew of reports and analyses published towards the end of 2020, not least of all the **International Energy Agency's** World Energy Outlook, which said solar would become the new king of worldwide electricity markets courtesy of significant price reductions and consecutive years of record deployment throughout the next decade. Leading that charge will be Europe and China, with the US not far behind, however concerns remain over the pace at which grid improvements may be needed to facilitate such an increasing demand for solar power.

New analysis from **Lazard**, published in late October, also concluded that solar's levelised cost of electricity (LCOE) had continued to fall, dropping to between US$31 – 42 in 2020, a drop of some 9% as technologies continued to mature. At those prices, solar is now cost-competitive with coal nuclear and combined cycle gas generation (CCGT) when US government subsidies are included, and baring down on those prices when they are not. PV, it would seem, stands on the edge of a grid-parity precipice, after which electricity markets will change for good. Solar is moving into 2020 with the wind in its sails, and wind and other generators in its rear-view mirror. ■

Joe Biden won November's election and will become the 46th President of the United States in January 2020.

Credit: Adam Schulz / Biden for President

Exhibit/Participate in Japan's most popular PV Show

Japan's most popular PV show – **PV EXPO**, organised by Reed Exhibitions Japan Ltd., will be held from Wednesday 3 March – Friday 5 March 2021 at Tokyo Big Sight, Japan, under World Smart Energy Week, the world's largest-scale smart energy show.

The event will be held on the back of World Smart Energy OSAKA, which was successfully held in September 2020 and attracted industry professionals despite thorough measures to protect against COVID-19. The event was also held as a hybrid event, featuring both on-site and virtual elements, with both filled with high-quality visitors.

Around 80% of exhibition space has already been sold, so do not delay in securing your space at PV EXPO 2021.

Video Highlight of 8th World Smart Energy Week OSAKA in September 2020

For Chinese Version >> https://v.qq.com/x/page/y3204gcgml3.html

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The third pillar: How floating PV can fulfil its potential

Credit: Lightsource BP

Floating solar | Despite its generation characteristics, floating solar has yet to truly fulfil its undoubted potential. Jules Scully explores why the technology continues to face hurdles, and what the industry is doing to surpass them.

Falling development costs combined with limited land availability in densely populated countries have seen floating PV (FPV) pitched as the third pillar of the solar sector alongside ground-mounted and rooftop installations.

Proponents of the technology point to its increased energy yield thanks to both the cooling effect of water on panels and the reduction in shading due to the surroundings. Colocation with hydropower plants – and taking advantage of existing transmission infrastructure – can bolster the generation of such assets and smoothen the generation curve, while also decreasing water evaporation and limiting algae growth.

However, as countries scramble to ramp up their renewable energy capacities to meet climate targets, floating solar remains underutilised, particularly in areas where space is not an issue, and tried and tested ground-mounted PV provides a less risky, cheaper proposition. Estimates suggest under 3GW of FPV was installed globally by the end of 2019 – less than 1% the world's total solar capacity.

Higher costs compared to ground-mounted PV, bankability hurdles and a lack of track record in terms of operations and maintenance (O&M) data are all reasons put forward by major solar developers, investors and financiers for having not entered the FPV market. According to Capital Dynamics, an asset management firm with a clean energy infrastructure portfolio of more than 7.3GW of power generation, FPV projects "are too unproven", while German developer Juwi says the technology is "relevant, but so far it is a niche application".

For CIT Group, the huge opportunity for land-based solar in the US means its client base has so far not approached the bank and renewable energy lender for FPV project funding. This is likely due to both economics and necessity, according to Mike Lorusso, managing director and group head for CIT's power and energy business.

Lightsource BP's only floating solar project to date, the 6.3MW install on the QEII Reservoir in the UK.

He says floating solar projects have more complexities and more risk factors to take into consideration: "It's going to drive up the cost of equity, it's going to drive up the cost of debt," he adds. Meanwhile, with high irradiation and large open space available for land-based PV in states such as California, Texas and Arizona, Lorusso says "there is no need" to develop floating solar in these areas, adding: "And it's going to be a lot more expensive."

Indeed, the cost of developing FPV systems is normally higher than ground-mounted projects of a similar size as a result of the requirement for floating structures, moorings and more resilient

electrical components. These costs are, however, expected to fall as the technology evolves and developers take advantage of economies of scale.

A landmark report published in 2018 by the World Bank and Solar Energy Research Institute of Singapore (SERIS) suggested that while floating solar systems are more expensive to install, their greater efficiency might partially offset the higher cost. The levelised cost of electricity (LCOE) for a generic 50MW FPV project "does not differ significantly from that of a ground-mounted system", the report said. Although floating solar projects are said to be 18% more expensive than a land-based equivalent, their performance ratio is 5-10% higher.

Though a considerable reduction in costs is difficult to predict, in part because floating structures remain dependent on crude oil prices, the World Bank and SERIS say FPV costs are approaching those of ground-mounted systems, and may eventually lead to an equal or lower LCOE.

The design of the floating structure and its anchoring system is based on each site, with costs depending on the engineering challenges involved. "Every water body is different and is exposed to varying climate conditions. These variables have a strong influence on the selection of the best floating structure and how the FPV system will perform over time," Thomas Reindl, deputy CEO at SERIS, says.

Noting that there are "different voices" in terms of O&M costs, Reindl is calling for industry players to share their experiences. SERIS is looking for launch partners to start the International Floating Solar Society, which would provide a common platform where information can be compiled and used by the industry.

Europe's FPV pioneers

One of the leaders in the European FPV market is German developer BayWa r.e., which completed the continent's largest floating solar facility – a 27.4MWp project built on a sandpit lake in the Netherlands – earlier this year.

After entering the FPV sector in 2018 with the acquisition of a 70% stake in Dutch firm GroenLeven and its project pipeline, BayWa r.e. went on to develop its own substructure suitable for large-scale installations, which is "much more easy to maintain over the lifetime of the system", according to Toni Weigl, BayWa r.e. product manager for floating PV. The GroenLeven deal combined with the creation of its own floating solution gave the company "the opportunity to really take off with floating PV", Weigl said.

As well as a high module occupancy rate because of its east-west configuration, BayWa r.e's solution features inverter boats, maintenance walkways, cable ducts, wave barriers and a floating transformer station.

In terms of O&M costs, Weigl said developing solar projects on water means there is no need for video surveillance, theft protection and grass cutting that is required for land-based sites. "We have actually lower operational maintenance costs in our floating PV systems compared to ground-mounted PV," he says.

Having completed an initial 2.1MWp FPV project in 2018, BayWa r.e. has now constructed six facilities, all located in the Netherlands. "With every (floating) plant we are building, the costs are going down further," Weigl says.

Despite a reluctance among some lenders to bankroll floating projects, Weigl says BayWa r.e. works with banks that are "happy to invest in and finance these projects".

"And after, they realised it was also very easy to find a long-term investor to step into the project and take over that project… There was a huge appetite from investors to get our floating PV projects acquired."

With its 52,000 hectares of shallow inland water surfaces, the Netherlands is also of interest to another project developer, Lightsource BP, which is currently exploring opportunities for FPV in the country. To date, the company has commissioned 1.3GW of solar capacity globally and has a portfolio of 2GW under management. But its only outing so far in the floating solar sector came in 2016 when the firm completed a 6.3MW array – Europe's largest at the time – on London's Queen Elizabeth II reservoir on behalf of utility Thames Water.

"We went into that space mainly on the motivation of innovation," Chris Buckland, technical director at Lightsource BP, tells PV Tech Power. "The feed-in tariff at the time was enough to pay for us to spend a significant amount of time developing that technology together with [FPV structure provider] Ciel et Terre."

The facility, which took 15 months to complete, covers around a tenth of the reservoir, features just over 23,000 solar modules and will generate enough electricity to power Thames Water's local water treatment plants for decades. "The reason that was particularly useful for Thames Water is clearly around that site," said Buckland. "A lake in a built-up area is ideal for floating solar."

While the feed-in tariff combined with the power purchase agreement with the utility meant that the project "worked from a financial point of view", Lightsource BP has since steered clear of floating solar, opting instead to develop ground-mounted projects as it pursues a solar development pipeline in excess of 12GW.

Buckland says that while private financing "is not an issue" in terms of floating projects, Lightsource BP would need a market pull to fully embrace the technology. Without such an incentive, the company will continue to "put in the most cost-effective solution, which is dropping solar onto a piece of suitable land well away from urbanisation and connect to the transmission [grid]," he added.

A government's role

Land constraints combined with favourable policies and government support

BayWa r.e.'s Bomhofsplas project in the Netherlands.

Credit: BayWa r.e.

for the technology mean that Asia is the leader in the global floating solar market, with Wood Mackenzie suggesting the continent has 87% of total global capacity of the technology. Noting that Asia also "dominates the technology's project pipeline", a Fitch Solutions report published in October 2020 highlights China, South Korea, India, Thailand and Vietnam as "key outperformers" in the sector over the next decade.

According to the consultancy, China is the largest market for floating solar installations and is also home to the world's biggest project, the 320MW Cixi plant that was completed earlier this year. An additional 820MW of FPV capacity in the country will also be tendered by state-owned utility Datang Power by the end of 2021.

The crown of world's largest floating project will move to South Korea in 2022, when the first 1.2GW of a multi-billion-dollar facility being built inside the Saemangeum seawall goes online. Approved by the country's government last year, the facility will feature 5.25 million solar panels and a total capacity of 2.1GW when fully operational in 2025.

In Taiwan, the government has offered higher feed-in tariffs for floating solar projects than for ground-mounted farms, while Vietnam will hold FPV auctions for up to 400MW of FPV by the end of 2021.

Though feed-in tariffs can be used to encourage the large-scale adoption of floating solar, Thomas Reindl of SERIS calls for alternative policies. "When governmental support has been provided and eventually turned out to be too generous, tariffs have been renegotiated at a later stage afterwards, which is not helpful for the industry as a whole, and certainly not for [an] investor's/lender's confidence," he says.

"In most countries, PV and also floating PV have reached grid parity. The governments should therefore rather set the right legal frameworks and support floating solar projects on the administrative side, for example by facilitating permitting and coordinating the relevant government agencies involved."

Abhishek Kumar, head of solar system technology group at SERIS, says that in terms of technical development, governments can support industry by providing incentives to innovate new technology, products and floating PV field demonstrations. "Such innovation and thorough testing would reduce the risk of large-scale deployment and improve the techno-commercial feasibility of FPV projects as a reliable and bankable source of energy," he adds.

Singapore, the Netherlands and India are among the countries that have supported pilot floating solar projects. The first of its kind in India was founded by the Ministry of New and Renewable Energy and became operational in 2014. Since then, other test projects have been developed, including one in the southwestern state of Kerala that has a water level variation of 21 metres between summer and monsoon seasons.

The massive potential for floating solar in India was revealed in a recent report from the Energy and Resources Institute (TERI), which found the country's reservoirs could be used to generate 280GW of solar power. The think tank estimates that figure would be achieved if 30% of the water surface area of the country's medium and large reservoirs were fitted with FPV.

With India aiming to reach 100GW of installed solar by 2022, TERI said alternatives such as such as floating PV "need to be explored and established". It is time to bring "a conducive policy framework to encourage tapping this potential", says Ajay Mathur, director general at TERI.

State-owned Solar Energy Corporation of India, which last year issued a tender involving 20MWac of floating solar projects coupled with 60MWh of battery energy storage systems, previously revealed plans to use the large availability of water of major reservoirs in the country to develop floating PV and bypass physical and legal hurdles regarding land acquisition when setting up ground-mounted solar projects.

However FPV could find its future prospects emboldened not by policy or tender initiatives, but by combining with another generation technology.

The ideal situation of FPV-plus-hydro

According to the Institute for Energy Economics and Financial Analysis (IEEFA), India is a country to watch among Southeast Asian states as it continues to remove roadblocks and ensure policy stability to accelerate renewable energy.

A recent report from the think tank says Southeast Asia's land scarcity, and the lack of primary energy resources and associated infrastructure, have created a high barrier for some land-intensive renewable energy options. The geography and demographics of the region present a "distinctive opportunity" for floating solar, IEEFA says. It is estimated that at least 24GW of the technology could be installed there by co-locating with existing hydropower facilities.

"Our research shows more and more ASEAN countries are building solar farms that float on rivers, dams, lakes and reservoirs – even the sea – to produce clean electricity at prices that can compete with power from polluting coal-fired plants," says Sara Jane Ahmed, energy finance analyst for IEEFA.

The report says much of the cost advantage of hybridising FPV with hydropower comes from having minimal site costs and the opportunity to connect to existing grid, substation and transmission infrastructure. "Focusing on the economics of generation assets in isolation does not make sense because of the need to invest in transmission lines. A grid-level solution, considering the cost of generation plus transmission requirements, is key," Ahmed adds.

The research highlights the potential for FPV-plus-hydro projects in Southeast Asia to increase power output while reducing variability, providing renewable energy

The 100MW FPV project along the Hunan River in China.

Credit: Sungrow.

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that can be dispatched as needed by grid operators.

These grid benefits were also noted in a recent study from a team of Michigan State University scientists who explored the potential of offsetting the underproduction of Brazilian hydropower dams with floating solar. While 68% of Brazil's electrical energy comes from large dams, the researchers say there is around 12GW of underproduction of rated capacity at these facilities.

The research, titled 'Floating PV system as an alternative pathway to the Amazon dam underproduction', indicates that FPV could increase hydroelectric plant production flexibility by 76% and the capacity factor by 17.3% on average. Although the Brazilian government is planning to build more dams to meet future power demand, the study says mixed generation resources could provide an alternative approach to avoid the environmental and social impacts of these developments. The research says floating solar on dams' reservoirs leads to a "significant improvement" in the overall system reliability, minimises load curtailment and could potentially add more flexibility to the operator to dispatch power generated by hydropower plants during peak demands.

Despite the advantages of collocating solar with hydropower, developers who take on such projects are confronted with a host of challenges that are not seen at ground-mounted sites. For example, problems may arise when designing insurance policies that include liabilities for potential damage of a hydropower plant, while there may be issues surrounding permitting and environmental impacts.

Chris Buckland of Lightsource BP describes PV-plus-hydro as an "ideal situation, in that solar itself, all of a sudden has a huge battery associated with it". However, he warns that transmission connections can often be quite a long way from dams.

"The other aspect is, particularly in mid-size hydros, what you're looking at is a flooded valley, and by definition they have relatively steep sides. It's impossible to anchor floating solar, in distances of let's say 30 metres or 40 metres," he says. "Dropping anchors down vertically is not a solution that is appropriate for solar, because you really don't want it floating around like a boat, it needs to be tethered and anchored in a shape or form."

Anchoring that has to withstand waves as well as large fluctuations in water levels may also require more complete solutions, further driving up the cost of floating solar projects. One company set to tackle some of these issues is Norwegian independent power producer Scatec Solar, which struck a US$1.1 billion deal in October to acquire hydropower developer SN Power, touting the potential for floating solar on reservoirs.

"SN Power will give Scatec Solar immediate access to existing reservoirs and grid infrastructure on which to build floating PV," says Terje Pilskog, EVP project development at Scatec. "SN Power has done extensive feasibility studies on floating pilot plants in the Philippines which will give Scatec immediate practical experience to leverage."

In addition to SN Power's portfolio of hydropower assets in the Philippines, Laos and Uganda that have a total capacity of 1.4GW, the transaction includes the firm's 2.5GW project pipeline, mainly across Asia and Sub-Saharan Africa.

As well as the Philippines, Pilskog forecasts "strong growth" in the FPV sector of countries such as Bangladesh, Malaysia, Indonesia. "We see great potential in countries that experience significant power demand growth, but at the same time have limited access to large-scale land areas for traditional ground-mounted PV," he says.

According to Pilskog, two factors are driving the potential of FPV globally: solar increasingly becoming the lowest cost form of new energy; and the rapidly maturing floating PV supply chain, with installations "increasingly both sufficiently reliable and cost competitive to compete head-on with thermal generation".

Pilskog now calls for government action to help unleash the potential of floating solar. "Currently, the cost development for FPV is still lagging traditional ground-mount PV. This creates a bit of a chicken-and-egg situation, where slow adoption. Due to, for example, FPV having to compete with ground-mount PV in tenders, limits the ability to build the large-scale supply chain that can bring down costs in the mid-term. The industry and authorities should therefore seek to establish framework that enable larger-scale adoption of FPV specifically," he says.

While new policies and regulations could help industry players expand their presence in the FPV market, a lack of standards to ensure quality as well as harmonised approaches when developing projects mean investors may shy away from backing planned developments. This is one of the issues that a collaborative joint industry project (JIP) launched by DNV GL looks to address. The risk management firm has brought together 14 industry participants – including BayWa r.e., Scatec and Norwegian hydropower company Statkraft – to develop a recommended practice for FPV facilities. It will focus on five topics: site conditions assessment, energy yield forecast, mooring and anchoring systems, floating structures, and permitting and environmental impact.

"Until now, the growth of FPV has been quite impressive, especially in Asia, and has taken place without standards and guidelines," said Michele Tagliapietra, project manager of the JIP consortium. "In other markets, such as Europe, the situation is slightly different and the FPV industry has faced some obstacles particularly in permitting processes because of lack of clarity and guidelines."

The recommended practice will therefore contain requirements on what needs to be taken into account to ensure that floating projects are safe and reliable throughout their lifetime. Tagliapietra says it is "imperative" to share lessons learnt and standardise procedures to increase quality in installations and prevent an impact on trust in the FPV sector. Publication of the recommended practice, which will be freely available to download and consult, is scheduled for the first quarter of 2021.

According to Tagliapietra, the main obstacles for harnessing the full potential of FPV relate to quality and procedures. "There is still a lot to be learnt and understood, especially on aspects such as environmental impact, O&M procedures, testing, safety and durability of floating structures under environmental loads and stresses."

Thanks to the falling cost of developing projects and an increased understanding of the benefits of floating solar, Fitch Solutions expects utility-scale floating PV "to take off globally over the next few years", forecasting nearly 10GW of new additional installations by the end of 2025.

As projects mature and collaborative standards develop, governments and investors should gain more confidence to back floating PV. Reindl of SERIS believes it is necessary for the sector to "learn by doing" and by sharing the experiences. "In any case, there are lots of developments ongoing, and like in other industries, those who take early-stage risks have the chance to gain a first-mover advantage." ■

Building Back Better: Can Biden turn the policy tide for US solar?

US election | Joe Biden's victory in November's US election may have taken some time to certify, but there's every chance his tenure in the White House will be worth the wait for US solar. Molly Lempriere looks at what a Biden administration will do for the industry.

President-Elect Joe Biden visiting a solar farm in the US.

Credit: Nextracker

Environmentalists clamoured to celebrate the election of Joe Biden after a tense and extended wait to find out who would become the next president of the United States in early November. Throughout his and his running mate Kamala Harris' campaigns, the need for action on climate change, including support for renewables, had been front and centre, giving hope to the solar sector of further support.

"President-Elect Biden's plan to combat climate change enables our industry to create hundreds of thousands of well-paying jobs across the country," says Abigail Ross Hopper, president and CEO of the Solar Energy Industries Association (SEIA). "We look forward to working with his administration and Congress on policies that reduce carbon emissions including tax policies that pave the way for greater adoption of solar energy and energy storage."

But while optimism pervades the sector – with multiple solar manufacturers seeing their stock prices rise in response to the win – much remains to be seen about Biden's clean energy policies and their prospective impact on the sector.

Industry bodies have begun to voice their hopes that some of the headwinds created during outgoing President Donald Trump's term, such as increased tariffs and reduced support, will now be reversed. But many remain cautious, highlighting the need for bipartisan support, and are apprehensively waiting for the results of the senate race, with a run-off election in Georgia set for early January 2021.

For example, in a statement congratulating Biden on his electoral victory, US solar manufacture First Solar said it was "hopeful that policymakers on both sides of the aisle will be able to embrace the need for a long-term renewable energy policy that

will deliver the certainty required to attract investment, drive R&D, and create stable solar jobs".

The significance of re-joining the Paris Accords

Throughout his campaign, Biden repeatedly stated that one of his first moves when he takes office on 20 January 2021 will be to re-join the Paris Agreement by executive order.

When the US formally withdrew from the historic agreement on 4 November 2020 – just a day after the election itself – the then presidential nominee took to twitter to declare: "Today, the Trump administration officially left the Paris Climate Agreement. And in exactly 77 days, a Biden administration will rejoin it."

This will send a strong signal to the US solar sector about Biden's priorities during his four-year term. Bill Parsons, COO of the American Council on Renewable Energy (ACORE), explains that it was both significant in terms of the symbolism of the action as well as making "tangible progress towards climate targets, and the critical role that solar and other forms of renewable power are going to play in achieving those objectives".

Beyond the commitment to re-join the Paris Agreement, there are not many details known about the incoming President's support for clean technologies. Speaking on a press call recently, SEIA CEO Abigail Ross Hopper confirmed that in her discussions with the incoming team, they had not yet indicated which direction they would take with regards the Investment Tax Credit (ITC), for example.

But Biden has announced one significant energy policy, committing to invest $2 trillion over his first term to accelerate America's transition to a carbon pollution-free power sector by 2035. While this may seem ambitious for a nation that still relies on fossil fuels for 63% of its electricity according to the US Energy Information Administration, it is within reach according to solar manufacturer Nextracker's CEO Dan Shugar.

Shugar says that in order to understand the trajectory for US solar, it's important to reflect on the journey the sector has undergone so far, and in particular over the last 15 years. In 2005, solar cost "over an order of magnitude more than it does now", Shugar says, and played a very small role in the US power sector.

"15 years ago we built the largest solar plant in the world, which was 10MW, and took us a year. We're doing 10MW now every day before breakfast, we do another 10MW by lunch, another by dinner, then we do another one overnight. So that's the clip we're moving at, how fast and how much things have happened in the last 15 years," he says.

The SEIA has set an ambitious goal of solar generating 20% of all US electricity by 2030, a significant jump from today's roughly 3%. That would require growing at an average rate of 18% annually, and installing more than 500GW of solar in less than a decade. Doing so would help hugely with reaching a net zero grid by 2035, but would require strong political support.

"I'm very optimistic we can land a zero or near zero grid, but in terms of how that plays out pragmatically, we need some cooperation with a broader constituency of our political leaders. Hopefully, we can get to more cooperation between our two respective parties to implement that soon," Shugar says.

Rolling back Section 201: the carrot not the stick

Looking forwards at the policy changes that could prove the most important for solar, changes to PV cell and module tariffs could bolster US manufacturing and the industry at large substantially.

In 2018, President Trump brought in tariffs for the import of solar cells under Section 201 of the Trade Act of 1974. These were set at 30%, with a 5% declining rate per year over a four year period, intended to boost US manufacturing. Following a challenge from the industry, bifacial tariffs were made exempt from Section 201, along with 2.5MW of cells.

But in November 2020, and following a long and protracted legal battle with the Trump administration, the exemption for bifacial panels was repealed in a proclamation issued by President Trump. The move was initially held off by Judge Katzmann of the US Court of International Trade, who issued a temporary restraining order, which meant the motion – which will see the 20% tariff extended to bifacial as well as increasing the tariff from 15% to 18% for CSPV and modules from 2021 – had to be further considered.

President Donald Trump said that the exemption of bifacial panels had "impaired and is likely to continue to impair the effectiveness" of the Section 201 safeguard measures. Additionally, he stated that exemption had prevented the tariffs from being as effective as envisioned, and as such would need to increase in order to "achieve the full remedial effect envisaged".

The duties have been consistently criticised by the US solar sector, and are largely viewed as creating an additional burden. Across the US and the world, solar has to compete on a cost basis with technologies such as wind and gas that are also seeing dramatic price drops. As such, increasing the cost of solar installations for homeowners, utilities and businesses will cause many to choose another energy technology.

Following the mid-term review of the tariff in early 2020, the SEIA's Ross Hopper stated: "While the solar tariffs have resulted in some new US manufacturing investments, total domestic cell and module capacity falls far short of demand. The tariffs have effectively constrained solar development in the United States."

There have been arguments made in favour of the tariffs, for example when they were first announced a number of international manufactures such as Hanwha Q CELLS, Jinko and LG established module plants in the US. But by the first half of 2019, just one cell producer remained in operation, according to the US International Trade Commission's review. There was an initial decline in imports of PV components between 2017 and 2018, but by 2019 it was again on the increase. Similarly the financial performance of US cell producers had declined just a year into the tariff.

The impact of Section 201 was compounded in some ways by the additional introduction of Section 301 tariffs, which placed a 25% tariff on Chinese imports. Nextracker's Shugar says that these were simply too large, and needed to be modified in an appropriate way. He highlights that it wasn't just the cells themselves being impacted by the tariffs, but the manufacturing equipment, which had become more expensive to import.

Going forwards, much of the industry is hoping for more "carrots versus sticks" policies, as SunPower's director of market policy and strategy Suzanne Leta explains. "With respect to the Biden-Harris administration, we would like to see them prioritise encouraging clean energy innovation through things like tax credits, loans, grants, those types of carrots, which are proven to be effective."

ITCs: the 'single most effective' clean energy policy

One of the most prominent hopes from the solar sector is for the extension of the ITCs,

with SunPower's Leta describing it as the company's "first, second and third priority".

First introduced in 2006, the ITC has been one of the most important federal policy mechanisms to incentivise clean energy. Since its introduction, the US solar sector has grown significantly and has a 52% average annual growth rate. In 2015, the policy was further extended by five years helping to provide certainty to companies looking to develop long-term investments, and is expected to have nearly quadrupled solar deployment by the end of 2020, spurring US$140 billion in economic activity.

The rate was set at 30% when it was extended, dropping to 26% in 2020 as part of a phased degression which, in the policy's current guise, will see the credit drop again to 22% in 2021, before the scheme is set to come to an end.

With the deadline approaching, it had been hoped that the credits would be once again extended in order to spur on the solar sector. But when the federal tax provision was released at the end of 2019, what the SEIA has referred to as "the single most effective current policy available to encourage clean energy deployment" was not included.

This came as something of a surprise to the industry, with SEIA's Ross Hopper suggesting in a recent press call that the "extension of the investment tax credit was sort of in the deal until the very last moment". "It was not necessarily congressional pushback, but perhaps White House pushback," she said.

Along with changes to the tariffs, an extension to the ITC is one of the SEIA's key legislative hopes for the Biden-Harris administration listed in a document released by the trade body detailing their hopes for the first 100 days. In addition to a long-term extension at the rate of 30%, the association is calling for a direct pay or cash grant option for the ITC in light of the poor health of the tax equity market, due in part to COVID-19, as well as the long-term ramifications of that on the pipeline of solar projects.

