POWER PVTECH

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About LONGi Solar

LONGi Solar is a world leading manufacturer of high-efficiency monocrystalline solar cells and modules. Headquartered in Xi'an, China, the Company has branches in Japan, Europe, North America, India and Malaysia.

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

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Introduction

Welcome to *PV Tech Power 19*. Intersolar Europe returns after a notably buoyant edition last year. Since then the continent has seen solar winning out in German tenders, France continue its own deployment schedule and both Spain and Portugal building up an impressive pipeline.

A lot of this optimism is built on a subsidy-free foundation. Solar is successful in these conditions for a number of reasons with global module pricing and demand for power purchase agreements (PPAs) getting a lot of the attention. It would be remiss to let these macro issues detract from the gains being made in system design and operation. Our cover story takes a deep dive into the ways buzzwords like big data, artificial intelligence and augmented reality can provide practical benefits to the industry. Engineers and data scientists from i-EM explain how predictive analytics and a 'democratic' future for big data access and analytics can bring big benefits (p.17) – not in the misty, distant future but right now.

Following up on that theme, we have some real world case studies as Enel Green Power, Aquila Capital and Pöyry discuss the impact of their own digitalisation efforts so far (p.32).

While rainy days are obviously no friend to the solar industry, poor site drainage and planning can create major problems. A paper from the construction and infrastructure firm HDR explores how erosion can destroy solar sites, and reputations (p. 70).

Sticking with the weather, hurricanes have the potential to level solar installations that fail to consider the impact of extreme wind speeds. The Rocky Mountain Institute and the engineering consultancy FCX Solar offer some first-hand insight on the special considerations required for many island states (p.74).

Our Storage & Smart Power section, produced with our colleagues from *Energy-Storage.News*, includes a superb read on the impact of a recent spate of M&A activity. Andy Colthorpe speaks to Sonnen, Younicos and Greensmith about life under the ownership of Shell, Aggreko and Wartsilla respectively (p.100).

Testing and certification has received a lot of attention in the solar sector but investors must be as rigorous when investing in energy storage. DNV GL provides some pointers on the criteria that should be assessed before choosing a partner (p.96).

Our correspondent in Shanghai, Carrie Xiao, provides an update on China's latest policy reorganisation (p.41). José Rojo assesses all the regulatory risks for solar projects in Europe that remain even after subsidies have become a non-issue (p.37).

There is of course too much to mention in this short introduction and we hope our assembled team of industry experts can help you make the most of solar's current buoyancy.

John Parnell
Head of content

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Smarter Energy for a Better Life

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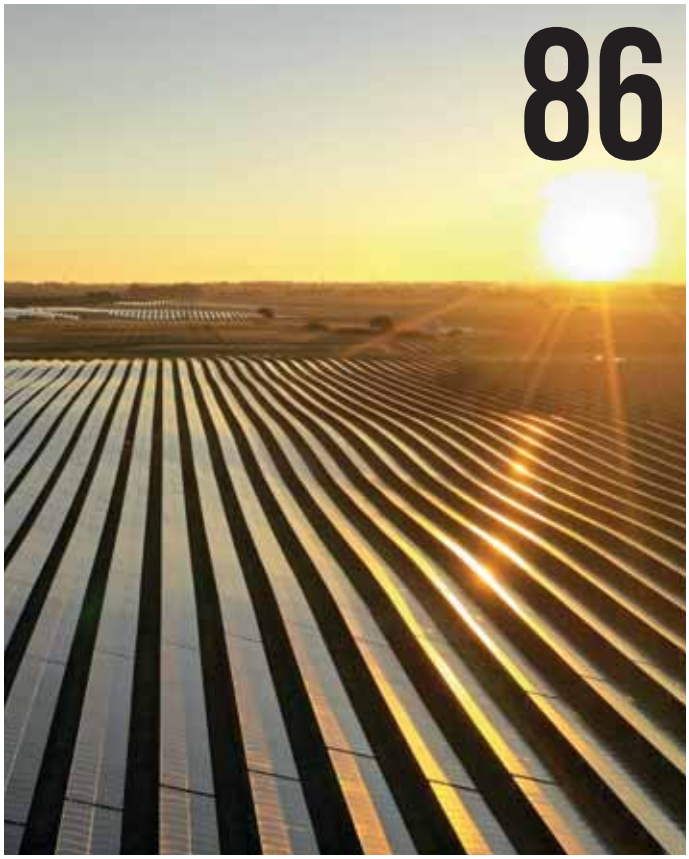

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EUROPE

Investment

Investors ready to pounce on subsidy-free solar momentum

Investment A-listers gathered at the Large Scale Solar Europe summit signalled their appetite for zero-subsidy plays, with some worrying however that government actions could put brakes on progress. The two-day event organised by PV Tech's publisher Solar Media, attended by top Portuguese and EU officials, saw representatives from Blackrock, Aquila Capital, Foresight and others map out their future moves in a continent now delivering large-scale projects on a market basis. Panellists and live event polling both pointed at Spain, followed by Portugal, as the two most promising markets. "Both are perfect for zero-subsidy assets," said Andrew Wojtek, director at Aquila Capital, speaking one week after his firm scooped up a 300MW PV pipeline in Spain. "Italy, and potentially also Greece, are on the horizon," he added. The focus on Spain and Portugal for now – eventually followed by Italy – was mirrored by Lorena Ciciriello, head of debt financing at NextEnergy Capital, and Blackrock director Giovanni d'Andria. "Sooner or later all markets will get there. We're all here in the long-term so we'll see unsubsidised projects coming through in the UK and the Nordics too," d'Andria remarked.

Credit: Solar Media

Andrew Wojtek (centre) has high hopes for Spain and Portugal

Policy

European Commission: Solar to be 'central' in post-2020 clean energy efforts

Legislative milestones of the past few years of Jean-Claude Juncker's European Commission will help EU solar play a decisive role in the next decade, a top official has said weeks before the bloc holds fresh elections. Paula Abreu Marques, who heads up the renewable policy unit at the Commission, spoke at the Large Scale Solar Europe summit last week to detail how solar will be supported long-term by laws adopted under Jean-Claude Juncker's cabinet. "After 2020, we believe the situation will move. Solar PV is expected to become a mainstream technology at the centre of our energy transition," Abreu said. "The market will have to double compared to today to achieve 2030's target, and double again in the years after to reach the 2050 goal."

Germany

Solar steamrolls wind again in latest joint German auction

Solar has emerged as the overwhelming winner of Germany's latest auction, securing all contracts where onshore wind bagged none. The entire 210MW contracted earlier in April went to 18 solar bidders, split between Saxony-Anhalt (five bids, 59MW), Brandenburg (five bids, 59MW), Schleswig-Holstein (three bids, 48MW), Hesse (three bids, 10MW) and Mecklenburg-West Pomerania (two bids, 33MW). PV players also dominated on the bidding front, submitting 109 bids for the development of 719MW worth of projects across the country. The solar projects were contracted at average prices of €0.0566/kWh, with individual figures ranging between €0.045/kWh and €0.061/kWh.

Spain

Spanish grid set for funding boom to accommodate renewables

Spanish grid operator Red Eléctrica de España (REE) will support the country's energy transition with a multi-billion investment push in the space of few years. The agency will deploy over €3.2 billion between 2018 and 2022 to expand Spain's high-voltage transmission network, in a bid to prepare for national clean energy targets of 32% by 2030. A great chunk of the total (€1.5 billion) will be earmarked for the integration of renewable capacity through new interconnections and access points, REE explained. This will come alongside €908 million for system reliability and security of supply, €434 million for digitalisation and technological upgrades and €54 million for power control systems.

Foresight's Spanish PV duo bags 10-year PPA with ArcelorMittal

Foresight's zero-subsidy solar portfolio has reached 116MW this week after PPA documents were signed for two plants near Toledo, central Spain. The deal struck with ArcelorMittal will see power flow from Foresight's 10MW PV cluster to the corporate's Spanish steel mills for 10 years, in return for an undisclosed fixed price. Escalonilla Norte and Escalonilla Sur, each boasting 5MW capacity, have been under construction since EPC contractor Solaer Group broke ground in June 2018.

Solarcentury to build Spanish 200MW portfolio after stake sale

Solarcentury has offloaded a majority stake in a 200MW PV portfolio in southern Spain, which it will start building this summer. The British solar developer has yet to disclose the identity of the majority buyer for the four 50MW projects 'Cerrado Cabrera', 'El Primo Alemán', 'Hazas de los Sesenta' and 'Los González', cleared for construction last November in Alcalá de Guadaira (near Seville). Solarcentury said it will build, run and manage the 'La Cabrera' group of four mostly on its own, once full financial close is reached. The developer will work alongside partner and local engineering firm Texla, as earlier statements had indicated.

Credit: Solarcentury

Solarcentury will build and operate the plants

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France

France's fifth ground-mounted PV auction ends with 118 winners

France's fifth major auction for ground-mounted PV concluded with 118 winners, including projects by Engie and Solarcentury. A spokesperson from the French Environment Ministry confirmed that 855MW in volumes had been processed at the auction of late February 2019, aimed at ground-mounted projects in the 500kW-30MW capacity region. The average price across all auction bids was €62.7/MWh, a 3% rise on the number recorded last year. Split between capacity brackets, mean prices reached €56.8/MWh (5-30MW projects) and €63.8/MWh (500kW-5MW).

Tenergie to acquire 108MW PV portfolio in France

French renewable energy company Tenergie, through its JV, Terres d'Energie, signed off on a deal to acquire 29 operating PV projects, representing a combined generation capacity of 108MW, from the DIF Infrastructure III and IV Funds. These 29 PV assets range from ground-mounted power stations to rooftop solar installations and are located in French regions of Nouvelle-Aquitaine, Occitania and other southern areas of the country.

AMERICAS

Patents

China to back-up Jinko and LONGi in Hanwha Q CELLS US ITC patent case

A national new energy industrial organization in China, Quanlian New Energy Chamber of Commerce has announced plans to support JinkoSolar and LONGi Solar through the ITC investigation triggered by Hanwha Q CELLS. The ITC case, which could take 18 months, could lead to exclusion orders preventing the companies from importing infringing products into the US market. The US ITC investigation is separate to the growing list of patent infringement litigation undertaken by Hanwha Q CELLS in various courts, over solar cell passivation layer structures.

Credit: Hanwha Q CELLS

The patent row is centred on specific structures of cell passivation layers

East Coast

New York State announces third tender round for large-scale renewable projects

New York governor Andrew M. Cuomo revealed plans to ramp up the third annual solicitation for large-scale renewable energy projects under the state's Clean Energy Standard. Last year's led to the approval of around 1GW of solar power projects. The latest solicitation is expected to generate over US$1 billion in private investment. That includes over 1,000 new jobs for New Yorkers. This is the latest step toward the state's proposed commitment to secure 70% of its electricity from renewable resources by 2030.

sPower gets permits for 500MW mega-project in Virginia

The largest solar PV project planned in the US state of Virginia, standing at 500MW capacity, has been awarded permits by the Spotsylvania Board of Supervisors after some weeks of local opposition. US-focused PV developer sPower now aims over a two-year period to build the project on land mainly used for extracting timber in order to supply electricity to the equivalent of approximately 111,000 homes. The company said the process would create 800 construction jobs and 35 full-time jobs, and drive local tech investment.

Dominion Energy develops six new PV projects for Facebook

Dominion Energy is developing six new PV projects that will generate renewable energy for Facebook. The solar projects are in Dominion Energy's service area in Virginia and North Carolina. Three are completed and all will gradually come online by mid-2020. These six new projects will have a total generation capacity of 350MW and will join two previously announced solar projects located in Surry County, Virginia.

Mexico

Mexico's IEnova in funding plea for 376MW PV portfolio

One of the Mexico's largest private energy firms is working to bag US$395 million worth of loans to finalise a 376MW PV portfolio, the first it has ever deployed. The World Bank's International Finance Corporation (IFC) is considering a request by IEnova, a gas giant and a subsidiary of US utility Sempra Energy, for funding to support four solar projects, all of which will be operational by the end of 2019.

Engie enlists Tokyo Gas to deliver 746MW PV pipeline in Mexico

Close to 750MW in PV capacity could be installed across Mexico by next summer under a joint venture between Engie and Tokyo Gas. The Paris-headquartered developer and Japanese utility have agreed to each own half of Heolios, a new entity that will develop, finance, build and run an 898.7MW renewable portfolio. Four of the six projects under planning will be PV plants, with the remaining two powered by onshore wind; all are backed by 15-year PPAs secured through power auctions.

Finance

SunPower in cashflow boost with 233MW solar sale to Goldman Sachs

SunPower looks set for a fresh cash injection after agreeing to offload a 233MW solar portfolio to financial giant Goldman Sachs. In investor filings dated on 27 March, the US high-efficiency panel maker confirmed a deal to divest for US$86.9 million assets it owns

on a leased basis across the country. The portfolio, scattered across some 200 sites in Texas, California, New York and six other US states, features Wells Fargo Bank, PNC Bank, MetLife, Regions Bank and SunTrust as lessors.

Duke to sell 1.2GW stake in clean energy portfolio to John Hancock

North Carolina-headquartered utility Duke Energy has agreed to sell a minority stake in a roughly 1.2GW portion of its renewable energy portfolio to the John Hancock Infrastructure Fund (JHIF) and John Hancock Life Insurance Company (U.S.A), for US$1.25 billion. The portfolio includes solar, wind and energy storage assets. The transaction is expected to close in the second half of 2019.

Colombia

Industry: Colombia ready for solar despite auction delays

Conducive regulation and enthusiasm from Colombia's very top leadership will ensure its success in tapping into abundant solar resources despite tendering setbacks, national PV trailblazers have said. "Everything is clearly set out by the government and the new regulation, so it's now down to all of us market players to get together, and undergo the learning process," said Gustavo González, head of PV generation at Celsia. González said the postponement of Colombia's first large-scale renewable auction in February was "unfortunate" but added that the clean energy campaign will prosper regardless. "Colombia is ready for the arrival of renewables – in fact, they have already arrived," said González. Read more about Colombia on page 48.

Canada

OPG completes 44MW PV project in Ontario

Ontario Power Generation (OPG), in partnership with the Six Nations of the Grand River Development Corporation and the Mississaugas of the Credit First Nation, has completed a 44MW PV project at the former Nanticoke Generating Station site. Back in 2016, the Independent Electricity System Operator awarded a contract to OPG and its partners to build the PV project at Nanticoke. This stands as the fourth partnership between OPG and Ontario's First Nation communities.

MIDDLE EAST & AFRICA

UAE

Dubai tenders 900MW of solar

Dubai Electricity & Water Authority (DEWA) has issued a tender for 900MWac of solar located within the Mohammed Bin Rashid Al Maktoum Solar Park. The tender comes shortly after Dubai's regional neighbour Abu Dhabi launched a 2GW solar tender via the Emirates Water and Electricity Company (EWEC). Dubai's Phase V project is due to be commissioned in Q2 2021 and the power generated by the plant will be purchased by DEWA.

DEWA, ACWA, and Silk Road Fund reach financial close on 950MW CSP and PV solar park

Dubai Electricity and Water Authority (DEWA) and a consortium led by Saudi Arabia's ACWA Power and Chinese government-

Tender

Zambia solar tender sets sub-Saharan Africa price record

The latest GET FiT tender in Zambia has awarded 120MW of capacity and set a record low price for Sub-Saharan Africa. The tender had originally been for 100MW but was extended, owing to the quality of the received bids. The lowest bid of US$3.999 cents per kWh is the first under the four-cent mark. The weighted average price across all projects was 4.41 cents. In related news, the first PV project to be tendered and financed under the World Bank's Scaling Solar programme, a 54MW system in Zambia, has been completed by developer Neoen and manufacturer First Solar.

Credit: flickr/UNIDO

The weighted average price across all projects was 4.41 cents

owned Silk Road Fund, have achieved financial close on the 950MW fourth phase of the Mohammed bin Rashid Al Maktoum Solar Park. This is spread between 700MW of concentrated solar power (CSP) and 250MW of PV.

Middle East

ACWA-led Kuwaiti consortium wins 500MW Oman solar tender

A consortium led by Saudi Arabia's ACWA Power, and including Kuwait's Gulf Investment Corporation and Alternative Energy Projects Co., has won a 500MW solar tender in Oman. To develop the Ibri II solar plant, it beat two consortiums led by Japan's Marubeni and Abu Dhabi's Masdar. The result of the tender process was announced by the Oman Power and Water Procurement Company (OPWP).

MoU signed for 2.6GW Mecca solar programme

Saudi prince Khalid Al-Faisal and energy minister Khalid bin Abdul Aziz Al-Faleh have laid the groundwork for the construction of 2.6GW of solar in the Mecca region of Saudi Arabia, under the Al Faisaliah scheme. Some 2GW of that total will be implemented directly by Saudi Arabia's Public Investment Fund (PIF) and selected partners, while up to 600MW will be publicly tendered by Saudi Arabia's Renewable Energy Projects Development Office this year.

North Africa

Tunisia awards 60MW of solar + 10MW

Tunisia's Ministry of Energy, Mines and Renewable Energies has awarded 70MW of solar PV projects in the second round of its 'authorisation regime'. In the overall tender, 60MW will be made up of separate projects with a maximum capacity of 10MW each, with another 10MW to be made up of separate projects with a maximum size of 1MW. Power from the projects will be sold exclusively to the Tunisian Company of Electricity and Gas (STEG).

Scatec Solar's first bifacial project goes live in Egypt

Scatec Solar has taken a bifacial PV project to commercial operation in Egypt, marking a first for the Norwegian developer. The firm spoke of a major milestone after connecting to the grid the first 65MW batch of the 400MW it is working to deploy at the Benban solar complex, in the Aswan governorate. The plant features bifacial panels supplied by LONGi.

Sub-Saharan Africa

Ethiopia eyes 500MW in Scaling Solar Round 2

Ethiopia kickstarted the second round of its World Bank-led Scaling Solar programme with a 500MWac solar tender, while the first 250MWac round is still approaching the final proposal stage. The Public-Private Partnerships Directorate General (PPP-DG) within the Ministry of Finance issued a Request for Pre-Qualification (RFQ) for the PV capacity. The next stage will involve a Request for Proposals (RFP) from pre-qualified bidders. The proposal is for four separate PV projects at Weranso, Welencheti, Humera and Mekelle. International bidders are encouraged to participate in consortia with local private partners.

Solarcentury completes PV mini-grids in Eritrea with Tesla batteries

Solarcentury has commissioned two solar-storage-diesel mini-grids in rural communities in Eritrea that are far away from the grid and have relied purely on diesel power until now. The hybrid power systems at Areza (1.25MW) and Maidma (1MW) took eight months to build, with a combination of solar PV, lithium-ion batteries from US firm Tesla, and backup diesel generators from Caterpillar. The sites, providing 24/7 and cheaper power to 40,000 people and businesses, will be operated by the Eritrean Electricity Company.

ASIA-PACIFIC

China

China's new subsidy programme could support up to 50GW

China's government could financially support more than 30GW of solar capacity in 2019 and potentially as much as 50GW. That's the assessment of a former official and analysis conducted by PV Tech China. China is still putting the finishing touches to the plans but each iteration is increasingly centred around an auction process. There is no capacity limit, instead, a pot of funding will be ring-fenced to support the successful lowest bidders. China's policy proposals remain in a state of flux with the industry increasingly keen for clarity around the new subsidy plans.

China's solar installs plummet 46% to 5.2GW in Q1 2019 - AECEA

China's PV installations in the first quarter of 2019, declined by 46%, year-on-year to only 5.2GW. NREC data suggested that majority of installations related to distributed PV projects, instead of utility-scale project, due to the lack of a new national support policy being implemented. The utility-scale PV market in China was impacted by the '531 New Deal' at the end of May

China

China's 2021 subsidy-free solar market plans could support up to 50GW

China will have a subsidy-free solar market with clear policies and frameworks in place, beginning in 2021. Utilities will have to provide the highest priority level for grid connection to approved subsidy-free solar power plants that can start construction in 2019. Projects requiring state subsidies are put on hold until the first batch of grid-parity projects in 2019 have been determined by the national authorities. PV power plant projects which were approved in 2018 or in prior years have the option to be converted into unsubsidized projects and would be given the overall highest priority.

Credit: Panda Green Energy

China solar policy is a hot topic for the global industry

2018. Since that time, utility-scale projects outside of the 'Top Runner' and 'Poverty Alleviation' programmes, supported at the national level have stalled.

India

India's short-term hurdles won't stop four-fold PV boom in a decade

Policy headwinds in India will not divert the PV sector from a decade-long path of colossal growth backed by the government, according to Fitch Solutions. Indian PV capacity will ramp up by an average, annual 15.3% between 2018 and 2028, jumping from 26GW to 105.9GW in the period. The government will keep up the momentum through a recipe of "aggressive" growth targets, numerous tenders and policies to unlock investment towards solar. India's adoption last year of 25% tariffs for Chinese and Malaysian cells and modules will create uncertainties and costs but these will lessen in the long term.

CSUN India dispute a 'one-off case', says ACME Solar

India's Ministry of New and Renewable Energy (MNRE) has warned domestic companies against using solar modules from Chinese supplier CSUN, having received complaints from several Indian firms. One complainant, a leading Indian developer, ACME Solar, said it was a special one-off case. The Consulate General of India in Shanghai has also reported that CSUN is a "high risk" company with more than 160 court cases filed against it in Chinese courts in the last five years, mainly for similar breaches of contract.

SECI tenders 2GW of local content solar under CPSU scheme

Solar Energy Corporation of India (SECI) has issued a tender for 2GW of solar to be procured by Central Public Sector Undertakings (CPSUs). This is part of the CPSU Scheme Phase II, which mandates cells and modules to be sourced locally. Projects will be developed on a build, own operate (BOO) basis. The minimum capacity for bidding is 10MW with a maximum of 2GW. The overall aim is for setting up 12GW of grid-connected PV projects by government producers with Viability Gap Funding (VGF) support. Power generated must be for the self-consumption of government entities either directly or through distribution companies (Discoms).

Unprecedented Indian solar tendering spree

India went on a binge of solar tendering since the new year with 1.2GW in Madhya Pradesh, 275MW in Uttar Pradesh, and a significant solar-plus-storage tender in Andhra Pradesh (200MW PV / 300MWh battery). SECI also announced a tender for 1.2GW of ISTS-connected solar to be combined with 3,600MWh of energy storage, 400MW of floating solar in Tamil Nadu and Jharkhand as well as 1GW in the North-east states and Sikkim that until now have seen very little PV development. These were just a few of the multiple gigawatts of tenders issued across India in recent months, up until the hiatus of the general election.

Central Asia and subcontinent

Pakistan poised to green-light clean energy goals

Pakistani targets for 30% of its power mix to come from large-scale hydropower and another 30% from PV, wind and other renewables by 2030 now stand closer to adoption. The government's cabinet committee on energy is to formally consider a national policy for renewables, featuring the twin goals. The country's Alternative Energy Development Board (AEDB) said a 30% target would be the "only viable" strategy to avert power crises caused by overreliance on fast-depleting gas reserves. IRENA's annual update singled the country out as a PV highlight after a doubling of installed capacity (742MW to 1.5GW) was recorded between 2017 and 2018.

Strong international interest in Uzbekistan's first 100MW solar tender

Uzbekistan's first competitive tender for 100MW of solar PV in Navoi region has received 23 submissions from international companies. State-run utility Uzbekenergo issued the request for qualification (RfP) for the project in February. This is the first phase of the government's plan, under the advice of IFC, a World Bank group, to set up 1GW of solar PV through transparent and competitive tenders to reduce the Central Asian country's dependence on gas.

Bangladesh solar gets World Bank support, Alfanar bags 100MW

Saudi group Alfanar has landed an agreement to develop two 50MW solar plants in Bangladesh together with the country's state-owned power company EGCB. A joint venture recently formed by both parties will work to deliver the project in the Sonagazi municipality (Feni district), towards the country's southeast. Bangladeshi PV developers are also poised for a financing boost under a new US$185 million credit package from the World Bank to build 310MW of capacity in the Asian state.

Product reviews

Inverter | Growatt's next-gen residential PV inverter gains CEC certification

Product Outline: Growatt's next-generation smart residential inverter, MIN2500-6000TL-X has been approved by Australia's Clean Energy Council (CEC) for installation under the Renewable Energy Certificate scheme. Certificates of the model in compliance with required safety standards have been examined and verified by CEC, which marks the official product launch of MIN-series for sales across the world.

Problem: Increasingly demanding requirements for residential rooftop PV systems are being applied as market adoption grows. These requirements include the need to provide user-friendly and robust products, while providing high efficiency, ease of installation and greater

safety features and protection.

Solution: The MIN-series PV inverters uses 'aerospace grade' flame-retardant lightweight materials, making it easy to carry and install. It is approximately 35% lighter than other common inverters and a 5kW Growatt MIN weighs about 10.8kg. Its OLED display with touch button is designed according to Australian consumers' preferences. Customers will have a better user experience with the touch button, which has a longer lifespan and can last for over three million clicks.

Applications: Residential PV systems.

Platform: Designed with the standard USB and RS485 interface, users can choose configuration options such as WiFi, GPRS, 4G etc. After setting up the USB + RF communication module, they can monitor the system and read power production and flow from smart devices by logging onto Growatt OSS (Online Smart Service) platform. Additionally, it has a high efficiency of up to 98.4% and better protection for PV systems with type II SPD and optional AFCI.

Availability: Currently available.

Module | Hanwha Q CELLS launches low-cost high-performance Q.PLUS DUO L-G5 module

Product Outline: Hanwha Q CELLS has introduced the Q.PLUS DUO L-G5 to selected European markets with initial availability in the Netherlands. Q.PLUS DUO L-G5 is the first multicrystalline solar module from Q CELLS to use half-cells, following in the footsteps of the successful Q.PEAK DUO module series, which is an award-winning half-cell monocrystalline solar module.

Problem: The Netherlands has shown strong demand for high power and low-cost PV products in the past few years. According to the Nationaal Solar Trendrapport 2019, the Dutch market expanded by 46% in 2018. Cumulatively, the Netherlands has more than 4.2GW of solar

capacity installed, and analysts and industry experts expect that a further 1.5GW of new capacity could be added in 2019.

Solution: The Q.PLUS DUO L-G5 has an efficiency rate of up to 19.1% and delivers a low levelised cost of electricity (LCOE) due to its high module power output and optimised design. Thus, the Q.PLUS DUO L-G5 is an ideal solution for the growing Dutch solar market – in particular the ground-mounted sector, which is currently enjoying strong growth.

Applications: Ground-mount commercial and utility-scale PV projects in the Netherlands

Platform: Developed as an ideal solution for ground-mounted solar power plants, the Q.PLUS DUO L-G5 is claimed to offer a higher yield per surface area and lower balance-of-systems costs than standard multicrystalline solar modules. It is available in power classes up to 375Wp and features the same technological and security features of Q.ANTUM DUO, including anti-LID (light-induced degradation) and anti-PID (potential-induced degradation) performance, as well as Hot-Spot Protect and traceable quality with Tra.Q laser identification to protect against counterfeiting.

Availability: April 2019, onwards.

Module | JinkoSolar's 'Swan' bifacial PERC solar panel uses transparent backsheet for lowest LCOE

Product Outline: JinkoSolar in collaboration with DuPont Photovoltaic Solutions has developed a new high-efficiency bifacial panel protected by clear DuPont 'Tedlar' PVF film-based backsheet. The 'Swan' panel is the latest addition to JinkoSolar's 'Cheetah' premium range. With a combination of high-efficiency Cheetah bifacial cells and clear backsheet, Swan panels can achieve a high-power output of up to 400Wp on the front side and up to 20% energy gain from the rear side.

Problem: Compared to a double-glass module structure, the breathable, clear Tedlar PVF film-based backsheets are said to allow for higher reliability, lower operating temperature, up to

30% lighter weight, and a lower module installation cost.

Solution: Leveraging clear DuPont backsheet materials, Swan panels can produce the same power output level as dual-glass bifacial module with lighter weight, easier installation and 30 years' power warranty. In addition, bifacial panels with transparent backsheet are claimed to reduce the overall system installation cost, as lower weight reduces cost related to mounting and module installation, compared with dual-glass bifacial module with frame, bringing higher IRR and lower LCOE for bifacial module photovoltaic (PV) projects.

Applications: Commercial and utility-scale PV power plants.

Platform: The clear Tedlar PVF film is expected to be a drop-in with most current manufacturing processes for backsheets and modules with little if any additional investment in equipment needed for most manufacturing processes. The clear backsheet materials can meet the requirements of light transmittance, weather resistance and ultraviolet resistance for bifacial solar panels.

Availability: Currently available.

O&M Pellucere Technologies offers world's first field-installable, anti-reflective, anti-soiling solar panel coating

Product Outline: Pellucere Technologies has claimed to have developed the world's first field-installable, anti-reflective, anti-soiling solar panel coating, which is said to boosts energy generation and reduces cleaning.

Problem: PV power plant performance optimisation has become a critical operating metric to secure the highest investment returns and lowest costs. Boosting plant performance without retrofitting PV panels is costly and time consuming.

Solution: MoreSun is a proprietary solar coating and application system that adds an anti-reflective (AR) and anti-soiling (AS) silica

shield to any solar array. MoreSun includes the company's Talus Dirt Rejection Technology. 'Talus DRT' optimises the unique physical properties of its silica shield's nano-structure to prevent buildup of dirt and other particulates. Unlike typical hydrophobic anti-soiling technologies, the unique properties of Talus DRT allow it to reject the dirt without waiting for rain or cleaning with water.

Applications: In-field application on PV panels as well as being applied in the factory to modules or glass substrates.

Platform: MoreSun helps solar modules without AR capture more light, increasing energy output from direct axis light by 3.4-3.8% and total energy output by up to 4.7%, according to independent testing. Pellucere's proprietary Talus Dirt Rejection Technology has been shown in testing to reduce the buildup of dirt, dust and other particulates by as much as 90%. Beyond the MoreSun chemistry, the company's patented field deposition technology allows far greater precision in installation to ensure a highly uniform and accurate application. Pellucere is currently testing a robotic applicator system that is expected to be released for field trials in the first part of 2020.

Availability: Currently available.

Module REC Group's 'N-Peak Black' series panels offer rooftop performance with stylish aesthetics

Product Outline: REC Group has launched its latest edition to its 'N-Peak' series panels, designed with residential rooftop stylish aesthetics and high-performance needs. The all-black n-type monocrystalline panels come with a performance rating of up to 325Wp with REC's 20-year product warranty.

Problem: Panel aesthetics for rooftop applications matter more than ever, while the demand for higher performance to reduce the balance-of-system costs in subsidy-free markets is also increasing. With solar uptake on the rise everywhere, more and more commercial and residential customers are looking for solar installations that look as great as they perform.

Solution: The entire REC N-Peak Series applies REC's TwinPeak technology for first time with n-type mono half-cut cells with a twin-panel design. The full black version (balck backsheet and frame) delivers high power output of up to 325Wp and is ideal for customers with limited roof space or partial shading. Its super-strong frame carries loads of up to 7,000 Pa.

Applications: Residential and commercial rooftops.

Platform: The REC N-Peak Series has extra support bars across the rear of the panel, greatly boosting its strength and durability, and allowing loads of up to 7000 Pa – far exceeding the 5,400 offered by conventional panels. A 20-year product warranty is given, and with an extra five years for installations carried out by REC-certified solar professionals. REC also guarantees a final warranted power output of at least 86% after 25 years of operation.

Availability: April 2019, onwards.

Module Trina Solar rolls out new range of mass-produced high-output panels

Product Outline: Trina Solar has launched four new series of high-efficiency modules to meet different needs. By using innovative integrated technologies, the maximal output of new series of modules has been 415Wp in mass production.

Problem: What kind of module is the right fit for a specific application scenario? What kind of module can better integrate with the whole system to further reduce system costs as well as levelised costs in a given application scenario? While a PV solar manufacture is able to adapt various individual cutting-edge technologies, it is difficult for end-users to find the right product for a specific project scenario.

Solution: Trina Solar is taking the lead to meet diversified PV application needs in multiple scenarios. The four new series of modules include Honey, TALLMAX in high-efficiency series, DUOMAX dual-glass series, DUOMAX Twin double-side series, and Honey Black M aesthetics series. The high-efficiency series can

be used in multiple application scenarios such as utility-scale ground mount and distributed PV projects. The dual-glass series features high reliability in extreme conditions. The double-side series features high power generation in snowfields and locations where sand is plentiful, among other high-reflection environments. The aesthetics series is designed specifically for the high-end residential market with its black-on-black design.

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

Platform: An increase in the output of modules from 370Wp to 415Wp will help reduce BOS cost by 4.5% to 8.5%, and reduce LCOE by 2.5% to 4.6%, according to the company.

Availability: Available since March 2019.

Product reviews

Module ZNSHINE's graphene-coated G12 PV module achieve the highest level of panel self-cleaning

Product Outline: PV manufacturer ZNShine has developed graphene coating for its G12 Series of monocrystalline panels, which is said to increase the transmission properties of the glass, while the hydrophobic effect of the graphene coating achieves the highest level of panel self-cleaning, reducing O&M costs for commercial and utility-scale PV power plants.

Problem: Commercial and utility-scale PV power plants typically use regular manual cleaning methods to clean the surface of PV modules. This type of cleaning method is difficult to unify and it is likely to cause problems such as cracking of the PV cell and generate residual water stains on the surface of the module. The regular cleaning costs using labour resources adds to the overall

O&M costs. According to industry estimates, a PV power plant with an installed capacity of 50MW could expend around US$150,000 per year for panel cleaning maintenance.

Solution: The application of a graphene film layer on panels increases the light transmission performance between 0.5-1%, resulting in a panel peak performance increase in the range of 2-3Wp. Being super hydrophilic, particulates on the glass are taken away quickly by the rain without any further water being required.

Applications: Residential PV systems, commercial, DG systems and utility-scale PV power plants.

Platform: ZNSHINE's graphene-coating module is compatible with PERC technology and black silicon technology. The G12 graphene series comes in a 12-busbar and 5-busbar format as well as a double-glass graphene module.

Availability: Currently available.

Module S'Tile launches smart solutions for BIPV and roofing

Product Outline: S'Tile's Linea module combines great aesthetics and flexibility with very high power performance. This allows modules to perfectly fit with designers' requests for installing modules on façades and roofs.

Problem: Each BIPV projects requires specific features which are challenging to bring together in one unique product: power demand per m2, customisation of module in terms of dimensions, transparency percentage, voltage, all characteristics complying with an aesthetic integration.

Solution: S'Tile provides custom designs of solar photovoltaic panels. Dedicated solutions are proposed for each project.

Solutions combine high efficiencies (>200 W/m^2) with singular visual aspect; a full paving of module area by cells without any ribbon visible at the surface allows for multiple unique solutions to market requirements.

Applications: Glass/glass modules for building facades, small and large area solar rooftops and urban furniture.

Platform: Two main families of products are proposed with flexible characteristics. Firstly, a 'Full Black' module that is particularly adapted for tiles, slates and applications requesting discreet integration. Secondly, 'Biomimetic' panels aimed for building's facades, parking shelters, railings or pergolas. Each range is proposed in glass/backsheet or glass/glass versions. Modules are IEC/EN 61730 and IEC/EN 61215 compliant.

Availability: The Linea modules are currently available.

Products in brief

Sharp provides p-type mono-PERC series with highest power output of 370Wp with 72-cell panel

Sharp has launched three new p-type monocrystalline PERC PVpanels to the NU product family. The renewed line-up of high performing modules offers customers a solution for every application, from residential projects up to large-scale commercial installations and free-field power plants. All three modules, the NU-AH370, NU-AK310 and NU-AK300B, can be mounted in portrait or landscape to maximise sunlight capture and suit the performance needs of different projects. The NU-AH370 offers the highest power output of 370W with 72 monocrystalline cells and a module efficiency of 19.1%, making it particularly suitable for large scale roof top or ground mounted facilities that demand highest yields.

HT-SAAE launches latest high-efficiency 'Multiway Series' panels

PV panel manufacturer, HT-SAAE has introduced its latest line-up of high-efficiency multi-busbar (MBB) technology panels under its 'Multiway Series', which comes with advanced electrical performance and lower micro-crack risk. For a 72-cell module, the power output can reach up to 400W. The Multiway Series module features a self-cleaning design. In a bid to help users save on cleaning costs, the module is designed to reduce shadowing on the surface of the panel caused by dust, rain and snow, which can increase the output of power generation and cut down on power seepage. Thanks to its durability, the module can be used in various environmental settings, including solar farms and regular rooftops.

Big data and predictive maintenance in PV – the state of the art

O&M | Big data-based predictive analytics techniques using artificial intelligence technologies offer exciting new possibilities in the field of solar operations and maintenance. Alessandro Betti, Fabrizio Ruffini, Lorenzo Gigoni and Antonio Piazzi examine how the power of data can be harnessed to safeguard the technical and economic performance of the PV fleet

Solar photovoltaic (PV) energy is nowadays one of the most effective alternatives to conventional dispatchable energy sources, mainly due to its increasing competitiveness, the growing energy demand of developing countries and the requirement of alternative technologies to alleviate pollution and reduce global warming. In 2017, the net capacity increased faster than any other power generating technology (Figure 1), reaching approximately 402GWdc globally [1]. Focusing on the European Union, solar additions increased by 36% to 8GW in 2018.

During the operative lifetime of the power plants, high-quality O&M activities are needed in order to maintain a high level of technical and economic performance over time. In the following, we will overview the O&M needs and the newest approaches to address them. Finally, we will discuss future trends and give conclusive remarks.

The importance of O&M activities in PV plants

O&M activities are undertaken by the O&M contractor, which generally shares its tasks with the technical asset manager, which is responsible for ensuring that the operations of the PV plant are compliant with the regulations and for reporting to the asset owner, and the O&M service provider, which instead has to monitor and supervise the PV site conditions and performances (operation team), as well as to carry out the necessary maintenance activities (maintenance service team). Supervision is usually done remotely in the operation centre (control room) by exploiting analytical monitoring software systems where all data collected by dataloggers at the PV site, down to inverter and string levels, are analysed to schedule short- to long-term operations to be followed by the maintenance team.

The procedure for fault management, when a failure is detected by the control room, is generally based on a three-levels support, ranging from restoring device functionality without the need for component replacement up to component substitution and software update, and relies on an escalation of corrective actions undertaken by professionals with increasing technical skills and access permissions, until the malfunction is solved, and the corresponding ticket is closed [2].

Key performance indicators (KPIs) are used for monitoring the operation of a PV plant and for comparing PV sites in a balanced fashion. They may be mainly divided between PV power plant KPIs, describing the PV site's production performances, and O&M contractor KPIs, which instead reflect the quality of the O&M service provided. Performance ratio (PR) [3] and availability [4] belong to the first group and are usually supervised by the asset manager by ensuring the optimal profitability of the plant over time. The availability, defined as the time percentage the plant operates over the whole time it should operate (usually required to be higher than 98% over a year), is also a striking indicator of the plant behaviour that needs continuous monitoring by the O&M service provider to undertake corrective actions when necessary. O&M contractor KPIs instead include the acknowledgement, intervention and resolution times, which monitor the time

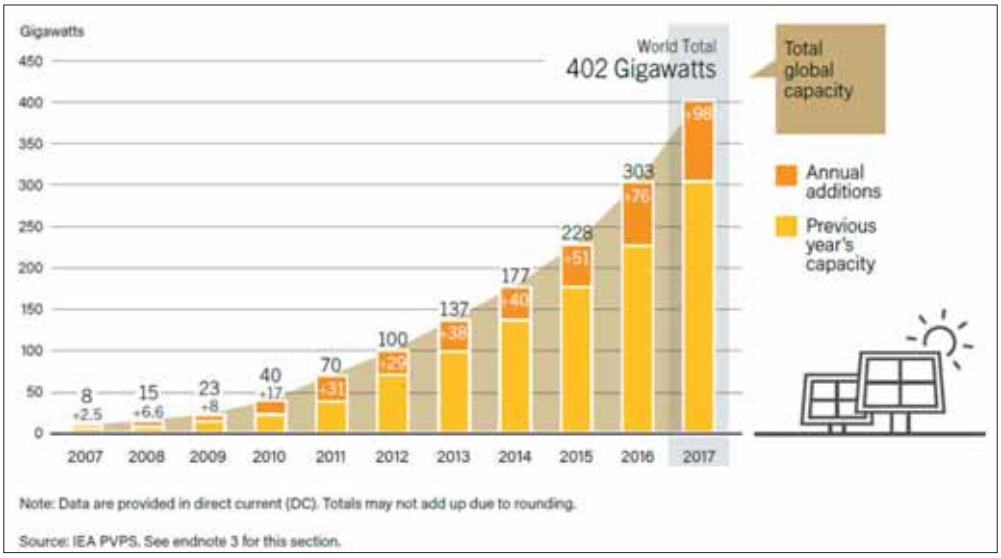

Figure 1. Solar PV global capacity and annual additions for the period 2007-2017 [1]

necessary to acknowledge an alarm, reach the plant and solve the issue, respectively.

Several kinds of maintenance strategies can be followed. **Preventive** maintenance is one of the typically followed: it includes regular visual and physical inspection of key components, such as string measurements or thermal scans of PV panels, in order to identify problems as soon as possible and start O&M activities. However, such a proactive strategy can involve expensive inspections with third parties and, since the frequency of such activities is not typically optimised, can lead to unsatisfactory results. On the other hand, the opposite **reactive** strategy, undertaking a corrective action only when a failure occurs, is usually more expensive as the losses due to downtime and repair or substitution of devices are higher.

In this scenario, the need for strategies able to predict incoming faults emerges, such as condition-based **predictive** maintenance approaches. Unlike preventive and reactive strategies, this kind of strategy optimises simultaneously the downtime periods, the lost production and the total cost of maintenance activities; therefore, it should be considered as the core strategy of the O&M contractor activities. A recent study for GE Oil & Gas of offshore gas facilities [5] showed a clear relationship between the followed maintenance approach and the unplanned downtime. In Figure 2 the annual financial impact of maintenance activities (blue bar, on the left) and the unplanned downtime rate (grey curve, on the right) are shown for the reactive, preventive and predictive approaches.

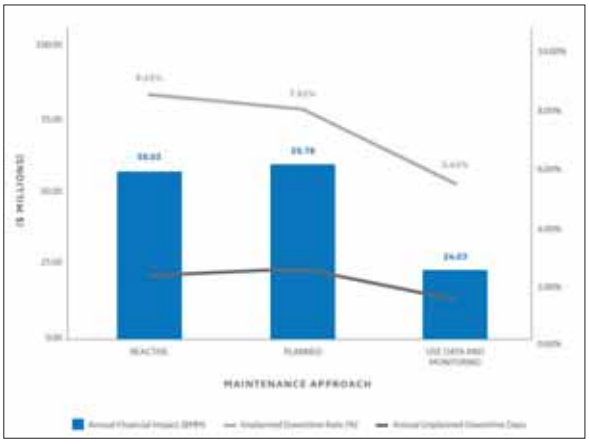

Figure 2. Annual financial impact of maintenance activities for offshore oil & gas facilities (in millions of dollars, on the left) and annual unplanned downtime rate and days (on the right, grey and black curves, respectively) for the reactive, preventive (planned) and predictive (use data and monitoring) approaches [5]

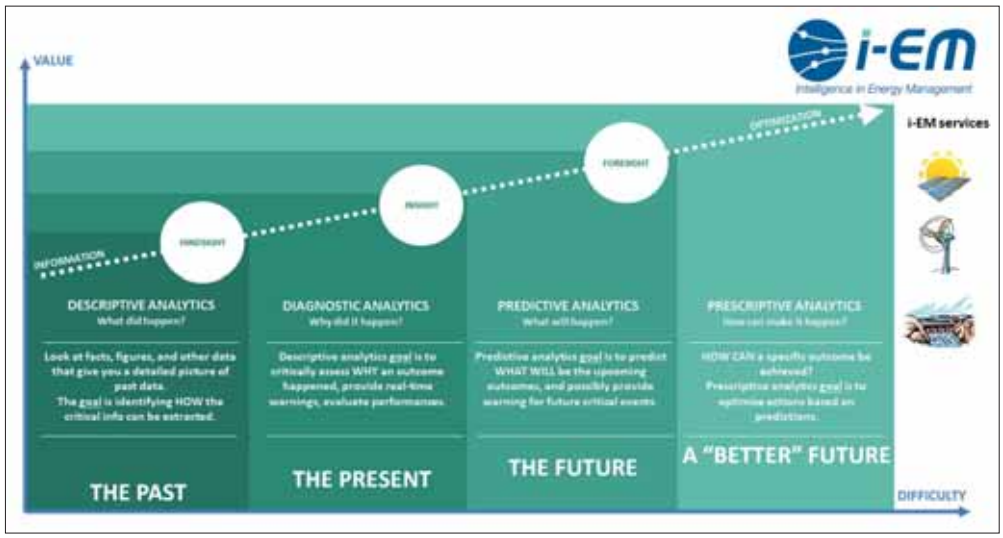

Figure 3. Chart describing the value added to the O&M activities undertaken by the four approaches – descriptive, diagnostic, predictive and prescriptive analytics – as a function of implementation difficulty (inspired by [6]). The higher is the service complexity, the larger is the value gained, up to predicting the future outcomes (predictive) and delivering the actions required to solve predicted failures (prescriptive)

According to this study, a 36% decrease in unplanned downtime activities, as well as a 60% drop in the annual financial impact, may be achieved by following a predictive strategy.

Towards a predictive maintenance strategy

Predictive maintenance usually requires the collection of a large amount of data at PV sites. Since data analytics is effective in extracting actionable insights from data, now companies are struggling to digitalise their processes. Data analytics may be split into four main groups depending on the growing level of added value they bring and also on the complexity they require for design and implementation: **descriptive, diagnostic, predictive** and **prescriptive** analytics (Figure 3). A descriptive solution provides valuable insights into the past by means of data mining algorithms and summarising raw data from multiple sources. No additional information is provided, such as the reasons why the event happens. Unlike the descriptive solution, the diagnostic approach discovers dependencies in data and identifies hidden patterns, getting into the causes of a past event or ongoing behaviour. However, this diagnostic level is still reactive, since it is applied to past/real-time events.

As information volume and quality increase, organisations may move towards the realm of a forward-looking (proactive) approach, adjusting their strategy according to what is predicted for the future. In particular, predictive analytics adds a level of complexity to the descriptive and diagnostic analytics, exploiting their findings to predict tendencies and future trends. It takes advantage of statistical models, either classical or machine learning, and it is based on a probabilistic foundation to forecast the likelihood of a future outcome and provide actionable insights to companies.

Prescriptive analytics, starting from predictive outcomes, finally suggests the action(s) to prevent a future issue of an asset or to take advantage of a predicted trend. It can be successfully used to optimise the production, the scheduling and inventory in the supply chain, or O&M actions (for example, operating only where and when necessary).

Predictive analytics on PV plants: benefits and challenges

While descriptive and diagnostic are well-established techniques in the PV energy sector, predictive and prescriptive maintenance are still at an embryonic stage and utilities and PV plant owners are only just beginning to turn their interest to such topics. These activities require a data-driven approach in O&M activities, where an accurate data collection including real-time data, historical data, data from similar assets and historical maintenance records is necessary, therefore delaying the shift from the feasibility-study level to real implementation.

The benefits of a proactive approach are manifold: a reduction in the component repair and replacement costs of factory equipment, a decrease in the

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revenue loss due to plant downtime, a reduction of capital investment by extending the useful life of devices, better inventory management, and, in general, more effective O&M activities.

However, challenges for the real implementation of a predictive service are also manifold: first and foremost, the need to gather at a predefined acquisition rate a huge amount of data related to both electrical and environmental signals, as well as archiving either automatic or manual alarm logbooks describing past failure events. Furthermore, as a predictive model is generally trained over healthy component-related instances and tested against unknown periods in which the component status should be predicted, a preliminary separation of historical instances into normal or abnormal classes is mandatory but often difficult in practice. Clearly, a stable internet connection and a speedy and reliable IT infrastructure managing field data collection are required, starting from low-level Internet of Things (IoT) sensors and SCADA software installed at a PV site, up to a big data platform at the monitoring room level where data from different plants and countries are archived.

The development of a predictive model must not forget to combine experience in the PV technical domain with data science expertise. This requires the inclusion of the O&M team in the whole lifecycle of the predictive service process and, in particular, in the phases of model features selection, model development and online model validation, where the accuracy of the model is compared to real-time events. But domain knowledge should not be limited to the interaction with the O&M team, as it should include also asset manufacturers in order to define, prior to the model design, a fault taxonomy table reporting, for each fault type that may be triggered in the field, at least the corresponding device involved, the alarm type, the manufacturer code, the event name and description, the event severity, as well as the potential cause of event and the actions to solve the issue. This is necessary to get the correspondence among the past events recorded in the fault logbook and the taxonomy file, to prioritise events and to customise and tune the predictive models against the failures considered more critical according to customer needs.

Figure 4. Artificial intelligence has infinite applications. Recently a research group adopted such techniques for predicting new patients affected by Alzheimer's disease [7]

Techniques for predictive maintenance on PV plants: the key role of artificial intelligence

The search for increasingly practical and accurate predictive maintenance tools has coincided with the simultaneous growth in artificial intelligence technology and the introduction of statistical methods based on machine learning. Such a discipline has infinite applications: some months ago, a research group from California claimed for example its application to diagnose patients with Alzheimer's disease based on brain scans made some years before [7].

A typical workflow of an artificial intelligence model is outlined in Figure 5. A dataset is typically extracted from an archive and preliminarily preprocessed to obtain clean data useful for further processing. Domain knowledge is usually required to select the best predictors for the problem of interest, as well as to combine different signals to achieve enhanced predictors (feature engineering). In order to handle signals concerning heterogeneous quantities, feature normalisation is typically applied. Then, traditional statistical or machine learning-based algorithms are used to create models based on these features and validated against a test set (historical and/or real time) to verify performances. Usually an iterative approach is applied in order to find the best coupling between preprocessing and processing phases which maximises performances. Finally, the developed model is deployed to deliver a periodical service to the customer.

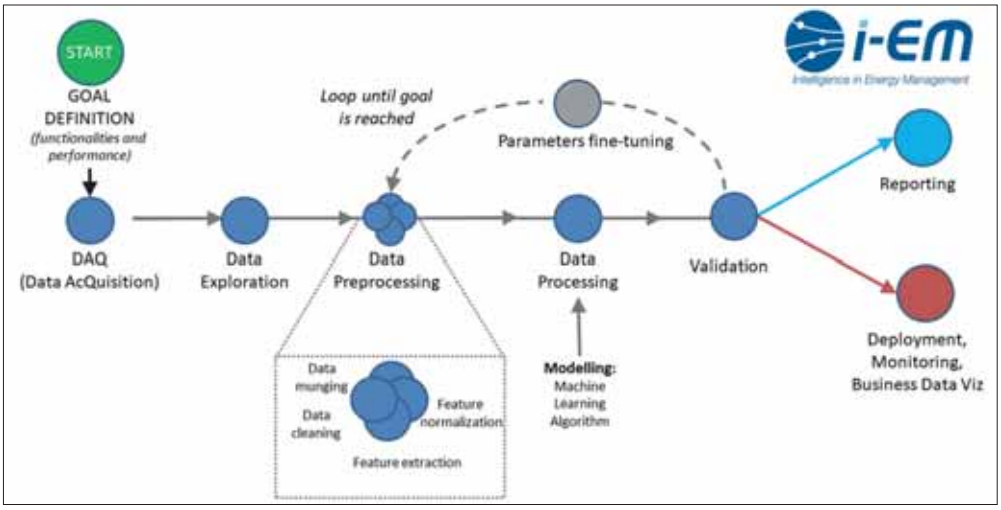


Figure 5. A typical machine learning workflow

Predictive maintenance models may be designed for different target PV components: PV module, string of PV panels, inverter, or the whole plant. They may be also grouped in three different categories, characterised simultaneously by an increasing level of details provided and by a shorter prediction horizon: prediction of generic faults and machine status, prediction of severity category of the incoming event and prediction of specific faults. In the first case, the model predicts a generic failure through a measure of deviations from normal operation, in the second scenario it returns the criticality of the fault event according to asset manufacturer taxonomy, whereas in the third one it provides the specific fault class among those available in the taxonomy archive. The algorithmic core of the model and its complexity, as well as the input features fed into the model and the training methodology adopted, change according to the level of detail required for the prediction. In particular, the prediction horizon may reach days or weeks in the first approach down to few days, or even hours or minutes, in the latter, depending on the statistics available and on the degree of correlations among the input predictor and the fault predicted [8].

An example of prediction of specific fault classes is shown in Figure 6 (next page) where the classification metrics accuracy, sensitivity and specificity, as

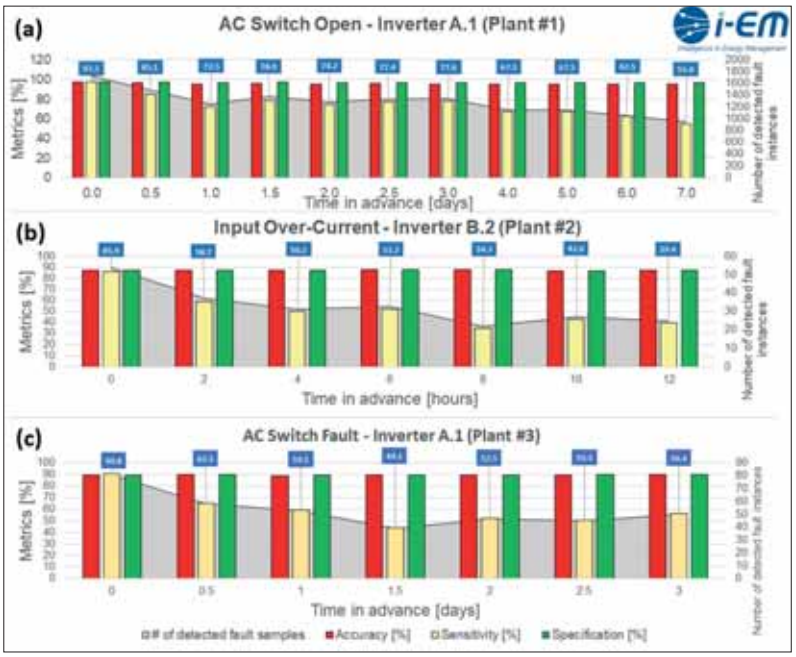


Figure 6. Classification metrics (bar plot on the left) and number of detected faults (grey area on the right) as a function of time in advance for predictive model developed by [8]. (a) fault class AC switch open (plant #1 in Romania); (b) fault class input over-current (plant #2 in Greece); (c): fault class AC switch fault (plant #3 in Greece)

well as the number of detected historical faults, are shown as a function of the time prior to the fault occurrences for different inverter failure class. Three examples for three different plants, one located in Romania and two in Greece, are reported (Figure 6 (a), (b) and (c), respectively). As can be seen, a strong correlation between statistics available and model performance is evident, since machine learning algorithms are black-box computing units which learn the underlying non-linear relationship between input and output according to the training dataset available. When thousands of occurrences are available (Figure 6a), the prediction horizon is as large as seven days, with sensitivity decreasing down to almost 50-60% about one week ahead. On the other hand, when the statistics amount to almost one hundred instances, prediction capabilities degrade much faster on the time horizon from one hour to 12 hours in advance (Figure 6b). It is worth noticing that, however, a strong correlation between input predictors and fault class may enlarge the horizon in some exceptional cases (Figure 6c).

Control charts and machine learning algorithms

The category of models predicting generic failures includes essentially statistical process control approaches trained over nominal behaviour periods of the modelled component and then able to early detect or predict a not-nominal trend. Such approaches may be divided between univariate and multivariate, depending on how many signals are

Going above and beyond

Aerial inspections heighten technical due diligence and provide valuable results in record time.


Drone inspecting modules on the undulating terrains of western Italy.

Above and PI Berlin worked together on a high-profile secondary market transaction of a 13MW solar asset in Italy. Technical advisors PI Berlin led the technical due diligence of the asset transaction. Above were commissioned to carry out thermographic and high-resolution visual inspections as part of the project's technical scope. An exhaustive analysis of module health was key due to the direct impact on the purchase price. It is worth noting that the plant was installed at a time when the module price represented more than 50% of the CAPEX. The on-site inspection and subsequent image analysis were framed within a technical due diligence process, conducted by the seller in order to establish the status of the plant before entering negotiations with potential buyers.

"Above were able to adapt to our needs in record time, creating robust solutions that had not been previously used in large scale PV plants."

Advanced aerial inspections

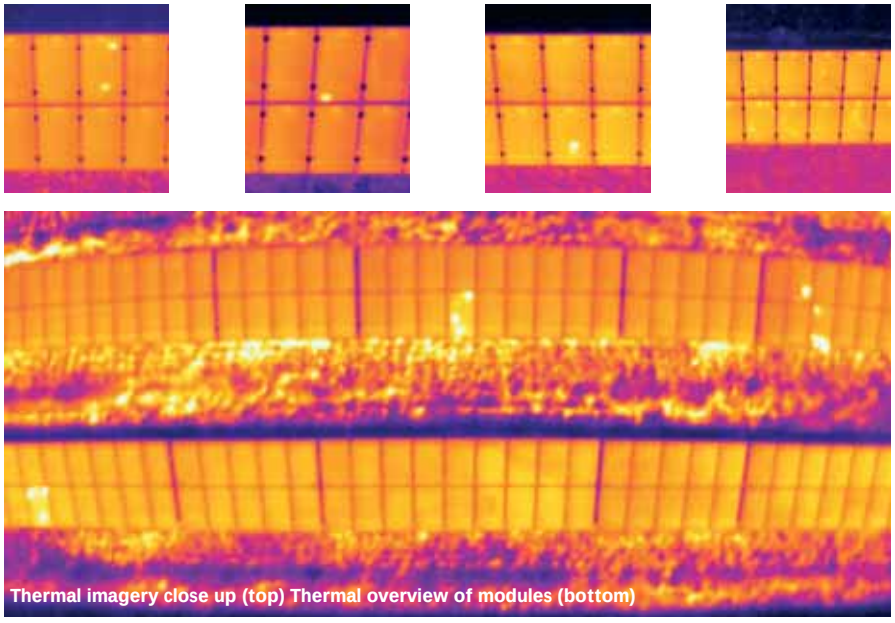
Above began with a thermographic inspection, collecting thermal and RGB imagery of all 57,000 modules. Using a patented methodology, Above successfully identified and located anomalies on 2,820 modules across the site. The interactive report produced by Above provided clear, actionable data, allowing ground engineers to locate the problems quickly and carry out further tests. During the ground-based visual inspection, engineers identified many other issues such as bus bar corrosion, yellowing, snail trails and glass cracks, not visible through thermography.


Module showing snail trails

This prompted the need to quantify the extent of these defects across the entire site. PI Berlin estimated it would take 56 working days to inspect the whole site using a ground-based approach: a labour-intensive task, at risk of suffering from inconsistency. Using a drone-mounted high-resolution visual camera, Above were able to complete the data collection in 4.5 days, more than 10 times faster than conventional methods. An industry first.

Cutting edge technology

The adoption of aerial inspections as a more efficient alternative to manual inspections is allowing companies to work smarter.


Thermal imagery close up (top) Thermal overview of modules (bottom)

PI Photovoltaik Institut Berlin

Asier Ukar, Senior Consultant at PI Berlin on the project outcome,

"Above were able to adapt to our needs in record time, creating robust solutions that had not been previously used in large scale PV plants. We were especially surprised by the highly user-friendly platform created by Above for the evaluation of more 300 GB of imagery taken during the aerial visual inspection."

above

Will Hitchcock, CEO of Above says, *"This was a great project for us to demonstrate the potential of drones in solar, beyond thermography. Prior to starting the project, there were several technical concepts that needed to be proved. And with very tight timescales, vision, fast decision making, and agility were vital."*

SolarGain Inspection Hub making the invisible

Above's new SaaS platform, SolarGain Inspection Hub, integrates data from multiple sources into a unified program – including Thermal inspections, High-Resolution inspections, Eyesite mobile app inspections and other third-party testing activities such as I-V curves and EL images. Seamlessly access, share, filter and compare inspection reports, data and imagery. Utilise the platform's powerful tools to transform your data into actionable insights. Inspection Hub maintains a lasting record of your existing assets and works alongside you as your portfolio expands.

SolarGain Inspection Hub

Features

- Portfolio Health
- Inspection Compare
- Maintenance Tracking
- Warranty Claim
- Anomaly List View
- Anomaly Map View
- Report Overview
- Filter Anomaly Tool
- Infrastructure Hierachy

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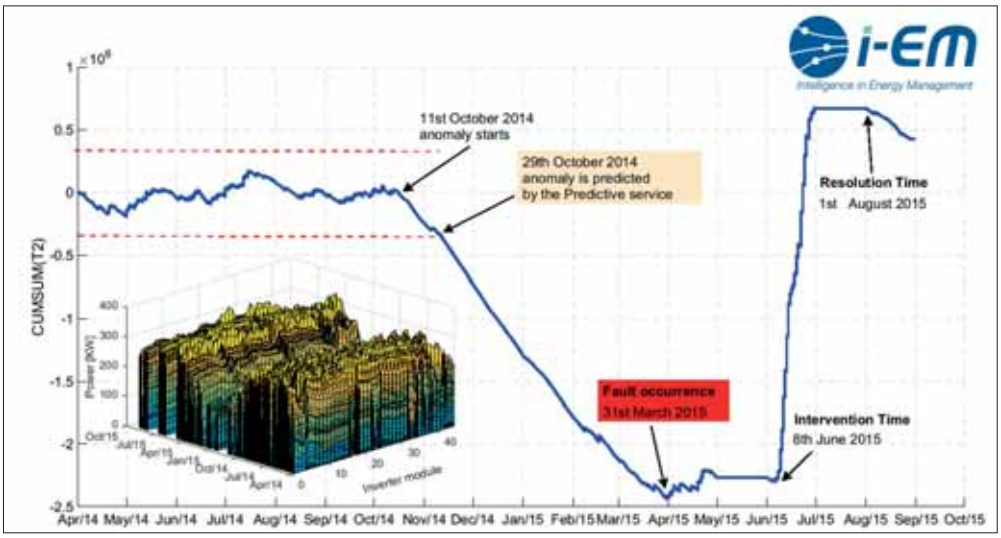

Figure 7. Cumulative sum of T2 as a function of time for a PV plant in Romania. Inset: AC power for the inverter module installed on site. Reproduced with permission of i-EM srl, Flyby Group (www.i-em.eu)

considered in the analysis. In particular, unlike the univariate method where a single signal at a time is analysed, the multivariate analysis accounts for a bunch of signals simultaneously, therefore including the effect of correlations.