It is a sentiment shared by many in the solar sector, and in a letter to the US House and Senate leadership following news of Biden and Harris's electoral success in November, 45 organisations and companies spanning the environment, conservation, and clean energy called for support for clean energy including an extension to tax credits. They highlighted the impact the COVID-19 pandemic had had upon the clean energy workforce, with roughly 450,000 clean energy workers – or 13% of the sector's pre-pandemic workforce – still out of work.

"These are good jobs that paid 25% more than the national median wage in 2019," they continued. "In addition to reviving jobs, support for clean energy improves the overall health of the economy as it leverages private capital and saves consumers money in difficult times. It is also vital to America's global competitiveness and energy independence."

Going forwards, ACORE is confident that we will see an extension to the ITCs, with Parsons commenting: "What I can tell you is regardless of the outcome in Georgia, on January 5, we do see growing bipartisan support for these extensions." He says that both Democrats and Republicans were

All eyes on Georgia run-offs as Dems seek Senate control

By Liam Stoker, editor-in-chief, Solar Media

With incumbent President Donald Trump having reluctantly allowed for the transition towards a Biden presidency to start, the dust finally began to settle from an election in late November. But as Trump continues to cry foul, the reality is the US solar sector remains uncertain over what shape the four years following 20 January 2021 will take.

While the US election has delivered a fairly resounding win for the Biden-Harris ticket, it was not quite the complete repudiation of Trumpism some had forecast and, as a result, the Democrats have not yet sealed the hattrick of winning the White House, Congress and the Senate. The result of the latter will be decided by two run-off elections in the state of Georgia, scheduled for 5 January 2021, which will now become arguably just as hotly contested as the presidential election.

For the Democrats to be able to push through as much of their legislative agenda as possible, they need to control all three. Failure to regain control of the Senate will allow Republicans to block any prospective policy they find umbrage with or, as has been the case of late, simply decide to blockade for the sake of it being lobbied for across the aisle.

For the US solar sector, this could mean two critical pieces of supportive legislation – the Investment Tax Credit and Section 201 tariffs – could become embroiled in political deadlock or allowed to be adjusted to meet the Democrat's aims, depending on what happens in Georgia. Speaking at November's Solar & Storage Finance USA event, organised by PV Tech publisher Solar Media, Marathon Capital's Ammad Faisal described the outcome of the Georgia run-offs as a "US$200 million question", saying that the "whole picture changes if the Dems control the senate", regardless of Biden's much vaunted ability to 'work across the aisle'.

For the ITC, there is – thankfully – a "healthy probability" that such an amendment could pass, according to Roth Capital's Philip Shen, who pointed to the fact that Republican house leader Mitch McConnell included an ITC extension in a Bill introduced to the House earlier this year, indicating bipartisan appetite for it. Indeed, renewables are no longer the bastion of the Democrats, and an increasing number of Republican senators have come to support the industry in the US.

What could be more difficult to push through is an ITC for standalone storage. As it stands, energy storage facilities can benefit from an ITC but only if they are co-located with solar and installed at the same time. There has been a considerable push to relax these rules to further promote the installation of energy storage but, as yet, that change has yet to happen. Shen says it would remain possible for the Biden administration to push through, but it would be harder without control of the Senate.

Talk has also turned to how amendments to or an extension of the ITC could be enacted, given that it would require legislative change. Democrats did try to include the extension in the US stimulus bill earlier this year, only to see their efforts thwarted. Shen said a continuing resolution could be added to two potential bills – both the COVID relief bill and the omnibus spending bill – however probability on these fronts is "low", Shen said, given to a potential desire to "keep the COVID bill clean" to give it the best possible chance to pass.

Regardless of how an extension is implemented, the path to one is all the wider should the Dems complete a Senate win in Georgia. "If the Senate flips, then I'm pretty bullish on a robust extension of the ITC for solar and standalone storage… there's definitely a path to an extension with a 50/50 split," Ja Kao, CEO at Onyx Renewables, said.

Of a more complicated nature altogether is the future of Section 201 tariffs, which, further to Trump's presidential proclamation in October are set to rise to 18% next year and extended once again.

There is said to be questionable appetite to push back on Section 201 tariffs within Democrat ranks given their protective nature over US manufacturing, but even then, the Trump administration could make life all the more difficult. Shen said there was every expectation that the US Trade Representative will request the Trade Commission to conduct a study of the impacts of an extension to the tariffs. This would possibly open the window for Trump to extend the tariffs by a further three years before Biden's inauguration on 20 January. If these were to be extended for three years, there would also be no mid-term review, meaning it would be 2024 before tariffs could be repealed.

The impact such a decision would have on solar deployment is, however, open for debate. Solar deployment has accelerated in the US over the last four years regardless of the obstacles and hurdles thrown in its path, and as Kao says, the industry has "had to bob and weave for much of the last decade".

Any change of direction from a Biden administration would simply be upside the industry can capitalise on.

now supportive of renewable power, with the later particularly keen to incentivise the private sector to deliver on public policy objectives such as the ITC.

Leading by example: changes to federal procurement

A further policy change Biden could enact upon taking office to support the solar sector is changes to federal procurement. The US government is the largest buyer of power in the country, spending US$5.8 billion on electricity annually. Bringing in legislation that requires the US Department of the Interior to procure clean energy like solar could dramatically bolster the sector, as well as reducing government energy bills and its carbon footprint.

The SEIA's Ross Hopper says there is an "untapped opportunity" in federal procurement, with solar installations on public buildings and public land. "I think it would be more than simply leading by example, it would also provide a driver to the market," she said.

Estimates from the SEIA suggests there are 350 million square feet of federal buildings across the US, and if fitted with solar panels, that area could accommodate some 2,000MW of generation capacity. The sentiment has already been echoed in the Democratic party, with US Representative Deb Haaland – who is reportedly a contender to lead the Department of the Interior – promoting changes to the leasing practices to expand the use of renewables at the expense of fossil fuels in an interview with Reuters.

Nextracker's Shugar points to the existing 'buy-American' federal policy, suggesting that solar would be a straightforward addendum.

"The advantage now is that where the costs are, you can see significant reductions in utility costs for these facilities," he says. "So [Biden] could directly require these facilities to use more renewable energy, which would lower their costs, provide more market and create more employment. And these are things directly under his control."

The beginning of change?

There is still a lot that we don't know about the Biden-Harris administration's policies and how they will impact the solar sector. While the new leader is set to have a much keener focus on climate change and be more supportive of the technologies that can support climate action than the Trump administration, with the burden of coronavirus and the economic impact the pandemic has taken, it is set to be an incredibly busy start to Biden's term.

Importantly, who controls the Senate – which we are set to find out in January 2021 - will have a considerable impact on the efficacy of Biden's administration, potentially leaving a lot of climate action up in the air despite numerous call for bipartisan support.

Throughout his campaign Biden maintained a strong focus on climate action, this alone is likely to give a boost to the renewables sector that views him as a safe pair of hands. Whether or not that can translate into direct action remains to be seen.

"Every plan is great on paper, but it takes leaders to implement it effectively," says SunPower's Leta. "And so we are looking forward to seeing who the Biden-Harris administration appoints. And we hope, or I should say we're optimistic that those appointees will have a deep understanding of distributed solar and storage in particular."

Hunting hydrogen: who's leading the race for green hydrogen leadership

Green hydrogen | As green hydrogen starts to gain a foothold in the decarbonisation journey, Alice Grundy looks at the more developed markets for the technology, the measures needed to scale further and the role of solar PV

Green hydrogen, despite its undeniable role in a net zero economy, remains a nascent technology and one which has sparked many a debate. Whilst it's not controversial to say it will be needed in some capacity, the extent to which it will be used as the world decarbonises - and in which sectors and specific use cases it is applied - is less of a clear cut picture.

Green hydrogen can help to power fuel-cell vehicles and is often thought to be best paired with shipping and freight land vehicles and aviation. It can also be used for a wide variety of industrial purposes - with industry being tipped as the main customer for green hydrogen - as well as for heating. In particular, it is seen as beneficial for energy intensive industries such as the ceramic industry, the steel industry and the cement industry.

Green hydrogen is produced through electrolysis, during which an electrical current is used to separate hydrogen from the oxygen in water. This electrical current is sourced from renewable generators, typically – though not exclusively – solar and wind. Green hydrogen differs from other forms of hydrogen due to it being produced using renewables, although blue hydrogen – which is produced from hydrocarbons but incorporates carbon capture and storage (CCS) – is also carbon neutral.

In the race for green hydrogen leadership, three markets have surged ahead. These – Europe, Australia and the Middle East – have benefitted from either favourable policy environments, large project commitments or a combination of the two. But how exactly has this been achieved, and how does solar play into this?

Building a success story for solar and green hydrogen

There are a number of examples of green hydrogen projects that include solar around the world. In Scotland, solar is to be paired with a 10MW electrolyser and wind power as part of a project run by Iberdrola unit ScottishPower Renewables, gas specialist BOC and ITM Power. In Singapore, the Renewable Energy Integrator Demonstrator has seen a microgrid combining solar with hydrogen, wind, thermal and storage technologies built by Engie and Nanyang Technological University.

Meanwhile, solar giants such as the aforementioned Iberdrola have moved onto the scene, with the Spain-headquartered utility having announced the creation of a new business unit dedicated to green hydrogen in September 2020. It is currently working on a project to be located in Puertollano, southern Spain, which will see 100MW of solar PV combined with a lithium-ion battery and an electrolysis system.

But what makes solar a beneficial technology to provide power to an electrolyser over other forms of renewables? One factor which may influence the pairing of the two is price cannibalisation, which in countries such as Spain and Portugal is making it difficult to push more solar onto the system due to these markets already being heavily saturated with solar. This is something which can be overcome by pairing the solar with an electrolyser and "directly producing hydrogen in hours when the sun is shining" according to Aurora Energy Research's senior commercial manager Alexander Esser.

Esser also suggests that solar will have a higher importance when it comes to green hydrogen production due to import needs, with countries with high demand from industry such as Germany requiring imports from southern countries such as Spain and Portugal. These countries will "play a big role" in producing hydrogen and exporting it to north Europe, which will be a "big upside" for solar due to the high levels seen in those countries.

Imports will not only come from other areas of Europe, however. Australia has joined forces with Germany to fund a feasibility study into the production, storage, transport and use of hydrogen from renewable energy, with the project looking specifically at exporting green hydrogen from Australia to Germany.

Indeed, Australia prides itself on its status as leading on green hydrogen exports. It has signed deals with Japan, South Korea and Singapore, although the Germany partnership is the first to explore exports to a European country. Commenting at the time of this announcement, Australia's energy minister Angus Taylor said Australia has a "natural competitive advantage to be a world leader in exporting hydrogen", with exports from the hydrogen sector expected to contribute an estimated AU$11 billion per year in additional GDP by 2050.

Alongside its import potential, another

Credit: Toshiba

Toshiba's Hydrogen Energy Research Field in Fukushima, Japan, is exploring the use of solar in hydrogen electrolysis.

driver for solar when it comes to green hydrogen will be that there are often site constraints next to the offtakers. Esser suggests the example of a steel mill, stating that in cases like this "it's often easiest to build a solar farm next to the site to then produce the hydrogen", describing this as "the big advantage of co-locating".

However, the benefits of solar are highly location dependent. In desert countries sunshine is predictable and follows a daily pattern, meaning solar can be blessed with a high load factor. In countries such as the UK, solar has a load factor of around 15% compared to offshore wind being able to reach a load factor of 50%, according to Siemens Energy UK & Ireland's head of strategy Matthew Knight, who describes the load factor of the electricity supply as being "the biggest cost driver of hydrogen from electrolysers". The company is involved in the H2Future project in Austria, which has been running since 2017 and has seen a 6MW proton exchange membrane electrolysis system installed at the Voestalpine Liz steel plant, going into commercial operation in 2019.

When it comes to the energy costs, and in particular solar, it still seems to be a little unclear what price it would need to generate at to make it truly viable. Whilst Knight says it should be "as low as possible", he suggests it's "hard to say" a definitive figure.

Christian Pho Duc, Smartenergy's managing director of H2 projects, suggests that €50/MWh was "on the higher side and not sufficient for all cases" and that €30/MWh is around "the benchmark today". However, prices which go below €20/MWh or even €15/MWh are likely to arrive in the next five to ten years. Despite an auction in Portugal that set record lows with prices of €13.9/MWh, "there are no standalone business cases which really work on this price by itself today", he added.

"If you look into it, nobody right now - even with the nice sun of Portugal - can operate with this €13.9," Pho Duc says.

Storage driving hydrogen

For any nascent technology, the big question is how to build a viable business case. Hydrogen has been hyped up in the past says Pho Duc, but was lacking in political will whilst largely suffering from renewable electricity costs remaining too high. As it stands now, the outlook is more positive with strong political commitments from both the EU and Australia, as well as low electricity costs.

Energy storage can also have an impact on the business case, however. Installing a storage system for a green hydrogen project is no different to installing one for a solar PV plant or any other type of generation. The storage system allows excess renewables to be captured and used – in this case to produce green hydrogen – when the sun isn't shining or the wind isn't blowing.

In particular, storage with a duration between 30 minutes and two hours "makes the business case better" because of its ability to overcome those short-term variations in renewables, Pho Duc says. However, whilst long duration battery storage which could reach over days "would be nice", it isn't currently economically viable, he says, with the IRR of the cost of hydrogen getting worse with long duration. With costs continuing to fall, this will become viable in the future, however.

One storage company that deals in longer duration – although not the sort that stretches into days – is Invinity Energy Systems, which is to install a 1.8MWh flow battery on the island of

Eday, Orkney in Scotland, which will combine with tidal power to produce green hydrogen.

Ed Porter, business development director at Invinity, lauds the combination of these technologies as being very complementary, with the nature of tidal requiring a heavy amount of cycling, something which flow can handle.

Describing the interactions between storage and green hydrogen production, Porter says that "the key principle of this is that you're taking intermittent generation in the form of solar or tidal or whatever it may be, and then you're using that to provide a baseload energy supply to the electrolyser," with electrolysers needing "very constant baseload".

Political commitment: Supporting scaling up

The need for green hydrogen production may be understood, but how to scale it up and integrate it into the rest of the energy system is a different question altogether. Much of this is at least somewhat reliant on policy decisions. A number of policy commitments have been made in the past year, most notably the EU's Hydrogen Strategy, which was released in July 2020. A key element of this is a goal of enabling at least 40GW of electrolyser capacity across all of Europe by 2030 and a target of 6GW of electrolysers by 2024.

Aurora Energy Research's Alexander Esser describes this as a "very ambitious target" but warned that it's "not clearly mentioned how those targets should be achieved". In fact, when looking on a country level, the targets of the different European countries individually do not add up to the 40GW outlined by the EU. But the fact hydrogen's role in deep decarbonisation has been acknowledged and commitments made – not only by the EU as a whole but by Germany and Spain among others – is perhaps to be celebrated.

Indeed, Smartenergy's Christian Pho Duc describes the political commitment to hydrogen as "very, very important", with the associated "huge investments" helping to improve investor confidence.

Australia, too, has published a national hydrogen strategy, which was released in 2019. This details its plans to continue to scale the technology and maintain its leadership. Key to Australia's approach is the creation of hydrogen hubs, which are regions where users of hydrogen are co-located in metropolitan, regional and remote areas. An AU$70 million pot has also been designated to help green hydrogen projects in Australia by the Australian Renewable Energy Agency (ARENA), which is an independent agency of the Australian federal government.

Meanwhile, Western Australia is to host to the Asian Renewable Energy Hub, a project focused on green hydrogen production that could eventually reach 26GW of solar and wind generation.

> "The key principle of [combining storage with hydrogen electrolysis] is that you're taking intermittent generation in the form of solar or tidal or whatever it may be, and then you're using that to provide a baseload energy supply to the electrolyser."

Approval of the first stage, which includes 5GW of solar and 10GW of wind, was granted in October 2020 and came not long after the Western Australian government announced a AU$22 million investment to boost the state's hydrogen industry across export, use in remotely located industries, blending in natural gas networks and use in fuel cell electric transport vehicles.

Alongside the EU and Australia, the Middle East is seen as leading when it comes to green hydrogen. Saudi Arabia in particular has cemented its position with a commitment to build the world's largest green hydrogen project. It is to be jointly owned by Air Products & Chemicals, ACWA Power and the city of Neom, which is to be a smart city near the border with Jordan. The plant will be powered by 4GW of solar and wind and will produce 650 tonnes of green hydrogen per day.

Other projects include a green hydrogen plant which was installed at the 1GW Mohammed bin Rashid Al Maktoum Solar Park in the United Arab Emirates. This plant is a collaboration between the Dubai Water and Electricity Authority and Siemens and was lauded as the first of its kind in the MENA region.

When it comes to the combination of solar and green hydrogen, the Middle East benefits from having very high solar irradiation and the lowest solar prices in the world. The Middle East also benefits from its experience in dealing with large scale oil, gas and power projects.

However, regardless of policy commitments or large project announcements, the question does turn to how to finance green hydrogen. The Netherlands has a subsidy for the electrolyser itself, whilst in Germany the demand side is being incentivised. In general, it is agreed that subsidies will be needed, with Pho Duc stating that it is "hard to have a business case without additional subsidy", with suggestions for incentives being a transfer of funds or a carbon trading scheme that is beneficial to hydrogen.

Power purchase agreements (PPAs) will also be a key part of green hydrogen production, with Aurora Energy Research's Alexander Esser stating in the case of solar this is due to the need to have "an offtaker for the hydrogen for the solar developer, and the electrolyser producer wanting to have a stable price for the power".

Most importantly, when it comes to green hydrogen, regardless of which country, continent or state we're looking at, the message seems to be that time is of the essence. Green hydrogen may be nascent, but it is "an essential part of the value chain", as Pho Duc says.

"Waiting is not an option," Pho Duc says, with the development time of hydrogen being longer than projects such as solar due to it being a chemical plant. "You need to be prepared once the framework to start the project is in place," he adds.

This was echoed by Siemens Energy's Matthew Knight, who said that the industry needs both speed and scale, with the challenge being building "the first handful of gigawatt projects this year to get the supply chain going".

Green hydrogen is an industry that needs a lot of time, money and political will funnelled into it. It has experienced some big wins on these fronts, but to truly develop the industry so that green hydrogen can be produced – and used – at scale, this must continue, and at pace. Lessons can be learned from the EU, Australia and the Middle East and adopted into other strategies and projects, but it is also important that these three markets, whilst leading now, refuse to rest on their laurels. There's a lot more work to do. ■

How do you solve a problem like the grid?

Credit: SMA

The grid | As the proliferation of grid-scale renewables accelerates, capacity on national grids is diminishing just as quickly, leading to harder to find and ever-costlier connection agreements. Liam Stoker assesses some of the alternative options grid operators are exploring to extortionate grid upgrades.

In a year that has witnessed marked advancements in the stated power of solar modules, documented significant decreases in levelised cost of electricity and seen financiers sidestep warnings of the deepest economic recession in living memory, it would be easy to consider there nothing left in solar PV's path to domination of the power market. But ask any seasoned developer to name one issue that continues to be a thorn in the technology's side, and the majority – if not all – will return the same answer: The grid.

In reality, the grid is not a particularly new or emergent obstacle to solar, or indeed the wider renewables sector. Shelved as an 'intermittent' or 'variable' generator, renewables' relationship with the grid hasn't exactly been harmonious since the first great quantities of renewable power were connected. Most electricity grids are decades old, consisting of legacy infrastructure that creaks under modest pressure, and managing an influx of nascent technologies has become an unenviable task of spinning many, many plates, all at once.

More established solar markets are now feeling the pinch years of express renewables connections, with grid connection capacity sparse and, in some regions, almost non-existent. Solar-rich regions such as the UK's south coast and Extremadura in Spain are now near battlegrounds for grid connection agreements, battling it out for whatever scrap of spare capacity they can identify.

As the proliferation of renewables accelerates, the grid has become the chief concern of solar developers.

Queues can be lengthy, backed up by a sea of requests. Earlier this summer, Spain's backlog of renewables projects vying for grid connection agreements was said to have stood at hundreds of gigawatts, a figure one developer described as "mindboggling". And as supply and demand dynamics play out, the result is grid connection agreements skyrocketing in price. Another UK-based developer told this publication that the sums quoted to his company for a grid connection agreement were "astronomical" compared to what they have been historically.

Some markets have indeed been handed legislative support. A national decree on grid access in Spain, passed earlier this year, requires guarantees

to be paid for grid connection agreements and certain project milestones to be met at specific deadlines. If those deadlines are missed without good reason, permits are deemed null and void, and the project cannot connect to the grid. A similar policy was enforced two years ago in the UK, after two of the country's distribution network operators (DNOs) fired warnings at so-called "Grid Grabbers" – described as companies amassing grid connection agreements only to idle projects or attempt to sell them on at profit – outlining measures to prevent distribution grids from descending into a "wild west scenario". Comprehensive evidence of intent to proceed with projects is now required for a permit to be granted.

Visibility also remains problematic, both in terms of spare capacity and what, exactly, is connected to distribution grids. A study conducted by UK DNO Western Power Distribution last year uncovered thousands of connected distributed energy resources – commonly residential solar installs and electric vehicle chargers – that were not acknowledged in its system, seemingly caused by installers failing to file the proper paperwork. Last September the UK's electricity system operator National Grid ESO launched its own study to map out so-called "invisible" solar panels on the country's networks in order to improve its own forecasting.

Grid capacity is, unfortunately, a finite resource and not every solar farm, battery storage facility – or combination thereof – will be able to connect to the grid. And with distribution grid improvements or capacity expansions proving extortionate, coupled with a lack of political will to pass those costs onto the consumer, attention has turned onto better understanding how to eke out every last spare drop of grid capacity, either through more flexible connection agreements, better understanding generation portfolios, or the adoption of more novel technologies.

Knowing your load

One particular lesson that most seasoned developers will share is to work with your network operator, and not around them, and identify precisely what kind of load and generation profile you intend to connect. In markets where grid capacity constraints have been long-standing, there have been many examples of renewables operators being able to find middle grounds that support, rather than hinder, development. Ian Cameron, head of innovation at DNO UK Power Networks, says solar developers can help themselves hugely by steering away from so-called 'Square Requests', described as unrefined bids for "big lumps of capacity" at any one time. Instead, Cameron says developers must better understand what precise capacity is available and where, and tailor applications accordingly. To that end, UKPN has launched a 'DSO Dashboard' tool, which aims to provide that information in near real-time. This kind of "symbiotic relationship", as Cameron describes it, is pivotal to the progress of renewables.

> "Precise projections and forecasts regarding grid feed-in and consumption are therefore becoming increasingly important for reliable, efficient and cost-effective grid operation."

More recently, network operators in the Netherlands struck an agreement with renewables organisations in the country which promise to accelerate the grid connection process. The deal, enshrined within a legal covenant, sees solar operators agree to maximum export limits of 70% of its peak generation capacity – reflecting how a solar asset's performance only exceeds that figure for around 3% of its operational lifespan – in exchange for grid operators identifying more spare capacity on the grid.

In addition, network operators in the country have also agreed to share details around what areas of the grid are more likely to be constrained and where more capacity may be available, helping developers identify more ideal sites for future projects. A roundtable of UK network companies and renewables developers organised by PV Tech Power's sister publication Current± last summer on the subject of facilitating change on the networks also found that this amendment would be warmly received. Members of trade body Holland Solar have also agreed to a further amendment which ensures grid connection agreements are signed for a minimum of 20 years to ensure grid investments deliver better value for money, although with solar project expected lifespans now exceeding 35 years – and product warranties expanding to follow suit – this should not be a particularly surprising leap.

This can also be seen in a recently unveiled programme between inverter supplier SMA and German grid operator TransnetBW, which will see SMA supply generation and feed-in data from solar systems in Transnet's operation area, with the aim of helping better understand how the behaviour of connected solar systems are changing due to the use of battery energy storage systems and other technologies boosting self-consumption rates. Transnet is to use the data to identify region-specific projections and forecasts for solar power, improving the management of bottlenecks on its network.

Speaking of the project, SMA's Jochen Bornemann says that the swift pace of the energy transition has posed serious challenges for grid operators. "Precise projections and forecasts regarding grid feed-in and consumption are therefore becoming increasingly important for reliable, efficient and cost-effective grid operation," he adds. Distributed resources like these could equally play a far more significant role in helping clear the runway for their larger cousins.

A more distributed resource

Research from TransnetBW indicates that increases in self-consumption witnessed on its network shows that around 10% of power that might have otherwise seen itself exported onto distribution grids is no longer arriving there. "At times, the grid feed-in in the control area of TransnetBW alone is around 500MW below the generation power as a result," Dr. Philipp Guthke, an expert in special prognosis and optimisation tasks at TransnetBW, said within a press statement accompanying news of the programme with SMA in early December 2020. Could that loss of grid demand make way for further renewables capacity?

A study joint-commissioned by US trade group Vote Solar and installer

New inverter technology set to maximize opportunities for bifacial module installations

One of the biggest trends in the solar market in recent years has been the growth in bifacial module installations, largely due a reduction in costs of the technology, which enables maximum energy performance utilizing both sides of the panel. A report from the International Technology Roadmap for Photovoltaic (ITRPV) earlier this year predicted that the market share for bifacial modules will increase from ten percent in 2020 to at least about 35 percent by 2030.

Similarly, in 2019, Wood Mackenzie Power & Renewables issued a report that predicted that bifacial module capacity will exceed 21 GW by 2024 with Asia Pacific, North America and the Middle East being cited as the biggest growth markets. And, although the Covid-19 pandemic has had an impact on some areas of solar, the growth in popularity of bifacial modules – which were seen as a novel technology just a few years ago - has been fuelled by the development of PERC (passivated emitter rear cell) technology, growing affordability and favourable tariffs and subsidies in some markets.

There are several benefits to using bifacial models. According a SolarPro study of PV module manufacturers, bifacial modules have shown energy yield increases of up to eleven percent for fixed tilt systems and 27 percent for tracker systems, when compared to similarly rated traditional modules. This trade-off between additional cost and extra performance is increasingly seen as worth the investment.

However – as with many technologies – there are still challenges. While the side facing the sun works in the same way as traditional modules, variables on the rear side will impact the level of reflective light it receives, for example, the quality or colour of the roof or ground. This unpredictability means that it is not a suitable technology for all applications.

That said, there has been an increase in the adoption of bifacial modules in the utility-scale, industrial and large commercial markets, as they benefit from higher solar generation and lower energy costs, particularly for tracker systems.

The role of the inverter

This growth in the bifacial market means that the challenge for inverter manufacturers such as FIMER has been to develop solutions that can respond to the higher level of input current generated by bifacial modules. In any installation, the inverter must allow for maximum current from strings – with bifacial modules, the inverters installed need to be able to cope with a higher current.

Therefore, the need for inverter load flexibility is crucial, which means that matching the right inverter to a bifacial module project is the first critical action to undertake.