The procedure in both cases generally consists of two phases: retrospective and prospective. In the retrospective phase a nominal period for the variable of interest is considered, where the variable may be a single signal or a KPI obtained by aggregating together different signals. In both cases, the model is built or trained against the nominal period identified by using domain knowledge (best case) or, at worst, by statistical considerations as explained earlier. Then, in the prospective phase, the algorithm is tested over an unknown period to predict out-of-control component behaviour, triggering a generic warning. Auxiliary information may be also provided along with the warning, such as the specific sub-class problem, if the tags more correlated to the anomaly were identified, and the fault severity, in order to simplify also the maintenance activities. Additionally, in the case that the sub-class problem was suggested, the action to solve the issue may be proposed by getting it from a look-up table storing the correspondence between issues and actions, thus turning the approach from predictive to prescriptive. However, since the information regarding specific failures are neither present in this approach, nor used for training, and, additionally, different tags may concur to the same anomaly or the same tags can lead to different anomalies, the prescriptive suggestions provided may have a limited effectiveness.

The most common statistical methods predicting generic failures include traditional approaches, such as Hotelling's T2 control chart [9, 10], and machine learning-based algorithms, both supervised and unsupervised. T2 is based on correlation analysis and describes the global system behaviour. It can be interpreted as a deviation of the process from a nominal condition. When deviation is below a threshold, the system is under control. On the contrary, when the threshold is exceeded, the process is declared out-of-control. Another control chart widely researched is the cumulative sum [10], which is efficient in detecting small shifts in the mean of a process. Cumulative sum is simply the partial sum of the variable of interest up to the current element and removing the mean value of the variable. By analysing its trend and unexpected and sudden slope changes, an out-of-control process can be easily detected or predicted.

An application example of cumulative sum is shown in Figure 7 for a historical failure of a PV plant in Romania, which suffered a severe thermal issue in 2015 that led to replacements of different inverters and to a prolonged downtime period. A deep valley with abnormal behaviour can be observed starting approximately at the end of October 2014, some months before the failure occurred at the end of March 2015. In particular such failure led to a plant downtime of some months, with the intervention time scheduled in June 2015 and the resolution time happening finally in August 2015, when the plant recovered its normal operation.

Besides traditional control charts, machine learning methods may be also applied: they include, for example, neural network (NN) and self-organising map (SOM) [8]. While NN belongs to the class of supervised algorithm, i.e. a target is present, SOM is unsupervised, i.e. it does not have this information. In a supervised learning model, the algorithm learns on a labelled dataset, for example represented by a set of input instances tagged with binary values identifying nominal or abnormal behaviour (the target), and provides an output that the algorithm can use to evaluate its accuracy on training (retrospective) data, before inferring over test data.

An unsupervised model, in contrast, provides unlabelled data that the algorithm tries to make sense of by extracting features and hidden structures on its own. In particular a SOM makes a non-linear mapping from an input N-dimensional space to a 2D space and preserves input topology by exploiting a competitive learning process. Changes in clusters emerging in the SOM map may be monitored by means of a KPI measuring a process variation from normal state towards abnormal operating conditions when a threshold is crossed [8].

Prediction of specific faults needs, first of all, an amount of information, such as alarm logbooks and categorised taxonomy files, which at the present stage is only sometimes available. Indeed, this entails not only a speedy, reliable and fault-tolerant acquisition chain but also demands cooperation of the O&M team and asset manufactures. From a design point of view, only supervised algorithms may be applied since they must be trained against specific fault classes: typical suitable architectures are pattern recognition feed-forward NNs [8] or deep learning structures such as a stack of auto-encoders.

A common issue is the so-called class unbalancing because the number of samples available for nominal class (the so-called negative or majority class) generally is much larger than that available for the faulty one (the so-called positive or minority class). Since training is done by minimising a cost function where the contribution of minority class is small, the model prediction is biased toward the majority class and, on average, misclassification of minority instances occurs with a higher rate. Different techniques may be applied to overcome such a problem,

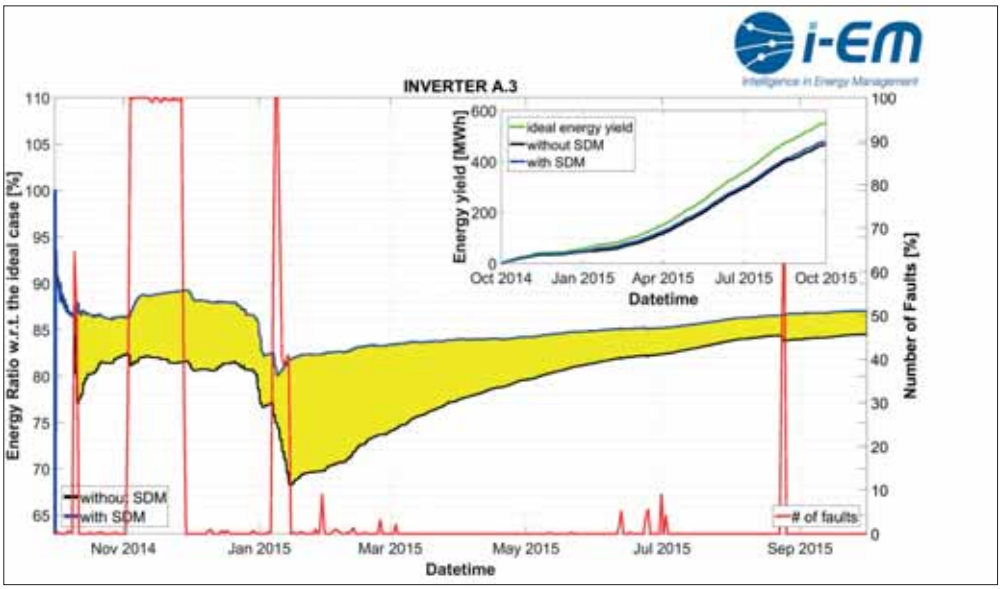

Figure 8. Energy yield time series with respect to the ideal case with (blue curve) or without (black) the predictive service: yellow area represents the energy gain enabling such service. Fault occurrences percentage is also shown on the right (red). Inset: energy yield in the ideal case, as well as with or without the predictive service. Data are referred to an inverter module of a PV plant located in Romania [8]

which may be grouped essentially in undersampling and oversampling. In the first case the number of instances of majority class is undersampled to make their number comparable to that of minority class; in the second case instead artificial instances are created to oversample the amount of minority faulty instances (e.g. SMOTE technique).

Prediction of specific faults formally closes the gap between predictive and prescriptive approaches because the fault taxonomy file may be used as a look-up table to suggest the action to solve the issue in correspondence with the predicted failure.

Further potentially effective techniques are those usually applied in the wind energy field, including bivariate analysis based on power curve modelling [11] and condition parameter-based models [12]. The latter approach, roughly speaking, consists in training over healthy instances and predicting the status of the component by monitoring the residuals between the forecasted and the measured target parameters: if such a residual exceeds a threshold, a warning is triggered. Such a method has also been applied in the PV sector to analyse fault classes affecting inverter power production (e.g. "lack of isolation" failure mode in [13]), using, as input predictors to a NN, the electrical and environmental signals correlated to production (e.g. internal inverter temperature, accumulated active energy of the inverter, irradiance, ambient temperature, etc.) and as a target the power production at the AC side of the inverter [13]. However, such methods fail to provide a comprehensive picture of the correlations among the component parameters. In addition, they cannot identify all the component failures, as their root causes may be classified according to their impact as affecting the system performance, the system availability and the cost of operations and reporting.

Profitability of a predictive service

Current literature regarding profitability of predictive service is still lacking and some revenue gain estimations have started to appear only recently. According to [14], application of a smart predictive service may increase the annual revenue of a typical standard-performing fleet of 100MW PV plants from €128,000/year up to €240,000/year and from €368,000/year up to €948,000/year for a low-performance PV portfolio. Considering a typical lifetime of 20 years, the cumulative impact will range from €2.5 million to €20 million. Similar estimations are presented in [15], where a 2% performance increase of a 100MW PV plant leads to €500,000 of additional annual revenue and a €420,000 saving in the annual O&M activities. However, it is worth noting that these benefit analyses address a suite of tools which includes not only the application of machine learning-based models, but also additional performance trend studies

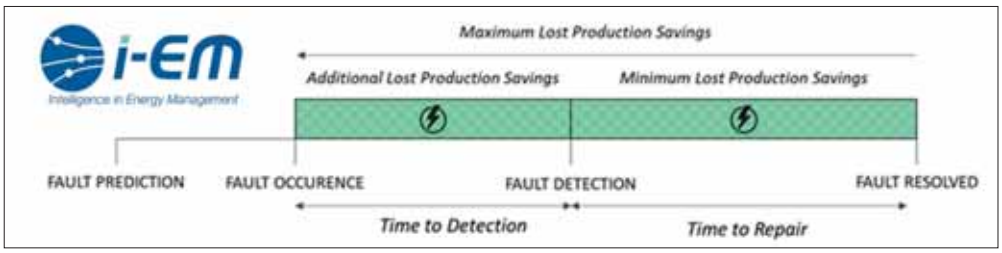

Figure 9. Fault events timeline. The positions of fault prediction by the predictive service, as well as the fault occurrence, fault detection by standard monitoring platform and nominal behaviour restored are shown. The predictive service allows a lost production saving from one month (assumed as the mean duration of time to repair) up to almost two months (assuming three weeks as the mean duration of time to detection according to current monitoring systems)

that support proactive maintenance. As a consequence, since predictive maintenance is not the unique benefit provided, the estimated values cannot be assumed as a precise indication of the profitability of a "standalone" predictive maintenance service based on machine learning techniques.

An interesting assessment of the maximum energy gain achievable, if a predictive service had been installed on-site and the ideal energy production instantly restored in correspondence of the fault prediction, is presented in Figure 8 of work [8]. On the left axis the energy yield with respect to the ideal case (i.e. where AC power is the theoretical one achievable according to actual irradiance) is shown as a function of time with and without the predictive service (here called SDM) enabled (blue and black curves, respectively). On the right axis the historical number of normalised daily fault occurrences is shown as a function of time (red curve). Such a number is computed according to the time duration of fault events recorded in the alarm logbook available for the PV site. The component under consideration is an inverter module of the same plant in Romania observed in Figure 7. As can be seen, if the predictive service had been applied in such a plant, energy yield would have been increased ideally by up to almost 10-15%, saving also the costs of inverter replacements and maintenance activities.

By considering a portfolio of PV assets and focusing on a predictive service at inverter level, the impact of its costs and benefits on the net yearly revenue gain may be assessed. Such benefits can be mainly grouped in decrease of revenue loss due to device downtime and reduction of O&M costs.

Figure 9 helps to address the impact of the first factor, depicting a typical situation encountered, with the predictive service anticipating the failure occurrence, unlike a typical monitoring platform where the failure is detected only after it has happened. In particular, a mean value of about three weeks has been assessed by considering standard operations activities. In addition, according to [16], the time-to-repair (i.e. intervention plus resolution times) is about one month. According to these assumptions, the predictive service may therefore enable saving periods ranging from one month (time-to-repair) up to almost two months (time-to-repair + time-to-detection). According to domain expertise, a further reduction of O&M activities cost of about 20-30% may be achieved.

Table 1 summarises the main hypothesis and shows the benefits provided by the predictive service, both in terms of revenue gain, ranging from €90,000/y up to €145,000/y, and O&M cost saving, ranging from €280,000/y up to €420,000/y (considering O&M activity costs of €14/kW). It has been assumed a portfolio of 100MW, a specific yield of 1,500KWh/KWp (utilisation factor of 17%), an energy price of €100/MWh, an inverter failure occurrence probability of 8% [12, 14] and a model sensitivity of 85%. In short, the total gain enabled by a predictive service ranges approximately from 2.7% up to 4.2% of the yearly net revenue of a solar asset.

Benefit Assumption	
Time to Repair	744h (1 month)
Time to Detection	504h (3 weeks)
Predictive Model Sensitivity	85%
Failure Probability	8%
O&M Savings	20-30 %
Benefit Evaluation	
Revenue Gain	*from* €90k/y up to €145k/y *
O&M Cost Savings	*from* €280k/y up to €420k/y **
Benefit impact on net revenue	*from* 2.7% up to 4.2% ***

Table 1. Benefit assumptions used for the evaluation of predictive maintenance service profitability and benefit values. The latter are reported both as absolute values and as percentages of the net revenue of a PV portfolio.

Internet of Things and the big data challenge

But why data are the new wealth just now? And how to extract value from such data?

Nowadays we live in the so-called era of the Internet of Things (IoT): a broad range of devices and objects are "smart", i.e. linked to the internet and to each other, and able to acquire and manage data. It is estimated that by 2020 the accumulated volume of big data will increase up to roughly 44 zettabytes (ZB), i.e. 44 trillion GB [17], due to the huge increase in things creating data and the refined granularity of data being produced. Big data are not characterised only by the Volume, but also by Variety, Velocity, Veracity, and Variability (the so called five "Vs" of big data"). Such data are generated by a great variety of heterogeneous sources, from social media to sensors and mobile devices, both in structured and unstructured forms. They are also collected at a high rate (velocity): every 60 seconds, it is estimated that there are 72 hours of footage uploaded to YouTube, more than 2 million Instagram posts and 204 million emails sent. In addition, data need veracity, i.e. they should be of good quality that is continuously updated in real-time. Finally, the meaning of data depends on the context in which they are collected, making important the use of technical domain knowledge (variability).

The IoT revolution occurs also in the PV energy sector: all components are now instrumented and data loggers allow the monitoring of many heterogeneous parameters thanks to specialised sensors. They include, for example, inverter internal parameters, generation data and meteorological data. Such data are typically pushed to a cloud server, which gives the flexibility of preserving a huge volume of historical plant data. The data are also stored at a local control room and can be retrieved in case of communication failure with the cloud server, thus ensuring reliable and accurate data availability.

But such a volume of data requires software and hardware infrastructure suitable for analysing in real-time this continuous stream of information in order to extract meaningful insights, and

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then convert such insights into actions useful to improve the overall business value. Application domains are manifold: transportation industry, media and entertainment industry, health industry, government industry, energy sector and many others. Here the big data analytics tools come into play, due to their capacity to handle large volumes of data generated from IoT devices. And this is also the right time to analyse such data by means of machine learning and deep learning techniques; indeed, the availability of massive amounts of data proceeds along with the advances in machine learning algorithms and the dramatic progress in computer processing capabilities.

Hadoop and modern big data platforms

It has been calculated that a PV plant, with an installed capacity of 500MW and single panels generating around 200W of DC power, produces almost 8GB of data every second [18]. Such a volume can be neither stored in conventional databases, nor processed by a single local computing resource.

In 2008 Yahoo released Apache Hadoop as an open-source project and in the last few years large companies have adopted it as a next-generation platform, collecting massive data assets in Hadoop Data Lakes. In particular, Hadoop is an open-source platform and framework for storage and large-scale processing of datasets.

Hadoop offers many advantages: first, it can store and process quickly huge amount of heterogeneous data and it can archive both traditional structured data and challenging unstructured data.

Secondly, Hadoop has an enormous computing power and may also handle virtually limitless concurrent tasks or jobs. In addition, it is fault-tolerant and flexible, since both unstructured and structured data may be stored without the need of pre-processing. It is finally low-cost and scalable.

However, while using Hadoop for broad predictive analytics, companies discovered limits in its use concerning both performance and complexity. For this reason, a new platform called Apache Spark has been developed on top of Hadoop, leveraging Hadoop's big data management capabilities while achieving higher performances by running predictive analytics in Apache Spark.

Many different Hadoop distributions exist. Top tier includes solutions such as Cloudera, Hortonworks, MapR, IBM and Pivotal. They may be deployed either on customers' premise, in a private cloud or in a public cloud. Additional cloud-based Hadoop distributions exist, such as for example Amazon Web Services and Microsoft Azure HD Insights: unlike the previous distributions, such solutions run on public clouds and cannot run on the customer's hardware.

Paradigm shift: "data to computation" to "computation to data"

The complexity of using Spark and Hadoop to develop predictive analytics applications on large data assets, however, makes it challenging for companies to find or train human resources with the right skills. For these reasons, recently Microsoft has launched a new flexible enterprise platform called Microsoft Machine Learning Server (previously known as Microsoft R Server), which allows R developers to conduct the different steps of data science, from data exploration to predictive modelling, on large data assets stored in Hadoop, but without the need to become Hadoop experts themselves. The solution is the result of the acquisition in 2015 of the company Revolution Analytics by Microsoft and of further improvements of the product already available in that year. A recent version supports also the Python language. Thanks to the availability of the RevoScaleR Package, such language may manage large datasets and develop machine learning algorithms without the need of loading them all at once in the memory. Additionally, it makes possible to run code in an efficient, parallel and scalable fashion, finally deploying the model on a remote server such as SQL Server or a Spark cluster with minimal effort, thus reducing the time-to-market of the product or service developed. R Server therefore shifts the computation methodology from the traditional paradigm "Data to Computation", i.e. data moved from the environment where they reside to that of computing unit, to the new one "Computation to Data", i.e. computation performed just where the data live. In this manner, the time to move data is avoided and, additionally, it may be taken advantage of the computing power, as well as of the scalability of the environment where data are located.

Future trends

As discussed, the digital revolution of the PV sector is just happening: due to the need of reducing the cost of maintenance activities, solar operations and maintenance vendors are now turning to innovative technologies to remain competitive and profitable. In addition to big data analytics, deep learning and augmented reality will be the next key innovations to enhance maintenance capabilities, by improving the efficiency of operational processes, and by strengthening the digitalisation process. PV systems require frequent diagnosis to analyse the effect of external agents on PV panels. Thermographic inspections are the most effective methods for PV module failure detection. However, manual analysis of massive amounts of images acquired by cameras mounted on drones or car roofs and resulting from inspection of large-scale PV power plants is time consuming and prone to human errors. Deep learning, which is a machine learning technique generally applied to classification and/or detection (i.e. classification and localisation) of objects inside images, may help in automating such analysis and locating earlier potential defects at cell, module and string levels such as hot spots, cracks or abnormal soiling, as well as classifying failures in real-time.

Automatic object detection may be combined also with augmented reality (AR) tools, in order to overlay on the detected asset its corresponding virtual object and support maintenance activities (see Figure 10 [19]). In particular AR and virtual reality (VR) tools have multiple benefits in maintenance activities: they reduce downtime costs, due to quicker intervention times, and enhance employee capabilities, by augmenting and speeding up their cognition by showing only the necessary information of the environment all around. In addition, they decrease travel costs worldwide of maintenance teams, allowing the operator to request online real-time involvement of remote specialists or to request online big data analytics processes to run on the interested site. Finally, they reduce costs and improve the effectiveness of training courses, allowing trainees to learn in an immersive VR environment synthesised from reality: for example, initially projecting augmented reality contents on to a virtual environment while the trainee is in its office and, as a second level of training, showing AR

Figure 10. Augmented reality for assistance in maintenance operations [19]

contents over the real environment as detected from a camera on the helmet of the user. An example of ARVR generic Software Development Kit (SDK) is that provided by Mapbox [20] that, based on most widespread 3D engine and libraries like Unity or OpenGL, allows developers to use their APIs with pay-per-use-fees (free for emerging applications). Instead Reflect Remote [21] is an interesting product of AR solution for remote assistance employed together with holographic or 3D glasses.

Additionally, Data Analytics as a Service (DAaaS) is now starting to attract attention also in the renewable energy field. It is an extensible analytical cloud-based platform approach where various tools for data analytics are available to users and can be configured by the users themselves to process and analyse massive amounts of heterogeneous data. It includes mainly two elements: a run-time environment, i.e. a platform for processing data, and a workbench environment where the users, from a skilled data scientist to a business user or a maintenance operator, may configure the system by using a set of analytics tools to handle different use cases. In this manner, it is possible for a maintenance team, which does not want to share their technical knowledge with external data analytics vendors, to analyse, interpret and predict underlying patterns in data even if they have no specific data science expertise. The direction is clear: make data science more democratic allowing everyone, even those not having a data science background, to analyse data and make predictions by means of automatic models built on raw data. Scientists at MIT are recently researching on this topic [22].

The future is just around the corner. ■

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Turn to next article, p.32, for insights into how the solar industry is taking advantage of the opportunities offered by big data

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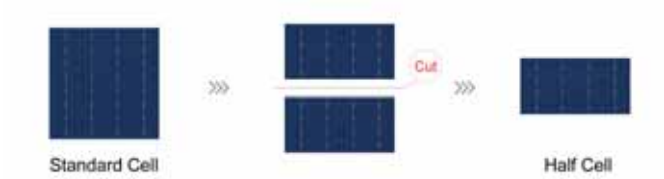
Jiangsu Seraphim Solar System Co., Ltd. ("Seraphim"), a world-class solar product manufacturer in China, has announced the availability of a new cost-effective Blade Bifacial module, integrating industry-leading half-cell technology and latest bifacial PERC cell technology into a single powerhouse PV product. A well-known innovator, Seraphim believes that the Blade Bifacial—with its low internal power loss, reduced hot spot potential, higher power output and improved reliability—will be another disruptive product after the success of its "Eclipse" and "Blade" modules, two previous bestsellers.

COMBINING DIFFERENT CELL TECHNOLOGIES TO PRODUCE A NEW MODULE STANDARD

Seraphim Blade Bifacial modules combine state-of-the-art Blade half-cell technology with bifacial PERC cell technology, creating a module that incorporates all the advantages of both technologies.

Half-cell modules, as the name implies, uses cells that are precision laser-cut into two identical pieces, which are then encapsulated within the module glass. Cutting cells in half produces lower current, which in turn reduces "Cell to Module" loss and increasing power output. The new module design is engineered with additional space between each cell to increase optical utilization. Compared to traditional modules, half-cell modules have lower current and series resistance, which work together to minimize mismatch losses, internal power losses, and shadow effects.

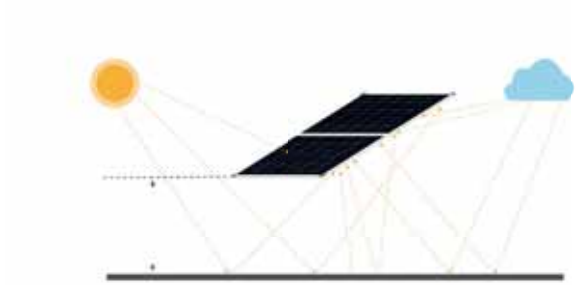


Blade Bifacial modules generate their additional electricity using scattered and ambient light that hits the re-designed rear side of the cells. Depending on the albedo of each project site, the extra power generation ranges from 10-to 30%, greatly reducing balance of system (BOS) cost and the levelized cost of electricity (LCOE).

Laboratory test results show that the bifacial factor of the Seraphim Blade Bifacial modules is at least 75%, making this module extremely cost-effective. For the high-performance and extra-reliable Blade Bifacial module, Seraphim provides an extended 30-year power warranty, five years longer than other products.

REACHING FARTHER TO ACHIEVE MORE

The new solar module uses 2.0 mm double AR coating tempered glass, compared with the 2.5 mm glass used by most PV manufacturers. That means the Seraphim Blade Bifacial module is lighter, reducing transportation costs and installer fatigue. For this bifacial half-cell module, Seraphim specifies the rail mounting method to guarantee its static load standards of 5,400pa. Double glass module advantages are a lower microcrack rate, excellent fire resistance, insulation performance and weather resistance, along with prolonged service life. The excellent temperature coefficient means increased production, even on the hottest days of summer.



The Blade Bifacial module demonstrates how Seraphim works hard to offer exceptional value to global customers. Seraphim's mission of innovation is trailblazing the fast road to a green energy future.

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Embracing the future

Digitalisation | As outlined on the previous pages, although still relatively embryonic in the solar industry, big data-based analytics innovations are already being deployed. Representatives from Enel Green Power, Aquila Capital and Pöyry discuss where their digitalisation efforts have so far been focused

Credit: Aquila Capital

Greater scale, greater precision

The growing PPA market will drive greater take-up of big data-based asset management tools, say Saul Butt, investment associate, and Christian Ahrens, head of asset management photovoltaics, at Aquila Capital

Big data and predictive analytics, together, offer a means to apply scalable maintenance solutions with more granular precision, quantifiable insight into operational amendments and early warnings, allowing managers to be more proactive in their duties.

Big data, naturally, is the resource upon which these new insights into PV assets' operational performance is founded. This area has changed significantly on two fronts: 1) the amount of information collected; 2) the variety of data sources becoming available.

The depth of information now available to analysts has increased drastically. The costs of sensors and the storage of data have fallen precipitously over the past decade and consequently a lot more data is being retained in a way which is easily processable. Additionally, more advanced monitoring systems have been included into the system architecture of inverters and sensors are being placed upon each PV panel to test operational performance. This allows the asset manager a very deep overview of the best and worst performing panels in a PV farm and can allow them to undertake further exploration or rectification as necessary.

The breadth of data allows for a more comprehensive understanding of asset performance, whereby aspects such as weather can be considered, allowing a fuller context surrounding fluctuations in production volumes.

With this increasingly detailed historical backlog of information, highly accurate and sophisticated statistical models can be established to develop insights into the key factors driving PV performance. From these models, optimisation initiatives can be implemented or data can be extrapolated into the future to predict the likelihood of events occurring. With probabilistic models in place an expected value calculation can be undertaken to understand whether preventative measures should be completed. This adds value by reducing O&M costs during the lifetime of the project. The closer monitoring of single components allows a better and more reliable tracking of quality issues and reduces spare part cost.

Big data and predictive analytics open up new opportunities for solar plant management

In a more generalised sense, once data is being collected and statistical models are put in place it allows asset management to run automated performance reviews which are scalable, cost effective and should result in improved performance.

We are currently checking the suitability of single-component sensors in field tests, as well as working with component producers to shape the IT environment for our needs. Furthermore, we are in the testing phase for analytical software, with the target of getting on time recommendations for our O&M providers to enhance the performance of our projects.

In a first step, we are going to be better informed regarding the standard issues like soiling and shadow issues, enhancing production and therefore revenue. Furthermore, a tighter monitoring of single components will allow a better quality management. The introduction of the analytics software will indirectly decrease the cost of the asset management, increase the efficiency of the O&M provider and thus reduce the overall O&M costs. In a PPA market, in some cases there is a contractual agreement that the producer guarantees to deliver certain amounts of energy to the off-taker within a given timeframe. The producer has to accommodate a trading capability to act on the spot market. The more the producer is able to forecast its production, the less risk he has to take on the spot market.

Risks

There are of course some risks associated with embracing these new technologies:

1) Insufficient data to establish actionable insights – A fatal flaw in developing any analytics initiative would be to utilise predicted results from a model trained on a limited set of observations. Utilising large data sets is key to establishing a suitably accurate statistical model to generate insights to act upon.
2) Overly complex models – when histori-

cal data is limited, it may appear that utilising larger models with a greater number of independent variables would be a solution to improve the model. However, this could simply be a case of over-fitting the model, where the model itself can very closely model the training data, but would likely not be generalisable on test data or in future occasions.

3) By neglecting the additional costs for implementing and running these new tools, the positive effect can be erased.
4) By implementing these measures, the asset manager is also bound to act on results of the analysis. This requires in some cases additional resources to handle the flow of information and recommendation.

Big data's future

In some years' time, and with a growing PPA market, the big data trend will become more and more significant.

As has been widely discussed the development of predictive analytics and big data will ideally lend itself to more accurate and nuanced predictive maintenance. This could potentially extend to the modelling of the effective lifetime of the asset, such that it becomes clear exactly how long assets on a PV farm will be productive.

Further applications could be based on weather and topographic analysis of PV plant locations. This could allow investment managers to deepen their project due diligence, considering how a project's geographic location or surroundings will likely support its performance.

The use of predictive analytics will be essential in effectively deploying energy reserves as the propensity of battery storage incorporated onto PV plants increases. In order to maintain the rollout of PV projects, the impact of production correlation on market prices needs to be, to the greatest extent possible, mitigated. This will be achieved through appropriately reducing simultaneous energy injection into the grid and increasing it at times of high price or demand.

The increasing number of sensors on plants, along with live streaming of data (likely to improve significantly with the 5G rollout) allows asset managers to be more cognisant of emerging problems and oversee a larger number of plants simultaneously. This should allow asset managers to scale their portfolios without becoming constrained by employee capacity so quickly, allowing for leaner higher margin operations.

Preparing for the digital age

Stephen Woodhouse, Alessio Giuffra and Lynn Dimayuga of Pöyry, and Horst Dulle of Pöyry Management Consulting, look at the many benefits of digitalisation in the solar industry

Digital applications in energy have the potential to transform the sector, by delivering greater efficiency throughout the entire supply chain, by revolutionising companies' relationships with their customers and by unlocking the potential for deep decarbonisation through automating flexibility to match production patterns of renewable energy. The earliest digital breakthroughs are in predictive asset maintenance, improved forecasting and real-time monitoring, and digital tools that aim to attract and retain customers. Drones and UAVs for remote inspections, as well as process mining and text mining, are also helping to improve efficiency. Digital twins allow 'what-if' and predictive analysis to be performed on virtual representations of physical assets. Artificial intelligence is unlocking value almost everywhere it is applied.

While still a nascent technology, predictive asset maintenance is becoming one of the more mature digital technologies in the energy sector – and it tells us important things about the changes to come. Today, predictive maintenance is at the cutting edge, but tomorrow it will be part of a much bigger system. We are still at the cusp of what the Industrial Internet of Things (IIoT) can do.

The guiding star for all "industry 4.0" technologies will be data. The data that these IIoT sensors gather will enable companies to identify and resolve problems remotely, allow engineers to deploy their time more efficiently and, eventually, machine learning might help plants automate simple engineering jobs. It will also allow plant owners to gain insights into their own operations and identify how assets can be used more productively.

Digitalisation in the solar industry is of major importance for different aspects.

Predictive asset maintenance: Simultaneous digital collection of information and data from different power plants across several countries with a certain level of details (strings, inverters, Scada, etc.) can be processed to assess each power plant's behaviour and evaluate any underperforming assets in operation. Big amounts of data can be quickly and accurately processed so that standard maintenance or alternative maintenance approaches can be evaluated and applied to increase each asset's performance. In addition, PV panel cleaning, for instance, can be suggested and predicted by the analysis resulting from a comparison of energy losses in a specific moment with cleaning costs.

Centralised control room: One of the most important deployments of digitalisation in the solar industry is related to the creation of a "centralised control room" (CCR), allowing for operation supervision of each power plant by remote in real time through a centralised, dedicated team with a comprehensive data analysis tool available to hand. One of the main advantages is that you will be able to plan maintenance, specific site visits and inspections, and avoiding permanent workers or staff at site, overall vastly increasing the site's performance. During the inspection by local staff, a virtual remote camera mounted on their helmets or glasses will facilitate the supervision remotely and allow a quicker and more effective identification of issues and subsequent solutions.

One more useful application is the use of drones in order to provide visual inspections and thermo-camera analysis, helping international experts to identify all critical panels without necessarily visiting the site.