As a result, the next generation of inverters are being designed to cope with the increased incoming current requirements for bifacial module systems. Inverter improvements also include greater granularity of maximum power point tracking (MPPT) and support to higher incoming currents, so, for bifacial module installations, a multi-MPPT string inverter is the optimal choice.

A new string inverter for a new solar era

To respond to this trend, FIMER has developed a new string inverter – the PVS-10/33-TL – which will be available in 10, 12.5, 15, 20, 30 and 33 kW units. Designed specifically for the commercial and industrial markets, the 20, 30 and 33 kW units are also suitable for bifacial module installations.

These three units of the new string inverter have four input channels, two that operate at 22 ampere - which are suitable for regular modules – and two that operate at 26 ampere - which can be used for bifacial modules.

As the inverter allows greater currents to flow into the unit, greater DC to AC overloading ratios also need to be factored in. FIMER's new inverter family allows for high overloading factors – 45 percent (or 1.45) – adding up to an already remarkable DC-side flexibility.

The new PVS-10/33-TL will launch in Q1 2021 in six countries, Italy, France, Germany, Australia, Thailand and India, before rolling out Europe, Asia and Americas in Q2, where there is growing momentum for bifacial module installations.

Choosing the right inverter partner for your bifacial module installation

As a result of reducing costs and an increase in successful projects utilizing bifacial modules, installations are expected to grow in almost all territories. While they do come with their challenges, the possibilities of a higher energy yield mean they will continue to be a popular choice for utility-scale, industrial and larger commercial installations, particularly tracker systems.

It is therefore crucial that installers choose the right inverter partner that has a solution specifically designed to manage the increased current required, so maximum power can be achieved. This is why FIMER's PVS-10/33-TL is the optimal choice for the new solar era.

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Sunrun would attest to just that conclusion. Published in December 2020, the study used an advanced grid planning tool developed by Vibrant Clean Energy which leverages big data and analytics to put together a complete picture of the clean energy resources necessary to achieve a truly decarbonised grid. The study itself concluded that developing 247GW of local rooftop and community solar, combined with 160GW of local, distributed energy story, would not only save consumers hundred of billions of dollars on their energy bills, but also pave the way to deliver the cheapest transition to a net zero electricity system for the US by 2050, some US$88 billion cheaper than expanding on existing models of deployment.

Deploying those quantities of solar and storage would "unlock the potential" of utility-scale solar and wind, allowing them to connect to grids more cheaply by opening more grid capacity. The study found that in achieving installs of the figures quoted above, nearly 800GW of utility-scale solar and wind each would be more efficiently integrated by 2050. "This study indicates that the current practice of ignoring (or assuming) distributed-scale resources in utility plans will result in higher costs for customers, higher GHG emissions, and lower job prospects for the industry compared with coordinated planning," Christopher Clack, founder and CEO at Vibrant Energy, said at the time of the report's launch.

Forecasts of this kind are invaluable in calculating the potential capacity that lies within existing grids, and how other energy generation technologies at the distributed scale can play a role in facilitating greater quantities to connect. Understanding of the whole energy system is continuing to evolve, but it is undeniable that infrastructure upgrades will play a pivotal role in opening up new grid capacity. But, in the true sense of innovation, network operators are now looking at other areas than simply deploying more, costly cables and substations.

Supercomputers, super grids

In addition to its DSO Dashboard and various other tools – including a 'Timed Connection' offer which flexes accordingly to match generation with demand – UKPN has also launched a trial of new technology at the distribution level. Dubbed 'Constellation' and described as a world-first, the programme will see new computers installed at a series of substations on UKPN's network. "At the moment [the infrastructure] has a bit of copper and metal, maybe some telecoms," Cameron says, with the intent of Constellation to future-proof legacy systems for a more distributed future.

Cameron uses the analogy of the grid being akin to an athlete, facing a race towards decarbonisation that it must win. It has the tools available (distribution infrastructure being an athlete's trainers in this analogy), but it still needs to operate as efficiently as possible in order to compete. The lack of fine tuning has left the grid "with a bit of a potbelly", Cameron says, and is not optimized to compete.

> "We already have smart control rooms and grid edge devices… having smart substations in the middle pulling it all together is a logical next step."

"Constellation is the six-pack of the grid," Cameron adds. It gathers enormous quantities of data, can be set to operate within different parameters and facilitates much more efficient operating conditions. The result is a system that can reconfigure itself according to demand, and release latent capacity by utilising and optimizing energy flows. The trial is to launch soon, but UKPN suspects that should it prove successful, as much as 1.4GW of spare capacity could be freed, ready to be taken up by renewables.

Efforts from network operators to open up more capacity are expected to grow, especially under the weight of legislation pushing hard for net zero targets to become enshrined. But there is, equally, more that developers could be doing themselves to put network operators at ease by taking some of the load off the grid, or at least at more opportunistic times, using technologies already at their disposal.

Storage to the rescue, again?

Smart grid technologies, like those seen in Constellation and a handful of projects, form just one of the missing pieces of a much larger energy system puzzle says Ann Davies, chief operating officer at developer Lightsource BP.

Davies' experience at oil and gas major BP, where she started her career and is seconded into Lightsource from, leads her to conclude that improving the relationship with the grid is a "natural progression" for solar, referencing her time working on gas pipeline projects spanning thousands of kilometres and crossing several countries. "None of these [grid] challenges are impossible," she says. "If you have the right alignment with policy and you have the right investment going in the right place, we will solve it."

Other technologies, more specifically those on the generation side of the meter, will play their role. Energy storage has of course long been regarded a crucial enabler to a more solar-heavy grid, and asset operators are quickly deepening their understanding as to how the technology can remove some of the grid burden from operators, helping solar more appropriately managed its load profile to offer more certainty over export profiles. While the need for a bidirectional connection complicates the process somewhat, it is by no means an insurmountable hurdle.

Davies also points to another potential energy storage technology in hydrogen – a market which has taken enormous strides in 2020 – as yet another potential enabler for a smoother grid connection process in the future. Negotiating a grid connection agreement at a certain export limit, with any excess used to generate hydrogen crucial to decarbonising other sectors of the economy, is emerging not only as a clear remedy for grid congestion, but opening up solar to deeper decarbonisation potential.

Problems with grid connections, their cost, availability and often complicated nature, are unlikely to disappear overnight. And situations could, indeed, get worse before they get better as connection queues extend. But it is evident that grid operators and developers have all the tools required to hurdle any constraints or issues that arise and, through more considerable dialogue between both parties, the worst grid constraints could become a thing of the past. ■

Principles to get the most out of grid modernisation efforts

Grid modernisation | The proliferation of renewables and other distributed energy resources is pushing existing grid infrastructure to the limit, prompting renewed efforts to modernise. But with new hardware coming at such a high price, it's imperative these investments get the biggest bang for their buck. Here, the US Interstate Renewable Energy Council establishes five key principles for grid modernisation.

Credit: NextTracker

While replacing aging infrastructure and incorporating new technologies may help to improve the reliability of the distribution grid, approached strategically, grid modernisation can achieve much more.

Grid modernisation investments can leverage the capabilities of new technologies to increase transparency, make the grid more resilient (particularly important in the context of increasing natural disasters and extreme weather), and make future grid investments less risky.

Not all grid modernisation proposals are equal—or even beneficial—however. Some may prioritise investment in legacy infrastructure that ultimately crowds out or impedes the adoption of clean energy resources, while others may prioritise newer technologies, such as advanced metering infrastructure, but have little alignment with public policy goals, such as resilience and climate change mitigation. Weighing the relative merits of these proposals to determine cost effective investments that will benefit consumers and the grid is a significant challenge for states in the US.

Recognising the complex nature of evaluating grid modernisation proposals, the Interstate Renewable Energy Council (IREC) partnered with GridLab, a non-profit that provides technical grid expertise to enhance policy decision-making, to develop a resource that establishes guiding principles and a framework for evaluating grid modernisation plans and investments.

As greater quantities of solar are connected, grids must modernise effectively.

'A Playbook for Modernizing the Distribution Grid', or 'The GridMod Playbook' as it is otherwise known, aims to help stakeholders make more informed decisions and ensure more efficient and impactful grid modernisation activities. This article examines the grid modernisation principles established in the Playbook and grounds them in several real-world examples of grid modernisation activities around the US.

Five principles for more effective grid modernisation

IREC and GridLab assert that, irrespective of specific policy objectives articulated for particular grid modernisation initiatives,

Credit: Tesla

the overarching goals of grid modernisation plans and investments should be to enable the swift evolution of the grid to integrate modern technologies that meet public policy and clean energy objectives, such as reducing carbon emissions and achieving 100% clean energy goals.

In particular, credible grid modernisation proposals will facilitate the decarbonisation and electrification of buildings and transportation; increased energy efficiency, reliability, and resilience; and the deployment of distributed energy resources (DERs), like solar, energy storage, and electric vehicles (EVs).

With these big picture goals as a foundation, the following five principles of grid modernisation provide a helpful lens for evaluating the strengths and weaknesses of grid modernisation plans, proposals, and investments:

Support and enable policy goals, including the decarbonisation of the electricity system and the beneficial electrification of the transportation and building sectors

As climate change intensifies and the urgency for solutions grows, decarbonisation and the related "beneficial electrification" of the buildings and transportation sectors will be crucial. (Beneficial electrification refers to replacing direct fossil fuel use with electricity in a way that reduces overall emissions and energy costs.) In the US, building and transportation contribute 40% and 28% of greenhouse gas emissions respectively. Appropriate grid modernisation proposals are grounded in this context.

Other DERs like electric vehicles and chargers should be accommodated wherever possible

As a baseline, proposals and plans should account for existing programs and policies that are driving increased adoption of DERs like EVs and rooftop solar. Beyond that, effective grid modernization proposals will leverage these consumer investments as alternatives to costly centralized grid investments.

Five principles of grid modernisation

- Support and enable policy goals, including the decarbonisation of the electricity system and the beneficial electrification of the transportation and building sectors
- Enable the adoption and optimisation of distributed energy resources
- Empower people, communities, and businesses to adopt affordable clean energy technologies and clean energy solutions
- Support secure and transparent information sharing and data access
- Enable innovation in technology and business models

Enable the adoption and optimisation of distributed energy resources

Similarly, strong grid modernisation proposals recognise the economic, reliability, resilience, and environmental benefits that can be achieved through DER adoption and enable their wider use.

There are a number of mechanisms that states can employ to reduce barriers to the development of DERs, including updating interconnection processes to account for the unique characteristics of energy storage systems.

Earlier this year, Maryland approved changes to its interconnection rules as part of the state's grid modernisation proceeding, Transforming Maryland's Electric Grid (Public Conference 44). Specifically, regulators adopted new provisions that require utilities to evaluate energy storage and solar-plus-storage systems based on their intended use rather than their maximum output based on nameplate capacity. By updating its interconnection rules to recognise the flexibility and varying operating profiles of storage, Maryland has provided a pathway for greater DER deployment that can help to increase grid resiliency and meet the state's clean energy goals.

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Grid modernisation can take many forms, from individual programs and investments proposed in relative isolation (e.g., advanced communications or control system investments proposed outside the context of comprehensive utility transformation processes); proceedings that target a wider set of select grid modernisation issues; and sweeping proceedings that attempt to establish a comprehensive framework for grid modernisation across a wide range of issues.

New York's Reforming the Energy Vision is an example of a more comprehensive approach to grid modernisation. It has, over the past several years, tackled a number of policy and regulatory matters, ranging from transportation and buildings electrification, to Non-Wires Alternatives, and developing new utility business models, rate designs, and DER valuation tariffs.

Among states that have launched more comprehensive grid modernisation proceedings, each jurisdiction applies a different set of priorities and often slightly differing definitions of "grid modernisation" and its objectives. However, many of them share common elements.

For example, DER integration and interconnection have featured as important components of the broader grid mod processes in the District of Columbia, New York, California, New Hampshire, and Maryland (as described under principle two above, however this is not an exhaustive list of grid modernisation efforts in the US). Other common elements can include a consideration of the role of energy storage in supporting a more resilient and transactive grid; the development of comprehensive benefit-cost analysis frameworks to guide investments; and distribution system planning that enables a more transactive grid, to name a few.

Regardless of the precise scale and scope of the undertaking, regulators should ideally take a holistic approach to grid modernisation that leverages the interrelated impacts and benefits of the individual issues the proceedings cover, in order to maximise the effectiveness of individual programs and investments in achieving state policy goals. For example, well-developed interconnection procedures are essential on their own, but pairing those rules with increased grid visibility and transparency, as well as Integrated Distribution Planning, can pave the way for even more DER deployment.

Empower people, communities, and businesses to adopt affordable clean energy technologies and clean energy solutions

Done well, grid modernisation should advance a more distributed grid that gives consumers greater control over their energy usage, costs, and carbon footprints—such as through DER adoption, increased energy efficiency, or greater transparency into their energy consumption. Streamlined processes for interconnection and leveraging emerging approaches like hosting capacity analysis can help. Grid modernisation plans and investments should empower consumers, while safeguarding grid reliability and safety.

New York has looked to stimulate the deployment of distributed energy resources

Credit: ConEdison

Support secure and transparent information sharing and data access

Transparency and ease of data access are pillars of effective grid modernisation. Increasing grid transparency, such as through the use of hosting capacity analyses (HCA) and maps, can help consumers, local governments, and developers to more easily identify optimal locations for DER development.

An excellent example of this can be seen in California's groundbreaking interconnection policy updates earlier this year. In September, the California Public Utilities Commission approved sweeping changes to Rule 21; among many other innovations, with this ruling, California became the first US state to use HCA results to allow simplified interconnection processes for certain projects and enable developers to select optimal project locations. The updates also recognise some of the unique characteristics of energy storage, making it easier for developers to advance these projects.

Enable innovation in technology and business models

Finally, grid modernisation plans and investments should support the development of new technologies and business models, allowing third-parties to provide information, services, and technical and financial support to consumers.

In the US alone, utilities are proposing grid modernisation investments that total billions of ratepayer dollars. These proposals can be shrouded in complexity, filled with technical acronyms and spanning dozens or hundreds of pages. With an eye toward the outcomes we want to achieve on our "modern grid" and an understanding of the principles of effective grid modernisation initiatives that will get us there, regulators and other stakeholders can more easily assess the merits of individual proposals. This will be particularly important as we collectively confront numerous challenges to the resilience of our grid resulting from climate change.

For a deeper dive into key considerations when evaluating a grid modernisation plan, proposal, or investment, download 'A Playbook for Modernizing the Distribution Grid' from IREC. In addition to the goals and principles of grid modernisation articulated in this article, the playbook also provides a detailed evaluation checklist and in-depth guidance on questions to ask about specific terms and types of investments. ■

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About IREC

The Interstate Renewable Energy Council (IREC) builds the foundation for rapid adoption of clean energy and energy efficiency, toward a 100% clean energy future that is reliable, resilient and equitable. IREC is an independent not-for-profit organization leading transformational work since 1982.

Product reviews

Inverters — Ferroamp's string optimizer provides greater install flexibility with solar plus storage applications

Product Outline: Ferroamp Elektronik has introduced its 'Generic Solar String Optimizer' (SSO) that is designed to work with the DC nanogrid architecture to enable the direct use of solar energy or to store it on the DC side for optimal flexibility with the least possible electrical losses.

Problem: There is a growing need to reduce the cost and complexity of adding solar power to new energy storage systems, thereby increasing the number of solar power installations and facilitating the energy transition towards renewable sources, especially in future-proofing for increases functionality and energy demand.

Solution: The solar string optimizer from Ferroamp enables a new, more flexible

way of planning, installing and maintaining PV systems. Each optimizer has a built-in MPP tracker as well as several security features that allow installations with any number of strings with the highest safety levels. This also allows for an expansion of the system to future-proof against increased system demand as adding strings to an existing installation is easy as the voltage from each SSO is identical and the new string is connected to the DC link instead of a separate cabling to the inverter. The optimizer is designed to work with DC nanogrid architecture to enable the direct use of solar energy or to store it on the DC side for optimal flexibility with the least possible losses. The SSO can handle voltages up to 990V DC and has an efficiency of over 99%.

Applications: Residential and small commercial rooftop markets.

Platform: The SSO deliver a fixed 760V output to the DC nanogrid for high voltage and low loss energy transmission to either the energy storage or EnergyHub inverter. The EnergyHub DC nanogrid simplifies the installation of multiple strings, each one with an SSO as the output voltage from each SSO is fixed. The SSO comes in two versions, 7kW and 14kW, and can support up to 9.5A.

Availability: Currently available.

Inverters — The Fronius 'GEN24 Plus' hybrid inverter with 'Multi Flow' technology enables parallel energy flows

Product Outline: Fronius International has launched the 'Symo GEN24 Plus' hybrid inverter that is designed to makes AC and DC-coupled hybrid systems possible. Its 'Multi Flow' technology means that loads can be supplied while the battery simultaneously charges during any power outages. The GEN24 Plus is available worldwide in power categories 6.0–10.0kW.

Problem: Hybrid inverters are needed to provide a range of functions for self-sufficiency, while meeting future needs of backup power, heating or e-mobility, while reducing installation complexity and compatibility with energy storage systems.

Solution: The GEN24 Plus is a future-proof self-sufficiency product. It already has the

most important interfaces for extensions for storage, water heating and electric car charging points or for connecting external systems on-board. The 'Multi Flow' technology ensures loads can be supplied with energy while the battery charges simultaneously during power outages. This results in a longer-lasting back-up power supply with 10kW output power, ensuring a higher degree of self-supply. It comes with four digital I/Os (floating relay contacts) allowing the parallel energy management of several consumers, such as heat and pool pumps. In addition, the compact housing offers sufficient space in its protected interior should further relays or overvoltage protection be required.

Applications: Residential and small commercial markets.

Platform: The Fronius 'SuperFlex Design' and the improved 'Active Cooling' technology give the design of the PV system maximum versatility. The inverter can be installed in a few simple steps due to the sophisticated wall mounting system, push-in spring-loaded terminals and 180° quick-release screws. Using the new Fronius Solar.start commissioning app, configuration and registration can take place in just three steps via smartphone, tablet or laptop.

Availability: Currently available.

Modules — FuturaSun launches n-type mono IBC 'ZEBRA' panel technology to PV markets across Europe

Product Outline: FuturaSun has launched its 'ZEBRA' Series n-type monocrystalline IBC (Interdigitated Back Contact) solar panel series to the residential PV and C&I markets across Europe.

Problem: The PV market, especially concerning rooftop applications, whether commercial or residential, has always been sensitive to the need for peak module performance, aesthetics, solid warranty and high energy yield to provide an acceptable energy payback period.

Solution: FuturaSun Zebra series modules use n-type monocrystalline (G1) 158.75mm x 158.75mm wafers, which are negative-based using phosphorus doping and have one extra electron, limiting carrier mobil-

ity while boosting conversion efficiency. The n-type silicon chemistry also makes the Zebra panel immune to performance limiting effects LID and LeTID. The n-type modules are characterised by a low temperature coefficient which allows excellent module performance also at high temperatures, something that translates to a higher kWh output of the system. These attributes lead to higher, longer-term operating performance, shorter energy payback times and longer yield times that exceed other module types.

Applications: Residential and C&I rooftop systems.

Platform: The ZEBRA IBC cells were developed by the International Solar Energy Research Center (ISC) Konstanz in Germany and feature lower cost screen printed firing-though contacts, no passivating contacts and rear-side only 3D-interconnection of fingers with busbars, enabling compatibility with any wafer format and interconnection technology. This generates cell conversion efficiencies of 23.5%. ZEBRA module dimensions (1004x1685x35 mm) are comparable to a standard 60-cell panel of 990mm x 1650mm typically used in rooftop installations. The current top power class is 360Wp with a module efficiency of 21.28%.

Availability: Currently available.

Trackers | Ideematec's Horizon L:Tec solar tracker deploys patented locking technology for extreme wind conditions

Product Outline: Ideematec has introduced its Horizon L:Tec solar tracker that features a two-module-in-portrait (2P) design with patented locking technology. The tracker integrates seamlessly with bifacial modules to generate more energy per tracker and accommodates the new era of extra-large PV modules, including bifacial versions.

Problem: With reinforced locking technology, large scale solar projects can be located in regions with severe climates using large-area modules and single axis trackers. There is also increasing demand for tracker equipment that is both fast to install in order to reduce construction costs and built to withstand worst-case scenarios.

Solution: The new two-module-in-portrait (2P) tracker features a patented locking

technology that secures modules in position against torsional galloping, caused by extreme wind loads, to reduce maintenance costs and extend product lifespan. The tracker integrates seamlessly with bifacial modules to generate more energy per tracker and accommodates extra-large photovoltaic modules. PV modules are able to remain in stow position, at a zero-degree angle, against up to 180 mile per hour winds, according to the company.

Applications: Utility-scale PV power plants using large-area modules, including bifacial modules.

Platform: Ideematec's signature decoupled drive technology transports dynamic loads into foundational posts, and away from gearboxes. Ideematec trackers require four-times fewer gearboxes and motors than conventional trackers, according to the company. This significantly reduces installation time and maintenance costs and improves overall system efficiency. The company plans to announce a one-module-in-portrait (1P) version of the tracker, using the same technology, which will enable customers to purchase either option from a single supplier.

Availability: Available in all markets in January 2021.

Inverters | Kehua Tech's SPI4167K-B-HUD central inverter fully compatible with 600W+ solar modules

Product Outline: Kehua Tech's latest 4.167MW central inverter solution, the SPI4167K-B-HUD comes with a unique power range to be fully compatible with the new era of large-area high-performance PV modules that can exceed 660W.

Problem: In 2021 and the new era of large-area high-performance, PV modules are expected to deliver in the range of 32% more power than module classes in the 500W range. However, larger sub-arrays need larger capacity inverters, transformers, distribution units and other system devices and also need to be grid friendly.

Solution: Kehua's latest 1500V central inverter is intended to improve system efficiency by more than 1% and reduce BOS

costs by over 5%, according to the company. The 4.167MW central inverter solution is based on full modularization from devices to power units and adopts multi-channel MPPT design, allowing for flexible redundancy for different project environments, power station conditions and system capability. DC parallel connection increases the overall utilization rate by 1%. Through a patented power grid transient analysis, the system handles refined scheduling of power stations in the future. Its intelligent wave-recording function enables fast fault location and saves 80% of fault recovery time, according to the company.

Applications: Utility-scale PV power plants

Platform: The SPI4167-B-HUD patented independent dual refrigeration circuits ensure higher security and reliability as they isolate power devices from magnetic devices, improving system reliability and operation life. The inverter can generate an extra 1.5 million kWh annually, based on a 100MW power station and an electricity fee of 0.046 US$/kWh, cumulative economic benefits increasing by US$1.9 million over 25 years.

Availability: Fourth quarter of 2020, onwards.

Modules | Q CELLS zero-gap module strikes balance between performance and ease-of-installation

Product Outline: Q CELLS has introduced its 'Q.PEAK DUO-G9' series module to the European market, which includes its Zero-gap technology for the highest power and density for applications in the European market.

Problem: Large-area modules have high-performance ratings but are difficult to deploy on residential rooftops and utility-scale projects using single-axis trackers due to size and weight issues.

Solution: The Q.PEAK DUO-G9 series are the first Q CELLS modules to use Q.ANTUM DUO Z technology, where gaps between the cells are closed to ensure a more effective use of the module area. By closing the

space between the cells, module efficiency is increased in relative terms by 4%, delivering an overall efficiency of up to 21.1%. Further innovations featured in the Q.ANTUM DUO Z range include the use of 12 round wires to connect the cells, and larger (M4) wafers measuring 161.7 mm in size.

Applications: Residential rooftop, commercial and utility-scale projects.

Platform: The number of cells contained within each module size is also increased. The Q.PEAK DUO ML-G9 version boasts 132 half-cells, 12 more than a standard module type, to deliver a module power output of up to 395Wp. The larger Q.PEAK DUO XL-G9.3 increases the number of cells from 144 half-cells in previous iterations, to 156 half-cells with power output of up to 465W– an increase of approximately 30W per module. The XL version is 8.3cm longer, but only 1kg heavier and the same width. A 25-year performance warranty of 98% nominal power in the first year, and at least 86% nominal power after 25 years.

Availability: September 2020, onwards.

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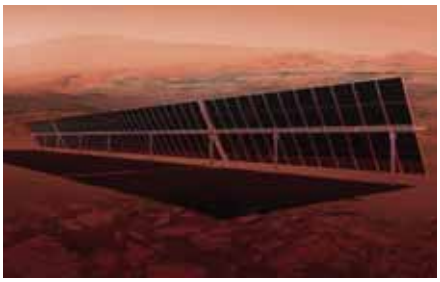
Product reviews

Trackers — Soltec's SF8 single-axis tracker system is designed for the new large-area solar panel era

Product Outline: Soltec has launched its next-generation 'SF8' single-axis tracker system to meet the needs of utility-scale PV power plants adopting the new wave of large-area solar panels.

Problem: The rapid transition in the upstream manufacturing solar sector to significantly larger modules to provide lower cost per-Watt means a new era for the industry in higher module performance and a leap in reducing PV power plants LCOE (Levelised Cost of Electricity).

Solution: The new SF8 tracker reinforces its structure to facilitate installation and favours high performance on any terrain. A reinforced torque tube with a new, improved geometry, together with an



autonomous self-stow system, contribute to increased tracker resistance to adverse weather conditions. The tracker increases the rigidity of its structure by 22% in comparison to the previous generation of Soltec trackers, the SF7. The SF8 has 5.16% fewer parts per module than the SF7, thus increasing cost and installation efficiency. Each tracker is equipped with, at least, four strings, contributing to easy electrical module connections.

Applications: Specially designed for larger 72 and 78-cell modules (including bifacial modules) for utility-scale PV power plants.

Platform: The SF8's four to six strings, 2 x 60 minimum configuration is designed to reduce installation and maintenance cost, yield more energy and increase overall PV plant performance. With a multidrive transmission system within the tracker structure and supersized torque-tube with improved geometry, the SF8 is designed to provide the highest resilience to wind conditions. There are two or more drives per tracker with better angle accuracy and wind reliability.

Availability: September 2020, onwards.

Modules — Trina Solar's 405W+ Vertex S series module designed as universal rooftop solution

Product Outline: Trina Solar's Vertex S PV panel has been designed to offer high-performance in a range of customizable options that caters for both residential and commercial rooftop markets. The new series features innovative Vertex technology to increase the output power of distributed energy products beyond 405W.

Problem: As the installed capacity for distributed photovoltaic systems continues to grow, there is an urgent need for photovoltaic module products that are able to support the beginning of a new ultra-high power era that reduces installation costs.