Big data analysis for energy trading: Analysing big amounts of data is useful for clusters of PV plants. For example, intraday meteo forecast (15-20 minutes) and expected power production compared with declared power production will be used to reformulate strategies to sell energy in the market and gain better revenue.

Incremental steps

Naturally the focus of these technologies should not be the technology itself, but rather the expected outcome. Utilities are looking at improving their predictions, minimising costs or reducing downtime, and want to empower the business functions to engage with technology to find the most suitable solutions. When we work with customers along their digital readiness journeys, we often see that the first steps that help business units discover new technological capabilities relate to small process improvements. Only once a broader group of key personnel has gained first-hand experience can these organisations improve key services or even business models.

Big data in utility-scale PV power plants

Gantner is a leading global full-service provider for the monitoring of utility-scale PV power plants and part of the Gantner Instruments Group, founded in 1982. Gantner develops and produces tailor-made solutions for the measurement and control of all required parameters in such plants. All these solutions are supported by local teams and partners worldwide.

Recently, we have experienced significant PV growth in most geographic regions. With declining costs for solar energy generation and increasing global awareness of the benefits of clean energy, we are confident that this trend will continue over several years. Now, the use of solar energy is not only justified by the benefits to the environment but has also become economically competitive.

Gantner has references in 34 countries, for example well-known projects such as Benban/Egypt (230MW) and the largest solar power plant in Central Asia in Kazakhstan (100MW) were equipped with our complete monitoring and control solution.

The solutions are based on 37 years of know-how in the development of measuring hardware and software.

The Gantner hardware portfolio includes string monitoring devices, DC and AC combiner boxes, weather stations, power quality meters, data loggers and the power plant controller "Q.reader".

Q.reader is a datalogger which performs the logging and control of all required PV plant information: string level current and voltage, inverter data, batterie (BESS), meteorological data, grid measurements and other state variables (e.g. switch gear and transformer status). Simultaneously it acts as power plant controller for the grid quality. Its accurate data acquisition is based on the industry-leading technology of the Gantner Instruments Group. The Gantner Instruments Group offers high-speed (100,000 samples/second) and high-accuracy data acquisition products required in today's demanding environments. The products exhibit the best in performance and flexibility yet remain simple to operate and easy to understand even in the most complex applications.

The well-engineered hardware that has been optimised for each application is a reliable basis for further analysis of the gathered data.

The base tool for data analysis is "Gantner.webportal", an independent real-time analysis platform for data acquisition, data storage and control of PV power plants. It is a cloud-based "Software as a Service" (SaaS) solution. Gantner's goal is to provide an innovative performance monitoring system to detect performance losses, failures and degradation mechanisms at an early stage, which will significantly improve and ensure quality of operation of grid-connected PV systems in order to fulfil and guarantee owner/investor expectations.

A challenge is to handle the big data accumulating over a period of years or even decades and keep it available on a 24/7 basis.

The massive amount of data can be seen at the recent 230MW Benban project. The data logger acquires 70,000 measured channels. "Gantner.webportal" adds another 140,000 arithmetic channels. This includes standard arithmetic functions like Performance Ratio on every level, variance and normalisation. Over 20 years the data volume sums up to 8TB at 1 minute data resolution.

To meet this challenge Gantner turned to a combination of Apache Kafka (data streaming) and CrateDB (distributed SQL database built for IoT/industrial use cases). The company uses CrateDB for real-time hot storage and Kafka for cheaper, file-based storage. Open interfaces (APIs) complete our system and enable interaction with external systems and integration into company wide data warehouses.

To turn measured data into valuable information we are using state-of-the-art technologies such as machine learning, neuronal networks and genetic algorithms.

This information helps to reduce levelised cost of electricity (LCoE) by increasing the lifetime output of installed systems and to design more efficient and reliable power plants in the future.

Gantner instruments

Monitoring and Control of Utility Scale PV Power Plants

- 100% Made in Germany
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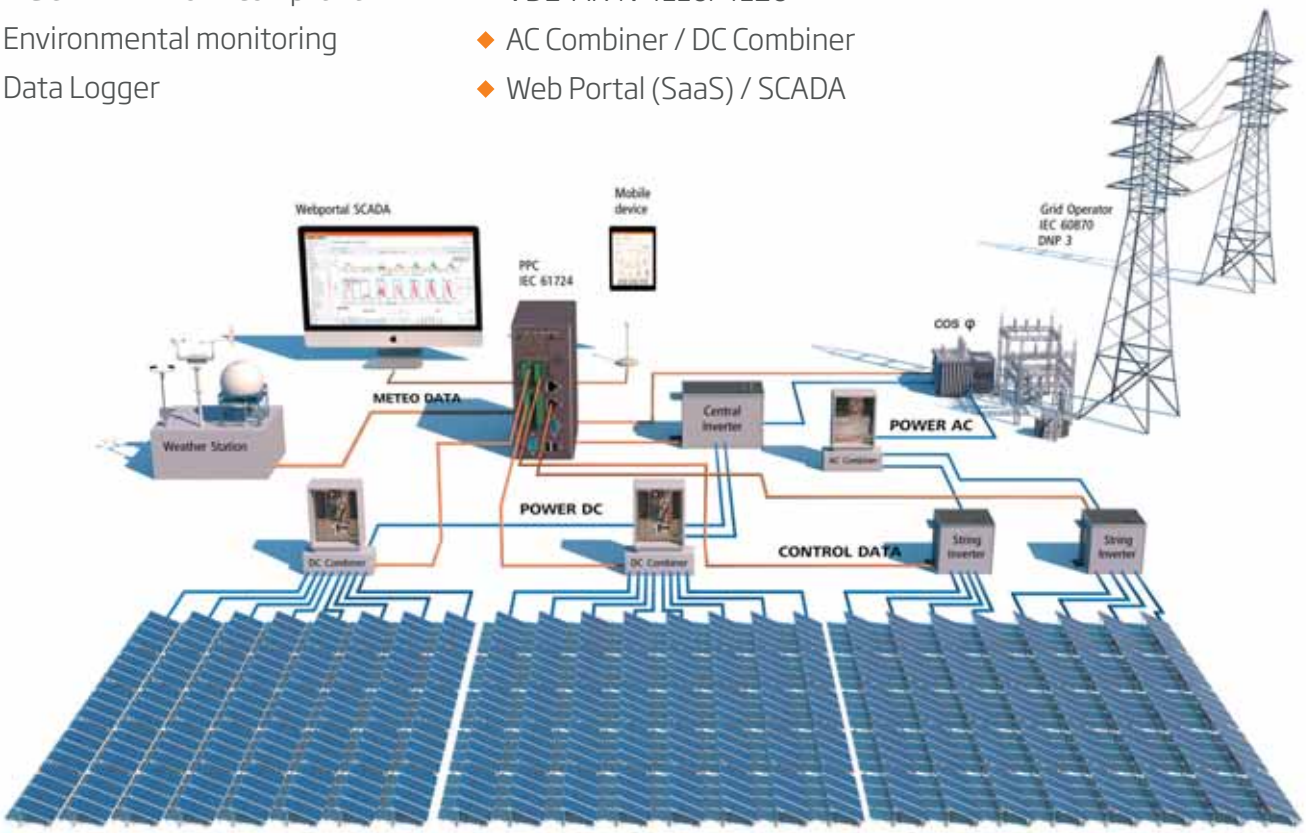
- Environmental monitoring
- Data Logger
- PPC Power Plant Controller
- DNP3/IEC 60870
- VDE-AR-N 4110/4120
- AC Combiner / DC Combiner
- Web Portal (SaaS) / SCADA
- RAS (remote access)
- World-wide Service



Top Projects in 2018

Complete monitoring and control for

- 230 MW solar project in Egypt
- 150 MW ground mounted systems in Germany
- 100 MW in largest solar project in Central Asia

AC Combiners / DC Combiners

- 120 MW in largest solar project in Israel
- 90 MW in projects in Australia
- 100 MW in the Netherlands

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Data analytics and predictive analytics technologies can add value in a wide range of applications throughout the value chain, from customer segmentation to operational excellence, from dispatching optimisation to operations and maintenance support. Different organisations and often different departments have adopted quite a range of innovative approaches to help them solve their specific needs. Most of the time the issues are very similar, but the current situation is very different from one organisation to another and solutions that add great value in one organisation are not necessarily suitable for another. A key success factor is therefore more about driving quick and effective progress and unlocking innovative ideas.

When working on digital transformation with our clients we don't see the biggest disruption from off the shelf solutions, but rather from innovative initiatives that empower the digital literacy of the entire organisation.

We conduct a "digital readiness check" to show a company where it is in comparison with best practice in the market. These results help identify measures that can elevate an organisation to high-performance status via digitalisation.

Drivers of change

Digital investments in the solar industry should start in the private sector and normally they are always driven by the biggest international IPPs or funds interested in increasing their revenue. In the PV sector, and in those countries where grid parity has been reached such as Australia, Germany, Spain and Italy among others, the convenience of increasing revenues from a more accurate and precise maintenance and operation, as well as a better selling strategy become of fundamental importance. This will undoubtedly be the driver of change in the solar industry, with significant investment predicted over the next couple of years.

Better results, lower costs

Luigi La Pegna, head of operation and maintenance, Enel Green Power says digitalisation is helping the Italian developer improve O&M processes while reduce operating costs

Digital technologies, together with even more sophisticated cloud computing capabilities and analytics, all present emerging opportunities to reduce operational costs and to increase asset performance as well as safety for workers.

The standard Enel Green Power solar O&M process is already highly digitalised. Our monitoring systems measure and process, in real-time, a huge amount of operative data from small- and large-scale solar plants. Advanced software (Computerised Maintenance Management System – CMMS) is also used in the management of operational data (interventions, reaction and resolution time, cost of interventions, logistics, etc.) with the aim to improve time of operation and maintenance of our asset and, finally, to reduce overall operative costs.

We use drones to capture visual and infrared thermal images of modules, wiring and other plant components. These data are stored and processed to detect anomalies and trends.

We are working on the development of algorithms to predict module degradation, component failure (at inverter or combiner box level) and, in general, to predict as much as possible all unplanned interventions and maintenance, with the main purpose to reduce the number of periodical visual inspections.

Specifically, we are using sophisticated algorithms developed internally that are able to predict soil quantity and debris on solar panels and to optimise cleaning.

Operational costs, performance improvement, Health, Safety and Environment (HSE), as well as sustainability are all key to addressing the implementation of every kind of innovation in our O&M processes. Big data and analytics are expected to generate improvement in all the above mentioned areas.

Advanced Internet of Things platforms and low-cost wireless technology can boost data collection at plant level. However, the solar industry is not currently fully leveraging on big data and predictive analytics, which are the only systems allowing for the operation of new, large-scale solar plants. In most cases, the main obstacles to widespread adoption of these innovative technologies are plant connectivity, which is difficult to extend to the full power units when the solar plant is spread across a wide territory, and the availability of reliable equipment at reasonable cost.

At Enel Green Power we are working on a programme called "Ro-boost", with the aim to increase the development and implementation of automated and robotic applications in O&M processes, not limited to solar projects. These applications include fully autonomous drones, cleaning robots and grass cutting machines. As such, our projects will employ an increasing number of "digital workers" through mobile technologies and smart glasses applications. Furthermore, technologies like augmented reality or virtual reality will support training programmes and will help best practice sharing. ■

Credit: Enel Green Power

Enel Green Power is developing algorithms to predict all unplanned interventions and maintenance across its PV fleet

Regulatory roadblocks ahead for EU subsidy-free solar

Policy | Despite its coming of age from the days of state support, European PV remains at the mercy of regulatory whims. José Rojo examines how bureaucracy, grid bottlenecks and other pitfalls of government action can cripple solar as it becomes the driving force of a clean EU energy system

Credit: BayWa r.e.

Goals for EU-wide installed solar capacity to double by 2030, and double once more between then and 2050. A widely lauded EU legislative framework setting how the technology must, alongside all other renewables, accomplish such explosive growth. Countries translating the big-picture EU vision into the nitty-gritty of predictable, hard policy plans. Nosediving technology costs curbing the need for subsidies. Is European solar poised for a golden age, mere years after hitting rock bottom?

The view on the ground is, as it turns out, not so rosy. The hundreds of attendees pouring into the Large Scale Solar Europe 2019 summit in March were, in equal measure, enthusiastic about the subsidy-free potential and clearheaded as to the trials ahead. Whether headline pledges are accompanied by a genuine will to bring down structural obstacles was a question looming over the Lisbon event; Portugal, the host country, was openly criticised for pushing for a solar surge – from 572MW in 2018 to 8.1GW-9.9GW by 2030 – without solving grid and permit issues first.

The questions extended well beyond Europe's westernmost state, however. Live audience polling found inadequate regulatory frameworks are seen as the top obstacle (53%) to zero-subsidy solar across all countries, far ahead of the lack of bankable PPA offtakers (26%) or inexperience with PPA negotiations (13%). From developers to investors and banks, all constituents of the solar ecosystem used panel discussions to voice regulatory concerns of some nature. The industry's fierce fight for independence from subsidies has left it all too alert to the dangers of government intervention.

The 175MW Don Rodrigo project in Spain has been a standard bearer for European unsubsidised solar

All eyes on Spain

That misguided policy can hurt is a lesson Spain, of all countries, is not likely to ignore. The country may be today a byword for unsubsidised potential – event polls placed it as top EU destination on this front – but few can have forgotten how quick and intense the collapse was when politicians scrapped feed-in tariff (FiT) support in the early 2010s.

Though far less of a threat, the Spanish current regulatory framework is not roadblock-free. José Donoso, head of national PV association UNEF, tells *PV Tech Power* subsidy-free projects in particular can be held back by the country's power market design. The marginality principle

Credit: UNEF

UNEF's Donoso is wary of the potential for the grid to hold back Spanish solar

of auctions – where all developers are contracted at the highest price of all tabled bids – muddles the price signals investors receive and raises financing costs for the merchant side of projects, Donoso explains.

Beyond the merchant sphere, PV projects of all stripes face a controversial 7% energy generation tax, applicable again after the end of a six-month freeze. The levy can significantly eat into developers' margins but will be, UNEF hopes, quashed by an EU court ruling expected in months, Donoso says.

Elsewhere, land procurement and project structuring are not an issue as much as a time-consuming administrative process. "Energy and environmental bodies need more resources to deal with the current avalanche of projects," Donoso says. UNEF is keen on decentralisation: the association believes allowing regions to directly green-light projects until 200MW, up from the current 50MW limit, would help clear the backlog.

Legislation specifics aside, Spain's old ghost – that of political disruption – lurks closer once more. The renewable vision of Environment minister Teresa Ribero, widely respected by solar players approached by *PV Tech Power* at the summit, is in the air after a snap general election was called for 28 April. Judging by recent polls, a triple coalition could bring the Popular Party – the author of the FiT u-turn years back – closer to power; if it wins, whether it will stick to Ribero's draft plans for 37GW of solar by 2030 remains anybody's guess at this point.

Italy plays catch-up

The zero-subsidy spotlight has mostly ignored Italian PV to date but the picture is slowly shifting, Bird & Bird partner Pierpaolo Mastromarini says. According to him, the phase-out of subsidies in the early 2010s brought large-scale deployment to a screeching halt. Deterred by high capex costs, investors shunned the country for years but are now looking anew as the economics improve. Although still muted, the budding pipeline now features unsubsidised Octopus projects, with PPAs signed with Shell and energy trader EGO Group.

Judging by Mastromarini's words, the regulatory roadblocks going forward are numerous. Projects typically wait up to two years to be authorised and face the prospect of uneven, unpredictable regional and local rules, such as Sicily's attempt – unsuccessful for now – to limit ground-mounted projects on farming land. Diverging grid dispatching prices, the costs and complexity of acquiring land and "unstructured" Italian developers add to the problems. "[Local developers] may not speak English very well, or promise investors results that may not be delivered," Mastromarini says.

Regulatory risks too are apparent across Europe's less-sunny reaches. Bird & Bird senior associate Levent Gürdenli says the planning and grid connection process in the UK – home to 4.2GW in unsubsidised large-scale projects – is "well understood" but acknowledges impacts from certain policy swings: behind-the-meter schemes, for instance, will be particularly hit by the embedded benefit phase-out under the Targeted Charging Review. There is also Brexit, the very embodiment of regulatory risks, to be considered; Gürdenli lists import tariffs, employee visas, FX rates and power price volatility among the potential impacts.

Cracking the PPA code

No regulatory barrier, not even Brexit, can match the long shadow cast by PPAs over the subsidy-free solar debate. Success bagging these deals is typically seen as dictated by market dynamics and negotiation skills, not government intervention. However, as evidenced by conversations for this feature, a host of factors in national frameworks – from macroeconomics to the legal fine print – can hasten or hinder the journey towards the PPA signing point.

Take Germany. The country may have built a colossal PV industry – 46GW at IRENA's latest count – off the back of a solid FiT scheme but has yet to become a "corporate PPA place", says Bird & Bird counsel Lars Kyrberg. German operators, he adds, are "warming up" to the approach but "minor barriers" exist in an otherwise conductive framework; one is ambiguity as to whether corporate PPAs are legally compatible with FiT support, a mix favoured by corporates.

The Netherlands, these days often singled out as a PV market-to-watch, retains generous subsidies under the SDE+ programme but also offers strengths for those mulling the subsidy-free route. According to Bird & Bird partner Sophie Dingenen, mandatory separation of commercial utilities and grid operators means corporate PPAs can be signed without the need of a traditional energy company; grid operators take care of sleeving, and balancing is handled by a specialist, she adds.

Her colleague Mastromarini paints a slightly more circumspect picture for Italy. The renewed attention from banks and investors creates hopes that the market for long-term PPAs will take off "very soon". However, he adds, many financiers are waiting to see the first subsidy-free projects realised. "They are at the window," says the partner. "A problem is the current PPA market is driven by pure traders, who unfortunately sometimes come with weak balance sheets."

Grid risks take centre stage

However helpful the regulation becomes, however adept solar players become at the PPA game, the zero-subsidy boom could falter if the grid cannot take it. Insufficient expansion was voted the top regulatory risk (50%) for unsubsidised projects at the Lisbon event, ahead of bureaucracy (30%) and policy swings (20%).

Congestion in Spain has been a particular concern for subsidy-free operators, with some predicting its grid could "collapse" if the current renewable pipeline went online. Operator Red Eléctrica de España (REE) pledged in late March €3.2 billion for grid upgrades between 2018 and 2022, earmarking €1.5 billion of the total for renewables integration.

UNEF's Donoso believes grid planning will be the "pivotal" element of Spain's ecological transition, which under draft plans has to deliver 37GW of installed PV capacity by 2030. "Flexibility and timeliness with grid concessions is key as the process is slow and troublesome," he says. "The administrative process for

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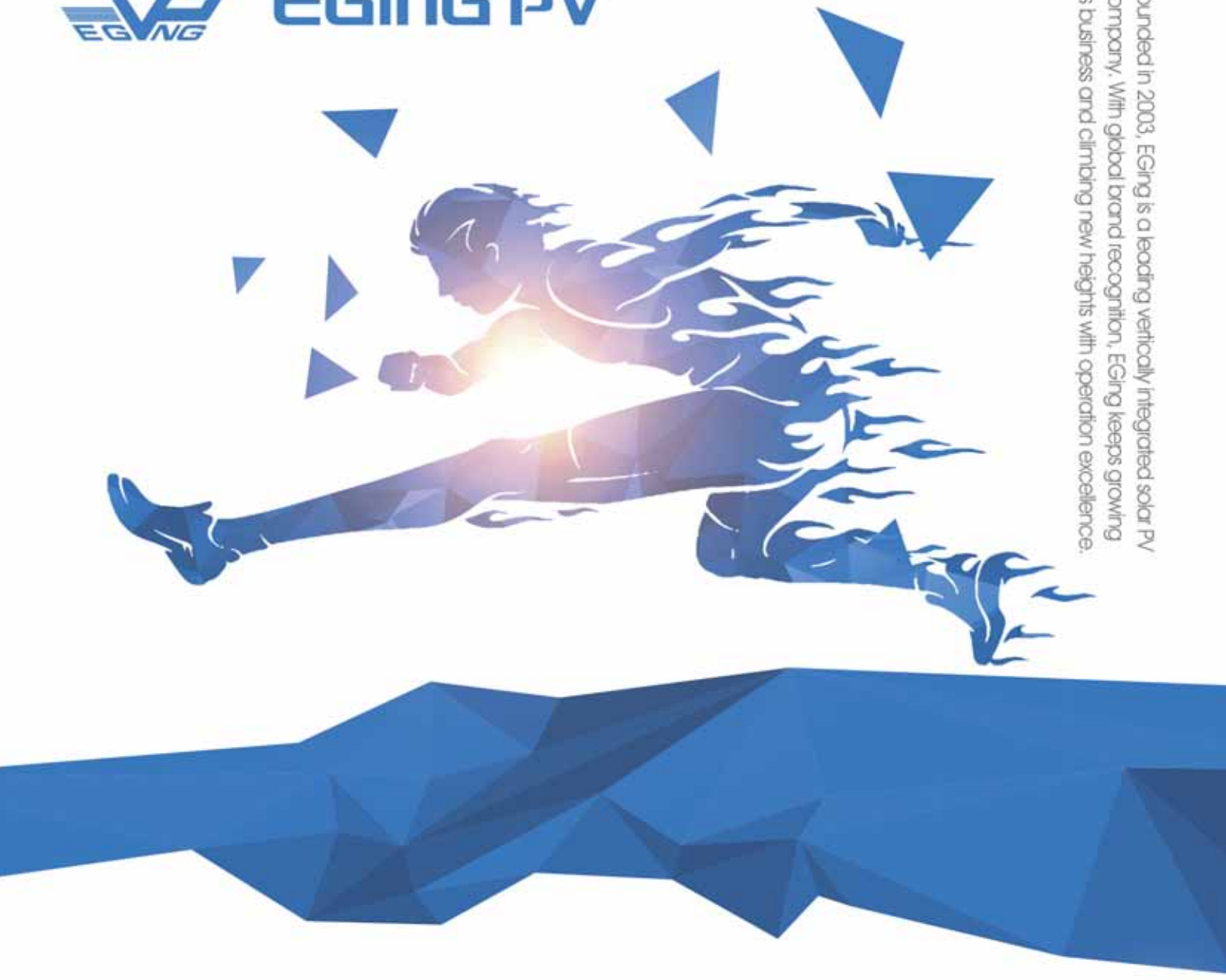

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new lines can take up to five years – this should be halved."

Donoso also calls for a crackdown on what he describes as "market abuse" by so-called hub interlocutors. Operators under this figure, created by the earlier government, are meant to quickly process connection requests but sometimes cause intentional delays to arrange auction-like proceedings, Donoso says, adding: "It's a position of privilege. REE should take control of the process."

The congestion conundrum

For its part, neighbour Portugal won't escape congestion risks either. Ângelo Sarmento, who sits on EDP's executive board, spoke at the Lisbon event of the challenges that will come with integrating the country's dispersed renewable generation with consumers clustered around the capital and the city of Porto. "Complexity will rise rapidly," he told attendees. "Intermittency will require investment in the networks, new technology and upskilling."

Others were explicit in their criticisms. "Grid and time-consuming permissions remain the top obstacle here…it doesn't come as fantastic news to hear the government is tendering anyway," said Dr Benedikt Ortmann, managing director and head of solar projects at BayWa r.e, as he explained why his firm opted for Spain as home to its unsubsidised 175MW Don Rodrigo project. Approached later by *PV Tech Power*, he warned one of Portugal's planned two auction modalities – allowing firms to bid for capacity in the grid – may result in "speculative" bids from players with still-hazy projects.

The grid concerns extend beyond Iberia, however. Bird & Bird's Mastromarini says Italy will need a "very detailed plan" to integrate renewables given the risks of local congestion, as well as costs from forced production freezes when authorities step in to resolve imbalances. Gürdenli says UK bottlenecks will likely worsen, particularly in Britain's southwest, amid pressure from EVs and other trends. UK policymakers, he adds, could help ease congestion by introducing a separate connection process for projects benefitting the grid, including those featuring grid-scale storage.

Across the North Sea, grid overcrowding is – together with opposition by protest groups – the top obstacle for Dutch subsidy-free solar, says Dingenen. "Capacity in congested areas is becoming scarce," she notes. Her German colleague Kyrberg says grid constraints in the country are more of a challenge for wind operators, whereas PV's issues are more localised. Unlike his peers, Kyrberg expects legislation to improve the situation. "In Germany, the operator must enhance the grid if there's a critical constraint for a renewable plant," he points out. "It's just a question of how long it takes."

PV: The Brussels view

European states may be tasked with the specifics of boosting PV in the decades to come but the unifying, big-picture vision will rest with Brussels.

Walburga Hemetsberger, CEO at SolarPower Europe, says the association is "very happy" with the direction of travel set by the European Commission. The heaps of legislation painstakingly proposed, negotiated and adopted over the past four years of Jean-Claude Juncker's presidency – including laws on renewables, energy efficiency and low-energy buildings – have been a "big success" for the solar industry, she says, adding: "The 32% goal for 2030 is very much what we wanted, while the governance framework will be instrumental to make sure countries deliver on it."

Speaking at the Lisbon event, Paula Abreu Marques, head of the Commission's renewable policy unit, outlined how the hundreds of pages of fresh legislation will help counter some of solar's *bête noires*. Countries will be banned from subsidy policy u-turns and forced to set out a clear auctioning timetable, as well as a single administrative contact point for projects. In addition, governments will have to quantify grid investment and will be supported by EU funding schemes as they work to upgrade the network, Abreu said.

Also, and in a nod to subsidy-free players, states will now be legally bound to remove "unjustified" barriers to national PPA markets. SolarPower Europe welcomes the move but acknowledges there are "a lot of question marks" over how the barrier-removal will work out in practice, says Hemetsberger. Her Spanish counterpart Donoso is not too keen on government intervention. "Spain lacks specific legislation for PPAs but we'd rather it stays that way – the risk is to end up with something worse," he says.

Credit: SolarPower Europe

Hemetsburger is keen to see the details of new European policies once the new executive is installed

An EU vision for solar

Whatever its victories, Jean-Claude Juncker's Commission is fast approaching the finish line. The new EU executive resulting from fresh elections this May faces an extensive list of asks from SolarPower Europe: a 20%-by-2030 solar target, together with 30 million solar roofs and 300,000 solar jobs by that year.

The new Commission is likely to sympathise with the demands – Abreu's Lisbon presentation showed it assigns a "central" role to the industry – but will have plenty to worry about other than PV. Brexit aside, the open fronts include economic deceleration, citizen unrest, the rise of populism and rebellious governments in Rome, Warsaw and others.

Behind-the-scenes conversations in Lisbon showed few believe the EU's structural woes can, however pressing, become a direct threat to subsidy-free solar. However, a reliance on free-market conditions and investor confidence means the industry could become a collateral victim of precisely the macro-instability experts warn is brewing in the bloc; bankable PPA arrangements could become even rarer if the Italy-driven Eurozone crisis some are now predicting comes to pass.

Whichever Europe emerges the other side of the current turmoil, the solar industry appears ready to continue the dialogue. "Who knows? Polls are polls, but we do very much hope we'll have a constructive European Parliament and Commission after the election," says Hemetsberger. "It's crucial that legislation continues bringing the European idea forward – this is not just about renewables but also ensuring Europe reaps social and economic benefits from the transition." ■

Turn to p.62 for further insights into the post-subsidy financing of European solar

China's bid to fill policy vacuum

China | Slowly but surely, China's solar policy void is being filled with a 30GW auction at the heart of it. Carrie Xiao digs into the details as the draft proposals take the first steps towards official status

Credit: JA Solar

The long-awaited new PV policy in China has not been publicised till now. Thrown into confusion by the rumour mill, the industry could do nothing but wait.

Such vagueness has left China's recent PV market in a slump. Data released by China Electric Power Union indicates that in the first two months of 2019, China only added 349MW solar capacity while new capacity added in the first two months of 2018 is 1087MW, a 739MW year-on-year drop (68%)

China's PV market is highly sensitive to policy changes. Any significant policy released before grid parity policy would shock the whole industry. The introduction of the so-called "531" new PV policy in 2018 was blamed for the accelerated slowdown of China's restricted PV market. New capacity added throughout that year totalled 44.26GW, a 17% decrease year-on-year.

In mid-February, China's National Energy Administration (NEA), Development and Reform Commission (NDRC) and the Ministry of Finance organised a symposium on PV power generation management, seeking advice from industry enterprises, experts and third-party organisations on PV prices and scale in 2019. This new policy under discussion and its completion became the focus of all sectors of the industry.

On 12 April, the new policy paper for China's PV industry was finally released. The General Affairs Department of the NEA opened the "Notice on Solicitation of Opinions on Wind and PV Project Construction Management in 2019" for public comments. Although it was still a draft proposal, the fact it was released by the National Energy Administration makes it an official record rather than a paper only for discussion.

This official notice is basically consistent with the draft from February. The NEA has proposed to prioritise the construction of grid parity wind and PV projects, which met the standards issued by the NEA on 10 April.

Regional authorities must submit the first batch list of areas suitable for building wind and solar projects at grid parity by 25 April.

This document clarifies the timing and order of these project applications. In short, the provincial power grids will determine the unsubsidised projects by the end of April. The subsidised projects will be identified by the end of May.

New PV projects requiring national subsidy support are to be determined by a market mechanism and competitive bidding. Starting from 2019, the subsidised projects will be managed by categories, namely poverty alleviation, residential, ordinary power plants (about 6MW or more), distributed C&I (less than 6MW), national special planning or demonstration and inter-provincial power transmission channeling PV projects.

Poverty alleviation and residential projects aside, all other projects will be tendered locally on a competitive basis. The proposal mentions bids should clarify technical standards, environmental protection, safety and quality, and construction conditions among other requirements.

Proposed pricing policies catering to different types of projects have also changed in line with the above classifications.

According to the "Interim Measures for the Administration of Additional Subsidy Funds for Renewable Energy" formulated by the Ministry of Finance , the total subsidy budget for new PV projects in 2019 is RMB3 billion (US$450 million), of which RMB750 million (US$112 million) is used for residential PV projects (equivalent to 350MW). The competitive bidding projects will get the remaining RMB2.25 billion (US$336 million), not including the PV poverty alleviation projects.

Prices for poverty alleviation projects will remain unchanged at RMB0.65, 0.75 and 0.85/kWh.

Table 1: Proposed 2019 feed-in tariff policy for China's PV industry (draft)

Time and Method	Full tariff for centralised plant (yuan/kWh)		Decentralised industrial /commercial projects (power generated for self-consumption with surplus power sent back to grid) (yuan/kWh)	Residential PV capacity (yuan/kWh)	Poverty alleviation projects (yuan/kWh)
	Tendering and bidding score		Bidding score	No bidding	Fixed tariff, priced per different regions
Quarter 1and Quarter 2	Region I	0.4	0.10	0.18	Region I0.65
	Region II	0.45			
	Region III	0.55			
Quarter 3	Region I	0.39	0.09	0.18	Region II0.75
	Region II	0.44			
	Region III	0.54			
Quarter 4	Region I	0.38	0.08	0.18	Region III0.85
	Region II	0.43			
	Region III	0.53			

The full subsidy received by decentralised C&I projects (power generated for self-consumption with surplus power sent back to grid) is RMB0.10/kWh (US$0.0149). One cent will be deducted every quarter from the third quarter on. The price for fully subsidised C&I projects is based on that of centralised PV plants located in that area.

One cent will be deducted for centralised ground-mount plants every quarter from the second quarter on.

The adjusted subsidy arrangements and competition rules will undoubtedly bring about major changes in China's PV power generation management mechanism in 2019, thus affecting the whole market.

Shi Jingli, a researcher of the Energy Research Institute of the NDRC, offered her opinion of this document after its release.

"RMB2.25 billion will be used specifically to support competitive bidding projects, which are ranked from low to high nationwide based on the revised power price. 2019 PV pricing policy has not been issued, but the revised quotation will be used for project rankings," says Jingli. "Region I,II, III [based on irradiation levels], power plants and decentralised power plants will be assigned revised scores from top to bottom. Various projects in different regions are able to remain competitive and cost effective. The notice is consistent with previous benchmark power price and the February symposium draft."

Wang Sicheng, a member of Expert Advisory Committee of China PV Industry Association, had analysed the subsidies before. "If the previous draft was not changed, the total controlled amount of subsidy will be around RMB3 billion (US$447 million), which equals to 60 billion kWh priced at RMB0.05/kWh (US$0.007/kWh). Let's say the average utilisation hours of 1,200, it is expected that 50GW of capacity will be listed as subsidised projects through tendering. This number is quite considerable. Even if subsidy per kWh is controlled at around an average of RMB0.07, there will still be 30GW of capacity, large enough to maintain the stable development of the domestic PV market."

Project type		Prediction of installed capacity (GW)
Residential PV capacity		3.5
Poverty alleviation projects		2
Bidding projects	normal power plants, decentralised commercial/industrial	30
	national special planning or demonstration and inter-provincial power transmission channeling PV projects	3
Unsubsidised projects		2
Total		40.5

Table 2. Forecast of China's photovoltaic installation volume in 2019

Keeping everybody happy

It is difficult to take account of all the different opinions and finalise the policy. This is a multi-player game with many problems to be solved all at the same time. One of the key issues is subsidy, past and present.

What is the scale of subsidy required for PV markets in 2019? Now that the first problem has been solved, when will the subsidy in arrears be paid? This year's new policy will not only arrange the subsidies for new PV projects, but also solve the problem of subsidy in arrears.

Calculations from the Gofa Institute and the Green Energy Think Tank show that by the end of 2018, China's annual renewable energy subsidy gap is about RMB50 billion (US$7.4 billion) and the duration for subsidy in arrears is three years, totalling RMB150 billion (US$22.3 billion). Projects listed in the eighth batch of subsidy catalogues are not included. PV subsidies in arrears reached RMB80 billion (US$11.9 billion). Such a huge amount renders the problem difficult to be resolved in a short period of time. The related authorities hope that there will be a reasonable solution to gradually resolve the same issue for power plants already built.

Many mainstream companies in the industry reacted strongly towards this issue. Jinko CEO Chen Kangping said: "Subsidy in arrears restricted the further development of PV industry to a large extent and even threatened the survival of some power plant investors."

He called on the authorities to appropriately raise additional charge standards for renewable energy tariff and proposed to reduce subsidies for coal-fired power plants to make up for insufficient funds allocated to renewable energy.

PV Tech Power found out that the current additional charge standards for renewable energy tariff (to be collected by a fund for all power sales, power used by residential and agricultural production not included) is RMB0.019/kWh (US$0.0028/kWh), which has been implemented since January 2016.

Sungrow chairman Cao Renxian proposed to increase the charge standards to RMB0.029/kWh. "There are two reasons for the huge gap in renewable energy subsidies. First, current collection standards are comparatively low. It is difficult to meet the needs of renewable energy development. Second, the self-owned power plants have not paid the charge in full and have accumulated nearly RMB80 billion in arrears."

Cao Renxian advised that the authorities should intensify their efforts to complete collection of additional charges of renewable energy tariffs in arrears over the year as soon as possible and at the same time, collect the charge in full and on time from now on.

In addition to subsidies, the industry has also debated the scope of "Top Runner" scheme, the management approach for decentralized PV and a series of other refined policies.

The start of China's PV market in 2019 is subject to relevant policies. The new policy draft is still under discussion. The industry is still waiting. However, a quarter has already passed in 2019 and there is not much time left for businesses.

Chint president Lu Chuan said: "From policy release to its implementation, it takes time for market to respond. It takes time for provinces and cities to understand the new policy and to prepare the tendering projects. Projects will not be implemented until the fourth quarter. The enterprises and power plant owners will face tight time constraints."

The industry expects that China's new PV policy will be introduced in mid-April, 2019, as this publication goes to press, while others claim that it will take seven months at the latest.

A PV company executive said. "It is really bad if it comes out in July, by October northern China has already started to freeze. If it is really the case this year, then the domestic market can be seen as 'shocked'".

Wang Sicheng said: "We've solicited opinions on this draft three times. Most of the opinions were accepted by the industry and we expect the new policy to be introduced as soon as possible."

What will be the final new policy like? Let's wait and see. ■

At the time of press Beijing was continuing to update its policies. This article is to date as of April 25 2019.

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FiT for purpose?

Policy | The UK's small-scale feed-in tariff closed to new applicants earlier this year, forcing policy makers and installers alike to run the rule over new models and legislation. Liam Stoker takes a look at the government's Smart Export Guarantee and what it might mean for UK solar

At the stroke of midnight on 31 March 2019, the UK's feed-in tariff (FiT) scheme slammed shut, effectively ending the subsidy era for solar in the country. Now, the sector is committed to operating outside of government assistance for the first time.

Between their introduction in 2010 and closure in 2019, the feed-in tariffs kick-started an industry now on the cusp of independence. Just shy of one million rooftops the length and breadth of the UK have adopted solar under the FiT, providing a significant and meaningful contribution towards the country reaching its current capacity of 13GW+.

The FiTs were the last bastion of renewables subsidies in the UK, and the mechanism's closure marks the end of the beginning for clean energy in the country. Now, renewables are expected to stand on their own two feet and pay their own way, with increasing confidence that they can do just that. The government's plans for small-scale solar and other renewables, unveiled earlier this year, are just the start.

Credit: STA

Campaigners have been urging the UK government to introduce an appropriate replacement for the now-defunct FiT

Export guaranteed

In January 2019, the UK's Department for Business, Energy and Industrial Strategy finally unveiled how it intended to replace FiTs. Energy minister Claire Perry at first committed to ensuring some form of export tariff would remain, then official proposals snubbed it entirely, despite European legislation deeming it necessary that all power exporters receive "fair" compensation for what they produce.

Strong condemnation from the industry followed, and the country's energy department eventually relented, albeit at a late stage in the game. Suggestions have been that civil servants were forced to work on the policy over Christmas in a move which, given Westminster's Brexit-related workload of late, would not have gone down well. Critics have lambasted a government that has known for at least three years that the FiT was to close, so to not have a replacement mechanism already in place appears slapdash at best. Indeed, ex-energy minister Lord Barker was busily mooting net metering as a possible FiT successor as early as November 2015.

But a re-FiT has been forthcoming nevertheless. Dubbed the 'Smart Export Guarantee' (SEG), it would replace the government-backed generation and export payment with a single tariff, paid for by energy suppliers, for any self-generated power that is exported to the grid.

There are, however, some caveats. Only large suppliers – those with more than 250,000 customers – are mandated to offer a guarantee, limiting the competitive pool somewhat. Smaller suppliers can still do the same but must comply with the same regulations and guidelines. In addition, tariffs must always be above 0p/kWh and cannot dip into negative pricing if the wholesale price happens to do just that, protecting consumers.

But perhaps the most significant barrier to the industry as it stands is the removal of deemed exports, requiring all export settlements to be metered. The most sensible way for this to be achieved is via a smart meter, however the UK's smart meter roll-out has proved costly, complicated and been delayed to such an extent that the government is on the brink of extending its own installation deadline.

One possible workaround would be for a standalone export meter capable of providing metered exports on a half-hourly basis to be fitted at the time of the solar installation, however the government's own analysis suggests that the cost of doing so, at £300 up front and an additional £50 a year on maintenance, is at risk of rendering any PV array uneconomical, depending on subsequent SEG tariffs.

This issue was keenly picked up by the Solar Trade Association, the UK's de facto trade group for the industry, which had spent much of the previous year stressing the importance of a FiT replacement worth its salt. "Our worry is that these [barriers] may impede the ability of suppliers to offer fair and meaningful rates, even though they may wish to," said the association's chief executive, Chris Hewett.

Crunching the numbers

The UK political system requires government departments to publish an impact assessment for each policy decision it reaches, and the energy department's assessment for the SEG reveals a minimal expected impact.

The assessment accompanying the SEG poses two scenarios with different self-consumption and adoption rates, the most beneficial indicating that between 11.1MW and 12.5MW of additional solar capacity could be stimulated between 2019 and 2026 as a result of the policy's implementation.

Given the UK's average domestic rooftop solar installation size of 3kW, that would equate to somewhere between 3,700 and 4,200 extra domestic solar installations each year, a mere fraction of the domestic installation rates which the UK solar industry has recorded in the past.

Aside from ensuring the right protections are in place, the UK government appears willing to leave the fine tuning of the SEG very much to the suppliers themselves. Such an approach bears all the hallmarks of the influence of Dieter Helm – a renowned energy academic in the UK with a feted distaste for government intervention in markets – who published a somewhat controversial white paper on future energy policy just a few months before the SEG was unveiled.

The only guidance the energy department has given energy suppliers to date – at least publicly – has been "the smarter the better", referring to the way it envisages export payments to track the wholesale price throughout the day and hopefully incentivising more flexible behaviour from consumers for the good of the grid.

It remains to be seen whether or not the UK's energy retailers, beleaguered as they are, are up to yet another challenge, but the early signs have been encouraging.

Early promises

Even without the SEG in full effect, at the time of writing a trio of suppliers in the UK are offering effective export payments.

The first two – established name E.On and challenger supplier Bulb – have introduced limited-supply export mechanisms that would appear to be almost trials for how their respective schemes will work in the future. Bulb is to trial a mechanism rewarding 50 homeowners with unsubsidised solar over the coming year, while E.On's so-called Solar Reward scheme is of a larger scale, and will honour the most recent export tariff price of 5.24p/kWh, for the first 500 customers to install solar under E.On's own deployment programme.

The most interesting on the market however is Octopus, which has a strong, vested interest in the UK solar sector already. Octopus' supply division has committed to "replace and improve" upon the export tariff with its own spin, starting with two individual tariffs: Outgoing Octopus and Agile Octopus.

The former is a simple, flat rate payment of 5.5p/kWh, equivalent to about £55/MWh on the wholesale market. Not only is that more than the previous export tariff, but broadly in line with fair market value on the wholesale market today. But the latter, which will see customers receive a fluctuating payment based on day-ahead, half-hourly settlement prices, is precisely the kind of smart export payment the government and industry have envisaged.

Octopus claims that its standard, Outgoing tariff could be worth around £287 per year for homeowners installing solar today on standard consumption and export patterns. As it stands, this is highly unlikely to be the kind of financial stimulus for deployment the feed-in tariff once was, but it represents a considerable benefit as equipment prices shift further.

> "Once again, the UK's domestic solar sector stands on a precipice, not knowing clearly which direction to turn. What is certain is that the industry's future is now far less dependent on government intervention"

What other suppliers make of the SEG remains to be seen. Ray Noble, one of the UK solar sector's stalwarts and adviser to the Renewable Energy Association, considers that most SEG tariffs will fall around the 2-3p/kWh mark, roughly half what was on offer under FiTs. Other installers in the sector are saying similar, with a broad recognition that they won't be FiTs, but they might just be fair.

Others, however, just aren't that interested in what little, or large, the SEG will have to offer, having placed far greater importance in other, more advantageous revenue streams and business models.

What's next?

While a handful of suppliers have unveiled their tariffs, it may still be some time yet until the SEG comes into force in earnest. The government's consultation on the matter closed on 5 March 2019 and while it is on the record as saying it intends to introduce the scheme post-haste, this is a Westminster that's very much gridlocked by Brexit. The SEG is not expected to be formally implemented until well into 2020 and although homeowners that install solar in the meantime will be eligible for the payments, they will not be backdated.

In the meantime, a handful of solar companies are thinking outside of the box and investigating other sources of revenue. Companies like Social Energy are now coming to the fore, working with solar installers to fit both PV and battery storage entirely unsubsidised, and bolstering consumer returns by aggregating storage capacities to provide local grid flexibility services.

Social Energy founder Ryan Gill says that in doing so, his firm will be able to deliver investment returns even more beneficial than the FiTs were at their most generous 43p/kWh. It's a bold claim, and while Social has worked with independent consultancy Baringa to cement the model's numbers, the industry remains sceptical about the potency of grid services in such a way given its possible saturation.

Once again, the UK's domestic solar sector stands on a precipice, not knowing clearly which direction to turn. What is certain is that the industry's future is now far less dependent on government intervention and more so on that of energy suppliers, a fact which may not sit well with some. ■

Credit: Octopus

Octopus is weighing into the post-FiT market with two tariff options

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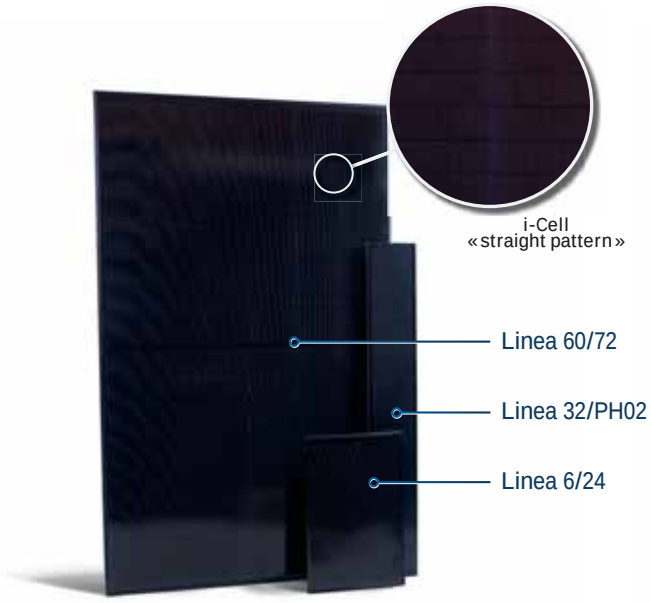

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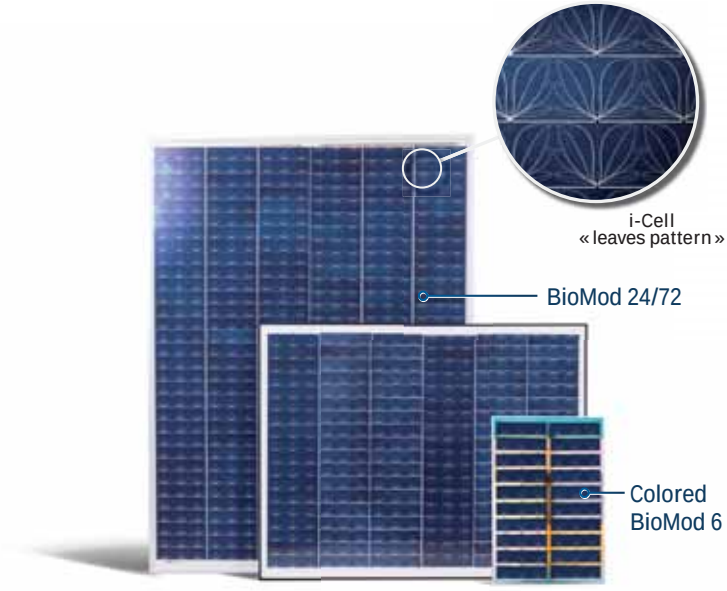

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Colombia at the crossroads

Latin America | Bogotá seems ready to kickstart its dormant renewable sector to bolster a hydro-reliant power mix but auction delays suggest the road may be bumpy. José Rojo explores the factors behind the country's slower PV awakening as Brazil, Mexico and other neighbours surged ahead

Credit: Celsia

Celsia's 9.9MW plant in Bolívar

For an illustration of Colombia's present approach to renewables, look no further than one of its national symbols.

Much like the fragrant, flamboyant orchids carpeting its valleys and cloud forests, the Andean state has in recent years waged a charm offensive for clean energy developers; an appeal to help boost non-hydro renewable capacity from the few dozen megawatts recorded in early 2019. The PR operation comes from the very top, with President Iván Duque and energy minister María Fernanda Suárez taking to Twitter to hail Colombia's "energy revolution" as they visit PV projects.

The campaign appears to be bearing fruit. As the government was keen to stress when *PV Tech Power* got in touch, Colombia last year overtook Canada, Mexico and Brazil in the World Economic Forum renewable rankings; it was also recently singled out by EPC firm Sterling & Wilson as a PV-market-to-watch. It helps that the country has the resources for a PV boost – irradiation in the Caribbean northeast reaches a daily 5.5 to 6KWh/m^2 – but also a very good reason; over-reliance on hydro makes it extremely vulnerable to climate-driven droughts.

And yet for all the potential, the going remains slow. While IRENA stats found huge PV capacity jumps from 2017 to 2018 in Brazil (1.09GW to 2.29GW) and Mexico (674MW to 2.54GW), Colombia hobbled along from 11MW to 87MW. Like bees drawn to an orchid, developers and investors attracted by the promise of Colombia's first ever renewables auction may have found the scent was not quite so alluring when the tender was postponed in February, with anti-trust concerns forcing the government's hand. Is it perhaps too soon for Colombia's quest for renewable success?

Lessons from the trailblazers

If recent conversations are anything to go by, faith in the country's odds for victory runs deep.

Gustavo González, head of PV generation at Celsia, is not overly troubled by the headlines on auction delays. His firm delivered Colombia's first two large-scale PV plants – twin 9.9MW installations near Cali and Cartagena – without the need for tenders, instead selling power via PPAs or directly to its 1,200,000-customer network.

Credit: Celsia

Gustavo González, PV generation head at Celsia

Having secured presidential visits for its first plants, the firm has now a third 9.9MW PV project under construction and is developing a further two.

Sterling & Wilson advisers spoke last year of Colombia's many regulatory challenges but González remains unconcerned. He points at the government's efforts to support via legislation – tax incentives under the so-called Law 1715 have particularly helped, he says – and adds that land purchases do not typically pose major challenges. "The first project raised some questions but we've now got a firmer handle on how permits, procurement and construction play out with a PV project," he tells *PV Tech Power*.

In line with others approached by this publication, Celsia's PV head does acknowledge delays with securing grid access: particularly in Colombia's high-irradiation, poorly linked north, demand for connection points can create a wait of several years, according to him. González plays down congestion risks, however. "The grid is ready for more renewables. Expansion is needed but the government is working to deliver it," he argues, pointing at upgrades both under construction by planning unit UPME and the substations built by Celsia across the Caribbean region.

Solarplaza consultants warned last year of "very challenging" interactions with UPME and other government agencies. González does not report those difficulties but speaks of "disorganisation"; uncertainty over who should first clear access points – UPME or the various grid operators – has left some projects in "limbo" in recent years, according to him. "My only ask for the government would be an easier process for connection points but to a great extent, the confusion has already been cleared up," he says.

Utility-scale picks up pace

Slow or otherwise, Colombia's PV awakening is unquestionable. The country drew eyes in April as Enel's 86.2MW El Paso facility, a project dwarfing Celsia's trailblazing duo, was linked

to the grid. As President Duque said on site, the 176GWh-a-year installation in the north-east department of Cesar is the first to provide power under the so-called reliability charge auctions, a Colombian creation where alternative sources are contracted to bolster the hydro-reliant power system in case of drought.

El Paso's status as Colombia's top PV dog looks set to be short-lived. At a whopping 240MW, Diverxia's facility would alone more than triple the current figures for PV capacity. Planning permission was secured in January. And it wouldn't be alone: PV was behind 17 of the 22 project bids tabled for this year's postponed auction; some 15 of all 22 submitted renewable bids – solar or otherwise – concerned projects in high-irradiation Caribbean shores.

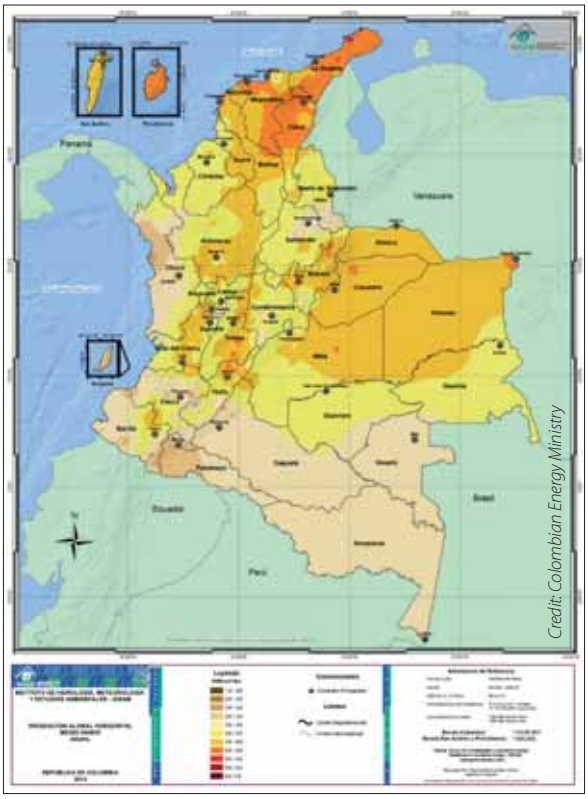
Germán Corredor, executive director of renewable association SER Colombia, echoes the talk of momentum in the Andean state. According to him, foreign developers and investors may have areas of concern – including long-term auctions, grid connection and environmental permits – but are nonetheless devoting increasing attention to the Colombian market, drawn by the potential and the government's recent legislative push.

"Since the adoption of Law 1715 and the efforts to regulate excess power sales by smaller self-generators, the country has set off on a slow but continuous path to build PV plants of all sizes," Corredor tells *PV Tech Power*. "The installation of small-scale plants, taking off only recently, is expected to gather steam as the potential is significantly high. There's still not a figure for nationwide installed capacity but we estimate there's over 50MW already being operated across small- and middle-size businesses, industries, followed at some distance by residential."

Small is good

Colombia's small-scale PV potential comes underpinned by its harsh geography, a tangle of impassable mountain valleys sandwiched between a tropical coastline and some 643,000 square kilometres of rainforest. Particularly around the Pacific and the Amazon basin, these features make it a challenge to supply grid-connected power to isolated residents, who may use little energy but can also typically afford to pay little for it.

Speaking at an event in March 2019, energy deputy minister Diego Mesa anticipated the government's plans to tap into renewables to keep the lights on across these so-called non-interconnected zones. Hard policy swiftly followed, with the publication later that month of proposals to subsidise the set-up of domestic PV systems. Once up and running, the scheme will help offset O&M costs via payments reflecting income levels, among other factors.



Irradiation potential across Colombia

The ultimate impacts of this government money remain unclear, but developers are not waiting for the outcome as they pile into solar distributed generation. According to figures circulated by Solarplaza, the pipeline currently under development nationwide reaches into the three-figure megawatt region. Clarity on what qualifies as distributed generation – below 10kW for residential, 100kW for commercial and 1MW for industrial – and how to sell surplus power is provided by rules laid out last year by energy regulator CREG.

Germán Corredor, executive director of SER Colombia

Celsia's large-scale projects may be hoarding the spotlight but the firm is also amongst those tapping into small-scale opportunities. According to González, a single-digit-megawatt rooftop portfolio has been deployed to date; going forward, he explains, the plan is to reach the 100MW mark via a further 50 installations. "The capacity of our [rooftop] projects is rising and rising," González adds. "We think the segment is becoming more popular and attractive for everybody."

The ball is in Bogota's court

However sizeable on paper, Colombia's PV potential will likely require auction support to materialise, particularly while the market remains at an embryonic stage. Does the postponement of the February tender herald trouble for its successor, due to be held before July? Speaking after the delay in the winter, Minister Suárez sounded optimistic. "This was a first for Colombia. We took the risk, knowing that…learning curves are fundamental to long-term success," she argued. "We're convinced we're closer than ever to realise this dream of all Colombians."

Crucially, the renewable industry appears to have come away with a similar interpretation. "Investors were understanding about the events in February. Their expectation now is that changes will be made so that the next auction attracts greater participation of both demand and offer," says SER Colombia's Corredor. "We now anticipate a tender this year and at least another under the current term of office, which the current government has shown interest in."

The blooming every year of Colombia's orchids is a delicate event, only made possible by a finely tuned mix of predictable sunlight, humidity and water conditions. Nurturing a buoyant PV ecosystem, where years ago there was none, will demand a similar balancing act, the combination of the right dose of policy incentives and market dynamics. Bogotá has seen greater challenges than boosting renewables – not least healing the wounds from decades of guerrilla conflict – and appears to count, for this particular task, on support from the PV ranks.

"Everything is clearly set out by the government and the new regulation, so it's now down to all of us market players to get together and undergo the learning process," says Celsia's González. "It was unfortunate that the auction didn't turn out as we wanted but Colombia is ready for the arrival of renewables – in fact, they have already arrived. Everything is set so that the business of solar PV continues and thrives." ■

Financing emerging solar: A-listers speak up

Solar finance | Development and private capital is fuelling a solar boom across the Earth's four corners, from India to South Africa and Mexico. Five finance heavyweights walk José Rojo through their learnings so far and their future plans to tap into an industry they see as key to a better world

The International Finance Corporation

In 2019's world, the bond between long-time bedfellows development money and solar appears stronger than ever. This source of finance is, BNEF analysts recently said, the ally emerging markets need as they navigate the renewable transition set out under the Paris Agreement of 2015.

Luckily for PV, the appetite for such an alliance seems solid in the development ranks; with US$1.9 billion of its own capital invested to date in some 5GW of PV, the International Finance Corporation (IFC), part of the World Bank Group, is no exception.

"We're active in solar PV and we'll continue to be. When you see PV procured at cost-competitive tariffs you realise it makes sense commercially as well as environmentally," Nuru Lama, the global solar investment lead at the corporation, tells *PV Tech Power*. The IFC, he explains, can typically provide up to 25% of project costs; as a lead arranger, it can invest alongside fellow development players, commercial banks and funds under its management.

What does the IFC like to see in the solar projects it backs? The key considerations are solar irradiation, project site, transmission arrangements, environmental and social issues and the quality of the sponsor and the contractors for EPC and O&M, Lama says. According to him, the corporation favours projects allowing it to "move the needle" at large scale. IFC's role, Lama explains, is to work alongside the World Bank to build institutional capacity at the country level so that the chief challenge – favourable policies and bankable concession documents – is dealt with and investors feel confident to come on board.

The conversation takes place just a month after the IFC invested US$75 million to anchor a US$300 million green bond tranche, raised by developer AC Energy to fund PV projects in Vietnam. "What we've seen [with bonds] is it allows to tap into a different, green-minded investor base," Lama says. "It can sometimes be more efficient than project finance, which is more negotiated, hands-on and document-heavy."

Credit: IB Vogt

Egypt's Benban solar park is among the emerging-market projects financed by the IFC

In its February report, BNEF called for a slight readjusting within development finance: as renewable energies reach maturity, analysts said, funds should shift to battery storage and the other less-developed technologies that mitigate intermittency. The IFC is moving in that very direction. "We're looking at storage as standalone or combined with solar or wind," Lama says. "You see a lot of activity in the US; we're confident emerging markets will follow."

With solar more broadly, the IFC's travels are already taking it to new geographies. "Through our early-stage engagement, including Scaling Solar, we have been working to create solar PV markets in countries like Argentina, Egypt, Senegal and Uzbekistan," Lama explains. "We'll continue to work in Africa, Middle East and South Asia but we're also finding opportunities in more developed markets in Latin America."

Actis

Bringing the private investor perspective is Actis, an emerging markets private equity house that is building or running 10GW in energy assets, 3.5GW of it solar PV. Barry Lynch, a partner for energy and infrastructure, explains the equity investor favours large-scale ventures – 50-350MW is the sweetspot – it likes to own on a majority, ideally full basis.

As Actis has expanded, its PV portfolio has diversified across Latin America, India and Africa. The investor has signed long-term PPAs with commercial players in Mexico, Chile and India but typically works more often through state off-takers or auctions. Many of the national tender schemes the firm encounters are competitive but India's is particularly noteworthy, Lynch says. "What we like is their auctions are regular and give us line of sight," he

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Credit: Asian Development Bank

explains. "Shorter timeframes mean when we get into an auction and win it, we know we're going to be executing the project within a certain period."

The firm's own investors, including public pension plans (38%), sovereign wealth funds (15%) and private pensions (14%), are very "happy and comfortable" with solar plays, Lynch says. For the investor base, environmental and social factors – a make-or-break factor across emerging markets, as top finance names recently warned – are front of mind. "We put a lot of focus on how land is acquired, its uses before the project, involving local communities through investment strategies and ensuring we use efficient cleaning methodologies where there's water scarcity," Lynch explains.

Looking ahead, Actis is contemplating forays across Southeast Asia, a region it has deployed capital into in the past. Lynch says opportunities could be considered in Malaysia – "we're beginning to see solar moving there," he notes – and Thailand, which he argues has proven its potential to deliver wind and solar developments at scale. Vietnam is "getting there", Lynch adds. "There hasn't been a huge amount done there," he says. "It's a good example of a country where there's a lot of debate as to whether PPAs being signed meet international bankability standards. That would be the next step, and bring in a lot more international investment."

The Green Climate Fund

A newer arrival to the green finance scene, the Green Climate Fund (GCF), has already had time to work up a strong appetite for solar PV.

Thailand is among the recipients of recent ADB investment in solar projects

The technology reaped the lion's share of the latest US$440 million funding round by the organisation, set up under the UN's auspices in 2010 to help the developing world mitigate and adapt to global warming. Four of the nine new projects rubberstamped during the GCF board meeting of February 2019 came with the shared mission of bolstering African solar.

Speaking from the GCF headquarters at Incheon (Korea), several of the fund's leading renewable experts walk *PV Tech Power* through its investment *modus operandi*. The institution's co-investment model sees it partner with governments and development banks, backing projects through a concessional mix of loans, grants, equity and guarantees.

Deployment takes place through public and private programmes. Pierre Telep, a senior renewables specialist who helps run the former, says the GCF likes large-scale, transformative projects but is keen not to distort the market nor displace other funding sources. Rajeev Mahajan, a senior project finance specialist on the private side, says additionality is key. "When we consider funding proposals our key question is: are we addressing any barriers in that market?" he says.

The new African ventures are a practical case study on the GCF's current PV thinking. There is support for 400MW of utility-scale solar in Nigeria; electrification through solar in rural Mali; and mobilisation of private finance towards West African PV. In South Africa, a fourth scheme is seeking to build 330MW of renewables that do not rely on troubled state utility Eskom, working with municipal off-takers instead. "What we want is to open fresh revenue sources, develop a market that doesn't involve sovereign support," Mahajan explains.

Through years of financing renewables, Telep adds, the fund has learned that the enthusiasm of private players sometimes comes with a "lack of knowledge" on exactly how to partner with the GCF's "unique" model. With mini-grids or rural projects, expectations around returns can be another deterrent, he says, adding: "This perception sometimes by developers that projects will not be commercially viable has been one of the key barriers."