Solution: The Vertex S 405W technology platform combines 210mm wafers, multi-busbars and non-destructive cutting and

high-density packing. Trina Solar has been able to boost Vertex S's output power to more than 405Wp, a power increase of up to 60Wp or 17% compared with previous product generations. Module efficiency has also increased by 1% to more than 21%. Due to its smaller dimensions relative to similar modules, Vertex S maximizes the number of modules that can be shipped per container, reducing carbon emissions caused by transportation. Furthermore, the new module series comes in completely recyclable wood and carton packaging.

Applications: Residential and commercial rooftop markets.

Platform: The product series is designed for compatibility with existing mainstream mounting systems, optimizers and inverters for residential and commercial applications. The product has a dimension of 1754mm x 1096mm and weighs 21kg. Electrical parameters are kept within the operating limits of standard inverters. The Vertex S product family comes in three versions: the DE09, DE09.05 and DE09.08. Each of these modules has been designed to feature an easy-to-handle format and light weight for ease of rooftop mounting.

Availability: November 2020, onwards.

Inverters — Sungrow's DC coupling ESS solutions offer advanced functionality and benefits to utility-scale PV power plants

Product Outline: Sungrow has launched its latest ST3727KWH(L)-D1250HV+SG3125HV-MV DC-coupling solution for utility-scale PV power plants across Europe that require EES.

Problem: As the proportion of renewable energy in grids continues to grow worldwide, large storage systems are becoming an increasingly important issue. In the case of high DC/AC ratio, the power limitation of POI (Point of Interconnection) has become an obstacle to increasing the revenue of photovoltaic power plants.

Solution: With DC coupling of ST3727KWH(L)-D1250HV+SG31250HV-MV, the battery and the PV array are connected to a central inverter on the DC side. The central inverter is then connected to a MV

transformer to complete the system. As a result, the battery inverter as well as an additional transformer and medium-voltage switchgear are no longer required. System costs are minimalised as there are fewer components. Short cable routes minimise energy losses in the lines, and the entire system becomes more efficient. A further benefit of DC coupling is that installation is faster since the system is made up of fewer components. Full load hours are also further optimised.

Applications: Utility-scale PV power plants requiring ESS or EES systems added to PV power plants as a retrofit or upgrade.

Platform: The DC coupling of ST3727KWH(L)-D1250HV+SG31250HV-MV system provides a number of key functions such as reactive power compensation, ramp rate control, PV smoothing, clipping recapture, frequency support and ability to connect larger units. The platform offers bi-directional inverter charging and discharging from the grid.

Availability: Currently available.

Electroluminescence inspection: Revisiting the hidden side of a PV module

Inspection | The advancement of solar cell and module technology has meant ever larger, higher power modules are being manufactured, shipped and installed at increasing speeds, placing renewed importance on product testing and inspection. Here, Enertis explores the role of electroluminescence inspection throughout the lifespan of a PV project.

Credit: Enertis

Electroluminescence testing underway.

The large solar PV deployment experienced in recent years is a consequence of dynamic advances and optimisations of several techno-economic and social features, so that the present state of the solar PV market is now healthier than ever. Today's PV plants are based on hundreds of thousands of large size crystalline silicon panels made of *e.g.* 150 pieces of state-of-the-art solar cells, linked through innovative connection approaches, with bifacial modules becoming a mainstream technology. These modules are, in turn, produced inline by gigawatt-based companies and shipped to sites in record times worldwide.

Regarding module manufacturing, the continuous – sometimes not properly validated –innovations and production line upgrades required to mass-produce brand new modules and serve the rising market demands have historically led to novel solutions, but also, to a misjudgement of not easily detectable quality defects coming from solar cell assembly into modules. Likewise, construction costs, mounting and grid connection lead times for utility-scale PV plants have been drastically reduced over the years.

Overall, this suggests that the implementation of increased levels of inspection by means of cost-effective and fast techniques is more than ever justified. Thus, considering that a PV module could be constantly subject to damages at different stages of a PV project, there is no doubt that the oft-used Electroluminescence (EL) inspection technique is one of the most widespread tools able to survey PV modules in a massive and affordable way. Indeed, today, everyone involved in PV project development is aware of the EL inspection as a non-invasive and hands-on methodology for the detection of electrical-based defects in solar PV modules [1].

Briefly, performing an EL measurement over a PV module implies injecting current in forward bias through a DC supply source, typically in dark conditions, in order to reach proper signal-to-noise ratios and then get good-quality EL outcomes. As a result, the PV device's active parts spontaneously emit luminescence radiation in a certain wavelength, which is then collected by a suitable detector. The EL emission is processed into a contrast image or map, unveiling regions with different luminescent activity, ultimately interpreted as defects, which cannot be detected by the human eye.

In practice, an EL analysis will reveal healthy or defective regions within the sample being inspected, presenting different series and shunt electrical resistances, in a qualitative, fast and straightforward way. Modulating the level of current injection will account for different electrical resistance regimes, therefore helping understand what is going on in the cell or module under test. Therefore, any low EL image contrast feature will generally infer the existence of hidden defects in its structure or architecture causing it to happen.

Since early times, from the works by Fuyuki *et al.* [2], the EL inspection keeps being implemented, together with the Infrared Thermal inspection (IR), as a reliable, cost-effective and massive quality screening

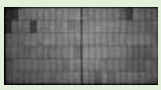
technique for PV module suppliers, laboratories and even EPC players. Over the years, the patent and extended implementation of the EL testing has motivated great improvements in operational inspection modes, such as mobile labs [3], drones [4] and also advanced image processing [5], to the point that, nowadays, the original and rather utopic ability to also perform EL imaging in standard daylight conditions has been realised [6].

A wide range of EL signal collection detectors are at present used for various applications; in short: silicon-CCD systems, cost-effective CMOS reflex cameras (duly adapted to the 1150 nm emission of crystalline silicon devices), or those based on InGaAs, expensive but especially efficient for certain cases. Choosing one of them is, in the end, a trade-off amongst resolution, sensitivity, spectral range and, ultimately, price, depending on the EL inspection context and eventual goal.

However, as a common evolution for every new technology that is rapidly and successfully applied in end-user market applications, the affordable, non-destructive and intuitive nature of EL has in turn led to certain overuses and misinterpretations, sometimes leading to major consequences influencing a PV project's economics. This comes from the use of the unquestionably valuable, but somewhat limited qualitative-based information that is accessible from an EL picture.

The interpretation of an EL image has always suffered from biases or a certain subjectivity, stemming from the lack of consensus in the industry about what an EL defect is. Also, the often rather unknown physical and chemical mechanisms and ensuing short-to-long term impacts behind the issues revealed in a damaged solar cell makes the consequences of EL analysis more complicated. In this regard, the TC 82 work group of the International Electrotechnical Commission (IEC), devoted to solar systems and devices, recently released the IEC TS 60904-13:2018 document [7], aimed at establishing a series of recommended practices for capturing, processing and interpreting an EL image, as a preliminary guideline of an eventual standard applicable in the PV industry.

In any case, even if the mainstream market ends up adopting these standard guidelines, it is likely that there will always be room for EL interpretation to eventually become a universal, conflict-free and unbiased methodology for defects detection and categorisation. This is especially relevant in cases where EL inspection is used to correlate images with PV module performances, despite the interesting attempts made to date [8]. In some situa-

EL defect	Supplier						
	A	B	C	D	E	F	G
Microcrack 	Severity: MAJOR q≤2; Q<1/20	Severity: MAJOR q≤3; Q≤6%	Severity: MAJOR 1) l<10mm ignored 2) q≤2; Q≤8 3) Total l; q=0	Severity: MINOR q≤1; Q≤8;	Severity: MAJOR 1) l≤1/5L; q≤1; Q≤4)	Severity: N/A A≤5%; Q≤8%	Severity: MAJOR q≤1; Q≤3
Breakage/Inactive area 	Severity: MAJOR A≤5%; Q<1/20	Severity: MAJOR q≤1; A≤5%; Q≤5%	Severity: MAJOR q≤1; A≤2%; Q≤2	Severity: MINOR A≤5%; Q≤2	Severity: MAJOR q≤1; A≤2%; Q≤3	Severity: N/A A≤8%; Q≤6%	Severity: MAJOR q≤1; A≤5%; Q≤3
Cross-shaped crack 	Severity: MAJOR l≤1/15L; q≤2; Q≤4	Severity: MAJOR l≤1/15L; q≤2; Q≤3	No specific criterium. Applying above microcrack criteria	Severity: MAJOR l≤8mm; q≤2; Q≤10	Severity: MAJOR l≤1/15L; q ≤1; Q ≤4	Severity: N/A q≤2; Q≤8	Severity: MAJOR l≤1/12L; q ≤1; Q ≤2
Soldering defect 	Severity: MAJOR 1) A≤5%; Q≤1/12 2) A≤10%; Q≤1/24	Severity: MAJOR A≤10%; Q≤5%	Severity: MAJOR q≤1; 2<Q<5	Severity: MAJOR 1) Total l, q=0 2) A<10%; Q≤10	Severity: MAJOR 1) Total l; q=0 2) W ≤1/6; Q≤10%	Severity: N/A 1) A≤6.7%; Q≤8% C 2) 6.7%<A≤10%; Q≤5%	Severity: MAJOR 1) l≤1/8L 2) Total l; q=0
Mixed-cell activity 	Severity: MAJOR Non-objective criteria Numbers of cells: no limited	Severity: MAJOR 1. Gray difference <25%, allowed. 2. 25%≤gray difference≤30%; Q≤5% 3. Gray difference>30%. Not allowed	Severity: MINOR Q≤4	Severity: MINOR Non-objective criteria; Q≤6	Severity: MAJOR Non objective criteria; Q≤5	Severity: MAJOR Non objective criteria; Q≤5	Severity: MAJOR Non objective criteria; Q≤5

** q: quantity of defects in an individual cell; Q: quantity of cells affected; l: defect length; L: cell length; A: cell area; W: defect/cell width*

Table 1. Variations among current EL defect acceptance criteria of several top-sales Tier-1 manufacturers applicable for different module datasheet products.

tions, extrapolating EL-based outcomes to financial or legal consequences does lead EL inspection to be complemented by other well-known module characterisation approaches such as I-V curve measurement or IR thermography, enabling a complete understanding of the mechanisms behind the defects and then draw more accurate and fair conclusions, especially in cases where penalties or warranty claims are involved.

Notwithstanding this, and thanks to the surveying role of expert third-party inspection and testing entities such as Enertis; EL will remain an essential means to check the quality condition of a PV module in different situations during the PV project lifetime: i) yet from the definition of defect criteria in a Module Supply Agreement (MSA) or EPC contract; ii) through the physical collection and assessment of EL images during modules' production; iii) prior to shipment; iv) upon delivery; v) and even after installation in fixed structures and trackers.

EL inspection is, therefore, of great interest and support for the implementation of reliable solar PV power as the main source of clean energy worldwide. Thus, sooner or later during the development of a solar PV project, the discussion about setting module's EL defect criteria, sampling rules for testing and derived liabilities in case of non-conformities shall ultimately come up.

At this point, around fifteen years after EL burst onto the solar industry, within the era of the innovative and high-powered PV cells/modules being at present launched by vertically integrated gigawatt-based manufacturers, produced and then installed in amazingly short times, we herein review the circumstances for which an EL analysis, designed and performed by expert independent advisors, can be an important decision-making tool for EPC companies and PV owners.

For this purpose, real cases devoted to EL inspection activities performed by Enertis in different project development and market contexts are reviewed and commented, namely:

- Manufacturing and pre-shipment testing.
- Delivery inspection.
- Post-installation inspection.

Manufacturing and Pre-Shipment Testing

By default, the PV industry assumes that a commercial PV module device, due to its complex composition and large surface, can present visual and hidden defects. However, the *PASS* or *FAIL* condition of a PV module, from an EL inspection perspective, remains unresolved, being entirely subject to every specific project case and associated MSA context. In addition, the acceptable limits are characteristically set per type of defect, without considering their respective accumulation.

> "Such inconsistency is patent both in terms of categorisation of defect severity – minor, major, critical – and its individual description, to the point that most suppliers keep using pretty much the same EL criteria for years."

Considering those imperceptible at naked eye, only revealed by means of EL inspection, a great disparity vis-à-vis the definition and judgment of defects among the so-called Tier-1 module manufacturers is systematically found. This trend is currently pronounced, as a result of the rapid development and release of new PV cell and module designs. Altogether, the release of these new products takes us several steps forward with needing to update the respective EL quality criteria.

Such inconsistency is patent both in terms of categorisation of defect severity – *minor, major, critical* – and its individual description, to the point that most suppliers keep using pretty much the same EL criteria for years, regardless of the introduction of new cell sizes (210mm), device architectures (PERC, both mono- and bifacial) and busbar interconnectors (from the not long ago common three to multi-busbar tiling/shingled connections). Non-negligible discrepancies can be even encountered within the same manufacturer, for an identical module datasheet and PV project location, with no apparent effect on module price.

To illustrate this, Table 1 collects examples of archetypal defects today reported throughout inline inspections, including the specific criterion and consideration made by several top-sales Tier-1 manufacturers. For clarity purposes, and also confidentiality reasons, the defect definition has been homogenised, with some criteria slightly construed, without any distortion of the original proposals from the manufacturers. Moreover, the EL

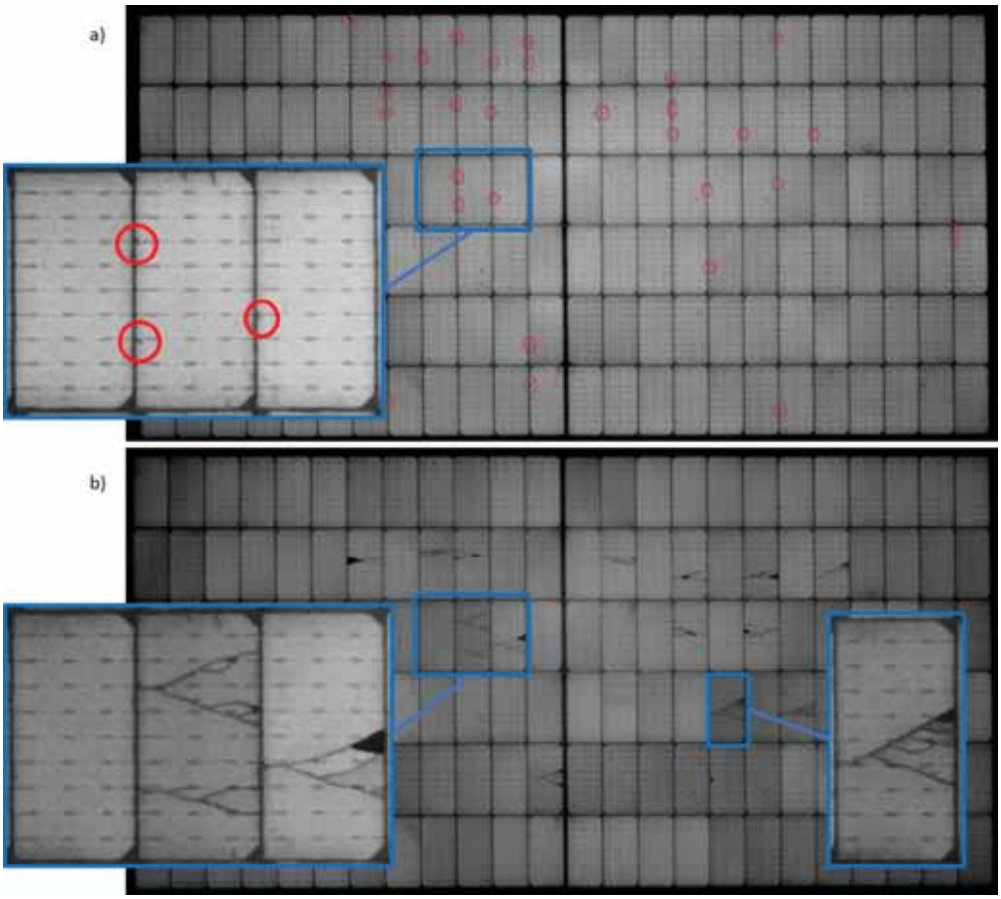


Figure 1. a) EL image of a PV module presenting cross-crack defects at cells' edges recorded by Enertis during batch acceptance testing; b) EL image after DML test (1000 cycles, 1000 Pa).

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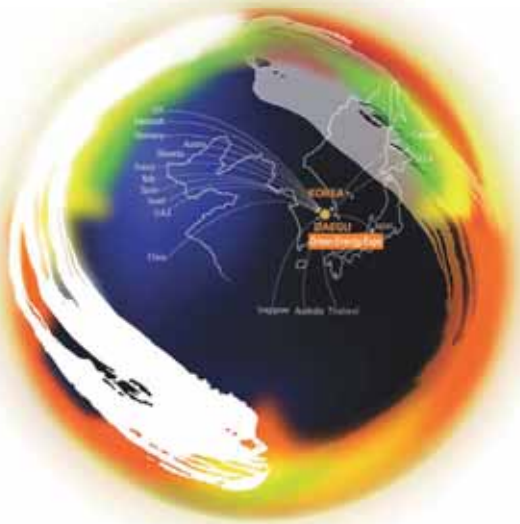

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image insets were selected from production inspections performed by Enertis, as representative examples of each EL issue. As can be observed, the variability among suppliers is evident, both in terms of defect definition approach (areas, lengths, widths) and acceptance criteria (defect severity and/or limits). This market reality evidences the said lack of objective consensus when performing and interpreting an EL picture. Especially difficult is the case of the frequently observed *mixed-cell activity* defect in a PV module (Table 1), ascribable to the development of potential hotspot phenomena in the field, and also possibly reducing the long-term reliability of the panel due to the different electrical properties of wafers/cells taking part of the module's series connected substrings.

Therefore, the historical and somewhat reductionist tendency to consider a PV module as a commodity is, at present, looser than ever, even just from the determination and classification of a PV module through the type and quantity of relevant EL defects that are present, among the many other ways to inspect and validate a PV module, not to mention the abovementioned innovative new cell and module designs available in the market, from different vendors.

Furthermore, as per Enertis' experience, the level of restriction and discipline implemented by a vendor regarding EL testing and related actions is, by and large, a practical indicator of the capacity and willingness to provide the best products they can, extrapolating such modus operandi to other operational (e.g. traceability) and technical (Bill of Materials control, operators training, etc.) strategies and actions influencing the manufacturing process.

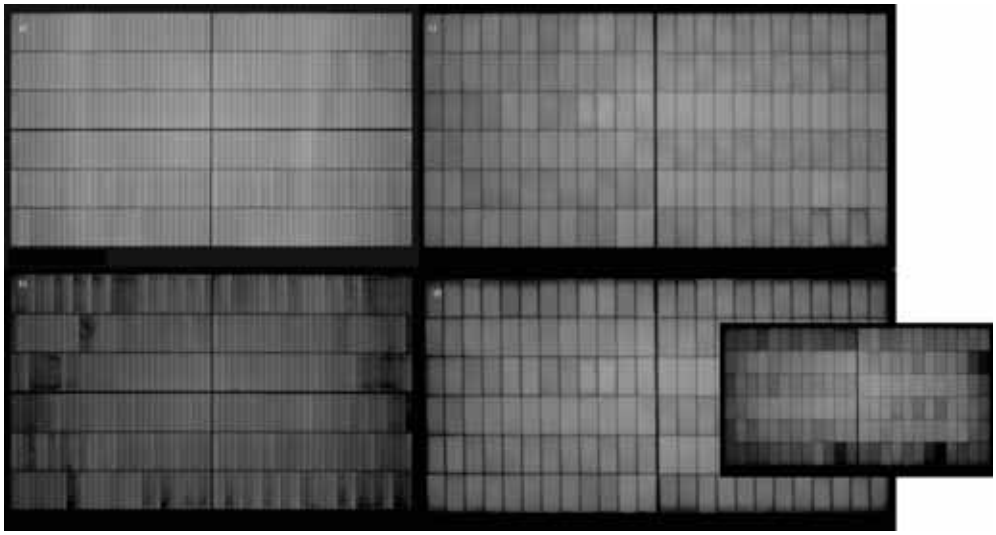

Figure 3. EL images of modules evidencing PID effects recorded at Isc; a) shingled PV module before PID; after PID test sequence, with many cells presenting low EL activity due to shunting phenomena; c) multi-busbar half-cut cell module before PID; d) after PID, for which several cells (especially those of module's borders) display poorer EL contrast, particularly at the perimeter, which might suggest the origination of shunt defects from cell cut process into halves. The inset EL image corresponds to module c) recorded at 10%Isc, in order to highlight the shunted cells in the module (PID test sequence: 96h, 85% relative humidity, 85°C, -1,500V). In both cases, from 4 to 6% degradations in maximum power were registered.

Today, it is well-known that reaching 600W+ output in a PV module implies enlarging module size and weight, basically due to the use of large silicon wafers going up to 210mm. Size increasing is to some extent palliated by all module suppliers via innovative cell interconnection approaches enabling non-active space reduction up to a few millimetres.

These novel welding methodologies, as well as the use of half-cut or even third-cut multi-busbar connected cells, can lead to rather insignificant, but harmful cross-shaped cracks in the vicinity of cell edges, particularly those affected by the laser cut into half or third sections, seldom reported by suppliers. This suggests that the mechanical stress occurring during cell soldering, plus the potential presence of chips at the wafers cut edges would facilitate the formation of such defects. Figure 1 depicts this effect in a visual and representative way. Despite the tiny affected surface and length of the micro-fissures, after a standard dynamic mechanical load (DML) test, as per IEC TS 62782:2016, nearly all cross-shaped cracks in cells from inner substrings in the module propagated into multi-cracks, also leading to cell disconnection issues in some wafer areas.

Another issue to tackle during manufacturing and pre-shipment inspections comes from the often-found variability among suppliers when capturing and processing the EL images inline. As mentioned before, diverse EL test conditions can account for varied defect mechanisms affecting the EL activity within the module, then resulting in differently nuanced EL outcomes. In Figure 2, a systematic weak soldering defect, not allowed by the supplier in the agreed EL quality criteria, could not be revealed in the inline controls performed by the supplier. In contrast, for the same module, the registered image by Enertis third-party laboratory during pre-shipment batch testing activities clearly unveiled the cell welding issue. In the present case, the EL technique triggered the rejection of a MWp-size batch on account of such defect. Furthermore, as corrective actions, the supplier adjusted the soldering process and EL test equipment accordingly.

In this regard, among suppliers, a noticeable disparity in terms of EL test setup can

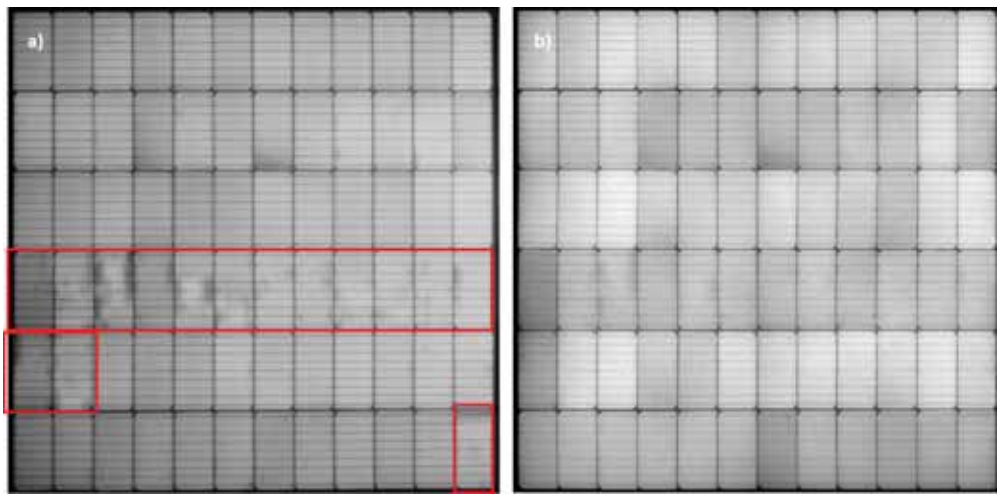

Figure 2. EL pictures of the same half-cut cell PV module (left side section) revealing marked defects associated to weak busbar soldering processes; a) registered by Enertis laboratory (10.6A polarisation DC current, CCD sensor); b) El picture recorded by the manufacturer (6.1A polarisation DC current, CMOS sensor) for inline quality control.

be evidenced during inline supervisions, even between workshops of the same manufacturer. In all the cases, polarisation current ranges from 5 to 8A, far below a module's short circuit current (Isc).

For many years, most PV module manufacturers have been declaring to sell products free from PID effects, including such condition in the respective panel datasheet through different labels such as *PID-free* or *anti-PID*. The usefulness of the EL technique as quick PID-detection means is well-known. Its use for performance-like issues such as PID (as well as LID and LeTID) remains effective to understand the propensity of modules to develop them. In fact, despite the efforts and undoubted advances made by most cell and module manufacturers so far, PID is yet to be fully overcome. Figure 3 illustrates this for two contemporary PV module designs, using the EL technique.

In summary, it seems clear that dealing with the assessment of EL defects during the shortlisting and future inspection process of a PV module supplier might not be as simple and standard as expected, especially if one pays attention to the current inconsistencies regarding EL-defect definitions, acceptance limits and potential consequences, considering the average thirty year-project's lifespan in front of the asset's owner.