Where will GCF's next set its sights? Tony Clamp, deputy director of the private facility programme, says the fund's replenishment this autumn will make 2019 a "big year". The institution's geographic remit will remain broad but highlights will include Indian rooftop PV, which the GCF wants to support now that utility-scale nears maturity in the country. Energy storage is also becoming part of the menu. "We know it will play a very important role so we're thinking of being much more active in the future," says Telep.

The Asian Development Bank

The Asian Development Bank (ADB) has become a ubiquitous name in the solar finance landscape. Within the past couple of years alone, the financier has invested in support of PV in Kazakhstan, green bond-financed plants in Thailand, wind-solar in Nepal, solar-wind-storage in Mongolia, solar irrigation in Bangladesh and large-scale facilities in Indonesia.

Since 2010, the institution has committed US$3.2 billion to 48 PV-related projects representing over 2GW in aggregate capacity, according to Yongping Zhai, the head of the Energy Sector Group at ADB's Sustainable Development and Climate Change Department. The bank, he explains, typically provides loans – sovereign-guaranteed or otherwise – but may also use credit lines, equity, guarantees and grants depending on project circumstances.

Pure PV aside, the ADB sees grid reinforcements as "crucial" and has backed transmission and distribution projects with a smart-energy or storage component, Zhai explains. He adds, however,

that policy intermittency can often be a bigger concern for investors than the technology's own technical intermittency. To mitigate risks on this front, Zhai says, the ADB works to help governments build a framework able to provide the certainty developers and investors need.

Asked to lay out the ADB's next steps, Zhai speaks of the same redeployment seen with other development players. Plummeting PV costs and maturing markets mean commercial banks are gradually taking care of projects, freeing the ADB to focus on more "innovative" technologies and business models. "Our lending volume may not grow substantially … but we will focus on solar energy storage, solar-based micro-grids, floating PV, solar pumps and PV charging for electric vehicles, among others," Zhai says.

The Climate Bonds Initiative

Sean Kidney, CEO of the Climate Bonds Initiative (CBI), is keen to promote an emerging addition to the typical ingredients – auctions, subsidies, PPAs, loans and grants – of the solar finance diet.

Green bonds, a trillions-worth market in the midst of explosive growth, is a funding avenue PV developers are increasingly turning to. According to CBI figures, this segment saw US$100 billion channeled to solar-related projects between 2013 and 2019. Countries of issue included developed states – led by France, Australia, the Netherlands and Germany – but also China, India, Thailand, Morocco, Nigeria and Colombia. Elsewhere, Kidney says, there is investor appetite for green bonds but not always products to satisfy it. At varying degrees, Philippines, Vietnam, Taiwan and Hong Kong are all making strides, he adds.

> "You're not likely to get away with bonds for project finance. However, once your projects are up, with a PPA and contracts in place, you issue a bond against them to curb capital costs, put liquidity back in and boost long-term returns"

Kidney acknowledges that green bonds are mostly a recourse for larger players. "You've got legal fees of US$250,000, and underwriter fees if you go public," he says. Investors, he adds, like to see big issuances – around US$300 million is "ideal" – raised to finance large-scale pipelines. For those PV developers able to pull it off, the benefits lie on the refinancing side. "You're not likely to get away with bonds for project finance," says Kidney. "However, once your projects are up, with a PPA and contracts in place, you issue a bond against them to curb capital costs, put liquidity back in and boost long-term returns."

Given the potential, why is green bond uptake still modest in the PV ranks? "Latency, probably," is Kidney's take. "People just don't move that fast – they look up and see a hill they've never climbed before." Those braving the ascent may find the benefits are not just financial; as Kidney puts it, green bond PV players become part of a "bigger story" than themselves. "We know solar is critically important," he argues. "If you're in the space, understand that you're not just a solar or wind player, you're a green player, and think and act accordingly." ■

Mooring Floating PV systems

Consider more than just ropes and cables!

One of the most commonly overlooked and under evaluated component of a floating PV system is the anchoring, or mooring, system. Have you ever asked yourself the following questions? If not, maybe you should!

Q: Are ropes and cables really enough to keep the array stationary? What about during storms?

A: In some cases, yes. When placed in bodies of water with relatively low water level variation and wind, the use of ropes or cables can sometimes be appropriate. In those cases, what must be considered is the life span of the material that is being used to ensure that you don't end up with a mooring system that needs to be replaced within a few years of operation.

In storm prone areas however, strong winds can cause an uneven distribution of force on certain points of the array. If the system is attached with just ropes and cables, there is not enough dampening of these forces; which can lead to broken attachment points on the floats. This creates a chain reaction that can overturn entire lines of floats and damage the solar panels.

Q: Why can't ropes and cables sufficiently handle moderate to high water level variation?

A: Ropes and cables are not elastic. If they elongate, they will never return to their original length. As a result, there will be slack in the line, and slack lines are dangerous in a mooring system since the application can start moving horizontally. In order to handle significant water level variation, the mooring lines must be able to both increase and decrease in length depending on the position of the floats. Non-elastic components such as ropes and cables cannot do this.

Q: Should I assume that a "turn-key provider" for floating PV systems will provide the best mooring solution?

A: Certain turn-key providers have partnered with Seaflex, the world-leading provider of elastic mooring systems. These providers can therefore provide highly technological mooring products as part of their turn-key proposals.

Unfortunately, other providers often have standardized mooring solutions and only offer the most low-cost, low-tech options. Therefore, it is important to know what type of questions to ask to ensure that you secure your array in a way that will hold and last.

Q: As a floating PV system customer, what questions should I ask about the mooring system?

A: It depends entirely on where you are building an FPV system, and what the potential risks are. But in general, the following questions should always be asked:

- Will it be secured with an elastic mooring system?
- What is the life span of the components used?
- How does this system handle natural or man-made water level variations as well as storm winds?
- What level of maintenance is needed to keep the system working properly?
- Does the system have a warranty?

Ultimately, it is crucial not to overlook the anchoring component when designing a floating PV system. Investments in solar panels and floats are often quite large, which means that it is very important to properly secure and protect these components against harsh environmental conditions. FPV industry leaders understand the importance of this and will use Seaflex instead of ropes and cables.

At Seaflex we have supplied customized, site-specific mooring systems designed by our in-house engineers to locations all around the world since 1987. Floating solar systems secured with Seaflex have survived hurricane-strength winds, and we have documented references dimensioned for 35-meter water level variations and 90-meter depths. We have the products, knowledge, and experience to securely moor your application.

If you have questions about how to properly moor a floating solar application, please do not hesitate to contact us at FPVmooring@seaflex.net.

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KERALA, INDIA

Achieving 100% renewables: supply-shaping through curtailment

Economics | How best to bridge the gap between the production of renewables such as solar and demand is the subject of much debate. Marc Perez, Richard Perez, Karl R. Rabago and Morgan Putnam argue the case for curtailment combined with storage as a cost-effective solution

Credit: BHE Renewables

Storage has long been considered the critical component to achieving high degrees of renewable penetration. This makes intuitive sense because it is readily apparent the sun doesn't always shine when energy is being used. Storage is indeed an increasingly important tool to bridge the "firm spread"—the gap between renewable production and customer demand.

Recent work has shown that we don't need as much storage as we might think to achieve high degrees of renewable energy penetration. This article demonstrates how renewable energy curtailment combined with storage enables the achievement of very high renewables penetration at much lower cost than with storage alone.

Background

A rapid decline in turnkey capital costs for solar PV systems has led it to be the fastest growing and often least-cost electricity generation resource. So-called "grid parity" of solar has already been achieved in many locations, with reports of PV PPA (Power Purchase Agreement) bids below US$0.02/kWh [2][4][19]. Contract energy prices at that level are lower than energy prices for nearly any conventional generation (nuclear, natural gas, coal, etc.).

Despite having achieved grid parity for energy prices, we must remember that not all kilowatt hours are created equal. A unit of energy supplied to the grid from a solar generator is not equivalent to a unit of energy supplied by a conventional generator. This is because renewable production

A higher penetration of solar and wind power at a lower cost is the holy grail of the future energy system

is inherently variable and non-dispatchable—its production relies on the weather. Solar generation cannot therefore operate according to the preferences of the grid manager. By contrast, a conventional generator such as a combined-cycle natural gas plant is fully dispatchable. Its capacity is available whenever the plant operator decides. Energy price parity is not the same as operational equivalence.

A threshold question for high-penetration solar generation is how to "firm-up" intermittent renewables and transform them into resources that can meet load at any time. Many "firming" solutions to bridge the gap between supply and demand are under discussion. Among these solutions, Internet of Things ("IoT") load control, micro-grids, smart grids,

load-shaping tariffs, and storage take prominence [1]. This article explains a counterintuitive and elegantly simple strategy that greatly reduces the need for these solutions solely to firm solar.

Energy storage: an incomplete solution

Transforming variable renewables effectively into firm generators is a necessary prerequisite to achieving their very high penetration on the grid. The issue with solar is that there exist gaps in supply when the sun isn't shining yet demand still exists. These supply/demand imbalances are present on multiple timescales. They stretch from intra-hour (passing clouds), to intra-day (rising and setting of the sun), to inter-day (weather fronts), to seasonal (rotation of the earth around the sun and axial tilt). In energy market terms, these imbalances give rise to a "firm spread". The firm spread is the differential between the cost of resources that are effectively always available to meet demand and those that are not.

Electrochemical battery storage is often cited as the solution that will transform solar into a dispatchable resource. The price of storage to firm any individual unit of solar capacity has therefore been cited as a metric to quantify the value of firm spread. Electricity storage will be a critical component to overcoming solar variability, but the combined effects of storage and solar costs will dictate that it is not the only one.

Longer-timescale solar supply gaps (in the order of weeks or seasons) require an expensive amount of storage to overcome. This is true even when assuming future electrochemical storage costs below US$100/MWh [10]. The cost is high because the amount of energy that must be stored to overcome the seasonal supply gap is large. In fact, it is more than one hundred times larger than the battery size needed to account for the shift from day to night; or to mitigate so-called duck curves. Using only battery storage as a solution to solar variability would push system costs far above grid parity.

Supply shaping through oversizing and curtailment

The least-cost pathway for effectively transforming variable PV into firm generation lies in a counterintuitive strategy: oversizing of solar generation assets and dynamically curtailing the output. Such a strategy reduces storage requirements by at least a factor of ten relative to the storage needed if it was the only solution. The effectiveness of this strategy is demonstrated in the recently-released *Minnesota Solar Pathways* study and a corresponding publication in Solar Energy Journal [8][12].

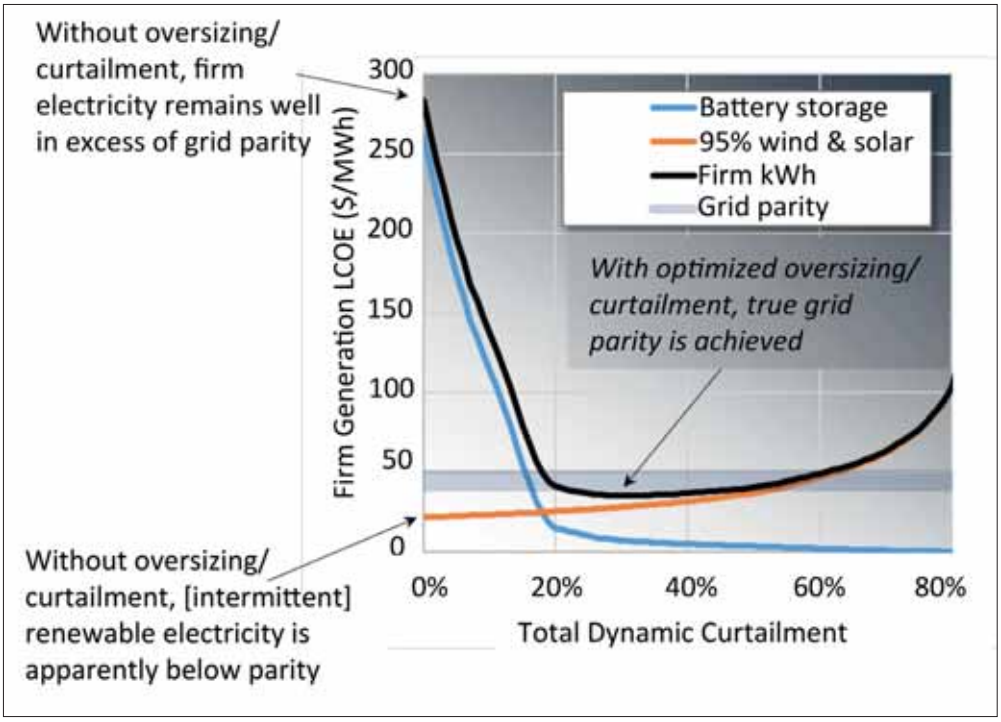


Figure 1. The levelised cost of energy (LCOE) to generate firm renewable electricity for the Minnesota power grid as a function of the fraction of oversized/curtailed renewable energy using utility-scale future (2050) PV, wind and storage cost assumptions

A strategy of oversizing and curtailment works because:

- Oversizing drastically diminishes the supply gaps stemming from resource variability at longer timescales;
- The cost of storage saved in so doing is much higher than the cost of oversizing renewables.

Figure 1 demonstrates the tradeoff between oversizing of renewable generation and storage. Though the figure demonstrates optimisation using future costs, this tradeoff is applicable even at today's prices.

The solid black line represents the LCOE to meet electrical demand 24/365 with an optimised blend of wind and PV, storage and 5% natural gas. This LCOE is the sum of the unconstrained RE+gas LCOE (orange line) and of the battery LCOE necessary to fill all intermittency gaps (blue line). The semi-transparent gray line represents the current [conventional]

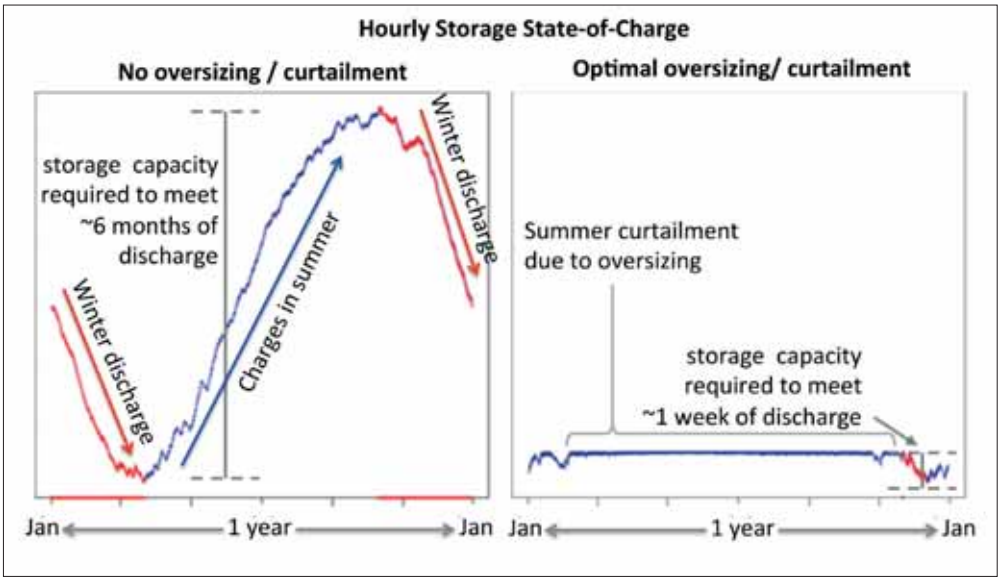


Figure 2. Hourly storage state-of-charge to meet MN utility load in the absence of oversizing (left plot) and with optimal oversizing + curtailment (right plot)

electricity production costs in the state.

At zero curtailment (i.e., no RE oversizing) the orange line is well below the grey line; i.e., it is apparently below grid parity. However, the storage requirements to transform unconstrained renewable energy into a firm 24/365 resource (black line) are overwhelmingly expensive. When optimally curtailing about one third of the production (i.e., oversizing RE by 50%), true grid parity is achieved.

Another way to visualise how this oversizing and curtailment strategy works is to look at the state of charge of the storage assets across a typical year. Figure 2 displays two subplots, each showing the storage state-of-charge dispatched to meet hourly utility load in Minnesota.

The plot on the left shows what this storage state of charge looks like without curtailment if 100% of a typical utility load is served by PV generation. Under such a scenario, storage must be sized to mitigate the seasonal supply-demand imbalance by soaking up excess production in the summer months and discharging all winter. The plot on the right shows what this storage state of charge looks like with cost-optimal oversizing and curtailment.

Storage size is decreased by a factor of 10 between the two scenarios pictured in Figure 2. This reduction exists because seasonal imbalance is eliminated through oversizing. By oversizing, PV produces more in the winter, mitigating the need for storage to do the same. Storage only needs to be sized to fill a roughly week-long supply gap as a result.

Complementary integration strategies

In addition to overbuilding and curtailment, other complementary strategies deliver cost reduction opportunities. These strategies include:

- Increased geographic diversity of renewable plant siting. Greater geographic diversity decreases aggregate variability [5][7][11][16].
- Synergistic blending of PV with wind where these resources are anticorrelated. See Figure 3 [1][3][8][14].
- A small degree of dispatchable conventional generation, such as gas generation operated infrequently [8][12][14][15].
- Demand-side management, including energy efficiency, demand response and dynamic load control [1][8].

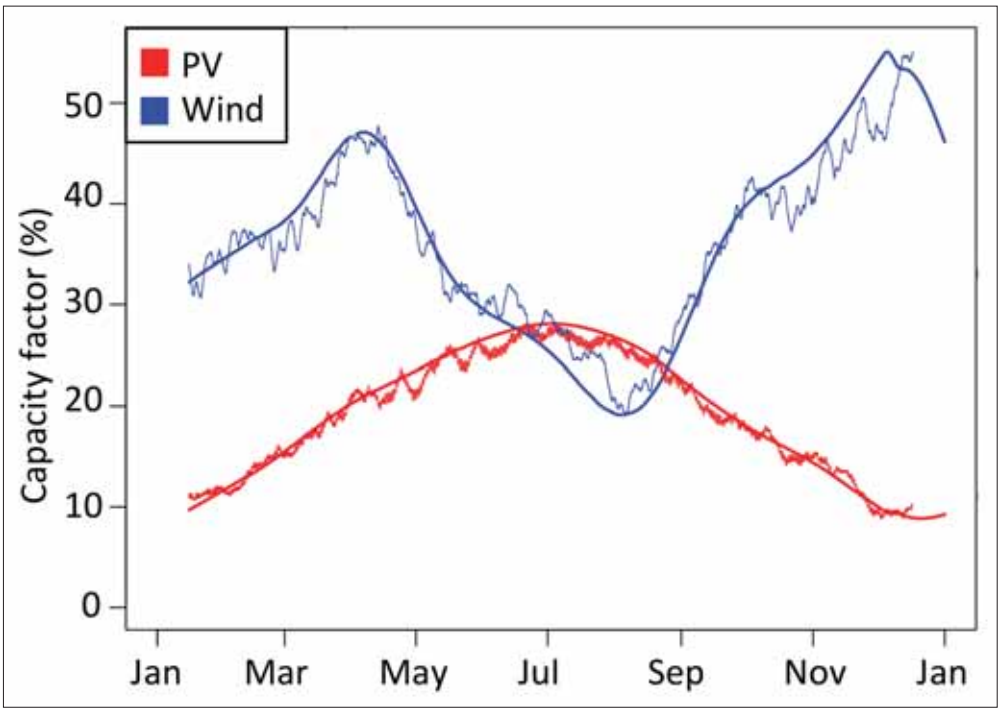
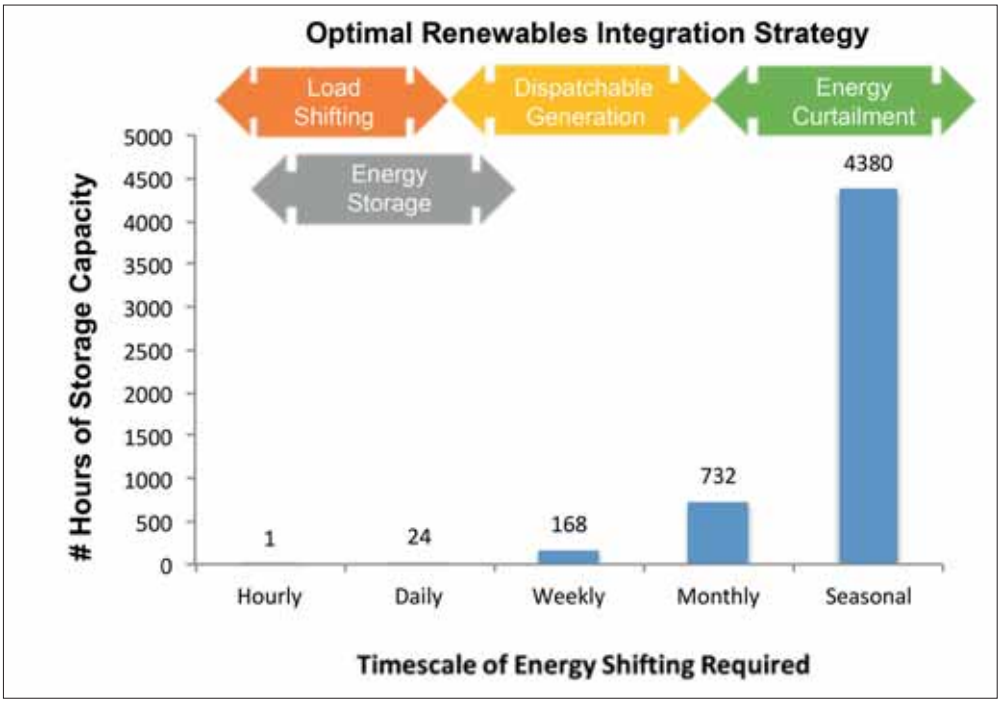


Figure 3. Solar versus wind resource across the State of Minnesota at the monthly interval in 2016. Pictured is both a 30-day moving average and locally weighted trendline for each resource. Strongly visible is the seasonal anti-correlation between the wind and solar resources across the state. Wind resource peaks in December and April (coming to a minimum in August) while the solar resource experiences its maximum and minimum at the solstices



Hours of storage capacity required to surmount supply/demand imbalances at various timescales along with optimised solutions that address each of these imbalances

It is useful to look at the magnitude of the supply/demand imbalances remedied by each of these solutions. Each solution is best suited to address variability on a timescale commensurate with its operational characteristics.

In Figure 4, the column bars represent the quantity of storage needed to overcome imbalances at various timescales, without relying on any other solution. The colored boxes near the top highlight the timescales at which a number of complementary firming solutions operate. Not surprisingly, different resources offer differing performance

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attributes that should be selectively applied in pursuit of an optimal solution—the right tool for the job.

Energy curtailment addresses inter-annual or seasonal imbalances. Dispatchable supplemental generation addresses weekly/monthly imbalances. And both storage and load shifting address timescales smaller than a single day. This is not to say that energy curtailment can't address variability at shorter timescales or that energy storage can't address variability at longer timescales. Figure 4 attempts to show the timescales which each of these solutions are best-suited to address given their costs and operational characteristics.

Least-cost 100% renewable energy

Using this strategy, the Minnesota Solar Pathways report shows that by 2050 wind and solar can firmly meet 95% of load at costs below current wholesale market prices [8]. The report shows that these savings accrue even when demand increases due to transportation, heating and hot water electrification. The implication is that true, firm grid parity is achievable on a direct cost basis, without considering any subsidy programmes, tax credits, or the monetisation of environmental externalities.

Thanks to the synergy between overbuilding and curtailment, PV and/or wind resources are firmed—effectively transformed into dispatchable resources capable of meeting demand at all times. By using such an approach, high penetrations of variable renewable resources can be seamlessly integrated into existing power grids at reasonable cost [12][13][14][15].

Policy implications for 100% renewables

At the time of writing, California, Colorado, Connecticut, Hawaii, Illinois, Maine, Minnesota, Nevada, New Mexico, New York, Oregon and Washington had committed to 100% renewables and/or 100% carbon-free electricity by 2050 or sooner [9][17]. Under a traditional single-solution approach of firming each incremental unit of solar capacity with storage, the intrinsic variability of solar resources stands as a fundamental barrier across multiple timescales. These 100% objectives can only be achieved if the supply gaps arising from this variability can be addressed and overcome at reasonable cost.

Curtailment is one of the primary levers to achieving 100% renewables at reasonable cost. But curtailment carries economically punitive consequences given today's regulatory structures. Renewable energy development policies, and hence the projects built under these policy structures, are largely predicated on remunerating generators based on the energy delivered, irrespective of the degree of firmness. Wholesale markets, on the other hand, do not internalise and fully price the attributes of renewable generation sought by pro-renewable development policy.

This situation threatens to penalise latecomers—the marginal PV or wind asset—as curtailment will be applied only after these facilities are built and try to operate. And regulators will be pressured by utilities to change remuneration structures, so that they are not required to pay for curtailed production.

A sound policy framework must be cognisant of the portfolio of synergistic solutions that leads to minimum-cost renewables integration. There would appear to be promise in rethinking the way in which electricity markets are structured so that they price not only day-ahead and hour-ahead time horizons, but also week-ahead and month-ahead horizons.

Supply-shaping through curtailment has value even before high penetration levels are reached

Oversizing renewable assets beyond what is needed on an energy basis in order to facilitate some curtailment can reduce the integration costs of both solar and wind. It does so by reducing the total amount of storage that would otherwise have been required. A small degree of oversizing results in the ability to accommodate unforeseen over-predictions in forecasted production and allows PV and wind plants to provide key ancillary grid services. This concept was recently put into operational practice by First Solar [6].

Conclusion: Oversizing coupled with curtailment is a key element in achieving high penetration renewables, and even offers benefits on the path to high penetration levels. This strategy drastically reduces the amount of storage needed to firm the effective output of renewables and thereby drastically reduces integration costs.

The Minnesota Solar Pathways study demonstrates that a 3.5¢/kWh electricity production cost to meet 95% of their electricity and transportation requirements is attainable. The policy and market frameworks necessary to support such overbuilding and curtailment are not yet in place, but there are no fundamental barriers to the approach. ■

Authors

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Richard Perez directs solar energy research at the Atmospheric Sciences Research Center of the State University of New York at Albany. He sits on the advisory board of the George Washington University's Solar Institute, and has served multiple terms on the board of the American Solar Energy Society and as associate editor of Solar Energy Journal. He has produced over 250 journal articles, book chapters and conference papers. He holds US patents on energy storage, and load management using photovoltaics. He has received several international awards.

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The changing face of European solar

Finance | Recent signs suggest that after several quiet years, large-scale solar is once again showing strong growth in Europe in spite of the steady withdrawal of subsidies. **PV Tech Power** caught up with six energy finance experts from the law firm Norton Rose Fulbright for the their take on some of the market and financing trends that will shape European solar in the years to come

PV Tech Power: Where would you identify as being Europe's key hot-spot markets and what are the drivers of what looks like being a new phase of solar growth in the continent?

Rob Marsh, partner, London: The Spanish market is seeing a lot of renewed activity and investment, with new legislation and government support providing comfort, notwithstanding the previous retrospective cuts that we saw a few years back. We are also beginning to see the first wave of meaningful subsidy-free projects, often underpinned by corporate PPAs, in the UK and Ireland.

Arnaud Bélisaire, partner, Paris: France remains a focus under the current scheme, with high levels of solar irradiation and recently implemented economic incentives providing a great deal of potential for the French solar market. Coupled with the deployment of an ambitious schedule of solar calls for tenders, developers, investors and lenders currently see the French solar PV market as an attractive one.

Dimitris Assimakis, partner, Athens: A national support scheme introduced in late 2016 together with scheduled capacity auctions for the period 2018-2020 have given a new impetus to the Greek solar PV sector following a relatively long period of limited activity. There is unprecedented interest from foreign and domestic investors for the deployment of new projects. Greek authorities have also set ambitious renewable energy targets under the new National Plan for Energy and Climate which, amongst others, focuses on adding 4.3GW of new solar PV capacity by 2030.

Felix Dinger, of counsel, Hamburg: Germany remains an interesting jurisdiction for the solar sector. This is evidenced by the fact that each tender for German solar PV plants in the last four years was heavily oversubscribed (typically three to fourfold). The German government has also increased the tender volume for solar considerably for the 2019-2021 period, opening up the German solar market. Solar PV plants selling their electricity outside the existing remuneration regime through a PPA are not subject to a 10MW limit for overall plant size and they are not constrained by site restrictions that are part of the tender scheme.

Matthijs van Leeuwen, of counsel, Amsterdam: The Netherlands remains a key market for solar PV (both rooftop and ground-mounted) with a significant increase in new investors and developers. With the last subsidy round of 2018 significantly oversubscribed (by €1.7 billion compared to an available budget of €6 billion) for a total capacity of 3.7GWp and the subsidy scheme expected to remain in some shape or form over the next year, we expect the Netherlands to remain a key market for some years to come. The subsidy scheme, ever decreasing solar PV pricing and the need to accelerate renewable investments to meet the Dutch renewable targets are important drivers of this growth.

Credit: Anesco

Unsubsidised projects such as Clayhill in the UK are beginning to appear in the UK

Ginevra Biadico, senior associate, Milan: Italy remains a key market for solar PV installations (both rooftop and ground-mounted). A new decree setting out the incentive regime for solar PV plants to be commissioned during 2019 to 2021 is expected to be enacted in the coming months. The new public subsidies that are expected, especially for ground-mounted installations in industrial areas and rooftop plants, combined with high level of solar irradiation and a lower cost of technology are the main drivers fostering a new era of developments of new large-scale projects.

In this new post-subsidy environment we hear a great deal about the importance of corporate power purchase agreements (PPAs). How central are these to the future of solar in Europe and how sustainable are they as a route to market for developers?

Rob Marsh: Corporate PPAs are certainly going to be important for the growth of the subsidy-free solar sector and lenders are increasingly getting comfortable with the concept, allowing projects to be leveraged. There remain challenges, with many corporates (particularly new entrants that have not previously entered into off-take arrangements of this nature) slow to move and having limited capacity they are seeking to fill. The advent of electric vehicles and an increasing requirement for clean power suggest

The Norton Rose Fulbright interviewee panel, clockwise from top left: Rob Marsh, partner, London; Arnaud Bélisaire, partner, Paris; Dimitris Assimakis, partner, Athens; Felix Dinger, of counsel, Hamburg; Matthijs van Leeuwen, of counsel, Amsterdam; Ginevra Biadico, senior associate, Milan

that other solutions will manifest in the medium term.

Dimitris Assimakis: In Greece corporate PPAs have not yet been considered by developers or corporates for a number of reasons, including a preference for the existing investment incentives and subsidies for renewable electricity, constraints in wholesale electricity market operations and financiers' preference for the national support schemes for renewables. We consider that grid parity, decreasing operating aid levels, and the need for predictability and affordability of properly sourced electricity costs for environmentally aware consumers on one hand and predictable project revenues for developers and their financiers on the other, can be expected to bring corporate PPAs into the mix in the near future.

Felix Dinger: In Germany, PPAs are not yet widespread due to the existing statutory revenue scheme, however it is expected that PPAs (corporate or other) will become increasingly more popular in the near future, particularly for solar PV plants. There has already been a notable reduction in the average price for solar projects in tenders from April 2015 to date, indicating that solar electricity generation is competitive and making it attractive for distribution through PPAs. One of the benefits of operating a solar PV plant outside the tender system is that the substantial site restrictions that are part of the tender scheme do not apply. At the same time solar PV plants with a PPA do still profit from the existing rules for preferential grid access and grid feed-in in Germany.