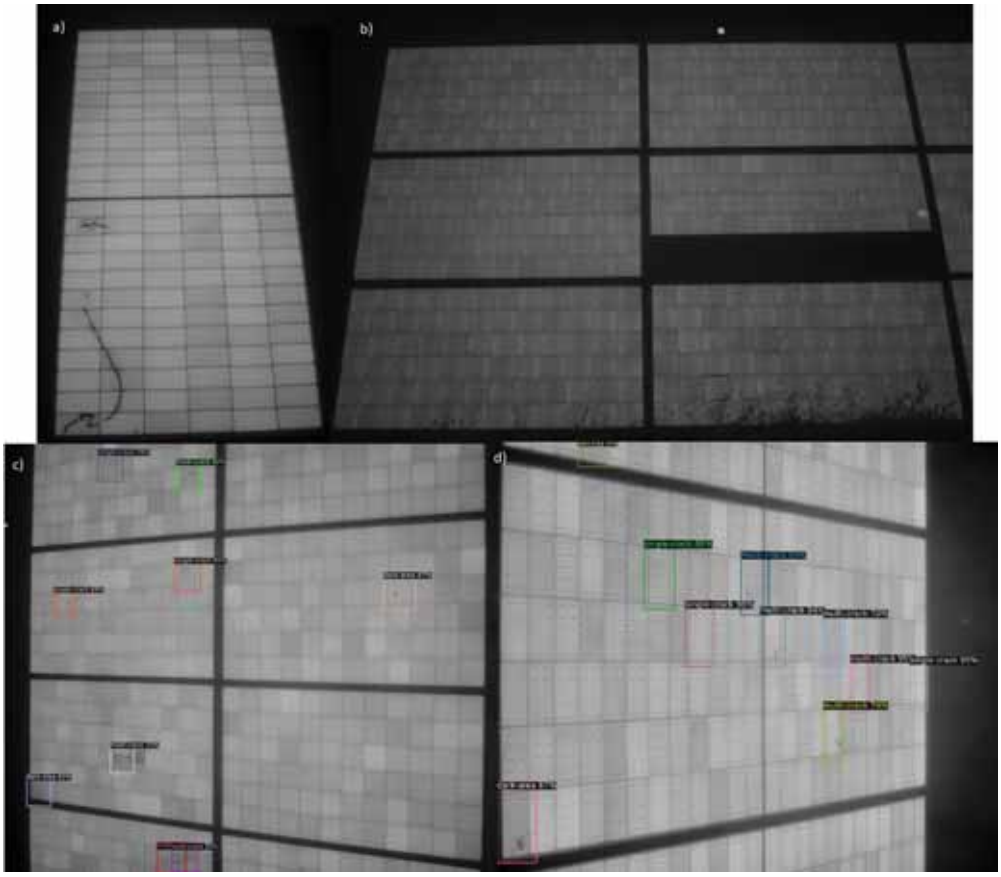

Figure 5. Examples of EL defects found on different PV modules installed in different locations worldwide; a) critical extended linear defect derived from rear side's cell damaging (typically from backsheet scratching issues); b) manifest junction box issue (either faulty diode or connection) leading to cell substring inactivity; c) and d) cell cracking defects and other minor issues accurately detected and categorised by Enertis EL software.

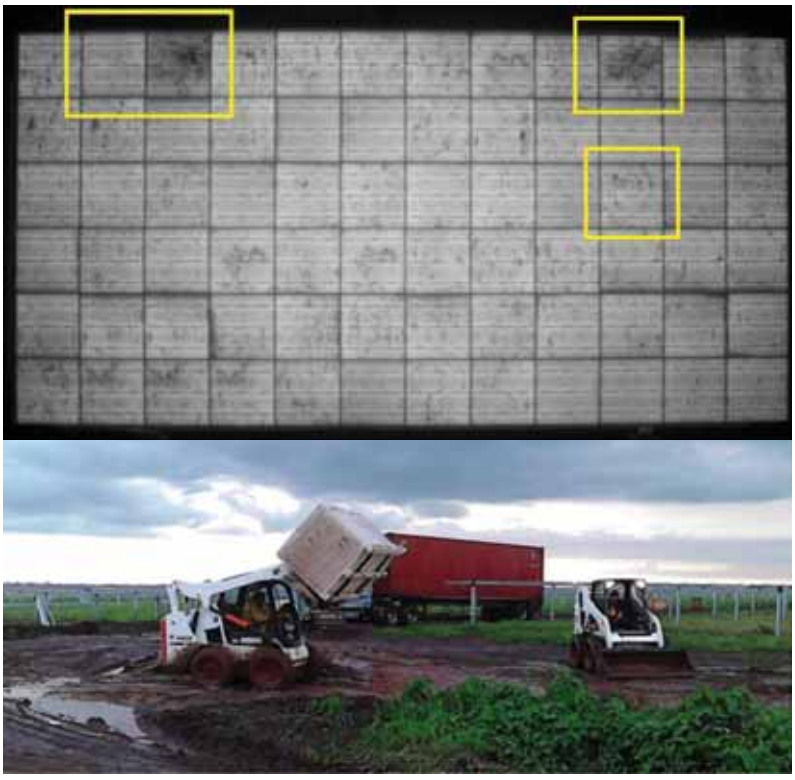

Figure 4. Example of mishandling onsite. The cracked cells in the EL image were produced by the toes of the forklift during transport of boxes across the site, which packaging were, in turn, upgraded for future shipments.

Moreover, safeguarding module traceability in a supply via EL inspection (all EL pictures from the factory should be shared by the vendor) becomes a powerful way to track down any sort of damage in a panel occurring upon delivery to the site, and then after mounting. This way, the evolution of the modules during the entire warranty period can be overseen.

Last but not least, the applicable sample selection strategy always depends upon the specific inspection context and purpose. In fact, very non-technical variables such as lead times, inspection deadlines and, why not say budgets, are often principal drivers. So, for any EL inspection action or campaign, a global understanding of the case and eventual objective, from the suitable investigation process turns out to be mandatory, in order to assure that accurate and valid conclusions from the convenient but sometimes limited EL technique can be drawn.

Delivery and Pre-installation Inspection

A suitable way to review the status of megawatt-based batches of acquired PV modules once they have been received

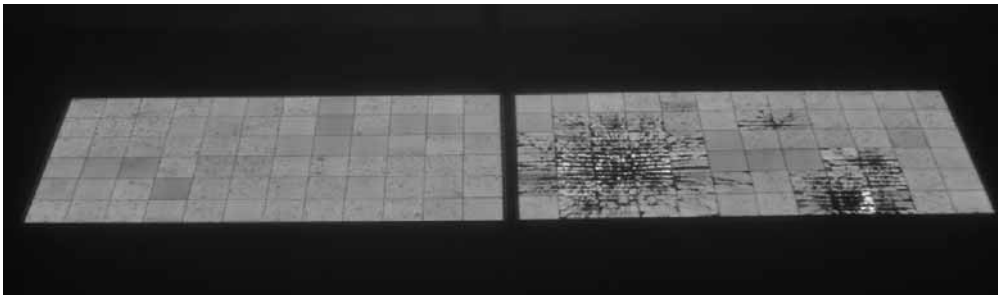

Figure 6. EL image of a mounted PV module showing critical damages (extended cell multi-cracks) due to an intense hailstorm.

at the port of destination *(CIF incoterm)* or at a project's site *(DDP incoterm)* is a post-shipment analysis of a representative sample per batch, carrying out EL and Visual Inspection. This way, possible damages suffered during transport from the manufacturing site can be detected, as well as other manufacturing-related defects, especially in cases in which no previous pre-shipment inspections have been conducted. Whether it has been properly arranged in the MSA, the results of the tests can lead to rejection of containers or lots with an excess of defects as per the agreed acceptance criteria.

Likewise, EL testing is ideal for situations of accidental overturning or hitting of pallets during module handling and mounting, despite there being no visual evidence of damage (Figure 4) to the naked eye. Also, for locations where road transportation to access the site from the port is not facilitated, EL inspection can be of great help to determine any potential damage in the modules upon arrival.

Still, despite the demonstrated usefulness of post-shipment inspections, as an increasingly usual practice in the PV sector in multiple geographies, not all players involved in a PV project are prone to carry them out. This happens even with supplies based on DDP acquisitions, with module suppliers reluctant to accept such inspections in the agreements with module buyers. Therefore, adding properly designed inspections at the point of delivery in the corresponding MSA and EPC contracts is a practical and affordable strategy to increase the level of confidence and modules quality traceability for a PV asset owner.

EL to installed modules: post-installation, technical due diligence inspections, O&M.

After installation and plant energisation, EL testing is a must-do activity in a varied range of contexts, namely:

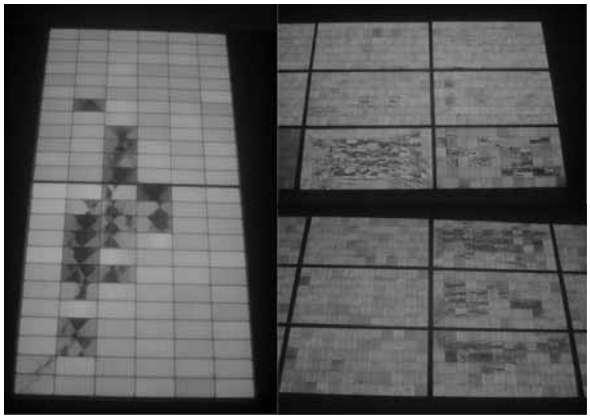

Figure 7. EL images of PV plants (both half and full-cell modules are represented) affected by harsh wind effects, showing remarkable cell multi-cracking issues.

Figure 8. Multiple defects found trough EL in a PV plant affected by a massive flood issue. The EL inspection made possible an integrated diagnosis of the asset condition. Power and electrical insulation tests were also conducted, correlating data with EL outcomes. Serious degradations affecting power (disconnected cells, severe cracking defects) and safety issues (contacts corrosion) were eventually reported, defining subsequent actions to be triggered.

- Post-installation tests: EL can be performed on a sample of panels already installed in the structures or trackers, with the main objective of evaluating possible damages during the installation process (of course, damages originated in previous stages such as manufacturing or transport can be also captured). As mentioned in previous sections, EL inspection is not a standard technique, based on standard rules and conclusions. Therefore, through expert technical advisors, ad hoc acceptance and rejection criteria, wisely adapted to every context, are typically used.
  Thanks to EL inspections, it is possible to identify which panels should be replaced or monitored after having suffered damages during installation that could affect performance or even electrical safety. Likewise, if it has been properly stipulated at the contractual level, the suitable liabilities in case of proven issues can be set.
- Weather events: EL inspection over mounted modules is an outstanding tool to assess the mechanical integrity of PV modules after being affected by extreme meteorological events such as tropical storms, wind or hailstorms, as represented in Figures 5 to 8. On account of the already mentioned merits, EL inspection has become a widely accepted technique by international insurance companies in expert reports, being of maximum relevance to determine the compensations to be granted to the coverage claimant, whatsoever the incidence that caused the damage.

Table 2 collects some interesting examples of EL inspections recently carried out by Enertis in PV plants

PV Plant Size	Modules tested	Tested/Total modules (%)	Defect type/Modules tested (%)			
			No defect found	Minor[1]	Major[2]	Critical[3]
55 MWp	5,560	3.4%	4.80% of non-compliant modules as per agreed criteria			
50 MWp	7,976	5.3%	51.96% of non-compliant modules as per agreed criteria			
24 MWp	26,320	38.5%	88.69%	5.51%	1.79%	4.01%
385 MWp	61,380	5.5%	67.93%	19.50%	7.07%	5.51%
110 MWp	103,454	31.50%	68.78%	19.23%	11.98%	

Table 2. Examples of EL inspections recently carried out by Enertis in plants affected by extreme wind events.

[1] ***Minor*** *defects are not considered to be a threat to the performance or the useful life of the panel currently or in the short-term.*
[2] ***Major*** *defects are not critical at the time of the inspection as they do not imply a significant power loss, but should be monitored as they might develop into critical in the future, isolating electrical areas within the cells, due to the effect of daily thermal cycles and environmental conditions such as wind, hail, snow or others.*
[3] *Defects deemed as* ***Critical*** *cause great impact on performance already at the time of the inspection and shall be replaced.*

affected by extreme wind events and their results:

- PV project lifespan: During commissioning, as part of Substantial Completion/PAC or FAC activities and O&M duties, for warranty claims, or in contexts related to asset acquisitions and financing due diligence processes, EL provides a non-invasive and cost-effective way to diagnose PV modules' status, also acting as an efficient preventive and corrective maintenance tool. Besides providing valuable information regarding a modules condition at a given moment, it helps understand the issues that may cause safety problems or lead to significant power degradations in the modules, even in the short term. Table 3 includes recent examples of EL test activities carried out by Enertis as part of technical due diligence activities of projects, prior to acquisitions:

PV Plant Size	Modules tested	Tested modules/ Total modules (%)	Defect type/Total modules (%)			
			No defect found	Minor	Major	Critical
9 MWp	36,476	100%	70.04%	16.47%	9.88%	3.61%
1 MWp	338	8.7%	31.07%	1.48%	57.69%	9.76%
2 MWp	329	3.8%	69.30 %	8.81%	15.20%	6.69%
1 MWp	80	2.0%	61.25%	1.25 %	32.50 %	5.00%
2 MWp	80	0.9%	81.25 %	1.25%	15.00%	2.50 %

Table 3. Examples of EL inspection conducted in the context of asset acquisition processes.

Taking the large EL test campaign for the 9MWp plant collected in the table, the translation of the significantly reported EL findings into economic impact led to a significant reduction of price of the asset, obviously far above the cost of the EL testing itself. Therefore, the EL inspection, in such contexts, provided the potential purchaser with optimal knowledge of the condition of the modules, becoming a powerful tool towards the negotiation of the transaction.

Final remarks

Nowadays, in the era of new PV cell and module designs, with the trend to build increasingly larger and faster PV projects worldwide, the EL technique has it all to live a second youth as a key tool to determine the quality condition of a PV module (and thus a PV asset) in a massive, intuitive, cost-effective and non-invasive way.

Paradoxically, despite the unquestionable currency of the EL inspection methodology, its proven virtues can in turn lead to misuses and practical limitations.

Also, in the absence of robust standards capable to regulate, in full, the EL technique, elucidating whether a specific microcrack, a busbar soldering issue or a cell mismatch may be acceptable or not will be subject to every inspection background. Therefore, the quintessential qualitative nature of the information enabled by an EL analysis should be properly refereed and tackled by expert third-party entities, so that any valid penalty, warranty or liability claim may be fairly addressed.

In the context of MSA negotiations between buyer and supplier (also in EPC contracts covering issues out of module supplier's responsibility), it is highly recommendable to define in advance, among other testing activities, what a hidden EL defect is and how it should be detected. By and large, this consensus should be systematically implemented for any project stage in which the EL inspection is involved: i) throughout manufacturing; ii) before/after shipment; iii) before/after mounting (O&M phase, acquisition's due diligence processes, etc.).

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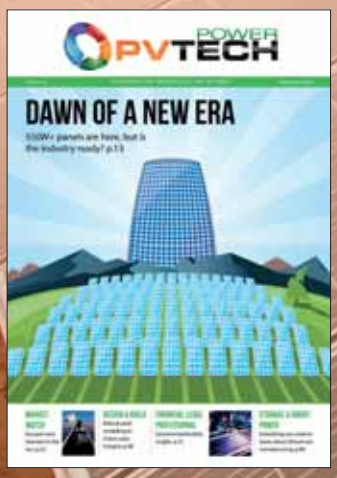

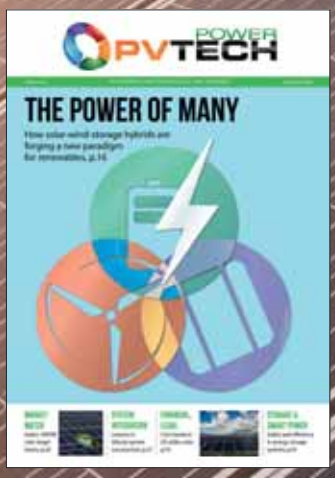

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Plant design and the age of the large-format module

System design | The introduction of large-format modules promises to pose both benefits and challenges to developers. Christopher West, head of central engineering at Solarcentury, explores the many considerations PV designers must bear in mind now large-area modules are on the market.

In 2019, an interesting trend started to appear in the PV market, in which the increase in module peak power was not being driven by significantly improved cell efficiencies, but instead by simply making the PV modules bigger. Over the course of 2019 and 2020 modules of over 400W started to appear, with some astonishing powers being announced by module manufacturers, including a module of over 800W making its debut at the 2020 SNEC trade fair in Shanghai.

But while in the past we were seeing incremental increases in power within the same size of module as the quality and technology of the cells improved, now we are seeing very dramatic increases in power being brought about simply by having larger module sizes. The 800W high power module, for example, has a surface area of almost 4m^2, while up until the current trend began, the standard 72 cell modules were about 2m^2 and were pushing close to 400W in peak power.

It is tempting to look at this trend and think that there is nothing really innovative about all of this. Haven't module manufacturers essentially just stuck two modules together? It seems as unimaginative as jumbo-sized bars of chocolate; the same chocolate, just bigger! But scratch beneath the surface, and the reality is that none of this could have happened without some important technological advances that happened previously, and that what we are seeing in the market right now is a phase of permanent readjustment to module sizes that simply weren't possible before. In particular, split-cell, multi-busbar and dense interconnection strategies have opened the doors to numerous possibilities of connecting cells together in a PV module, and this has led us to the baffling range of modules now available in the market.

The use of these large format modules does allow for some important cost savings on the module itself, since one large module uses less metal framing than two smaller modules, and there are some important Balance of System (BOS) savings when constructing a utility-scale PV farm, particularly with respect to cabling and racking systems. These must be traded off against some critical design considerations that arise as a consequence of the increased module size, especially regarding wind-loadings, electrical sizing and planning considerations. But all indications are that the use of the large-scale format genuinely reduce the costs of building utility scale PV plants, and right now they are being rapidly adopted into new PV plant designs. The large-scale format is definitely here to stay.

Although this phase of readjustment is disruptive, all major manufacturers are now embracing the new large-scale formats and are settling around certain

The combination of large-format panels with trackers will pose some challenges for PV system designers.

Credit: Nextracker

Credit: PV Tech

A selection of the 550W+ panels on display at SNEC 2020.

standard cell and module sizes. There are signs that the market will start to consolidate around a couple of new 'standard' module sizes for utility plants, reducing confusion for installers, and that once again we will start to see incremental increases in power driven by innovations in efficiency, along with an increasing trend towards bifacial modules.

Development of large-format modules

The main technological driver pushing the new large format PV modules has been the changing sizes of wafers, which have increased in size from the original standard 156mm sizes up to the two new competing cell sizes in the market, which are 182mm and 210mm respectively. In the past using such large cell sizes would have been problematic because of higher losses deriving from the higher currents, but the last few years have seen the innovation of split-cell modules. With split-cell technology, the cells are cut into two or three pieces, and the current is divided throughout the three pieces, recombined at a common busbar later on. This reduces the thermal losses and increases the overall thermal performance of the cell.

Additionally, there have been important technological advances such as multi-busbar technology, which has in turn led to methods of reducing or eliminating the distances between cells such as paving, tiling and shingling. These methods greatly reduced the gaps between the cells, and sometimes the cells can even overlap each other. These technologies reduce the resistance of a cell, as well as the resistance between cells, and therefore the larger format modules are not quite as large as they otherwise might be.

These technological innovations ultimately opened a floodgate that have allowed module manufacturers to try out different cell sizes, cutting them up and recombining them in various ways, creating a myriad of new module sizes and types, while still keeping the current and voltage parameters within manageable values for system designers. In some cases the module voltages are even less than those of the 72 cell modules, potentially allowing module manufacturers to use longer string lengths in their design.

All this has led to a somewhat confusing proliferation of different modules in the market, and different manufacturers made their bets on different cell sizes, trying to guess which technology and combination will be the best in the long term. This makes it a confusing time right now for system designers who are being marketed a number of different products, but find it difficult to know which one is really best for their project.

The good news is that module manufacturers have now invested a lot of money in their manufacturing lines to cope with the new cell sizes, and the current state of play is that most manufacturers are now banking on either the 182mm or 210mm size cells. Additionally, all these changes have been disruptive to suppliers further up the supply chain, who need to produce ingots for the new cell sizes, as well as glass, backsheets and other balance of material items to handle the new module sizes, and the more they can standardise, the cheaper the product becomes. This means there is a strong motivation now for manufacturers to consolidate around just one or two module sizes, since it is in the interest of the entire supply chain servicing the production of PV modules to standardise as much as possible, and hopefully the choice will be reduced in favour of economy.

General principles of design

The use of large format modules can potentially provide important savings on the balance of system costs when building a utility-scale plant, particularly on the racking systems and the cabling.

A good example can be illustrated by looking at trackers. A tracker is designed to carry a certain quantity of modules, and it can generally be compatible with larger sizes than the 72 cell with minimal adjustments. If a tracker has been designed to carry 84 modules that are 2 metres long, it's not that difficult to adjust that tracker to cope with 2.2 metres long, and you have a situation where almost the same tracker, with the same motor, is now handling a


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greater power. Less modules also mean less fixings, bolts or clamps on the frames, for both fixed and tracker systems.

There are also important potential savings on cabling: string cables are generally designed with plenty of spare current carrying capacity, with system voltage being the limit of how many modules a string is coping with. If a module has suddenly jumped up from 400W to 600W, but the string voltage is essentially the same, then suddenly the same cable is dealing with 1.5 times the amount of power, meaning less cabling for the same peak power.

Both of these lead to a potential reduction on installation cost as well, since there are fewer trackers to assemble, fewer modules to mount and fewer strings to crimp and connect.

However, for the PV plant designer, the use of large format modules introduces some interesting challenges, and there are a few key points to bear in mind. Firstly, it is very important to understand that the additional power of these modules is not driven by efficiency, but by size, and so when a designer is looking at their current portfolio of project designs, they cannot simply think they are going to replace all their 360W modules with 800W modules, and have a PV lant with more than double the capacity.

Up until the advent of large format modules, a plant designer could keep the pitch between module rows exactly the same, and an increase in power would simply mean a potential premium to be paid for a more efficient module, but this is no longer the case – the PV designer needs to increase the spacing between mounting structure rows in proportion to the increase in size of the modules in order to keep the ground-cover ratio the same. If they do not do so, then there is the impact of increased inter-row shadings on a fixed system, and increased shadings of the diffuse sunlight on a tracker system.

This is also important when considering planning applications. If a developer has achieved planning consent on a tracker system, for example, by assuming the maximum height reached by 72 cell PV modules when the tracker is at maximum rotation, then they might well be restricted in the use of the large-format modules, because these modules will attain a higher height when the tracker is fully rotated. Therefore, designers and developers alike should consider the maximum size of any modules they are potentially going to use early on in the planning process, in order to avoid problems of planning compliance later on.

Additionally, the height and weight of the modules produce interesting physical challenges during installation. Something that might only have required one person to handle might suddenly require two people instead. On a ground-mount installation, this is definitely manageable, but on a commercial rooftop under windy conditions, this can open up important Health and Safety implications – when carrying these larger modules on a roof, an installer is essentially walking around at height with a massive, heavy sail in their hands. Extra care must always be taken for safe working practices and anti-fall protection when working at height, but this is especially true when using large format modules.

Wind design

Wind considerations are of particular importance for ground mount tracker systems. Over the last few years, there have been a number of wind incidents that have caused large amounts of damage. There have been quite extreme incidents where entire PV plants have been wiped out by hurricanes, but additionally quite a lot of destruction has been caused by relatively low wind speeds on some tracker systems. Under certain wind conditions, resonant vibrations can be set up on dynamic systems such as trackers, and these resonances can cause destructive effects such as torsional galloping along the torque tubes of the trackers, tearing the system to pieces under wind speeds that aren't particularly violent themselves.

> "One should definitely consider whether sufficient spare modules have been considered to last the lifetime of the project."

Luckily, over the last couple of years, tracker manufacturers have made massive improvements in their understanding of the dynamic wind effects upon their product, but the larger surface area of the new generation of PV modules means that the force of the wind upon them is greater, making them even more vulnerable to such effects. Therefore, it is very important to engage the tracker manufacturer early on in the design process, since they might need to make some important adjustments to the proposed design in order to accommodate the modules.

A PV designer might consider designing the entire plant using trackers that can hold three strings of 28, so 84 modules each. However, the tracker manufacturer may well see that the extra wind load caused by using the large format modules will mean that the tracker cannot withstand the increased wind load, especially around the edges and corners of the PV plant where wind effects are stronger. They might say that the trackers in those locations should only carry two strings instead of three, ie: 56 modules instead of 84. This could eliminate the BOS advantage of using the large-format modules in those locations, and it may even make the overall installation more expensive. Therefore, it is very important to understand the wind speed of a site early on, and to discuss the implications of larger format modules with the tracker manufacturer, otherwise estimated cost savings might be significantly over-estimated.

Additionally, something that is true for all tracker projects, but especially so when using large format modules, is that it is important to perform *site specific detailed dynamic wind load studies*, including wind tunnel testing, for the tracker/module combination with an established wind consultant, and not just rely on static wind load reports. Failure to do so means that

Credit: TrinaSolar

The addition of larger, heavier modules to existing tracker designs will require more thought when it comes to wind.

the projects will be potentially vulnerable to torsional galloping and vortex lock-in.

Electrical design

The large format modules have been designed in such a way as to keep the voltages as similar as possible to the 72 cell formats designers are used to. In some cases, open-circuit voltages have increased slightly from 45 to 50V, but in other cases they have stayed the same, and some designs have even reduced the open-circuit voltage down to 40V. This is very important with respect to the string lengths that can be selected for a particular site, and in the latter case allows for string lengths of longer than 30 modules on a site, which can reduce cabling costs.

The fact that voltages are controlled means that the increase in power is driven by increases in the current, and ampacity of cabling becomes very important, especially so when considering bifacial modules. String cable typically has plenty of spare capacity, however, DC cabling running from string combiner boxes back to central inverters may need larger cross-sections than expected in order to cope with the higher current.

There are some important caveats with respect to the electrical design. Firstly, the existing generation of trackers are typically designed with strings of up to 30 modules in mind, and so pushing the string length over 30 may not yield any benefit, especially if such an increase in the number of modules exacerbates the problems with wind loadings. Therefore, before the BOS savings of large format modules can be fully achieved in the market, it is important for tracker manufacturers to develop products that can cope with longer string lengths and that are more resilient to wind effects.

Secondly, a large number of PV plants are being built with string inverters, that typically have a maximum number of strings that can be connected. The power rating of these inverters has been optimised for 72 cell modules. For example, in the market there is a 185kW inverter that can receive up to 18 strings. If the designer uses 400W modules in strings of 28, this adds up to 201kWp, giving an oversize ratio of 1.08, which is reasonable. But if the module used is 600W in strings of 28, this gives a total of 302 kWp, and an oversize ratio of 1.6, which is pretty excessive for most designs. If a designer wanted to achieve the same oversizing ratio as the 400W modules, only 12 strings would need to be connected to the inverter, but this means the other inputs and available MPPTs that are available are being wasted. The problem is exaggerated even more when using strings of longer than 30. Inverter manufacturers have a tricky job to guess which large-format design is going to win out, and to create products that are better tuned to the new generation of modules.

PV system designers will have to consider how the large-format modules will affect DC/AC oversizing ratios on inverters, and manufacturers may need to develop products more compatible to the new modules.

Credit: Huawei

Large-format modules in the long term

One final important question is the long-term reliability and maintainability of these products. These products have been in the market a very short time, and although they have undergone the same testing as other PV modules, there are questions over whether larger cell sizes will be more vulnerable to mechanical stresses and therefore micro-cracking, and whether the denser interconnection methods will put more stress on the PV cells than the older designs.

Although these sorts of problems are covered by manufacturer warranties, there is an additional factor to consider: with such a large variety of module sizes and electrical characteristics suddenly available, and with market consolidation likely to happen quite soon, how easy will it be in the future to obtain replacement modules of the same type for covering guarantees or replacing breakages? Modules should only be replaced in a string if the voltage and currents roughly match those of the original modules, and the combinations currently available in the market are very diverse. Therefore, until the market has settled on a new standard size, there is always the risk that the large scale PV module that's been chosen for a project is the one that will go out of fashion in a year or so, and limit the options for fixing problems in the future. For imminent projects, one should definitely consider whether sufficient spare modules have been considered to last the lifetime of the project, just in case it is a challenge to find them in the future.

It is certain, though, that these large format modules are here to stay, and they are quickly becoming the new normal for utility scale PV plants, since the potential advantages they bring are quite significant. Most of the disadvantages that these modules cause are more about the disruption to an existing supply chain, and to designers of trackers and inverters who have built their products around the 72-cell module. However, the good news is that as these manufacturers adapt to the new reality, the BOS costs have a continued pathway to drop further. Hopefully the large-format market will consolidate and settle down to a new 'standard' module size, both in terms of size and electrical characteristics, in order to give clarity to the rest of the supply chain about which direction to develop their products, and in order for asset owners to feel comfortable about the long term maintainability of their projects.

Beyond the large-scale module there continue to be interesting innovations that will continue to improve cell efficiencies, and in parallel there is also a trend towards using bifacial modules. It is very likely that the module of choice in the near future for utility scale projects will not look at all like the 72-cell modules we've been used to for some time. The module of the future will be larger and it will be bifacial, and it's just the exact dimensions of this module that we are all holding our breath to see. ■

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Project briefing

DEFYING COVID AND PROTESTS IN SOLAR'S LATIN AMERICA HOTSPOT

Project name: Atacama Solar
Location: Pica, Tarapaca, Chile
Capacity: 170MW
Expected generation: 485,000MWh per year
Developer: Mytilineos
Asset owner: Sonnedix

Chile has emerged as one of the brightest hotspots in Latin America's solar sector, helped by generating conditions so ideal one seasoned developer referred to them as "unmatched" when the results of a tender earlier this year were announced. Hundreds of megawatts of solar have been deployed in 2020, with industry stalwarts all vying for their share of the prize. That pace of development only looks set to accelerate after the aforementioned tender awarded 2.6GW of capacity and a follow-up competition, slated for next summer, will hand out gigawatts more.

One party to have witnessed first hand the rise and further rise of Chilean solar is Mytilineos, the Greek engineering, procurement and construction (EPC) company tasked with the development of the 170MW Atacama Solar Farm, belonging to independent power producer Sonnedix. The project is one of a number Sonnedix has in the country, with its total pipeline of projects at various stages of construction in the region topping 1GW.

But, amidst the rush to develop projects in Chile, the development of the Atacama Solar Farm, built near Pica, Tarapaca – with the Atacama Desert towards the north east of the region – has been far from straightforward.

Mytilineos signed the contract with Sonnedix in April 2019, with a notice to proceed issued on 3 September 2019. Construction started shortly after, only for works to be somewhat beset less than a month in. In October 2019, protests erupted in the country sparked primarily by an increase in fares for the subway in the capital of Santiago, but grew throughout the month as citizens rallied against spiralling inequality and increased privatisation. The situation escalated until Chile's President Sebastián Piñera declared a 15-day state of emergency in Santiago before, on 25 October 2019, more than a million people in Santiago and thousands more across the country demonstrated, prompting swathes of the country's cabinet to resign.

The protests triggered significant disruption to Chile's infrastructure and Nikos Papapetrou, general manager of renewables and storage development at Mytilineos, says the protests sparked some concern as a result of constrained logistics in the country. However, any concern sparked by the riots would pale into insignificance just a few months later.

Chile: Solar's LatAm hotspot

While other Latin American markets on solar's radar may have cooled somewhat in 2020, especially Mexico, Chile has emerged as the leading destination, with the Atacama region of particular interest to many developers. Previous editions of *PV Tech Power* (23 and 24) have detailed not only the rise in prominence of Chile's solar market, but how the Atacama region in particular has emerged as one of the most highly sought-after areas for solar development in the world. This summer, a raft of renewables heavyweights including EDF, Engie and Solarcentury were amongst the winners of a 2.6GW solar tender that represented a total investment value in excess of US$2.5 billion. Solarcentury bagged three projects with a total generating capacity of just over 1GW/963MWac and, once complete, those projects are expected to generate as much as 3,000kWh per year for each kWp deployed. This, the developer said, was attributable to Chile being an "unmatched" solar resource due to its location and altitude. "The land we have secured in this auction represents some of the best land in the world to develop solar as it combines great irradiance with cool temperatures," Cristian Fuenzalida, business development senior manager at Solarcentury LatAm, said at the time. Chile is now looking at a repeat process, with authorities in the country confirming in November 2020 plans for a new auction for both solar and storage projects, aimed at procuring 2,310GWh of power. The auction is due to take place in May 2021.

A view of the protests in Chile's capital of Santiago on 25 October 2019

Credit: Hugo Morales

Counter-COVID measures

The onset of the novel coronavirus from the start of 2020 onwards had a drastic impact on the entire solar supply chain, but deployment felt the brunt of this impact from March and April onwards. Entire continents were placed into significant lockdown measures at this time in an attempt to control the virus, affecting logistics and construction altogether.

Papapetrou says the Atacama Solar project was nearly half-way through development at the time of the 'first wave' of COVID-19, and Mytilineos first

suffered delays as a result of restrictions being put in place at ports. These ports, critical to getting components on site from manufacturers, were understaffed and "almost closed" during first lockdown period. There were further issues in the overall supply chain which was suffering at the hand of factories being shutdown or not operating at full capacity, transportation problems and raw material shortages. As a global issue, there was unlikely a facet of construction that was untouched.

Thankfully, mechanical and electrical construction activities were not as significantly impacted as other infrastructure sectors, perhaps most notably building construction. Once sectors have adapted to the confines of operating under the auspices of COVID, it would seem, activities can resume fairly quickly as long as governments allow for it. Papapetrou says that despite concerns of lengthy delays to construction, in total the project was set back around two months in the early stages of COVID-19, time that was managed to be made up during the construction phase.

In order to restart construction, Mytilineos implemented a number of safety measures, consisting of both those imposed by Chile's Ministry of Health and others considered by the company to be essential as well. All construction workers on site were submitted for frequent COVID tests to ensure the site remained virus-free, and personnel were checked daily for any potential symptoms or signs of the virus. Offices were rearranged to ensure social distancing was adhered to, and all on-site activities were conducted in a similar fashion. Enhanced personal protective equipment (PPE), such as face masks, were issued to each worker and regular briefings were held with those present on site in order to ensure that they were understood. The measures went as far as to include travel to and from the site, as well as the accommodation booked. Replaceable plastic covers had to be installed in vehicles used during construction and no more than two people were permitted per trip.

The 170MW Atacama Solar project

Credit: Mytilineos

Likewise, accommodation was limited to just two people per house, and even food deliveries were made differently, limiting the vectors that could possibly transmit the virus.

Despite these measures being implemented solely for the virus, Papapetrou says some have become the standard in all of its project developments moving forward. Right the way from the recruitment phase, construction personnel are inducted and acquainted with all HSE rules and standards to ensure their compliance with the intention that, should the virus or any other pandemic flare up again in the future – with most epidemiologists warning that the coronavirus could be here to stay – any changes to construction practices are minimal.

But as any developer will attest to, there are multiple hurdles to overcome when it comes to connecting a project on time and, COVID aside, the Atacama Solar Project was no different.

Navigating the desert at altitude

The Atacama desert is famed for its aridity and altitude, with parts of the Antofagasta region averaging an altitude of around 10,000ft. This, coupled with its irradiation portfolio, make it a near unrivalled placement for solar projects. But this comes with its challenges, both in terms of construction, module selection and even personnel.

Papapetrou explains that logistics were not of a particular concern – aforementioned issues aside – due to the project's location of less than 170km from the nearest port of Iquique, which allowed for freight to be delivered easily. Port closures associated with COVID did create a bottleneck in component imports, but this was cleared shortly after they reopened and approached normal activity.

But issues did arise surrounding factors like site security and telecommunications, with basic internet lacking in an environment that, for all intents and purposes, remains a desert. Security measures were tasked with a reputable provider to limit breaches and also help control the daily in/out activities of personnel and visitors. Internet was sourced using a satellite connection, common in such remote project sites.

Papapetrou says the remote desert environment also contributed to another perhaps overlooked area of project construction in the health and wellbeing of personnel. For workers to relocate

Mytilineos' COVID-compliant measures

- Frequent COVID tests
- Daily checking on personnel about potential symptoms
- Distancing with regards to offices and on-site activities
- Enhanced PPE clothing, such as masks
- Regular briefing about the measures
- Plastic replaceable covers in all vehicles
- Vehicles with no more than two persons per trip
- Accommodation with no more than two persons per house
- Food delivered in isolated covers

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"We tried to keep everyone focused on the work. Team building activities, frequent family visits and similar activities were promoted so as to retain the consistency of the team."

to the desert for a buildout time of 15 months is no short ask – despite this being somewhat common for Chile's workforce, a possible throwback to the country's mining industry – and this did take its toll on personnel.

To overcome these, Mytilineos shifted priority onto the needs of the team, Papapetrou says. "We tried to keep everyone focused on the work. Team building activities, frequent family visits and similar activities were promoted so as to retain the consistency of the team," he says.

The desert also contributed significantly to component selection. At 170MW, the Atacama Solar Farm remains amongst the country's largest and is expected to generate around 485,000MWh each year. For those expectations to be met, the project must maintain as high an operational availability performance as possible in an environment that has been proven to be corrosive to electronics.

Papapetrou says this meant that all components, from the inverters to component boxes, to electrical boards and motors, had to meet at least IP55 standards to protect against any dust ingress. Modules were too selected with this in mind, however bifacial panels were avoided for this particular project. Backsheets were selected in order to specifically preserve the mechanical and electrical characteristics of the module throughout the site's expected lifetime, Papapetrou says, with backsheet-related failures of modules on the rise, a study conducted earlier this year by DuPont found.

Attention has also been granted towards the ongoing operation and maintenance of the site, and more specifically on the kind of module cleaning required in such arid, dust-laden environments. Frequent cleaning is an absolute necessity, however water scarcity is rife in the region. Alternative but equally suitable solutions were required, and a full solution was sourced to allow for water-free cleaning of modules.

Chile looks set to continue its climb up the solar ranks, with gigawatts set to be deployed over the coming years as a result of government solar tenders. But while contracts and the promise of spectacular solar generation conditions may tempt developers, navigating the country's desert environments poses myriad challenges, right the way through from component selection to finer development details, with staff wellbeing also an often overlooked, but critical component.

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The challenge of benchmarking PV module suppliers in 2021

Bankability | Finlay Colville, head of research at PV Tech and Solar Media, offers exclusive insight into the PV ModuleTech Bankability Ratings and explores how the industry's major module manufacturers can be grouped entering 2021.

Selling photovoltaic (PV) modules remains an activity that many companies wish to excel in. The more modules shipped each year, the better; add in special kudos for having a global footprint and being a leading player in overseas markets.

Each year, many companies exit the sector, often simply to be replaced by new entrants, seemingly trying to do what others had done before with little change to the recipe. Indeed, each time a domestic downstream end-market is thriving, the lure for new manufacturers only increases.

Yet, it is possible to count on one hand the number of companies that have sustained a profitable module business over several years. The PV industry has seen literally hundreds of casualties in the past couple of decades, in particular across Europe, the US and the whole of Asia, and this is something that is unlikely to change going forward.

This article examines what is behind the leading PV module suppliers to the industry today, and during the next 12 months. It explains why segmenting the business models of module suppliers into specific groupings can go a long way to help module users/investors make more informed decisions on preferred suppliers.

The basis for the analysis used in the article is PV Tech's latest *PV ModuleTech Bankability Ratings* report, with the Q4 2020 findings used as the backdrop for 2021 module supply activity.

After an overview of the methodology used to assess PV module suppliers' bankability ratings, the results of the Q4 2020 analysis are presented. This reveals the leading global module suppliers for large-commercial and utility-scale projects in 2021. Using the module suppliers occupying the highest bankability ratings, new groups are created that capture the underlying motives and business models pursued by these companies. The results of this are then discussed, and how they can be of use to companies required to differentiate between module suppliers in the near to mid-term.

Credit: Trina Solar

A small group of companies occupy the A and B ratings within the PV ModuleTech Bankability Ratings

The PV ModuleTech Bankability Ratings method

After more than a decade tracking and analysing almost every PV module manufacturer's operating features and characteristics, the PV Tech market research team undertook an intensive six-month research project to develop a fully-validated model that could allow any PV module supplier to be benchmarked across a range of manufacturing, technical and financial performance metrics.

The full methodology, with supporting data, was outlined across a range of featured articles on the *PV-Tech.org* web portal between July and August 2019 . Further enhancements to improve the accuracy of the analysis were then undertaken during 2020, in particular how to compare the financial health of private and public-listed module-owner entities, and the need to optimise best fit scaling and power coefficients on a quarterly basis.

While the full analysis uses extensive and time-consuming data-gathering for all the module suppliers each quarter - across many manufacturing, technical and financial metrics - the underlying principle of the ratings method is remarkably simple.

To achieve high bankability 'scores' (zero-to-ten), any given PV module supplier needs to have above peer-average manufacturing and financial health. A deficiency in either yields a low rating. Furthermore, quarterly ratings use trailing blended values, essential to eliminate one-off events that are frequent occurrences in the PV industry. At any time in the past, the analysis effectively mirrors the PV module suppliers that were winning the major deals in the industry (large-commercial and utility-scale, typically institutional investor bankrolled).

Each quarter, a refreshed rankings hierarchy is obtained with the most bankable PV module suppliers in the highest AAA-Rating band, and the lowest (least-bankable or highest risk) in the C-Rating band. Typically a small group of companies (10-15) occupy the A and B grade bands; every other PV module supplier then falls into the risk-heavy C grade bands. This is exactly what is seen in the PV industry; for large volume deals globally, only a select group of companies are ever in the running at any given time as viable candidates.

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SOLAR MEDIA MARKET RESEARCH

The Q4 2020 bankability ratings hierarchy pyramid

Every quarter, PV module suppliers are ranked by their bankability rating score, with the highest graded (AAA, AA and A ratings) shown at the top of a pyramid graphic, and lower-ranked suppliers allocated to bands in the B and C grades. The hierarchy pyramid for Q4 2020 is shown in Figure 1.

This shows a total of 13 module suppliers in the 'premium' A and B grades, with LONGi Solar the only highest-ranked AAA-Rated company. Most of the module suppliers in the sector today actually fall into the 'unlisted' lowest C-Rated band, with many of these being low-capacity operations or contract/OEM suppliers only. The CCC and CC-Ratings tend to be highly populated each quarter, characteristic of suppliers shipping sub-GW-level volumes and often single-country dominant.

The main grouping for global large-scale site selection are those in the A and B grade bands, the validation here being in our regular checks with downstream investors and global developers/EPCs that are undertaking supplier due-diligence at any given time. With utility sites today being in the hundreds of megawatts often, it is also not surprising that suppliers with limited volumes or focused on covering a range of small rooftops segments are absent from these supplier selection processes.

Therefore, the focus should be on working out how to group together the 13 top ranked module suppliers here, and seeing if there are common business models and groupings that can be established to better explain the different strategies at large. This is undertaken in the remaining sections of this article.

New categorization of the leading rated PV module suppliers

There are many obvious ways in which the 13 companies can quickly be segmented. Before looking at the new categorisation framework, a few of these are discussed first.

The easiest segmentation is by country of company headquarter operations. Most of the companies are Chinese-run entities: LONGi Solar, Canadian Solar, JA Solar, JinkoSolar, Trina Solar, Risen Energy, Astronergy, Suntech, GCL-SI, Seraphim and Talesun. Of the remaining two, First Solar is a US-run company and Hanwha Q CELLS is Korean.

Another route would be to assign by module capacity location. Many of the companies have high volumes of cell/module capacity in China, and various owned/joint-venture activities in South-east Asia: LONGi Solar, Canadian Solar, JA Solar, JinkoSolar, Trina Solar, Astronergy and Talesun. Others are China capacity-centric today, but have plans to add Southeast Asia capacity in 2021: Risen Energy, Suntech and Seraphim. First Solar has capacity in the US and Southeast Asia. Hanwha Q CELLS has capacity in Korea, China, Malaysia and the US. GCL-SI falls into an 'other' category here, as the only supplier with China-only owned capacity today.

However, the most valuable means of segmenting the leading ranked module suppliers is by combining some of the above aspects with parent/reporting-entity revenue streams. This is potentially one of the most critical ways at looking any PV module supplier today.

To explain this better, consider a couple of examples. If PV module revenues form a very small part of reporting/listed company turnover, there is a risk that the module business can be eliminated at any time as it is often deprioritised in any company strategic changes. This becomes a big deal for example if parent company finances are challenged, or the module business unit is consistently loss-making. The flipside to this are the companies that are almost 100% reliant on selling modules. Here, the entire company is dependent on module sales being profitable in the long-term, although short-term losses can be sustained.

Many of the high-profile 'bankruptcies' or periods of market-share losses from module suppliers to the industry can often be tracked back to the module supply business unit falling into one of the two scenarios above.

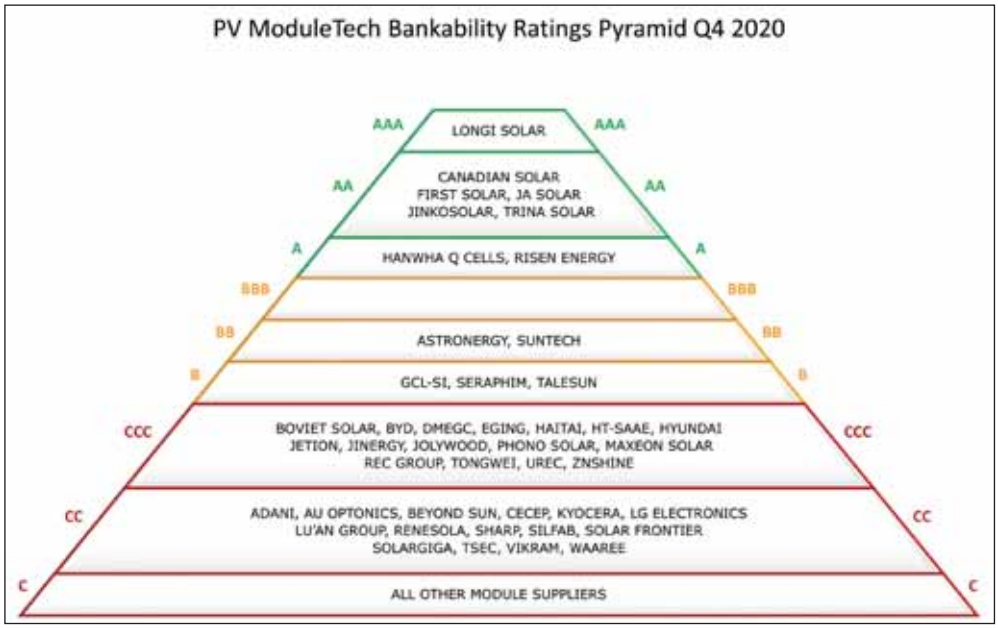
The 'middle-ground' - where module revenues form a 'significant' part of parent/reporting entity turnover – can often be seen as a prudent operating model. Here, module revenues may account for about 40-70% of turnover, implying that module activities are the key business focus, but still allowing for secondary revenue streams often phased to compensate for any downturn in module profitability.

Before looking at the new categories for the A and B graded module suppliers, it should be noted that some of the listings in Figure 1 are for 'brands' in the market, not necessarily the company selling the product (warranty guarantor). This is true for Hanwha Q CELLS, which is the module supply brand offered today by Hanwha Solutions. Astronergy is the module offering from Chint Group. Talesun is the brand offering of Zhongli Group. Until recently, Suntech was the module offering within Shunfeng International, although the company has now been carved out in China under private ownership.

The new categories are shown in Figure 2. Here, companies are grouped according to perceived strengths in two different areas.

The first area relates to 'Own-brand Module Business Priority', shown on the x-axis. Essentially, companies furthest to the right on the graph are those that have prioritised module business in-house the

Fig. 1



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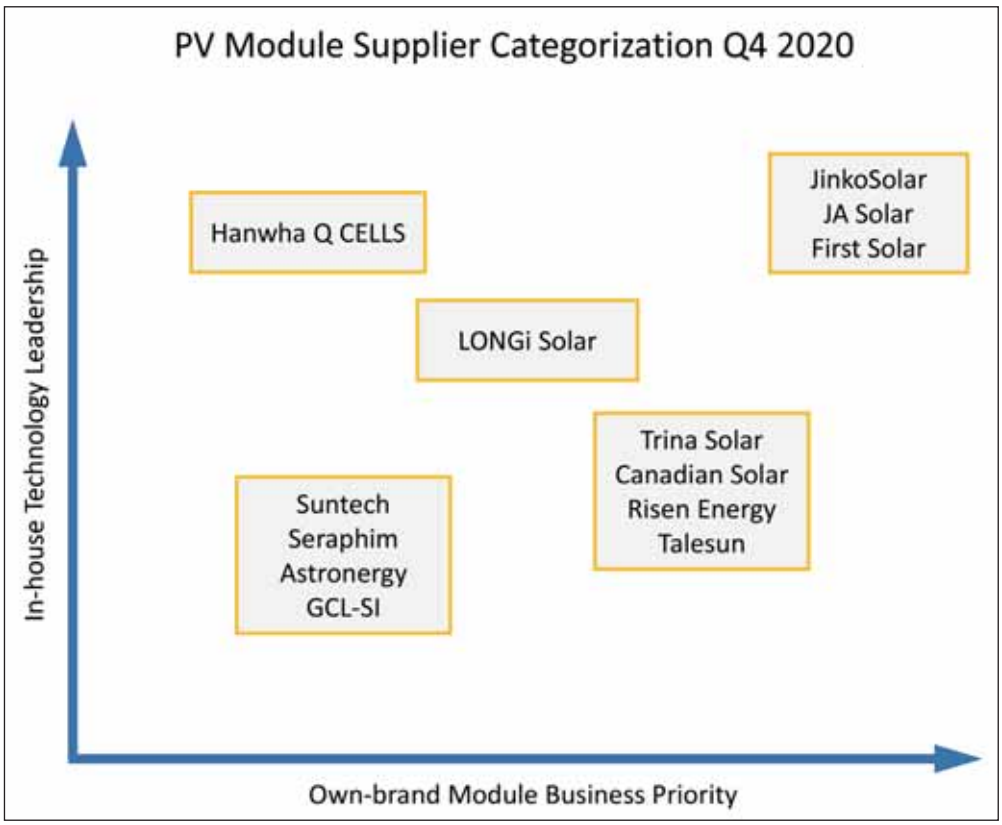

Fig. 2

most over the past few years, compared to all other business avenues. Companies more to the left on the x-axis either tend to prioritise other business activities (PV or non-PV) or have been chopping and changing business models frequently.

The second area is what is called 'In-house Technology Leadership'. This is based on the degree to which the company has concentrated on in-house investments/supply from wafer-to-module (or thin-film in the case of First Solar), where this in-house activity is entirely for the benefit of own-brand module supply. The contrast is when companies are cell/module or module-only focused, supply to competitors when the need fits including wafers, cells and modules, or operate lines under contract or OEM deals.

Therefore, the module suppliers that have the most focused in-house technology emphasis on using own products through the value-chain for own-brand module supply (and this being the major focus of the parent/reporting entity) will appear in the upper-right of the graph.

The three companies shown together in what is a best-of-class grouping near the top-right are JinkoSolar, JA Solar and First Solar. These three companies can easily be grouped together, despite the fact that First Solar is thin-film specific. The three companies are somewhat unique in the PV industry today because their focus on in-house capacity and production goes back to raw-materials (glass, polysilicon), and the entire focus of this including all technology-investments is to drive own-brand module supply. They are the only PV module suppliers that can claim this in the industry today. Every other module supplier tends to rely on being part of a network of supply-deals or offering its services and products to other PV manufacturers on a regular basis.

Trina Solar, Canadian Solar, Risen Energy and Talesun have also been grouped together. These companies are still module-heavy, despite having made considerable investments into cells and wafers over the years. They have tended not to drive technology-change (compared to JA Solar and JinkoSolar for example), and have a far more relaxed stance when it comes to full in-house audit trail or production through the value-chain.

The other grouping of companies is the box containing Suntech, Seraphim, Astronergy and GCL-SI. These module suppliers have each been subject to quite a bit of change in the past, either being part of financially-risky parent entities (Suntech, GCL-SI), or making changes from legacy strategies to try and play in the same league today as the other module suppliers shown on the graphic.

Hanwha Q CELLS and LONGi Solar are somewhat outliers today, as they cannot really be grouped with any peers. This is just a consequence of how the group/parent operations are structured now. Hanwha currently has Q CELLS reporting within the Hanwha Solutions entity, and the company's PV operations have seen wafering terminated in recent years. LONGi Solar also has no direct comparison, and has managed to be both a leading wafer supplier and module supplier at the same time – something that is somewhat at odds, given that most of the wafer customers are in theory module competitors if they make both cells and modules.

Concluding remarks

The PV industry does remain a very challenging sector to operate within, in particular having a module-focused business model and staying profitable each year while adapting to a constant flow of unexpected changes.

Certainly, there is no magic formula to succeed, and the fact there are different business models and drivers across the leading most-bankable suppliers backs this up. However, over time, the suppliers that regularly feature in the A Grade bands are clearly the ones that have been managing to adapt appropriately to end-market conditions, while staying sufficiently profitable for share-holders or private owners.

In this regard, tracking the suppliers that make the move from CCC-Rating and B Grade bands, up to the A Grades, over the next couple of years may be of more interest. In particular, how will these companies have to change their strategy and focus on module supply in order to compete with the top half-dozen players in the segment today? If this fails to happen, then module supply for mega-sized solar sites may simply be an area where only a few suppliers truly compete. This type of supplier re-organization would represent a significant change in the industry and may perhaps be the final piece of the jigsaw needed as PV moves truly to the mainstream energy supply stage. ■

https://marketresearch.solarmedia.co.uk/collections/pv-tech-research/products/pv-moduletech-bankability-ratings-quarterly-report

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Introduction

Welcome to another edition of 'Storage & Smart Power', brought to you by Energy-Storage.news.

Despite the pandemic this year dominating our thoughts and limiting our activities, there's been a lot to talk about in energy storage and a lot of that has been positive. A quick look at the most-read news stories from Energy-Storage.news shows that the falling cost of storage remains a key topic, informing our collective insight into just how fast and feasible the global transition to clean energy supported by energy storage can be.

"Much faster and totally feasible" is the answer. On a related note, the high popularity of our content on Tesla's Battery Day in September made clear that the drive for innovative, mass-scale technologies to accelerate the global transition to sustainable energy - to paraphrase the company's mission statement - is catching the imagination and interest of people everywhere.