From a project finance perspective, what is the view of the investment community of the emergence of corporate PPAs in Europe as the main route to market for solar, given the added risks that they entail? We reported recently that there is a fair amount of caution among investors vis-à-vis corporate PPAs – what is your view of the extent to which investors are prepared to back deals based on corporate PPAs?

Rob Marsh: There is an increasing synergy between the investment community and the corporates that are active in these spaces. With technology and transport increasingly driving a requirement for green power, investors are finding like-minded dynamic corporates entering this space and providing interesting partners for projects, as well as a strong credit covenant.

Arnaud Bélisaire: In our view there will be prospects for investors in France to back deals based on corporate PPAs in the near future. The Paris team is currently participating in the elaboration of a standard corporate PPA with the French wind energy association, France Energie Eolienne, in collaboration with a dedicated working group which includes many stakeholders in the sector to map out individual comments and proposals. This contract is intended to become the standard contract for the entire profession in France. It will primarily facilitate the financing of wind projects for which electricity will be sold through a corporate PPA within a standardised framework. This standardised framework could be adapted to the solar market.

Ginevra Biadico: Lenders generally want to see, amongst others, predictable cashflows with appropriately sized volumes, fixed pricing and robust default provisions. If no public subsidies are available, lenders' pressure on the PPA as the exclusive source of revenues will be high and the focus, from a lender perspective, will be on long-term PPAs that at least match the term of the facility agreement as well as an assessment of the corporate buyer's credit risk, track record and reliability.

To ensure the bankability of renewable energy projects in markets where public subsidies are no longer available, corporate PPAs may be a solution, but developers, investors and lenders should be open to agree on contractual innovations. Lenders may be available to offer loans for a shorter term which at their expiry require the project to refinance or face the inability to meet the balloon payment due on expiry of the loan. Developers may look at pricing models on a put and call basis to help mitigate price risk and insurance products could also help in mitigating volume and shape risks.

Aside from PPAs, what other routes to market do you see as offering the greatest potential for underpinning future growth in European solar?

Rob Marsh: The twin drivers of technology (notably in the form of data centres) and the requirement for sustainable urban environments will have an impact on the future growth of solar. The electrification of transport must be coupled with green energy, as must new urban developments and district heating networks. As technology and electric mobility drive infrastructure development and a new manufacturing sector, so captive (inside the fence) solar solutions increasingly make sense and the pool of off-takers will grow/change.

Dimitris Assimakis: Solar projects in Greece enjoy a fairly streamlined licensing and regulatory framework whilst sharing a common corporate and tax regime with other investment projects. However, while the licensing and regulatory regimes have been improving over the years, the general tax regime of Greece still remains complex.

Felix Dinger: In Germany tenders replaced the tariff system as the main source of revenue for solar in 2015. They are currently the standard revenue source for plants between 750kw and 10MW. The key issue with the existing tender system is that the capacities offered in the solar tenders were rather small.

However, the German government has decided at the end of 2018 to offer substantial additional capacity for solar plants through the tender system (1,000MW in 2019, 1,400MW in 2020 and 1,600 MW in 2021).

What effect have the new market conditions had on the nature of project financing for solar? For example, we have reported in the past that with the shift from a subsidy-driven to post-subsidy market, debt finance is perhaps no longer the most efficient way to finance projects. What trends have you seen emerging in the way projects are being financed in the post-subsidy world?

Rob Marsh: Project finance perhaps remains the dominant source of debt and the commercial banks are increasingly understanding the risks and methods through which these can be sufficiently mitigated to allow for limited recourse financing solutions. Green bonds and other forms of "green lending" are becoming increasingly popular and offer alternative sources of funding at a corporate level, while institutional debt continues to show an increased appetite for financing opportunities in the solar sector.

Aside from the question of how developers are getting projects to market, what other policy-related risks do they face?

Rob Marsh: Connection issues remain a challenge in certain jurisdictions, along with the risk of curtailment. Planning regimes and real estate laws could also be revisited to make development easier and remove some of the front end development risk. Battery storage has a role to play in the European solar story and policy and regulations to further enable this solution are required.

Dimitris Assimakis: Solar projects in Greece, similar to other renewable energy projects, enjoy a fairly streamlined licensing and regulatory framework whilst sharing a common corporate and tax regime with other investment projects. However, while the licensing and regulatory regimes have been improved during the years, the general tax regime of Greece still remains complex.

Ginevra Biadico: New developments in Italy may suffer from certain policy-related risks, such as: (i) delays in the issuance of new permits given the high number of applications filed in 2018; (ii) difficulties in finding large plots of lands free of landscape, archeological, historical and environmental restrictions; (iii) connection timing issues; (iv) risk of challenges from third parties in relation to the annulment of permits; (iv) risks of annulment or revocation of the permits as a result of an action in self-defence (azione in autotutela) by the public administration; and (v) requests from local authorities (especially municipalities) to compensate the impact of the project on the environment.

Matthijs van Leeuwen: Following the adoption of the Dutch Climate Act last year, a wide range of stakeholders are negotiating a climate accord that should provide a clear path to meeting an ambitious target for 2030 and beyond. Solar is expected to play an important role in meeting the targets. However, grid managers both at distribution and transmission levels are facing serious restraints in their respective networks that could have an impact on accelerated development of solar projects. We see a significant increase in alternative grid connection options being considered and implemented, ranging from direct delivery to cable pooling that have a specific impact on the project financing of the projects. In a densely populated country as the Netherlands, securing sufficient land rights for construction of ground-mounted projects can also be considered a challenge, whereas significant availability of suitable rooftops for solar projects is an opportunity for solar developers.

Overall, what is your assessment of the likely future growth trajectory of European solar?

Rob Marsh: As a technology in its own right and in the context of the wider sustainable and tech-driven changes to our urban environments, solar continues to make sense and will remain the dominant renewable technology of the next decade. As the manufacturers of cells further develop the uses and potential applications of PV technology, it will have an increasing impact on our commercial and residential environments, as well as being developed at utility scale.

Arnaud Bélisaire: The Energy Transition Law (ETL) sets an ambitious target for renewable energy in France. By 2030, 32% of final energy consumption and 40% of energy production should come from renewables. To reach this target, the ETL provides for a multiannual energy plan (PPE), which assigns a compulsory installed capacity target for each generation technology, including solar energy. As of 31 December 2018, total installed capacity of French solar plants reached 8,527MW. The draft PPE circulated in February 2019 sets an objective of 20.6GW for 2023 and an objective between 35.6 and 44.5GW for 2028. To reach these ambitious objectives, the draft PPE notably provides that calls for tenders for ground-level solar panels with a capacity volume of 1GW per year will be launched as from the second half of 2019.

Dimitris Assimakis: Given the recent advance of photovoltaic projects in Greece under the new national support scheme for renewables and the improved economic conditions and investors' confidence in the country, we expect such progress to continue in the short to medium term. Future growth trajectory beyond 2021 cannot be easily assessed in advance in view of the multiple parameters that need be taken into consideration such as those briefly described above.

Ginevra Biadico: The goals set out by the 2017 National Energy Strategy for Italy include amongst other things: (i) achieving the target of a 28% share of renewable energy sources on total energy consumption by 2030; (ii) fostering low energy consumption initiatives having the best cost benefit ratio, so as to achieve 30% of energy savings by 2030 with respect to their trend in 2030 and give impetus to the Italian energy efficiency industry (e.g., construction of energy-efficient buildings and installation of energy-efficient facilities); and (iii) to speed up the decarbonisation of the energy system and to introduce measures spanning the entire energy process, thereby achieving significant environmental and health benefits, and contributing to the attainment of European targets.

For the renewable energy sector, the 2017 National Energy Strategy proposes long-term PPAs for new large-scale power plants and diversified support schemes for small-scale plants. We would expect that 2019 will be a year of transition from the era of secondary market transactions to an era of new developments of projects. We would expect that the first permits to new large-scale solar plants may be issued in the next months of 2019, and that such plants may be ready for connection and operation at the end of 2020 or at the beginning of 2021. ■

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Codes, standards and certification for safety and performance of distributed energy resources and systems

Standards and regulation | The advent of distributed generation and renewable energy sources is requiring a swathe of new regulatory standards to ensure safety and grid stability. Scott Picco, Laurie Florence and Tim Zgonena of UL look at some of the latest and upcoming codes designed to addressing the proliferation of battery storage systems and distributed energy resources

Credit: NEC ES

A proliferation of distributed energy resources and systems is necessitating new codes to govern safety and grid operability

Modernising the world's electric grids is a critical enabler for achieving the societal benefits and avoiding brownouts or blackouts that come from optimising the way the world generates, distributes and uses electricity. If implemented properly, distributed generation and energy storage with advanced functionality and communications capability may even increase the reliability and stability of the grid. As electric utilities continue to modernise their grids through the use of larger amounts of distributed generation and renewable energy sources, standards and regulations must adapt to meet the ever-changing needs for safety, performance and grid support functionality.

Energy storage systems: UL 9540 and UL 9540A

With the expanding use of renewable energy such as solar power, wind power and energy storage there is a need to ensure that these sources of renewable energy provide reliable power on an ongoing basis, regardless of whether the sun is shining or the wind is blowing. In order to improve reliability, energy storage is demonstrating that it is a key component to renewable power installations whether it is at the utility-scale level or even for residential installations.

If energy storage systems are going to be installed where they are needed to support renewable energy and for other applications, they will need to demonstrate a sufficient level of safety. They should be determined to be safe through compliance to an appropriate safety standard and installed in accordance with the applicable installation codes. The codes impacting energy storage include NFPA 70, National Electrical Code, NFPA 1, Fire Code and ICC International Fire Code (IFC).

There is also a new installation standard under development, NFPA 855. There has been a lot of work to bring these various codes up-to-date so that they appropriately address the safe installation of energy storage systems including those systems using newer technologies such as lithium-ion and flow batteries. All of these codes including UL NFPA require that the energy storage systems be listed, which means evaluated for compliance by a third-party organisation; and reference ANSI/CAN UL 9540, which is an American National and Canadian National safety standard for energy storage systems that is to be used for that listing. UL 9540 covers electrochemical, chemical mechanical and thermal energy storage systems that can be operated in parallel with a public utility grid, or in a standalone application, or for use in various ancillary services. UL 9540 can cover ESS for utility, commercial and residential application. The focus of the codes though has been on battery energy storage as that is the most common technology for the various applications utilising energy storage.

ANSI/CAN UL 9540, which is a bi-national standard for the USA and Canada, references critical component standards for the major portions of the energy storage systems. This includes reference to ANSI/CAN UL 1973, which is a safety standard for stationary batteries. The scope of UL 1973 is non-technology specific, and covers requirements for cell, module and battery system criteria. It includes criteria for rechargeable lithium, nickel, sodium beta, lead acid and flow battery technologies. Both UL 9540 and UL 1973 require that a safety analysis of the system (battery and energy storage system) be conducted and that any electronics and software controls including the battery management system (BMS) relied upon for safety meet

appropriate functional safety standards and be demonstrated to reliably maintain the batteries and system within specified operating parameters.

Another important component standard referenced in ANSI/CAN UL 9540 is UL 1741, which is the safety standard for power converters, inverters and distributed energy resources (DERs). UL 1741 provides a means to determine that inverters and other renewable energy power conversion electronics are constructed per common industry requirements, can be installed in accordance with US codes, are operated per industry specific required ratings and perform safely under rated normal worst case conditions and foreseeable abnormal operating conditions and failure modes. In the case of energy storage applications, the converter/inverter is exposed to bi-directional power flow and as such is also subject to bi-directional fault conditions from the grid-tied output source and the battery and/or PV input source. The failure modes to which the inverter/converter are subject must be able to withstand the short circuit current contribution of all sources including PV, batteries and the grid. When comparing a battery source to a PV source the available short circuit current is a significant multiplier relative to a PV source. Where a PV source may have a short circuit contribution of 2 to 3 times the normal continuous current, a battery source may be a factor of 10-30 times depending on the size and construction of the battery. Fault testing with appropriately sized sources during abnormal testing is key in the evaluation of the inverter/converter as well as within the context of the overall energy storage system.

One of the main concerns with installing energy storage systems utilising batteries is primarily with fire hazards if these systems are to be installed within or near buildings that are of mixed uses. The methods for limiting the potential fire hazards are through limiting the energy of the systems installed and maintaining suitable separation distances between the systems and between the systems and walls or exposures to mitigate fire spread. The codes also limit the maximum aggregate energy allowed. In order to avoid strict limitations on sizes or separation distances, the codes include exceptions that large-scale fire testing and approval by the AHJ can allow for larger sized systems and smaller separation distances. UL developed a test method to meet the needs of the codes, UL 9540A, Standard for Safety for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. UL 9540A test method is a step by step process starting at the cell level and concluding at the installation level that evaluates the fire characteristics of those battery energy storage systems that have demonstrated a capability to undergo thermal runaway (Figure 1). The data generated during the UL 9540A testing can then be used to determine the fire and explosion protection required for an installation of a battery energy storage system.

Figure 1. Fire safety concerns of batteries across different levels

In addition to the various UL battery and energy storage standards, UL published ANSI/CAN UL 1974, which covers manufacturing process requirements for repurposing batteries such as electric vehicle batteries for for another application such as stationary battery applications. UL 1974 is not a product safety standard but provides minimum criteria that should be part of a repurposing manufacturing process. ANSI/CAN UL 1974 will be referenced in the next editions of both NFPA 70, NEC and ICC IFC for battery systems utilising repurposed batteries. This provides another market for used batteries that may have as much as 80% of their energy capacity still available but do not have enough energy capacity for a vehicle application. As the use of EVs increases, this provides a means for utilising batteries that are still viable for another application, until their energy is spent and they have to be disposed of and potentially recycled.

Energy storage, especially battery energy storage, is necessary to enhance the reliability of renewable energy sources. In addition, storage systems are being installed in locations such as urban centres and mixed-use buildings, where there is a concern of potential fire and deflagration hazards from these systems. Various codes impacting these systems understand the importance of third-party listing of these systems to an appropriate safety standard such as ANSI/CAN UL 9540. In addition, the instillation of the battery energy storage system needs to be provided with protection in the event that there is around or initiating within the system. Because of the unique nature of battery fires, especially lithium-ion battery fires, UL 9540A provides the data necessary to establish the suitability of the battery energy storage system installation, including the fire suppression, the deflagration protection that may need to be provided. All of the efforts put into suitable safety standards and installation codes assure the various stakeholders that the battery energy storage system is safe and the installation has sufficient protection in the event of a fire incident. Energy storage can be a real asset to the PV installation and ensure the continued adoption of renewable energy.

Grid support utility-interactive inverters and converters

As discussed earlier, UL 1741 is the safety standard for power converters, inverters and distributed energy resources (DERs). For products that are capable of back feeding/operating in parallel with the public utility UL 1741 references IEEE 1547 and IEEE 1547.1 for utility interconnected products. IEEE 1547 and IEEE 1547.1 establish the rules for interconnecting with the public utility and include requirements for items such as voltage regulation, power quality, abnormal voltage/frequency, unintentional islanding and a variety of other interconnection requirements. For a full list see Figure 2 (next page).

In areas with high percentages of distributed generation (DG) a change was needed to shift from products that not only are interconnected but also offer grid support functionality. This change was primarily needed to account for the traditional IEEE 1547 DG approach in which DERs were required to monitor the grid for stable conditions and upon recognising instability were required to disconnect and wait for five minutes of stable grid condi-

tions before the DER could resume normal interconnected operation. This traditional approach sometimes was referred to as the "get out of the way" approach in which the philosophy was that the DERs should remain offline until whatever the problem causing unstable grid operation was fixed before the DERs came back online. As the concentration of DERs increases this approach becomes more and more of a disadvantage to overall grid health and stability. This is due to the larger power production capacity attributed to DERs of the overall grid capacity. If all the DERs are turned off in the event of grid instability the loss of this capacity can lead to an even more unstable grid and in some serious situations the grid may experience outages.

With the above situation in mind grid support functionality was necessary to allow for stable grid operation in areas with high percentages of DERs. The UL 1741 SA standard was created to define the requirements for grid support utility interactive DERs. Under this approach, DERs are required to monitor and adapt their behavior to stabilize the grid in the event of instability. DERs are expected to stay online longer, provide a variety of power types and modify their behaviour in response to changing grid conditions. This results in an advanced DER capable of fast monitoring and reaction capability. The list of grid support functions required per UL 1741 SA are noted in Figure 3.

As outlined in Figure 3, DERs can be evaluated for a variety of safety, grid interconnected and grid support functions. Figure 4 graphically outlines the available options and how the standards partner together.

Some key considerations for grid-support, utility-interactive DERs include software considerations and communications for interoperability. Software is the key safety-related component as the response times and functions required are only practically possible utilising software. Control of the software for safety-related functions is critical to ensuring not only a safe product but also ensuring a product that can deliver the required grid support functions within published tolerances. The application of software safety standards such as UL 1998 (The Standard for Software in Programmable Components) ensures software development cycles are controlled and maintained, quality control is present and changes tracked and reviewed for compliance, and if necessary validated through repeated testing for safety, grid interconnection and grid support functions.

Figure 2. Existing power conversion and grid interconnection standards

Figure 3. Modern grid support interconnection tests

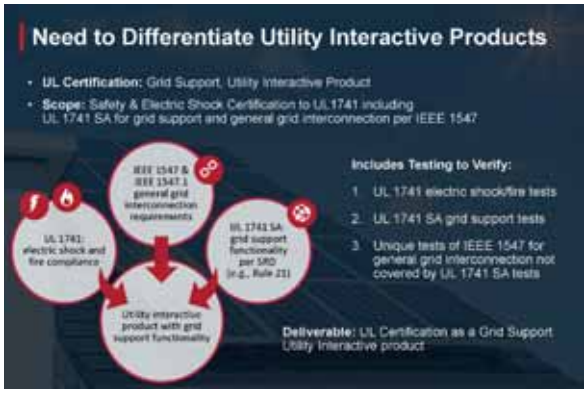

Figure 4: Safety, interconnection and grid support standards picture

With DERs playing important roles in maintaining a resilient and stable grid, as the percentages continue to increase, two-way communications and interoperability are becoming increasingly desirable and necessary. Today, the DERs have default settings as per the Source Requirement Document (SRD) for how and when to respond. Going forward, utilities will leverage standardised communication as per standards such as IEEE 2030.5 (Standard for Smart Energy Profile Protocol) to allow for two-way communication so that utilities can adjust the settings in grid-support DERs based upon real-time grid conditions. With the inclusion of standardised communication, cybersecurity will become an even more important key focus point in the future to ensure safety and security of DERs and their interconnection to the utility.

Distributed energy resource systems: UL 3001

Distributed energy resource systems (DERS) are likely to be comprised of sources such as photovoltaic arrays, wind turbines, or other renewable sources such as hydroelectric power or more traditional fuel-based approaches such as diesel generators. These systems may be composed of homogenous or hybrid configurations of energy storage systems, grid interfacing equipment and other related equipment to accomplish the functionality of the DER system. A new UL standard under the name of UL 3001 is intended to address microgrids, DERS and other forms of decentralised power. UL 3001 is intended to address safety and performance of DER devices not only at the individual component level but additionally at the system leve. Under its scope, the safety of system design, integration and operation as well as performance as it is related to grid operability and compatibility with installation wiring systems in various modes of system level operation are included.

The coordination of DERS equipment is required to operate safely under normal and foreseeable abnormal system conditions. There is a need to differentiate between system faults, to which equipment needs to respond, and single fault failures within a single piece of equipment. The interaction between energy source and power conversion equipment must be fully understood and accounted for at the system level. Operational ranges of all system-facing equipment must also be accounted for.

The development of UL 3001 is well underway. A Standards Technical Panel (STP) was formed in late 2018 and new UL 3001 task groups composed of various manufacturers, regulators, test labs and other relevant stakeholders have been formed to refine and deliver a draft standard. The intent is to make use of existing standards for UL, IEEE and IEC where applicable. In addition, alignment with ongoing 2020 NEC code proposals are also a key task included in the scope of the ongoing task group work. The task groups have several defined

scopes including but not limited to DERS interoperability communications inside the DERS, DERs protective functions, grid connection, coordination and interoperability, lab and field testing, and electrical interaction between sources.

Outlook

Advanced inverters with grid support functionality, energy storage systems and various other distributed energy resources configured with varying renewable power sources will continue to expand. In doing so their functionality will become more advanced, requiring additional regulatory requirements, codes and standards, and system-level safety and performance considerations. UL will continue to lead and involve the DG industry in preparing manufacturers, regulators, utilities and other stakeholders with what new requirements are applicable to gain market access. It will be necessary to create an environment where new regulations meet the pace of innovation for the ongoing goal of decentralisation of power production and the continuing shift to renewable energy sources.

Authors

Scott Picco has worked for UL since 2005 and is currently the business development manager and a regional lead reviewer for distributed energy resources equipment and systems. His responsibilities include business development for new programmes and service offerings in UL's Energy Systems & E-Mobility Segment within the Energy & Power Technologies division, managing large power conversion equipment certification projects globally, and he serves as the technical sales lead for inverters and other solar equipment within UL's E&PT Division.

Laurie Florence, principal engineer (stationary/motive batteries and ESS), represents UL on a variety of UL standards technical panels as well as other industry standards and battery committees across ANSI, SAE, ISO, IEC, IECEE, CSA, and NFPA. Laurie participates on NFPA 855 installation standard for energy storage systems and is a member of the NEC CMP 13 covering the energy storage and storage battery articles. Laurie is also the convener for IEC SC21A Working Group 5 responsible for developing standards for performance and safety of industrial lithium ion batteries such as IEC 62619 and is a member of IEC TC 120 developing the IEC 62933 series of energy storage system standards. Laurie is also responsible for the certification categories related to these various battery and energy storage standards at UL.

Tim Zgonena has worked for UL since 1990 as principal engineer for distributed energy resources equipment and systems. His responsibilities include the development, maintenance and application of UL's certification requirements and delivery of UL conformity assessment services for utility grid interconnection systems equipment, inverters and converters, PV BOS equipment, engine generators, wind turbines, and wind turbine system components.

Eroding soils, eroding image, eroding profits – why erosion control and drainage matter in solar

Design | A little more time and money spent upfront on properly understanding site drainage and soil conditions and designing solar projects accordingly can avoid much larger profit losses and reputational damage further down the line. HDR's Gretchen Dolson looks at some of the methods for ensuring PV sites stay afloat

In the race to build utility-scale solar at reduced capital costs and at record speeds, stakeholders are increasingly faced with tough decisions during initial project planning and financing—decisions that influence long-term profitability.

An area under intense scrutiny is improperly planned drainage and erosion control at large solar PV facilities. In an effort to save on up-front costs, many have overlooked the benefits of a well-planned drainage and erosion control approach. The result is an increase in post-construction site drainage and erosion control issues resulting in negative public perception and reduced profits.

Historically, the industry has focused on maximising electrical production to benefit from power purchase agreement (PPA) terms. This has driven industry improvements in panel, inverter and energy storage technologies. Tracker manufacturers have improved performance with enhancements to layouts and detailed evaluations of location-specific criteria, while increasing flexibility of the topographic grade tolerances for their systems. All of this has driven efficiencies in site layout to minimise electrical wire sizing, lengths and overall material use, while increasing the pace of systems installation nationwide. The missing link for our industry is in improving drainage and erosion control.

Time for a new approach

As the industry continues with hyper price competition for PPAs and construction, it's approaching site-specific challenges in the same manner as electrical and structural systems: applying a "less is more" approach to the manner in which site drainage and erosion control are evaluated, designed and constructed. In many areas of the US, less is not more when it comes to water and erosion management. It creates risk for all parties, leading to reduced profits over the life of a facility.

Proper installation of erosion control materials is critical for function during and after construction of PV power plant, particularly in regions with high rainfall

So how does lack of a site-specific drainage and erosion control management plan create risk, and whom does that impact?

The developer's perspective

Developers typically acquire only the land needed to construct a facility of a target size, and perform initial assessments:

- Siting;
- High-level environmental reviews to ascertain the ability of a site to transition from current land use to use as a solar PV facility;
- Preliminary estimates for a site layout;
- Estimated production to assess potential revenues and return on investment.

If those high-level assumptions do not consider the impact of events such as flash flooding in the southwest or hurricane potential in the Gulf and Atlantic regions, or the risk of not being able to contractually meet a utility interconnection accessibility obligation, the developer's investment model may overlook critical aspects that could affect land purchase or use.

Consultants assisting third parties in the

Depending upon the location of facility installation, the figure shows some common challenges associated with site drainage and erosion control

Design for high water flow diversion. Do not assume large, sudden storm events can pass over a facility without water depth and velocity damage. Consider conveying large flows around the site rather than flow over land

diligent evaluation of a site for sale review these high-level assumptions to validate the decision to construct a solar PV facility on the site. It's vital to include evaluation of a site's drainage and erosion control risks in these transactions, as well.

CASE STUDY: the lost customer

Improper design and construction of facilities places the solar industry at risk with some of our industry's largest preferred customers – utilities and corporate buyers. As they engage to own or directly oversee operating facilities, these customers are critical of the lack of quality and foresight in sustainable development for currently operating systems.

In one instance, a utility purchased assets as well as PPAs with third parties nationwide, and later learned the facilities developed by others did not properly address grading and drainage. To resolve the issues, protect the utility's reputation and prevent potential lawsuits, it's planning to invest more than US$1 million over the next few years on grading and drainage improvements. As a result of the experience, the utility is considering self-development of all future solar PV.

As an industry, we are in a limited time window to turn around the construction quality of facilities on the market for utilities and corporate buyers. If construction quality does not improve, utilities and corporate buyers will construct themselves and bypass the many long-term developers and contractors who have helped build the solar industry.

Urgency isn't just confined to those working in the industry: shareholders are requiring greater value for their investments, which means greater diligence at the time of sale or contract closure to ensure facilities are built with sustainability in mind; for example, not just producing carbon-free power, but also making minimum impacts on the environment.

The buyer's perspective

Two main scenarios can play out with many buyers in the solar industry: a PPA or the buyer taking primary ownership of the facility.

In a PPA scenario, the buyer is purchasing power and environmental credits from a facility owner. Risk is carried by the facility owner (developer or whomever they sold the facility/PPA to), and the buyer is typically contractually protected from a facility that violates any permits. However, buyers risk social and political fallout if their name is tied to a facility with a known issue. Utilities and corporations' shareholders demand ethical business practices. If their name is tied to a facility called out for a violation or damage to surrounding property, it can quickly create a public relations issue. Once a utility or corporation experiences this situation, it may be hesitant to invest further in solar, particularly with a past development partner.

The second scenario is an asset transfer where the buyer is taking primary ownership of a facility. When this occurs, it often spurs investigation and investment. Few utilities' operations divisions are satisfied with the quality of construction at a typical solar PV facility, particularly in regard to facility access and site drainage.

When our key clients invest in solar and don't meet expected returns, they will not continue to voluntarily invest in the technology for the long term.

When utilities acquire these assets, addressing issues up-front helps avoid the inherent social and political risk of doing nothing where there is a drainage or erosion control problem. However, the dollars spent decrease the economic value of the asset purchased to the utility as a whole.

CASE STUDY: more time or more money

An independent power producer (IPP) is developing a site for a corporate buyer. As part of this work, the utility interconnection will be owned, constructed and maintained by the utility. Access to the site is the responsibility of the IPP. The site access route was determined by the engineer-procure-construct contractor without regard to existing site drainage and soil conditions. With excessive weather events, the access route was not passable and will not be for the foreseeable future. This affects the utility's ability to build its interconnection substation on schedule, and potentially puts the project at risk of not meeting contractual obligations to the corporate buyer. While there is a solution that will work to remain on schedule, the additional US$500,000 cost of this solution to overcome saturated soil conditions is affecting project profitability; it could have been avoided with some early project planning to avoid this low area.

To protect project value and our industry's reputation, focus needs to be placed on enforcing sound design and construction approaches that support sustainable site development practices, without breaking the bank on initial capital costs. Correctly designed drainage and erosion control systems integrated into site layout can enhance the functionality of sites for greater sustainability and public benefit, and reduce life cycle costs. Failure to recognise the increasing cost impact of neglected site drainage and erosion control will create long-term impacts to profits on individual sites, and long-term damage to the solar industry, which claims to be more environmentally sensitive than other power-generation technologies.

Promising profit draws financers

Not evaluating a site for water management is a liability most project financers prefer to avoid. In the long-term need for project return, reduced profits not only result from lower production on a site, but also through additional, unscheduled maintenance and engineering study costs required to resolve ongoing regulatory and operational permit violations. As important, if surrounding landowners make a claim for damage, all parties are at risk of having to defend themselves, regardless of contractual terms.

Reduced warranty claims motivate epc contractors

An EPC (engineering, procurement and construction) contractor's contractual requirement is to build a facility that meets the priced terms and conditions. If an owner in a hurricane-prone region does not require its EPC contractor to consider lifecycle costs, or does not acknowledge there may be additional capital costs to build a road to withstand hurricane rain volumes, there is little incentive for the EPC to do otherwise. However, EPC contractors are beginning to push for greater consideration of facility design that considers the operations phase to prevent warranty

claims once they have demobilised from the site. Regardless of the claim's outcome, the result is lost profit.

CASE STUDY: taking one for the team

A facility already in operation has consistent roadway access issues during seasonal rain events. The facility was designed and built to the minimum standards contractually required by the developer and allowed by permit. The EPC contractor continues to receive requests to repair the site access road by the third-party operations management company on-site. While there is no contractual reason to provide the service, the EPC contractor's reputation is at risk.

It's discouraging for the developer, EPC contractor and operations company to spend profits working through an item that was not included in their design, and to experience reputation fallout as a result of the ongoing roadway access issues. Reviewing the long-term facility requirements post-award may have uncovered the need and opportunity to build a more durable roadway within the contracted price, given the seasonal water management requirements.

Three recommendations to build site reliability and profit

For all parties engaged in the development of a new facility, consider the following practical recommendations:

1. **Prior to construction, ensure sufficient technical analysis is completed on the site and surrounding area for both water management and erosion control.** It's important, and it's simple.

The additional cost to complete a detailed hydrology assessment for a large site (50MW+) is negligible compared to the legal fees associated with a claim of water disturbance with a surrounding landowner. A study also protects all parties from unanticipated impacts due to climate change by demonstrating the assumptions and methodologies used for design and construction were reasonable at the time it was completed. Sites should to be evaluated by a technical professional and documented as part of the project development process. A key consideration in regions with high-intensity rain events is the potential for high-water diversion paths on-site that also consider adjoining property impacts.

The standing industry approach for erosion and sediment control has been to install the minimum best management practices (BMPs) required for a permit during construction. A shift to installing the appropriate BMPs to avoid site erosion failures would prevent many issues. Installation of appropriate devices does not have to mean a significant initial capital cost addition if considered during the early development of the site. However, it might require avoidance of marginal lands/agricultural wetlands in areas such as the southeastern US, and may require additional acreage be set aside for water quality buffers in the northwest. Often the cost of the additional acreage is less than the combined cost of capital and operations and maintenance cost challenges on a site where the water has not been adequately planned.

2. **Consider a vegetative management approach or pollinator plan prior to construction.** This applies to every site, regardless of size.