Innovation is a key theme of any technology-based industry, but it's important to note that it's not just technology that can innovate: business models and market structures can too. This year a hugely popular blog on the site from Florian Mayr at cleantech consultancy Apricum broke down the key features of a low-cost, innovative power purchase agreement (PPA) deal in California, for example.

While the majority of our coverage is lithium-ion battery focused, new options are always interesting to our readers. Almost every article on hydrogen has been widely read, as have articles on flow batteries and other new or less commercialised tech such as zinc batteries of different kinds. We're yet to see a strong commercial outlook for many of those but it is becoming clearer that for achieving decarbonisation, a mix of tools including long-duration energy storage will be necessary.

Then of course, there were the projects. So many projects. From the US to Europe to Southeast Asia and beyond, it's been such a privilege for our team to report on them. From the largest systems in the world to the first large-scale systems in new markets, we've certainly been kept busy.

In this edition, fire safety is top of mind in the excellent article 'What the fire service wants you to know about your battery'. Energy Safety Response Group (formerly known as Energy Storage Response Group) discuss some of the most important aspects of creating a safe industry and strong relationships with first responders, authorities and fire code officials.

In 'The future of the energy storage system integrator in a maturing industry,' Julian Jansen from research firm IHS Markit takes a close look at the evolution of the role of the likes of Tesla, Fluence, Wartsila and others play in shaping the battery storage space. Jansen talks about the dynamics of growth, consolidation and competition in a rapidly changing world.

Finally, I've spoken with the CEO and COO respectively of Key Capture Energy and FlexGen, two companies that demonstrated during 2020 that despite the coronavirus-induced economic slowdown, energy storage has been resilient and continued to thrive, in 'US energy storage in 2021: Notes from a maturing industry'.

Next year, we will work hard again to bring you the very best in industry content on the topics you care about, as well as hopefully drawing your attention to exciting new developments. As someone far wiser than myself said recently of the energy transition and the fight against climate change: "we haven't got a lot of time - and we have a huge opportunity".

Andy Colthorpe
Solar Media

Credit: AES Gener

A virtual groundbreaking ceremony marking the start of AES Gener's massive battery storage project in Chile.

AES begins work on 560MWh battery project in Chile

AES Gener held a virtual groundbreaking ceremony in mid-October to mark the start of construction on a 112MW / 560MWh battery energy storage system project in Chile, Latin America.

Multinational electric power generation and distribution company AES Corporation's local subsidiary said the system, which can store power from nearby solar and wind facilities for up to five hours, is the biggest battery storage system in Latin America to date as well as being Chile's first solar-plus-storage project.

The batteries will be paired with 253MW of renewable energy generation, including the 180MW Andes Solar II B project in Antofagasta. The solar energy will be integrated into the national electricity system with the batteries will be built on mountain ranges in Antofagasta in the Atacama Desert, enjoying a combination of high solar irradiance at relatively low temperatures. Meanwhile, the output of the 73MW Campo Lindo wind farm, the first phase of a total 480MW cluster of wind turbines being built in the region.

Approval for UK's 640MWh largest battery project

The Department of Business, Energy and Industrial Strategy (BEIS) in the UK has given the green light to the country's biggest ever battery storage project.

InterGen has gained planning permission for a 320MW / 640MWh lithium-ion battery site at DP World London Gateway, a new port and logistics centre on the Thames Estuary in Essex, south-east England. The £200 million (US$267 million) project will also have the potential for further expanding, as far as 1.3GWh.

Fluence is providing the technology for the site, having worked in partnership with InterGen for the past two years following a competitive tender process. The companies initially signed an exclusivity agreement for another project at Spalding, which was since been extended to the Gateway project.

South Africa began unique 2GW tender

South Africa's Ministry of Mineral Resources and Energy is conducting a fairly unique procurement programme for 2GW of energy capacity, to come from a "range of energy source technologies".

Deadlines for participation closed in late November with projects needing to be in commercial operation by mid-2022 after the government, together with the national energy regulator determined that it quickly needs to bridge the gap between demand and supply on the grid.

Independent power producers (IPPs) were invited to prepare bids for projects with an installed capacity of between 50MW and 450MW, for 20-year power purchase agreements (PPAs). Winning projects need to be dispatchable under terms defined by the tender: the main requirement being that they can dispatch power to the grid as needed between the hours of 05:00 and 21:30.

With the tender closed off to coal and diesel plants, this opens a pathway for renewable energy projects paired with energy storage, it also leaves the door open for natural gas.

Fire at grid-scale battery storage plant

Project owner Ørsted confirmed that there had been a fire at the Carnegie Road 20MW battery energy storage system (BESS) project in Liverpool, England in September.

Merseyside Fire & Rescue Service, local first-responders, said that crews were alerted shortly before 1am on 15 September and arrived to find a "large grid battery system container well alight".

The fire service said that it had used main jets and ground monitors in tackling the fire, asking residents nearby to keep their windows and doors closed due to smoke from the incident.

The blaze went on for several hours, with an update from the service at 7:30am noting that although operations at the site had been scaled down, firefighting was ongoing, with two ground monitor units and a main water jet still in use.

The Carnegie Road project was Danish power company Ørsted's first standalone grid-connected battery project, built using storage system equipment supplied by the now-defunct Energy Solutions division of NEC Corporation, housed in three containers. The project's completion was announced at the beginning of 2019.

Canadian Province Alberta's first grid-scale battery storage brought online

10MW / 20MWh of Tesla Megapacks used for Alberta's first-ever large-scale battery energy storage system have gone into action as TransAlta Renewables announced the project has reached commercial operation.

Called WindCharger, the project's batteries charge up in about two hours from TransAlta's 66MW Summerview II wind farm in the Canadian Province. Energy-Storage.news last reported on the project in August as it looked set to go into operation that month, TransAlta in October said that it has successfully done so.

Wind, solar and hydroelectric company TransAlta Renewables purchased the project from power generation and distribution player TransAlta Corporation, its majority shareholder. TransAlta will pay a fixed monthly charge for the right of operation and dispatch of the battery system in the Alberta market.

California Community Choice groups seek up to 500MW of long-duration energy storage

A group of Community Choice Aggregators (CCAs) in California, US, are seeking long-duration energy storage to add resiliency to their electricity networks serving around three million customers.

Eight CCAs have jointly issued a Request for Offers for up to 500MW of long-duration storage that can charge up from the grid and then discharge for between 8-16 hours. The winning project, or projects, would obtain minimum 10-year contracts and would be expected to be completed and online by or before the year 2026.

CCAs are permitted to supply energy to residents in several US states and in California operate in the service areas of the major investor-owned utilities, benefitting from existing transmission and distribution infrastructure, while being able to freely determine their energy suppliers and generation mix.

The long-duration grid-connected storage systems that the group of CCAs is seeking should be able to charge up during peak renewable energy production and then discharge to the grid at times when renewable generation output is lower.

What the fire service wants you to know about your battery

Fire safety | While fire incidents involving lithium-ion batteries in energy storage systems are rare, they can have devastating consequences for the industry and pose a threat to safety. Tom Bensen, Nick Warner, Ryan Franks and Michael Bowes from energy storage and fire safety expert group Energy Safety Response Group (formerly Energy Storage Response Group) discuss some of the most important aspects of creating a safe battery storage industry.

Energy storage projects can range from a few hundred kilowatt-hours to multiple megawatt-hours in capacity. They can be located in arctic, desert, or tropical environments, in urban or rural settings and in a variety of property ownership situations from a solar development, to a utility substation, to a commercial or industrial facility. Each project has a variety of stakeholders present including potentially:

- Battery manfacturer
- Inverter, container/structure, HVAC, fire protection and other component manufacturers
- Engineering, procurement and construction (EPC) firm
- Authority Having Jurisdiction (AHJ), including permitting and inspection agencies
- Financiers, insurance entities and law firms
- Other professional advisory services (fire protection, communications, environmental services)

As a project is proposed, conceptualised and built, one entity is often overlooked – fire departments. While the circumstances and details surrounding an energy storage project can vary greatly, each one needs buy-in from first responders and public safety agencies. Energy storage projects have experienced opposition at public hearings, missed timelines, cost overruns and unrealised revenue from delayed operations in recent years. One remedy to these issues is engaging with the fire department from the outset.

It is Energy Safety Response Group's experience that forthright engagement with the fire department providing response for any planned energy storage system (ESS) instills a high level of goodwill between the fire professionals and the project team, eases friction at public hearings, and speeds up project deployment.

Credit: ESRG

All images show burn testing at ESRG's facilities.

Each of the stakeholders named above has a role and responsibility in the development of an energy storage system. The fire department does as well - it should be an integral member of the project team. Engagement with a fire department starts by understanding their concerns and addressing them and culminates in development of an emergency response plan and training. None of the stakeholders wishes an incident to occur in an ESS, but should one occur, the fire department wants you to know and explain certain pieces of information about the site, your system, and its operation.

Concerns of the fire department and how to address them

Energy storage is a relatively new technology to fire departments across the US. While different fire departments have differing levels of exposure to battery energy storage systems (or BESS for short), the primary concern of each is the same: the safety and well-being of their first responders.

Departments and local officials are, however, becoming increasingly aware of the hazards associated with battery storage and it is important that their concerns be properly addressed. Addressing these concerns in a complete and transparent manner has been seen not only to promote overall first responder safety but also to ensure project success. Perhaps the most defining characteristic of lithium-ion battery failures is a state known as "thermal runaway," in which a battery cell experiences uncontrollable overheating, often accompanied by the release of large quantities of flammable off-gases. Thermal propagation from the failing cell may lead to incipient thermal runaway of adjacent cells, thus creating a cascading failure across the system, resulting in

tremendous amounts of heat and gas.

When these gases are allowed to accumulate in an enclosed space (such as a BESS container), an explosive atmosphere may develop, which, given an ignition source, may lead to a devastating deflagration (explosion) event. This blast wave can cause damage to nearby buildings and structures, as well as first responders who may be arriving on the scene, as was seen in the incident that unfolded in Arizona in 2019.

Deep-seated fires are also common in lithium-ion failure events. These fires are not easily extinguished and may continue for hours, fuelled by heat and gas from cascading cell failures. Even if suppressed by water, stranded energy within the cells often causes reignitions, thus perpetuating the event.

Concerns based on environmental risks are also often cited by fire departments across the country. Large quantities of smoke and gas are often released during battery fires, with high levels of carbon monoxide and hydrogen cyanide measured on-site in Arizona at the time of the incident. Contaminated runoff water may also affect the surrounding area. Electrical hazards also exist during and after battery failure events and should not be overlooked.

Industry is introducing measures to mitigate effects of battery failures

As the hazards associated with battery failures, such as those mentioned above, continue to be researched and more well understood, more effective protective measures are being utilised by industry to mitigate their effects. For instance, battery management systems (BMS), which can be thought of as the "brain" of the energy storage system, are becoming increasingly robust, providing granular thermal and electrical measurements at the cell level, as well as providing more effective system responses to abnormal battery conditions.

Deflagration vent panels are also emerging as a common solution for mitigating the effects of blast waves emanating from battery enclosures. These vent panels, which act as pressure relief points in the container, are used to direct the blast away from first responders and are thus often found on the roofs of the battery enclosures. Ideally, however, explosive atmospheres are never allowed to develop within an enclosure.

Exhaust systems, while less commonly utilised, are also finding use by battery system integrators to release flammable gases from the container before explosive limits are reached.

Gas-phase suppression systems such as Novec 1230, FM-200, inert gas or aerosolised gas-based agent have often been included in battery system enclosures to suppress electrical fires which may spread to nearby battery modules. It is important to note, however, that these types of systems are not effective for the extinguishment of battery-related fires, nor will they directly prevent thermal runaway from occurring. To date, water-based extinguishing methods remain the most effective means of providing thermal cooling to battery fires and preventing thermal propagation to adjacent units.

Smoke and gas detectors are widely employed by battery systems and depending on various factors may be effective in identifying an incipient failure event, though they have not proven to be reliable for extracting critical real-time data after an event has occurred. New detection technologies designed specifically for lithium-ion off-gases, however, are beginning to emerge, though are still in relatively adolescent stages of production and have not yet seen widespread adoption within the industry.

The shift towards safety

Recent incidents involving lithium-ion battery storage, such as those in Arizona, South Korea and the UK, have gained the attention of industry, fire departments and code officials worldwide and have led to a noticeable shift towards safety within the industry. Fire departments across the US are beginning to look to recently developed codes and standards for the safe installation of energy storage systems.

For example, a chapter solely dedicated to energy storage was added in the 2018 edition of the International Fire Code (IFC), which is adopted by many states. The upcoming 2021 edition of the IFC contains the most robust ESS requirements. Additionally, the National Fire Protection Association (NFPA) has recently developed its own Standard for the Installation of Stationary Energy Storage Systems – NFPA 855 – which local jurisdictions across the country have begun pointing to for BESS deployment.

Updated requirements around energy storage have recently been adopted by California Fire Code (CFC) and New York State – both based on updated Sections 1206 of the International Fire Code. New York City, known for its historically conservative stance with regards to the permitting of battery storage, has played a particularly substantial role in the development of BESS requirements, having led many of the early conversations around safety.

To account for the densely-populated urban landscape unique to New York City, and to ensure the safety of its firefighters, the NYC Fire Department (FDNY) created its own set of requirements – 3RCNY 608-081: Outdoor Stationary Storage Battery Systems – published in October 2019.

In the US, UL 9540 battery safety certification is also becoming widely adopted by code officials, as is large-scale fire testing per UL 9540A. Test data from UL 9540A – a destructive battery test method

Even if suppressed by water, stranded energy within lithium battery cells can causes reignitions.

Credit: ESRG

conducted to determine properties of batteries undergoing thermal runaway – can be used to substantiate safety claims by battery manufacturers and integrators and is required by IFC and NFPA 855 when increasing maximum allowable quantities of storage or decreasing separation distances between units. UL 9540A has also found adoption by the NYC FDNY and Department of Buildings (DOB), who require testing be conducted for all lithium-ion battery systems looking to be installed in New York City.

Credit: ESRG

Developing an Emergency Response Plan

Only recently have best practices around emergency response planning and firefighting tactics for battery storage systems begun emerging, guided largely by a deeper understanding of the dangers of BESS failures gained through research and recent battery incidents. Site-specific emergency response plans and comprehensive first responder training programs are quickly becoming the norm. Defensive firefighting tactics are also becoming more widely encouraged, as it has been seen that direct intervention with systems may have catastrophic consequences and in many cases may prove less effective than simply protecting the surrounding area and letting the system burn to completion.

Proper fire department training and more transparent communication by industry members have led not only to increased safety and awareness of the hazards associated with energy storage systems, but also led to the development of deeper relationships between parties. Trust building is an under-appreciated component of the project development process and is often overlooked by eager developers and battery companies. It is imperative that local fire departments and agencies, regardless of their size, are assured that their safety is the number one priority; in general, project success is quickly seen to follow.

The successful management of an incident begins long before any actual incident begins, including the reduction in risk and safety to human lives, property and environmental impact. This process should be started at the early stages of facility design and construction and be a continuation throughout its life span with an Emergency Response Plan (ERP). The emergency response plan is too often a document that is viewed as a box-checking document or is inadequate. Too often, entities ask that the emergency response plan be completed prior to the selection of the site, container type, fire protection/detection system or even batteries being utilised.

Throwing together an emergency response plan at a preliminary stage is setting up for failure and, frankly, a liability if an incident were to happen as there is no way the true hazards can be taken into consideration. If something goes amiss during an incident, the emergency response plan and implementation of the plan will be criticised. Some items that shall be contained are listed in Chapter 4 of NFPA 855 as well as 1910.38 (OSHA Emergency Action Plans). Considerations that should be covered with an ERP are equipment, roles, and responsibilities. Individuals should be placed into roles based on their availability and competency in the role. Many times, individuals are placed into a critical role, which they are not likely to be able to fulfil because of their normal work condition. This issue may even be more of a consideration in today's new norm of working remotely.

In short, if an individual is to meet the first responders on the scene, the individual fulfilling this role should not be located an hour away from the site location. The lack of local personnel will only leave the first responders to have to make hard decisions on their own and the basis of the rest of the ERP will be questionable in their minds. The issue of equipment in an Emergency Response Plan is often generalised, assuming either that first responders know what equipment they need or that the individuals preparing the emergency response plan do not know what equipment is needed and what the local first responders have on their apparatus.

UL 9540 A test data can be used to substantiate safety claims by battery manufacturers and integrators.

One common mistake involving equipment specifications occurs when a statement such as "wear appropriate personal protective equipment (PPE)" is written into the plan. Such a statement begs the question to many, even in the fire service, as to what appropriate PPE is for the incident. Is proper PPE a hazmat suit, a duty uniform, or full firefighter turnout gear with self-contained breathing apparatus? The appropriate answer would be full firefighter turnout gear with self-contained breathing apparatus as a thermal event is the highest hazard that will likely be encountered. Further information should be obtained from the local public safety jurisdiction, including the availability and type of gas monitoring equipment, barriers to protect water runoff from streams, storm drains and other waterways and thermal cameras.

Information provided in an Emergency Response Plan supporting the main body of the plan may include maps of the facility which easily and readily identify key or critical features of the site. Key features may include water sources, water shuttle routes, identification of containers, safe zones, command posts, and identified hazards. Safety Data Sheets (SDS) of the material(s) shall be included at the end of the ERP. SDS aid in identifying the specific hazards of the incident relating to environmental concerns or in the event an individual sustains an exposure event. In the case of an exposure event, many times medical facilities will want to know what materials and substances the individual was potentially exposed to.

The ERP should cover types of incidents which have been identified through a

detailed Hazard Mitigation Analysis (HMA). For example, appropriate consideration should be given regarding how to protect a system in a remote location where the property is bordered by trees, for example in California in relation to the threat of wildfires. However, this would not be necessarily be a valid threat in the a different location, for example in middle of the Arizona desert.

Without the complete HMA being performed, real hazards may be overlooked or missed altogether. Missing hazards may be catastrophic if and when that type of incident was to occur with not having the appropriate individuals, equipment, or plan of attack to manage the incident. The beginning stages of an Emergency Response Plan should start with having the proper competent individuals involved in the development and review of the document. These individuals should know the system being installed.

Knowing the system

Knowing the system means knowing what types of batteries are being utilised and how these batteries may react to different situations. Those situations may include overcharge, heat-related issues, or mechanical damage. Through hands-on experience with ESRG, we have had the privilege to test many different types and configurations of cells and modules.

One of the most significant learning points drawn from the experience of live fire testing is that a cell failure may not and often time does not react the same way once it is within a module. The same holds true when you take a module and place it within a rack and then racks within a container. Once you know what type of batteries are being utilised, you have to look and consider the type of container these are being placed in. Containers may look very similar with a quick glance, but oftentimes vary vastly in their design and concept. A walk-in container is vastly different from a container that only has exterior doors from a response and potential rescue standpoint.

Venting and pressure relief doors must be taken into consideration not only from the viewpoint of how the system may react but also form a life-safety standpoint as we always want responders at a safe distance but also do not want them standing in front of one of the pressure relief points or within the blast pressure wave. Many systems in the ground now do not include any type of pressure relief, meaning we must identify the weak points of the container which may become the pressure relief point. The fire protection system and how it is designed to operate must be known. A clean agent system will react drastically different from a system that would flood the interior of the container with water. The fire detection system and system monitoring (BMS/GEMS) system operations are imperative to understand. Personnel face increased risk without knowing what is being monitored, where the monitored equipment can be viewed, and how to interpret the data as this scenario leads to incompletely understanding what type of incident and the conditions within the container. The site location to include exposures, environmental concerns, access roads, the staging of response equipment, and prominent wind direction shall all be considered in the development of the emergency response plan as well.

Engage everyone involved and keep them informed

The development of the ERP shall include representatives of all entities which will be involved in an incident response at the facility. This list will include, at a minimum, representatives of the facility, the facility subject matter expert (SME) and public safety first responders (fire, law enforcement, and EMS). All these individuals shall be listed on the ERP with name, position, and phone number as well as their back-up in the event they are not available. It is critical to understand the staffing, capabilities and resources available to the first responders in the Emergency Response Plan. A large municipal public safety agency typically varies significantly in staffing, available resources, and response time from that of a rural volunteer agency. This information will affect how the public safety agency will approach incidents.

All parties should have input and be allowed to review and suggest changes to the plan. Once the ERP is reviewed and agreed upon, it should be signed off by all parties and made available to all parties for review at any time. Once the plan is finalised, that does not mean the work is done on it, however.

Training on the Emergency Response Plan for everyone involved must be conducted on a regular basis. Waiting until there is an incident to try to remember what the plan says under stress will not aid the situation. The ERP must be reviewed annually to see what changes may be needed. The changes could result from any of the entities that have interest in the response to the incident at the facility. The plan should be immediately amended if there is a change to the facility, operation of the system, or a change in personnel that is listed on the ERP. The plan should then be tested using either tabletop exercises or full-scale exercises which are independently evaluated and then debriefed on. These exercises will not only allow for training to make sure all parties involved understand their roles and responsibilities, but also allow for any deficiencies in the plan to be brought to light and corrected. ■

Authors

Thomas A. Bensen has been a full-time fire investigator since 2000, working both public and private fire investigations. Thomas holds a Bachelor of Science in Fire Protection Safety Engineering Technology from Oklahoma State University and has trained at the Georgia Fire Academy and the Ohio Basic Peace Officer Training Academy. Thomas also has experience as a firefighter and in law enforcement as well as with the Bureau of Alcohol, Tobacco, and Firearms. Tom has conducted numerous large-scale fire tests on lithium batteries. Tom is a current committee member of NFPA 855.

Michael Bowes holds a Bachelor of Science from Clarkson University and Data Analytics certification from Columbia University. His professional career has been concentrated in the advancement of the New York City energy storage landscape with a strong focus on battery safety and permitting. Previous roles have been at groups including the New York Power Authority (NYPA) and Sustainable CUNY of the City University of New York where he worked with stakeholders to streamline permitting of energy storage systems.

Ryan Franks graduated with a BS in Engineering Mechanics from the University of Illinois, an MBA from John Carroll University, and is the inventor on two patents. His industry experience includes serving as Global Energy Storage Business Manager at the Nationally Recognised Testing Laboratory (NRTL) CSA Group and led the development of that organisation's battery and energy storage business. Ryan has also led international and domestic standardisation projects for energy storage, microgrids, smart cities, and other strategic and emerging electrotechnical concepts at NEMA, the National Electrical Manufacturers Association, and the U.S. Green Building Council.

Nick Warner holds a holds a BS and MS in Mechanical Engineering from The Ohio State University. His professional career has focused primarily on safety topics related to battery storage integration and fire safety as well as failure analysis of energy storage systems. This includes supporting battery degradation and performance validation, failure analysis and the evaluation of materials and sensors for passive and active safety applications. Nick also works on due diligence and bankability studies, including hardware and safety reviews, and performs field inspections on ES systems and has become heavily involved in standards activities as well including all UL standards related to ESS as well as NFPA and ICC codes for fire safety and ESS deployment.

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The future of the energy storage system integrator in a maturing industry

System integrators | Key to the rapid success and growth of the energy storage industry in the US, China and other maturing markets has been the presence of a small number of system integrators. IHS Markit association director Julian Jansen examines what it is that system integrators do that makes them so vital to the industry and why the future ahead looks to be one characterised by growth, competition and consolidation.

The global energy storage industry continues to rapidly expand, creating opportunities for new entrants and incumbents alike. As the market grows, many system integrators are evolving their business model to create a stronger competitive footing. To capitalise in the long-term, different stakeholders focus on growing share as the market accelerates. While this creates price pressure for incumbents, both upstream component suppliers and downstream developers are also looking at ways to diversify and protect their own margins. With the influx of capital to the industry, this creates the perfect platform for diverging competitive scenarios and a fascinating position to explore how the industry could develop.

Despite a market leading position, NEC Energy Solutions has exited the industry.

Credit: NEC ES

Rapid growth, influx of capital set scene for an evolving competitive landscape

IHS Markit projects a tripling in annual grid-connected energy storage installations from 2020 to 2025, reaching 15.1GW/47.8GWh. At the same time, annual hardware revenues (battery modules, PCS and balance of plant) of US$4.2 billion in 2020 will rise to US$9.5 billion in 2025. This rapid acceleration is happening - despite a continuous decline in hardware prices - both for lithium-ion (Li-ion) batteries and balance of plant. This growth is accelerating competition across the industry and is driving the creation of a more global supplier landscape.

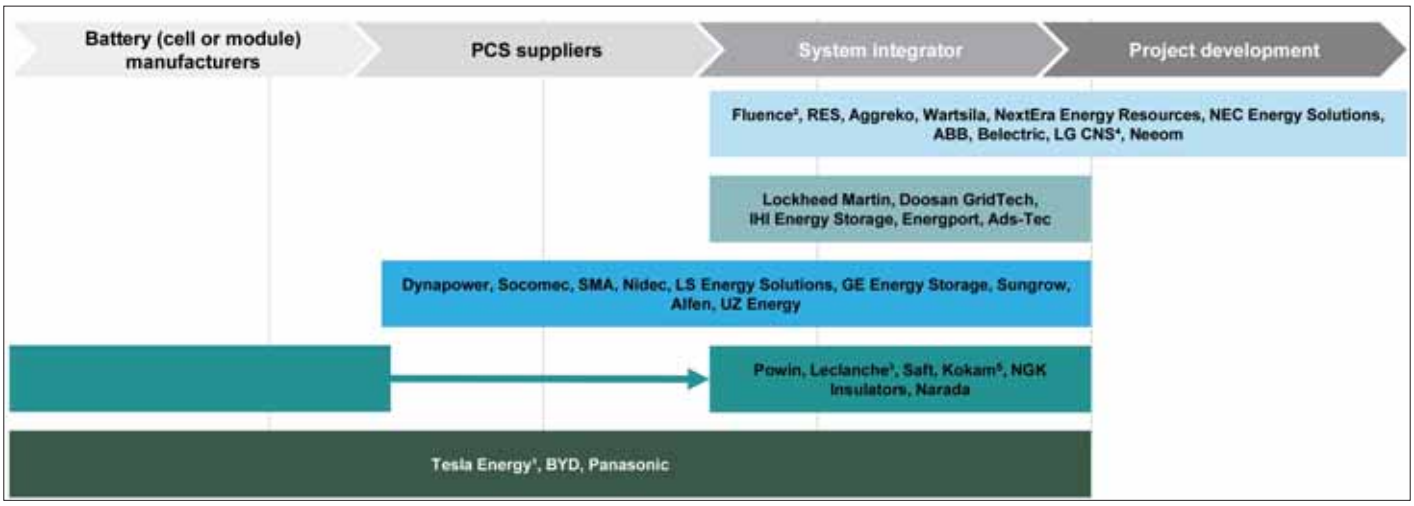
Despite some recent market consolidation, the industry is attracting significant investment. Targeting this market – and in particularly focusing on the role of system integrators – battery and component manufacturers, and increasingly major energy companies and technology conglomerates are joining incumbents in a highly competitive market. At the same time an influx of capital from investors looking to diversify into clean technology industries, is facilitating incumbents and new entrants to compete for market share through the industry's next phase of rapid growth.

The competitive landscape is diversifying. With significant project pipelines dwarfing the existing installed base, energy storage inverter (power conversion system – PCS) manufacturers are expanding their presence targeting solar plus storage applications and existing integrators are challenging the incumbents. As Figure 1 highlights, there are many players active across individual or multiple segments of the value chain, with especially inverter (PCS) manufacturers moving across to offer fully integrated solutions.

There also remains a large degree of regional diversity in the market. As the

What is a system integrator?

- A system integrator is a company that specialises in combining component subsystems and ensuring that these subsystems function together as a whole.
- In the energy storage industry, a system integrator supplies the full battery energy storage system (BESS). As such it is usually responsible for procuring individual components, primarily the battery modules / racks, power conversion system (PCS) and other balance of plant; assembling the system; providing a wrap on warranties; integrating the controls and energy management system (EMS); often providing project design and engineering expertise; and providing operation, monitoring and maintenance services.
- As the industry continues to evolve, many system integrators vary in the degree of both upstream and downstream integration, with specific responsibilities often varying by contract and customer requirements.



Credit: IHS Markit

Figure 1 - Overview of the system integrator landscape.

energy storage market initially grew in selected regional pockets – California, PJM, the United Kingdom, Germany, South Korea, Japan, and mainland China – many local technology firms and new entrants targeted the segment. Following a first phase of acquisitions around 2017 and the development of new regional markets, an increasing number of global players is emerging. However, some markets such as Germany, South Korea and mainland China remain dominated by local players.

The system integrator landscape remains diverse, but market share is becoming more concentrated and signs of consolidation are appearing

Globally, Tesla Energy, NEC Energy Solutions, and Fluence have historically been the leading system integrators. In the future, the system integrator landscape will further diversify, primarily driven by energy storage inverter manufacturers expanding their presence, targeting solar-plus-storage applications and existing players such as Wartsila and Powin Energy targeting strategic opportunities to drive expansion.

At the same time, there will also be consolidation—as illustrated by the recent market exit by NEC Energy Solutions—particularly challenging smaller, regional players. Major system integrators are globalising and can offer more cost-effective solutions based on the scale of their operations. Figure 2 outlines the current installed base and contracted project pipeline by select system integrators (correct as of August 2020, as tracked in the IHS Markit Global Energy Storage Project Database).

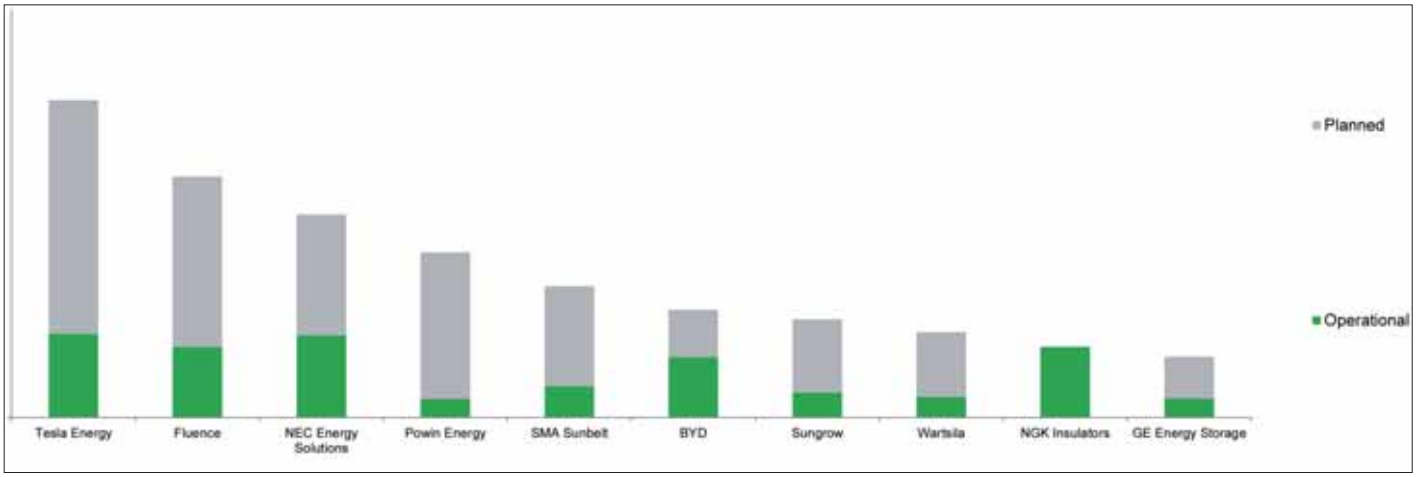
Regional diversity remains significant

In the United States, prior to its exit NEC Energy Solutions was the market leader. Pressure to stay price competitive has led to a recent announcement that its parent company is exiting the market, while honouring existing project commitments. Since then, Tesla Energy, Fluence, Powin Energy and Wartsila remain the strongest competitors in the United States, with rapidly expanding project pipelines.

Smaller suppliers such as GE Energy Storage, Doosan GridTech, IHI Terrasun, Energport or RES are increasingly focusing on perceived higher value, smaller volume projects or targeting specific market niches. Inverter manufacturers such as Sungrow are increasingly targeting the United States market because of the significant pipeline of solar-plus-storage projects, which play into the experience gained and distribution channels established in the solar industry.

As the market is highly price sensitive, most integrators have launched lithium iron phosphate (LFP)-based products in the United States.

In the mainland Chinese market, the upstream supply chain in the energy storage market is highly diverse while the downstream system integrator landscape is more consolidated. A large base of battery manufacturers - especially for LFP batteries - as well as inverter manufacturers, lead to a highly diversified supply chain with many players looking to capitalise from a growing stationary energy storage market. Most recently, UZ Energy and



Credit: IHS Markit

Figure 2 - Competitive benchmark of BESS system integrators globally.

Sungrow have been the most aggressive in expanding their project pipelines, especially as the solar-plus-storage market accelerates. Tier 2 inverter and battery manufacturers are also pushing into the market with very low-cost systems using LFP batteries. Overall, low prices and the strong links between grid companies and local suppliers create an environment that limits the opportunities for international players enter the Chinese market.

The traditional system integrator model will be challenged by new entrants and potential disintermediation

Despite the growth in the market and the continued diversity of suppliers – especially on a regional level – challenges in the system integrator model are being laid bare. In the long run, simple procurement and assembly of components without any further vertical integration will lead to erosion of margins and eventual market exits. New entrants and potential disintermediation will increase price competition as the addressable market for system integrators simultaneously shrinks. While pure-play integrators, i.e. those without in-house manufacturing of components, will face heightening competition and lower hardware margins, they can also pursue a range of strategies to mitigate against decreasing margins from the hardware business.

New market entrants increase competition, with future consolidation likely

For energy storage inverter (PCS) and battery manufacturers, forward integration to supplying the full BESS is a means of differentiation and margin stacking. By focusing on product and component sales and expertise in managing core components of the full system, the supply of standardised BESS provides a logical strategy to deliver growth. This trend is being amplified by increasing commoditisation and decreasing margins in their core component businesses.

Especially PCS, but also solar PV inverter manufacturers are rapidly pivoting towards BESS system integration – Sungrow and SMA Sunbelt being the primary examples. Further competition will likely come from other Chinese inverter suppliers pivoting towards the energy storage market. Nonetheless, many system integrator incumbents will continue to have a competitive advantage in their ability to provide more holistic solutions integrating advanced EMS, analytics, engineering, and long-term operations and maintenance (O&M).

Project pipelines in the US for leaders including Fluence have rapidly grown.

Upstream battery cell and module manufacturers fundamentally have different priorities, as stationary storage is not a primary market for Tier 1 battery OEMs, leading to mixed interest in forward integration. Notable exceptions are leading integrators Tesla Energy and BYD who already have vertical integration from (at least) battery module and PCS, to full system assembly. While forward integration may not be a priority for most Tier 1 battery OEMs, increasing commoditisation and supplier competition could force them to chase perceived higher margin opportunities for full BESS solutions. Battery manufacturers also retain a significant advantage in that they supply the most integral part of the system – both from a cost and operational perspective. Secondly, Tier 2 manufacturers of LFP batteries with under-utilised manufacturing capacity are also likely to forward integrate, starting in the domestic Chinese mainland market and through international distribution partners.

As developers grow project pipelines and leverage engineering expertise, the system integrator model could be threatened

The current consensus role of project developers / IPPs is that they primarily are a buyer or customer to system integrators. However, large incumbents with considerable experience in the renewable business are becoming comfortable to take a growing role in system design and engineering responsibilities to improve project margins. This strategy could follow the example of NextEra Energy Resources which often takes on full system integration or in contrast RES, which will procure standardised integrated BESS, but take on project design and engineering as well as utilising its in-house EMS. Furthermore, as larger developers look to leverage the scale of their project pipelines to procure battery racks at favourable prices, the integrator role as technical expert may become disintermediated as developers gain experience developing and operating storage systems.

Changing product and solution strategies will help strengthen the system integrator model, but the supplier landscape will inevitably change

To thwart the threat of vertically integrated suppliers, new entrants and potential backward integration from developers, the energy storage system integrator must evolve. This evolution will be characterised by offering more holistic solutions that include stronger software and operations offerings and superior project execution. Product standardisation will help reduce system assembly cost and drive procurement scale. Lastly, integrating upstream component expertise or downstream project development and operations capability – mainly through acquisition – will help diversify revenues and stack margin.

Nonetheless, energy storage is characterised by a unique mix of technical, commercial, regulatory and development challenges that will play into the strengths and experience of traditional system integrators to take on and offer a full wrap of technology risk. Therefore, the system integrator model will not become obsolete in the coming five years. Instead, continuous evolution of their business models will create a smaller number of solution providers, while hardware commoditises and smaller regional players consolidate. ■

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Previously, Julian lead IHS Markit's global energy storage research team, providing deep insight on key value drivers and emerging business models accelerating storage deployment across the world, as well as covering technology development and the competitive landscape. Prior to joining IHS Markit, he established and managed the energy storage research area at specialist consultancy firm Delta-ee.

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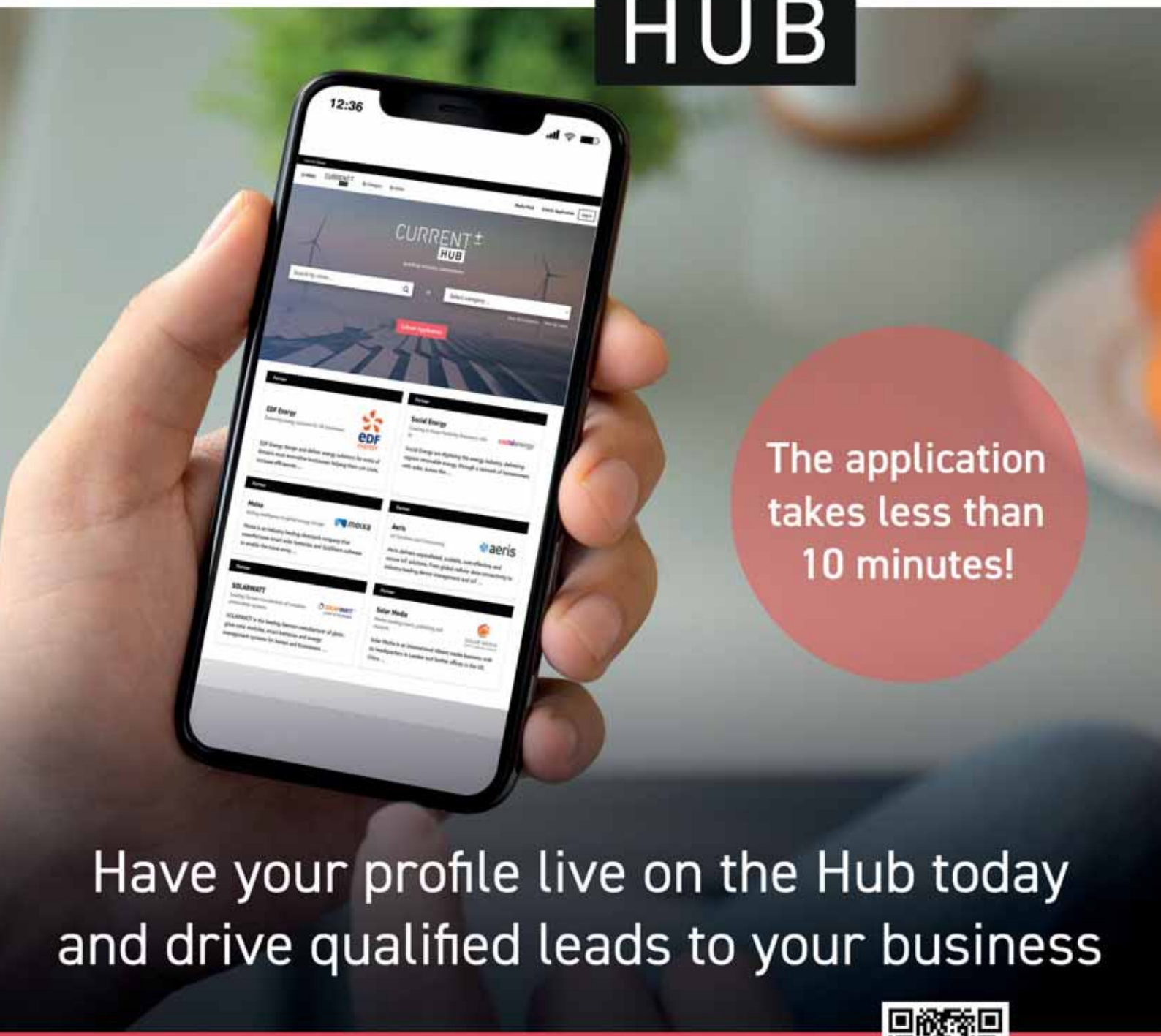

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US energy storage in 2021: Notes from a maturing industry

US energy storage | The US energy storage industry remained "remarkably resilient" during what most of us have found to be a difficult year - to say the least. Andy Colthorpe speaks with Key Capture Energy's CEO Jeff Bishop and FlexGen's COO Alan Grosse - two companies that made 2020 one of growth in their energy storage businesses - to hear what lessons can be learned and why economics rule.

Credit: FlexGen

One of several FlexGen projects the company has delivered, stabilising power supply to communities around Houston, Texas. Each is around 10MW / 11MWh.

For so many reasons, 2020 will be a year that is remembered for a long time, but not remembered with fondness. It will be difficult to forget the pandemic which has taken so much from us all and whichever side of the political fence you are on - or even if you take no side at all - the world seems a very divided place. And that's before we even start thinking about the climate crisis.

For the US energy storage industry, still the world's leader in adopting batteries for the grid and for renewables, it has however been a year in which clear steps forward have been taken. Research firm Wood Mackenzie Power & Renewables found that in the third quarter of 2020, 467MW / 764MWh of energy storage was deployed around the US across all market segments. This was more than double what was recorded in the previous highest deployment quarter and Wood Mackenzie head of energy storage analysis Dan Finn-Foley described the industry as having been "remarkably resilient" to the impacts from coronavirus lockdowns.

All this, despite reported supply chain slowdowns earlier in the year, permitting delays due to officials staying at home and the difficulties of getting onto sites and customers' properties. In an interview for Energy-Storage.news in late November, US national Energy Storage Association (ESA) CEO Kelly Speakes-Backman said that 2021 will be an "important year for energy storage" and that the industry will continue to grow at an accelerated rate - with at least 3.6GW of storage expected to come online.

The prospect of working with the incoming Biden-Harris administration, which included climate protection and environmental concerns prominently in campaigning during the election is also a welcome one, Speakes-Backman said. Meanwhile, a lot of progress happens at state level, and the ESA CEO pointed out in her interview that Arizona, Maryland, Nevada and Virginia were among states to step forward and show leadership on energy storage policy, along with the more commonly talked-about likes of California and Hawaii.

Speaking for this article with Jeff Bishop, CEO at developer Key Capture Energy (KCE) and Alan Grosse, chief operating officer (COO) at installation services and technology provider FlexGen - two contrasting companies that have managed to make 2020 a pretty good year, energy storage-wise - we hear how they approach the industry and its variety of business models; which regional markets in the US work best and why; which technologies and partner companies they rely on to get the job done and the future of energy storage both as an enabler of renewable energy and a cleaner grid and as a competitive alternative to existing grid infrastructure options.

Expecting everything to be in flux

Jeff Bishop, Key Capture Energy's CEO says that 2020's been a year of "expecting everything to be in flux," which for someone involved in an industry as nascent and disruptive as energy storage is perhaps a more familiar feeling than it would be for many others. Yet KCE's plan to get more than 1GW of projects in operation by the end of 2023 remains on track, Bishop says, and 2021 "will be an exciting year".

"We knew going into this industry that storage was going to be really hard. Each project presents a unique mix of technical, commercial, regulatory, and development in ways that didn't exist with wind or solar as those industries were emerging and taking off," Bishop says.

The way KCE has made energy storage project development stack up, is by looking at the energy landscape and trying to "figure out what the grid needs in five to 10 years from now," Bishop says.

Credit: Key Capture Energy

Key Capture Energy's KCE NY 1 project in upstate New York, on which the developer worked with NEC.

"There are opportunities that allow for certain technologies over others and we approach energy as if we were a thermal independent power producer (IPP). So: if you were a natural gas company 10 years ago, what are the fundamentals you would need and what are the core competencies that you need in a company?"

The answer, Bishop says, is strong project development teams, engineering, procurement and construction (EPC) teams or partners, market development staff that watch what's going on day-to-day, combined with commercial structuring that allows KCE to recover its capital expenditure (CapEx) to put back into growing the pipeline of projects still to come.

"That's how we approached the industry. Because we do not have tax equity, we do not need the same structures that a wind or solar company would need, or the 20-year contracts. Instead, we're able to go out into the market, get, let's say, four to 10 year off-take contracts that cover a debt service, so that we can put project debt on these projects and then be able to construct projects that are above our cost capital."

Typically, KCE will go into states and regional transmission organisation (RTO) territories of the US where the company figures and expects there will be a market in two to five years' time, but isn't one yet today.

"We start small, and do 10 or 20 megawatt projects initially to figure out all the known unknowns within a given market. And then once we get comfortable with the revenues, with the market structure, with the regulatory environment, commercial structures, then we expand and go bigger into the 50 to 200 megawatts-sized projects."

Opportunities driven by competitive advantages

Flexgen's path into the grid-scale utility energy storage market has been a very different one, COO Alan Grosse says, if only because the company actually began doing microgrids, including several projects for the US military.

The opportunity for batteries really came onto FlexGen's horizon with equipment cost reductions from around 2014 onwards. Before that, battery storage's cost was "prohibitively high," Grosse says, and the majority of FlexGen's projects were megawatt-scale microgrids using ultra-capacitors that "only had enough storage for about 30 seconds worth of full power deployment".

But FlexGen also made its way into Texas from 2018, focusing on the one-hour duration battery storage systems that make economic sense trading energy and grid services in the state's Electricity Reliability Council of Texas (ERCOT) market. The "lion's share" - or indeed the Li-ion's share - of what the company has delivered this year as a technology and project services provider have been one-hour batteries in Texas and elsewhere.

"The perspective is one in which, wherever the market provides an opportunity, that's obviously where you want to play. And so we are seeing a number of these ancillary services markets in Texas, in particular," Grosse says, along with energy arbitrage and trading, to a lesser extent.

FlexGen's next year or so is also expected to be busy - Alan Grosse says that the company "will probably buy a little over 1.1GWh of energy storage for delivery between now and the first half of 2022". FlexGen has done some international projects but focuses mainly on the US.

"Within the US market, which is obviously the one in which we play the most, our biggest markets in order of where we see quoting activity, where we're building systems and where we see the market opportunity, are Texas, California, and then the northeastern US, so Massachusetts, to some degree and some of the independent system operator (ISO) zones in New York. Those are the areas that we see and then if I had to take a fifth, I would say of all places: Indiana."

Grosse mentions Indiana, he says, because of the phaseout of coal. FlexGen is not an avowedly climate agenda-driven company with a mission, but Grosse says the economics of renewables-plus-storage are a "slam dunk" while states, utilities - and hopefully eventually the Federal government once more - are decarbonising and adopting clean energy policies and goals.

While the coal shutdowns also mean that more natural gas could be expected to come online in many places, FlexGen's COO argues that a recently completed project the company did in Indiana epitomises how energy storage can be paired even with natural gas to provide efficiency and reliability increases and ultimately, a transitional pathway to decarbonisation.

FlexGen added 12MW / 5.4MWh of lithium-ion batteries to a natural gas plant for a utility in Indiana that can black start the turbines. Previously, this was done exclusively with diesel engines which are dirtier, noisier and less reliable, requiring frequent maintenance and incurring fuel costs. That customer is doing a Request for Proposals (RFP) for multiple gigawatts of solar, and has a number of coal plants in the process of closing down.

"Our black start project is colocated at an 800MW coal plant. They're closing that coal plant down and they put the battery in to make their gas turbines more reliable because they're in the process of building out a massive, massive footprint of solar and battery - solar-plus-storage."

Forecasting the unexpected

One of KCE's major system integrator partners, NEC's Energy Solutions division, exited the industry in 2020, with reports

claiming the company had not been able to make the business profitable despite a market-leading position. It's hard to tell what the industry will exactly look like in a few years from now, but again, this in itself is perhaps no surprise.

"In any new industry, there will always be consolidation, there will be growth, there will be new owners. That's the maturity of an industry as it continues to grow," Jeff Bishop says.

"As we look at the system integrator landscape, there are starting to emerge 'Tier 1' system integrators and who they will be a year or two or three from now, it may change, but that still doesn't change the ultimate underlying economics that so many of these projects have. Whenever you go with somebody that has really strong warranties, you can get project finance on them."

Speaking of warranties, much industry discussion in 2020 centred on lithium iron phosphate (LFP) batteries versus nickel manganese cobalt (NMC) for building energy storage systems. FlexGen's Alan Grosse says that his company and many others remain firmly technology agnostic. Largely, the strength of warranties and performance guarantees currently dictates which technology is bankable for any given project.

The number of LFP providers' batteries and systems that have undergone UL 9540A testing has grown, Grosse says. With UL 9540A test data available, "the end customer is going to be able to get insurance". Without UL 9540A for battery systems and UL 174 for inverters, it's a "non-starter" for larger projects to get that insurance, he says. LFP providers are increasingly also able to offer performance warranties down to 50% state of health of the system.

"When you open up that additional range - people talk about cycles, again, we try to avoid talking about cycles, because it really boils down to what's the megawatt-hour throughput through the system - the more you can put through the system, the higher value system."

In other words, so much is dictated by the economics. KCE's Jeff Bishop says that ultimately, the energy storage industry's success or failure will come down to whether the industry is able "to compete in order to provide the attributes the grid needs".

Credit: Key Capture Energy

After focusing on relatively small projects in Texas like the one pictured to figure out the market, Key Capture Energy is now developing much larger battery storage systems.

The early success of solar and wind was closely tied to the US states that had high renewable energy aspirations. A growing number of US states - seven at the time of writing - have in place energy storage deployment targets at policy level. So, how much does energy storage still need policies to push it through, versus providing economic competition for existing infrastructure solutions?

"One way of looking at it would be what happened with wind and solar, where you initially had the state mandates that created local ecosystems of jobs and opportunity and economic development in California, in Massachusetts, in New York," Jeff Bishop says.

"Then, once the economics fully hit everywhere, it became purely economics. And so in a similar way, for energy storage, there will be places that will really be looking at the next generation, and how to incentivise your overall workforce for the next 10 years.

"They may want to come out and really be leading the transition with pilot projects, etc. But then fundamentally - and it always comes down to economics - how do you compete? And in those scenarios, you're going to be seeing really interesting markets popping up and in ways that people weren't expecting two years ago.

"When we started developing in Texas, everyone told us it wasn't a real market. Nobody would be building projects there. Today, we're the largest owner of storage - we're currently building 200MW more in Texas, and everybody follows Texas right now."

Stepping on the gas

With coal on its way out and decarbonisation across many parts of the US now an integral part of state level policies, could the demise of natural gas be the next step? Gas is seen by many as an interim solution in the energy transition and provides flexibility to energy networks that have adopted a greater share of renewables, but the tide could be turning against this last great dinosaur of the fossil age.

Tom Buttgenbach, CEO of developer 8minute Solar Energy, says that projects such as his company's Eland Solar & Storage Centre, currently being constructed in the Mojave Desert in California, pairing 400MWac of solar PV with 300MW / 1,200MWh demonstrate both the "cost and reliability advantages in pairing solar with storage".

"For the first time ever, solar paired with storage is not just lower cost but also more reliable than fossil fuel power plants," Buttgenbach says.

Not only has the Eland project achieved the lowest cost solar-plus-storage power purchase agreement (PPA) in history, costing less than fossil fuel generation (<US$20 per MWh for solar and <US$40 per MWh combined with batteries) but the 8minute CEO points out that projects such as Eland "offer 98% to 99% reliability - much higher than a gas plant in the mid-80% range".

"Our solar-plus-storage power plants can come online in a fraction of a second, compared to several minutes for a gas plant and can be optimised to deliver a range of flexible grid services depending on what a utility needs."

"Eland, for example, with a record-high capacity factor of 60% during the summer months, will be able to dispatch power during the day and well into the evening and night – and will do so with existing transmission capacity more efficiently, our Eland plant will deliver low-cost renewable energy to Los Angeles quickly and is helping avoid multi-year, multi-billion-dollar investments in new infrastructure."

Credit: 8minute Solar Energy

Rendering of 8minute's Eland Solar & Storage Center in California.

Meanwhile, the inauguration of President-elect Joe Biden and the US' re-entry into the Paris Agreement could mean a policy landscape much less favourable to all fossil fuels, Key Capture Energy's Jeff Bishop says.

"The Clean Power Plan under the Obama Administration really drove utilities to rethink their entire playbooks. Overnight, no utility board was willing to sign-off on a new coal plant when there was not a clear path to long-term cost recovery. Similar motivations - political or regulatory - could take place in the next few years, effectively removing new natural gas plants from the utility integrated resource planning framework. I am unsure what form this will take in the next four years, but it's quite clear that changes at the federal, regional, and state level are further accelerating the clean energy transition".

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