It may be mowing challenges in the southeast, mesquite management in Texas or dust control in the southwest. Every solar PV facility has site conditions that affect erosion control. Each of those challenges can be solved with minimal cost (increasing profit) through site layout and equipment selection. Decisions are typically needed early in the project lifecycle while there is still opportunity to see the full economic benefit. The use of a pollinator plan would provide benefits to a project in many areas of the US and should be considered wherever possible. If vegetative management is not considered until after the site is designed and piles ordered, the additional marginal value is lost.

3. **Evaluate soils on-site during early project planning**. Invest up-front to save down the road.

Preliminary geotechnical borings are valuable in their ability to support a site development approach that solves permanent drainage and erosion control challenges for little additional capital cost. Understanding materials that will be used for trench compaction, roadway construction and general grading activities is important when concerned with long-term site stabilisation. Such knowledge can prevent soil loss or regulatory permit violations for discharges.

Failure to properly evaluate and build solar PV facilities that manage on-site drainage and erosion control is reducing the anticipated profitability of some solar facilities today. Post-construction failures lead to increased maintenance costs and regulatory non-compliance issues. Regulatory notice of noncompliance during the operations phase can negatively affect specific company and broader industry reputation.

Consideration of drainage and erosion control approaches, as part of initial project development, will benefit the long-term functionality of a site and avoid public relations challenges, which emanate from operations and maintenance failures after construction. With sites now being developed specifically for utilities and corporate buyers, there's a need for developers and contractors to adapt and price to accommodate. ■

Develop a vegetation plan for pre- and post-construction erosion control and vegetation stabilisation

Note: scenarios presented in this article are based upon the experiences of the author and co-workers while acting as director of the renewable energy programme at HDR over the past 10 years. Since 2008, the renewables team at global architectural-engineering consulting firm HDR has worked with clients to install more than 5,000 MW of utility-scale solar PV. Project names, exact locations and timelines are omitted in accordance with nondisclosure requirements associated with these scenarios.

Author

Gretchen Dolson leads HDR's renewable energy programme and is a professional civil engineer experienced in the design of renewable energy and industrial land development projects. Her leadership in the renewable energy space includes the development of more than 5,000MW of renewable energy globally. She currently leads business development and technology thought leadership efforts in the areas of solar, wind, and energy storage development at HDR. With HDR renewables staff working in more than 25 offices, Ms. Dolson and HDR's focus is on utilizing global technical expertise and local presence to deliver sustainable facilities to HDR's renewable energy clients.

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Weathering the storm

Solar resilience | Hurricane-strength winds are a clear threat to solar installations in island nations, where PV is becoming an increasingly popular solution to climate change-related issues. Joseph Goodman and Frank Oudheusden, co-authors of a recent study on designing hurricane-ready solar systems, offer an insider's view of how the challenge is being met

Credit: Jocelyn Augustino/FEMA

Island nations and coastal regions globally are increasingly mobilising climate change mitigation and adaptation efforts due to the local economic benefits. Distributed solar deployed in concert with complementary technologies such as batteries and/or micro-grids has growing momentum as a dual-purpose solution (mitigation and adaptation). While the case for solar as a mitigation solution is on a solid footing, the case for solar as an adaptation solution looks strong but requires field validation. Adaptation for island nations includes a need to protect electricity-dependent functions through increasingly frequent and extreme wind events including hurricanes and typhoons. For many decision makers, positive field validation will occur when PV systems resume power production promptly after an extreme wind event with little to no isolated damage.

Designing and optimising a PV power plant to be resilient to extreme wind is an emerging field. In 2018, the Rocky Mountain Institute published a report, 'Solar Under Storm' [1], which highlighted the emerging best practices for designing solar systems in hurricane-prone regions. The following article draws together some of the key lessons from the report.

One size fits all solutions rarely translate to island nations and solar is no exception

In response to temporary incentive programmes and dynamic markets, solar industry players have survived and perished on their ability to enter new markets with speed.

Hurricanes can damage or entirely destroy ground-mount solar installations without the correct design measures

Standard PV plants have been one of the tools for rapid market entry. In the design of standard plants, tensions exist between cost reduction and site flexibility. Rarely does a standard plant have extreme wind resilience as an intrinsic functionality. Yet, no aspect of PV components or systems is technically or financially incompatible with extreme wind. These bookends teach us that systematic design for extreme wind can result in resilient PV systems that provide mitigation and adaptation functions. Yet, failure to explicitly address the regional specific requirement will lead to likelihood of equipment failure when extreme wind strikes.

Extreme wind cannot be ignored

The Caribbean region has experienced a palpable increase in high-wind events over the past 20 years. Just looking at Category 5 hurricane events (Saffir-Simpson Scale >157mph 1-minute sustained wind speeds), the Atlantic region saw 22 Category 5 hurricanes between 1924 and 1998. Sixteen of those storms passed through some part of the Caribbean. Since 1998, the Atlantic region has seen 10 Category 5 hurricanes of which nine have passed through some part of the Caribbean. One of the latest of these storms, Irma (2017), holds the record for the longest sustained period at Category 5 status in the modern satellite era.

Sustained wind speeds on many of these modern storms are being measured in excess of 175-180mph and have spawned the apt discussion of creating a Category 6 on the Saffir-Simpson hurricane scale.

From a PV fleet management perspective hurricane frequency is only half the story. The increasing overall (industry) population of PV systems and their geographic distribution will make extreme wind interactions more common, if not an annual trial by wind. Designing PV plants to be resilient to tremendous wind forces poses a design challenge for the industry with great stakes at play.

Cost and value are both at stake

PV plants are subject to three cost categories in a wind damage event: 1) scrap removal and recycling (disposal); 2) reconstruction; 3) damage liability.

Removal of scrap material from a site can incur long re-start delays and transportation cost, especially on remote installations in regions with broad damage. Reconstruction after a regionally catastrophic event can incur labour premiums and supply chain delays.

While damage liability is better quantified by insurance agents they may consider the likelihood and severity of liberated modules or hardware striking surrounding infrastructure or vehicles as observed at one site by 'Solar Under Storm' authors.

While cost may be insured against, value might be the most precious asset and un-insurable. The growing market for adaptation solutions is fuelled by the confluence of rising sea levels and storm severity. In the last decade, solar has been taking market share from gas and diesel generators due to an operating cost advantage, and bolstered by the desire to eliminate generator noise and particulate emissions.

For the solar industry, growing market in high-profile regions drives investor confidence and a virtuous cycle. From our perspective, the customer's belief in PV's inherent resilience to extreme wind underpins this market share. Every PV installation that haphazardly copies a standard plant designed for low-wind applications into an extreme-wind application puts the value of a growth cycle at risk.

A starting point for the design challenge

As an industry, we can ask what features and benefits should be part of a competitive dynamic and what features should be ubiquitous. Given the overall market risk, it is our perspective that resilience to extreme wind should be ubiquitous across every installation in high wind locations. Not failing under wind aside, let's compete over: cost, speed of delivery, aesthetics, customer experience, brand and other attributes that the customer values.

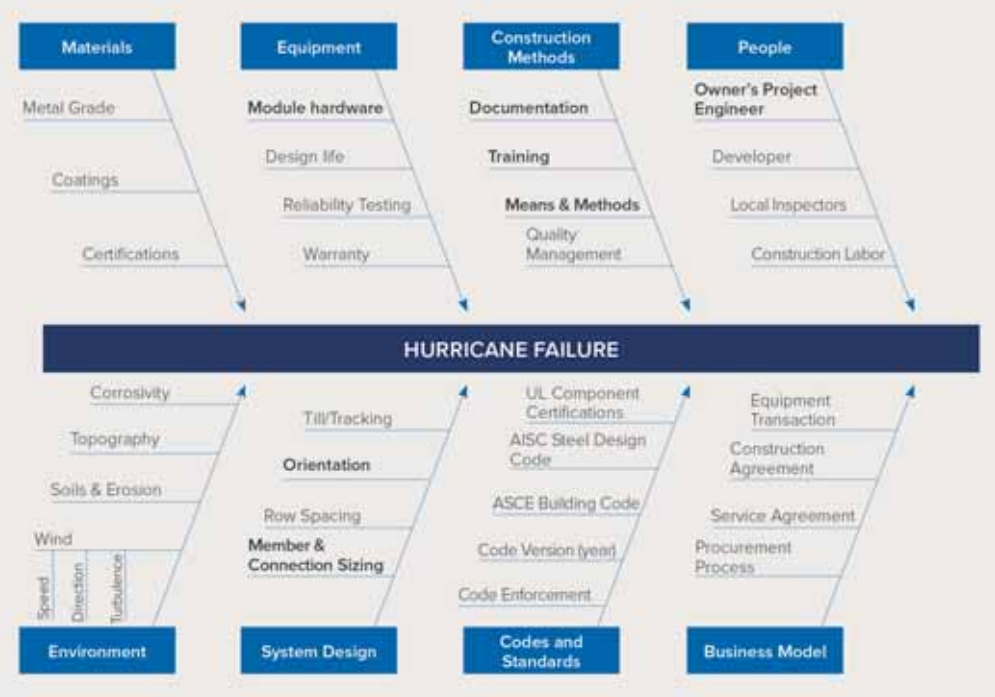
With this perspective in mind, Solar Under Storm team members from The Rocky Mountain Institute (RMI), FCX Solar, NREL (National Renewable Energy Laboratory) and Solar Island Energy set out on an ambitious reliability study. The team attempted to visit every ground-mount system in the Caribbean affected by the 2017 hurricane season. The map in Figure 1 illustrates the seven sites we visited, that included three damaged sites and four operational sites. While the human and economic impact of the 2017 storm season was utterly catastrophic, the scientific implications were also unprecedented; no other hurricane season has provided such a large sample size to learn from.

The reliability method used by the team was based on a 'failure modes & effect analysis' (FMEA). Documented field observations were fed into the FMEA process allowing the team to collaboratively analyse the underlying causes and effective mitigation actions.

Rather than having to postulate potential mitigation actions, the team drew on two proven sources of mitigation actions. First, we had over half a century of design experience across the team including deep expertise designing for wind hazards. Second, we had a population of surviving systems that taught us new tips and tricks. Collectively our confidence was greatest in the mitigation actions with a pattern of deployment across our team's experience

Credit: RMI

PV Sites visited for the 'Solar Under Storm' study. Three had been destroyed in the 2017 hurricane season, four were still operational



Credit: RMI

Root cause analysis can help identify the cause and effect of hurricane-related failures

and the population of affected surviving systems.

While we count on innovative PV plant solution providers providing equivalent or better answers over time, our published best practices attempt to set a starting point that ensures protection of system owners, electricity consumers and the solar industry.

Six best practices

Six of the highest priority best practices and the failure modes they address are presented here as a fast starting point for readers. Ultimately we hope professionals working on extreme wind projects will pick up the full report. Figure 2 shows a tool for identifying the detailed cause and effect of hurricane-related failures.

High load rating PV modules

Module frame bolthole failure was observed on multiple sites. The team found this failure mode could be mitigated with two specifications. First, specify high-load PV modules consistent with module pressures reported in the wind tunnel test (see the guidelines Appendix for instructions). Second, ensure the module connection hardware is evaluated and stamped for the site-specific wind conditions by a structural engineer.

Yet, a robust frame is not adequate alone; in lab testing conducted by the authors, laminates consistently tore out of frames under applied loads in excess of their rating. We treat laminate tear-out as a critical lurking failure mode because under-engineered modules tended to have frame failures before laminate tear-out.

Secure connection (bolt) hardware

Failed module connection hardware was another common observation across multiple sites with failures. Bolt self-loosening was the most common cause of connection failure. For most systems, dramatic improvement is possible through a combination of a hardware locking solution in combination with a carefully monitored QA/QC process. In a short time, we expect even higher levels of reliability will be achieved through pre-assembly and factory-attachment solutions.

> "We do not anticipate zero component failures in PV systems. This is neither technically nor economically justifiable. Yet,by systematically eliminating cascading failure modes a single failure can be isolated"

Failure isolation hardware

Our root-cause-analysis found that a majority of failed module connections were cascading failures. In theory a system might use a wind-proof module but we saw wind-born debris impact and liberate one module that in turn propagated a cascade of module failures.

Rather than directly failing due to wind pressure, an adjacent module failed first, allowing a shared top-clamp to rotate and liberate the adjacent modules. In the worst cases, failure cascaded across an entire row. In response to this observation, the team recommends use of failure isolation hardware that prevents an initial failure from propagating down the system. Two fail-safe options include through-bolting and single-module top clamps.

Design for lateral loads

Lateral loads in extreme wind events proved capable of failing PV racking, especially racking on the perimeter of the PV array. Lateral loads occur due to normal wind forces on electrical boxes (inverters and combiner boxes) as well as racking structural elements.

While wind tunnel studies tend to focus on normal forces (perpendicular to the module) ASCE 7 building codes and good design both require consideration of lateral loads. Structural engineers and third-party reviewers should ensure site-specific lateral load analysis includes racking and electrical elements. Site inspectors can check actual electrical box placement against engineering calculations.

We saw two simple tricks to address lateral loading.

First, the lateral structural load can be reduced by mounting inverters on freestanding posts rather than on the posts of the racking structure if the racking structure does not have adequate capacity.

Second, the lateral capacity can be increased with cross bracing on columns. Some designs even require cross bracing to be incorporated into the module rails to avoid shear load transfer through modules and cascading failure after one module liberates.

Dual foundations

Foundation overturning was observed at some sites where modules and racking remained intact. One approach to mitigating overturning is specification of

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dual foundation designs. Dual foundations use structural coupling rather than bending, to resist overturning. Complementary (or alternative) mitigation measures can include use of low-tilt or dual-tilt module angles that reduce peak module pressures and overturning moments.

Single-post foundations also suffer from an engineering phenomenon known as the inverted oscillating pendulum. It's a very fancy way of saying the wind buffeting on the structure is amplified due to the natural frequency of the racking structure being below a certain point. Foundation sizes typically grow tremendously (in embedment depth) to overcome this issue. Provisions for how that's accomplished are done through industry-standard 'pluck testing' and through factors in the wind tunnel study.

Design for erosion

High-sloping terrain is common on island projects because flat terrain is less common and demands a premium. This leaves high-slope terrain for infrastructure projects such as PV plants. Hurricanes have extremely high winds but also bring extremely high volumes of rain. That rain cannot be absorbed by the earth in such large quantities in such short periods of time and often runs off to the ocean. This high-volume run-off creates erosion hazards both in access roads and around structural foundations. Our team recommends that projects engineer a water mitigation plan to slow the waters speed and spread its volume over as wide an area as possible. Mitigations such as rip-rap application, culverts and other engineered drainage systems are possible resolutions but subject-matter experts should be consulted.

Solar Under Storm is really just a starting point

In multiple lengthy debates the authors discussed how to balance the need for immediate actionable recommendations with leaving the largest potential for open-market innovation. On one hand, project owners are seeking tangible recommendations that can be incorporated into procurement specifications; on the other, some equipment suppliers may provide hurricane-resilient solutions through novel design strategies.

This tension resurfaced through public comments on the report. The best practice to use "vibration resistant hardware such as nylock nuts", for example, was a source of debate among the online community. Some practitioners prefer that the example of nylock nuts be not directly incorporated into specifications because a more cost-effective and higher reliability solution might exist.

This feedback indicates that, over time, a transition away from prescriptive specifications and development of performance-based specifications may better support continued industry innovation and advancement.

A second limitation of work is that we do not anticipate zero component failures in PV systems. This is neither technically nor economically justifiable. Airborne debris during hurricanes can come from anywhere and is very costly to engineer against. Yet, by systematically eliminating cascading failure modes a single failure can be isolated. String inverters or even module-level power electronics allow a damaged module to be isolated and go unnoticed by the electric consumer and system financiers. Meanwhile, the plant monitoring software can order up a replacement and dispatch a crew. Overall, we expect fault detection and isolation to be a cornerstone for how the solar industry rises to the resilience challenge.

The call to action

For industry professionals working in regions that experience extreme wind events, 'Solar Under Storm' must only be a starting point. The authors bet that robust collaboration will prove far more valuable than any initial set of best practices. The most exciting collaboration models include:

- Collaborate with module suppliers for implementation of static and dynamic load tests representative of Category 5 hurricane winds.
- Collaborate with racking suppliers for full scale and connection test representative of Category 5 winds.
- Collaborate with equipment suppliers to document material grade and coatings are consistent with professional engineering assumptions.
- Collaborate regionally and internationally as a community of practice that regularly shares lessons learned and best practices.

To help instantiate the recommendation to collaborate as a community of best practice, RMI has formed a PV resilience working group on the online Caribbean Renewable Energy Community (CAREC) which is hosted by CARILEC to connect innovate and collaborate. Join the working group at http://community.carilec.org/c/PVResilency

Proving the point – a 100kW early adopter

The Rocky Mountain Institute has developed a 100kW pilot project based on these recommendations on the island of Mayreau (Saint Vincent and the Grenadines) for 2019 construction. FCX Solar has consulted on the application of the 'Solar Under Storm' recommendations and RBI Solar has provided the structure to meet these guidelines. Mayreau will provide the region and its utilities with a prime example of what a resilient system design should look like today. ■

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[1] Burgess, C., Goodman, J. 2018, 'Solar Under Storm', Rocky Mountain Institute, https://www.rmi.org/wp-content/uploads/2018/06/Islands_SolarUnderStorm_Report_digitalJune122018.pdf

Authors

Joseph Goodman, PhD, has 20 years of professional and educational experience in renewable energy. While on the faculty of Georgia Tech, Dr. Goodman developed advanced wind-resistant racking technology that formed the basis for Quest Renewables and his PhD dissertation. Currently at RMI, he provides technical leadership to solar and storage programmes and directly supports Amory Lovins in scaling the impact of integrative design.

Frank Oudheusden is Co-Owner of FCX Solar, along with Christopher Needham, co-author of 'Solar Under Storm'. FCX is an engineering consultancy and intellectual property development firm. FCX has led and supported cross-functional teams in the release of PV products in all major structural platforms, and qualified and completed due diligence on niche PV growth opportunities such as floating PV, bifacial module applications and 2,000/2,500V design on behalf of world-class developers. FCX Solar has over 20 years of experience in the PV industry and subject matter expertise in standard plant design, wind tunnel testing and design for manufacturing and assembly.

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A tested and proven wind mitigation strategy to minimise risk

Trackers | Ensuring the stability of solar tracking systems and modules during wind events is one of the top concerns of solar site owners, project developers and EPC contractors. A poorly designed single-axis tracker can result in damage to solar trackers and modules, leading to costly downtime, insurance claims, or even possible injury. Todd Andersen outlines the innovative methods that engineers at Array Technologies have uncovered and use to address this major potential setback for solar projects

Credit: Array Technologies

Avoiding wind damage to trackers and modules is a key concern for solar project stakeholders

Single-axis trackers require that special attention be devoted to managing wind events. Dynamic wind forces can amplify the load on single-axis trackers, which can lead to damage, downtime, and higher cost of ownership.

During Array Technologies' 30 years as a leader in the solar tracker industry, our engineers have extensively studied and tested how wind interacts with modules and tracker systems. Both in simulations and in the field, they have vigorously tested wind's effects on solar sites and have closely examined the various solutions for addressing these issues that have become prominent in the industry.

In order to avoid accepting status quo methods or falling into "this is how it's always been done" thinking, Array has continued to observe and push forward to improve our methods.

Our perspective has been that if we truly understood the way tracking systems respond to various types of wind events, we could engineer a solution that is simpler and more intuitive, as well as far more effective, than previous iterations of tracker technology. It's a continuous process, and Array plans to continue this exploration of system response to wind events.

Through constant observation, adjustment, and implementation, our teams have developed the DuraTrack HZ v3, a tracker specifically designed and field-tested to withstand harsh weather and environmental conditions and operate in a simpler, more intuitive way.

DuraTrack reliably handles wind events with a fully integrated, patented, mechanically passive wind load mitigation system. Array's unique approach to controlling resonance minimises risk, protects the structure, and optimizes production, all without the use of complex communication systems, batteries, or power.

Typical wind mitigation methods and Array's patented, innovative approach

Many tracker mitigation methods stow the entire solar field in a flat position at 0 degrees, or at a low angle of up to 30 degrees. (Fig 1)

Array Technologies explored these stow angles with rigorous performance and reliability studies and experiments. As a result, our engineering team found that several problems arose with these typical stow methods and sought more effective ways to handle dynamic winds.

Below, we will outline the issues our engineers repeatedly found both in our own tests and in the solar industry's publicly available data.

Problem 1: Active stow requires an

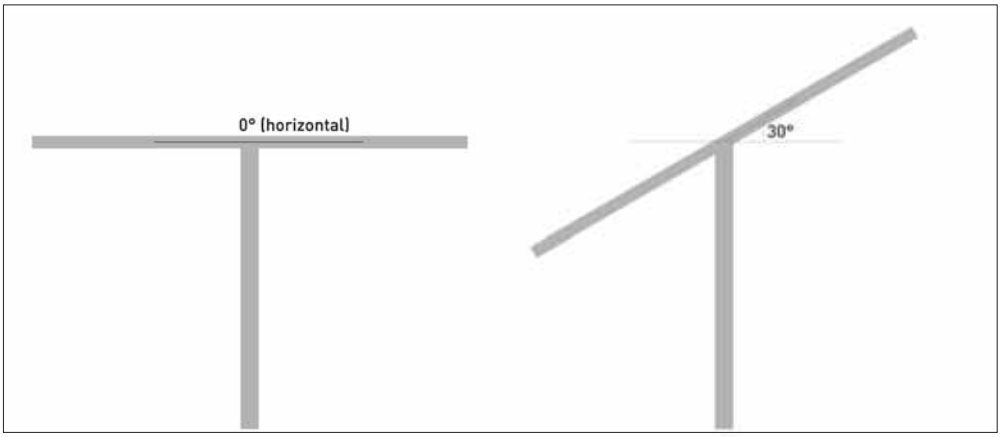

Figure 1. Traditional tracker stow angles

uninterrupted power source (UPS) system or a battery backup, which adds complexity and more opportunity for the process to fail in real-world situations. These systems rely on an electronic sensor of some kind, such as an anemometer or another wind measurement tool. When this sensor picks up the signal that a certain threshold of wind is exceeded, it electronically sends the message to the trackers that they should transition into stow mode. This is usually a flat position parallel to the ground, or close to such a position.

The reasoning is that the wind drag loads are lower on horizontal modules than they are on modules at higher tilts. This is because at low tilts, the area of the module that is exposed to the wind is very small compared with the area that is exposed at high tilts.

As such, it is generally accepted that since wind loads during extreme wind events are lower on actively stowed trackers with modules at flat tilts, the tracker and surrounding support system do not need to be as heavy or substantial. In theory, structural demands are reduced, which allows for a lighter-weight, less expensive product.

Two major issues arise with this method:

- The complex signalling system leaves unnecessary room for error. If any part of the lengthy control chain of electronic components fails – from the sensor reading wind speed and velocity to the message travelling to the control system telling the tracker to move to stow – the results can be catastrophic. Every link in the command chain must be functioning properly in order for the system to work.

  For this reason and because of the increased probability of a power failure during a severe wind event, the tracker may not properly stow, and the modules may be left at a high tilt position.

- When this happens, trackers designed to support lower wind forces from lower tilt angles may be structurally inadequate to support higher forces from higher tilt angles. This can result in solar modules twisting, in much the same way as an ice cube tray, which can cause structural damage to the torque tube, bearings, posts, and other structural components.

  The perturbation can lead to cracking or dislodging of modules and even damage to the tracker itself. Microcracking is also a major concern. Even if there is no visible damage, there may still be tiny abrasions on the solar modules that significantly reduce or even halt the site's ability to produce energy.

  Since trackers that take advantage of lower design forces from lower tilt angles are often constructed with less steel than average trackers, they may cost less up front. However, if lighter-weight trackers do not adequately protect against wind damage, using them can be far more expensive in the long run due to the costs of repairing structural damage and associated system downtime.

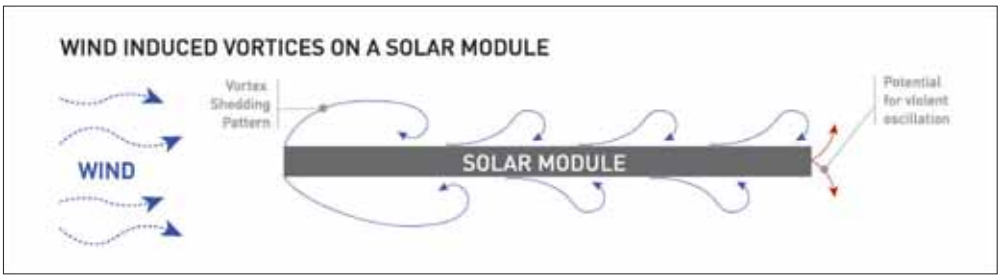

Figure 2. Vortex shedding

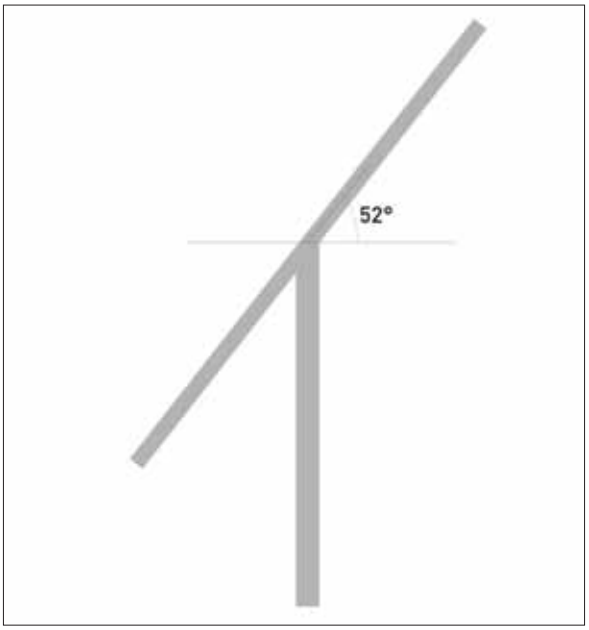

Figure 3. Array Technologies adjusts to full tilt angle

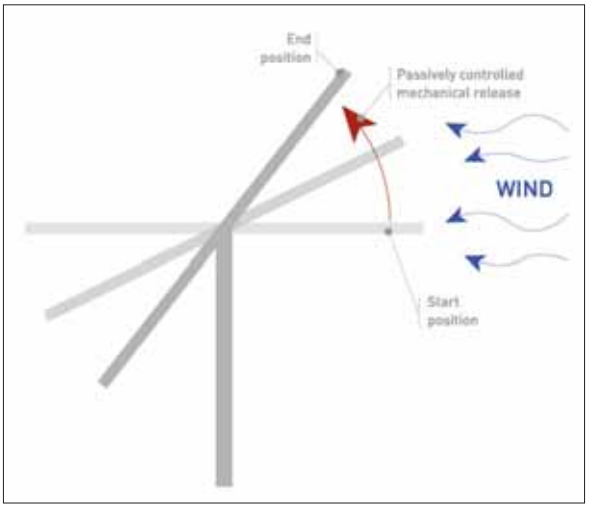

Figure 4. Array Technologies passively reacts to wind

Problem 2: Even if everything does work correctly and the system stows flat, torsional galloping can still occur. Torsional galloping is the result of harmonic wind forces and vibrations destabilising single-axis trackers and modules. This occurs due to a phenomenon called vortex shedding, or sudden bursts of torque that build and release, causing modules to oscillate violently.

Vortex shedding (Fig. 2) and subsequent torsional galloping build more easily with trackers stowed at angles parallel to the ground. These destructive phenomena can happen at any wind speed, even low speeds if the wind is at the right angle to generate vortices that resonate with the natural frequency of the tracker system with the module stowed flat. This happens much more often when the modules are flat and very rarely at full tilt.

Systems affected by torsional galloping can experience significant issues with cracked or broken modules, and even twisted or damaged tracker structures. Obviously, the costs of this damage are significant. Not only must solar modules, trackers, and other hardware be replaced, but the fiscal effectiveness of the site decreases every minute that it's nonoperational.

Looking at things from a different angle with array solar trackers

Array's single-axis tracker and its inherent robustness, on the other hand, passively adjusts to a full tilt angle (Fig. 3). This relieves the wind load on the system and prevents the buildup of resonance, oscillation, and torsional galloping.

Introduction to DuraTrack HZ v3 key wind mitigation features

Array continuously studies wind mitigation by using extensive wind tunnel testing

data. In addition, Array implements unique system simulation models on which wind tunnel-derived time series loads can be applied.

These system simulation models allow Array's engineers to understand not just the static wind load on the tracker but also the dynamic response of the tracker to different wind conditions.

The DuraTrack HZ v3 is the solar industry's only tracker to manage wind forces on a row-per-row basis without using active stows, sensors, or electricity, by implementing a fully mechanical, passive wind mitigation system.

This independence from an electrical power source is important because it also reduces the risk of danger to workers and equipment during a solar plant's construction. Trackers that need power leave contractors and installers subject to on-site weather conditions during the transitional period before such trackers are fully operational.

During powerful or even standard wind events, trackers which require power to stow can pose significant safety concerns to EPC contractors and workers. Panels that experience torsional galloping as a result of wind bursts can not only bend trackers even if they do stay in place, but they can also come loose and act as projectiles.

Array's wind mitigation system is fully operational immediately upon installation, with no need for power to the site. This means that the trackers will tilt and adjust as needed right away, avoiding potential damage to the new solar site and any potential hazards to the people building it.

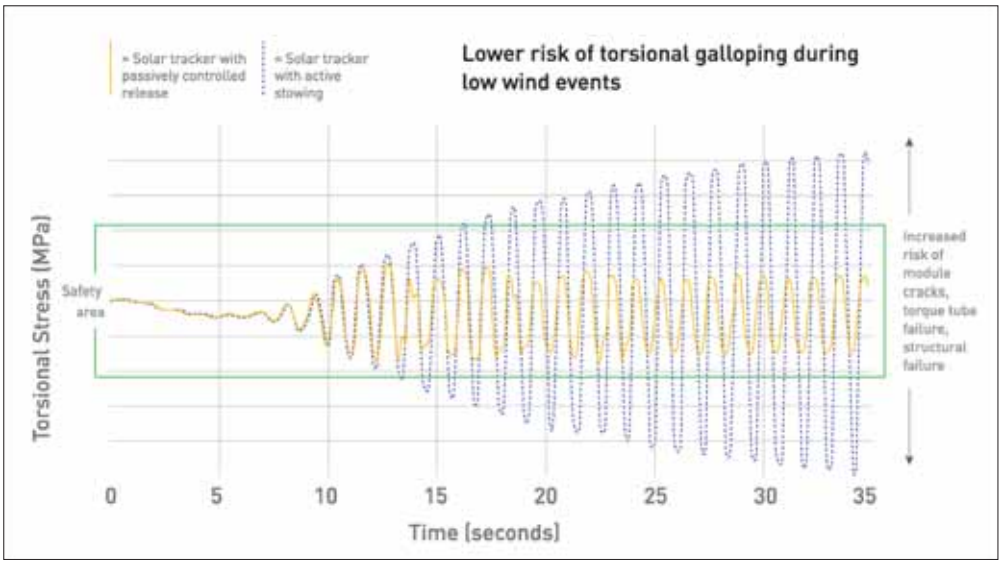

Figure 5. Tracker simulation performed by Array Technologies using multi-body dynamics software and wind tunnel data provided by industry leading wind consultants

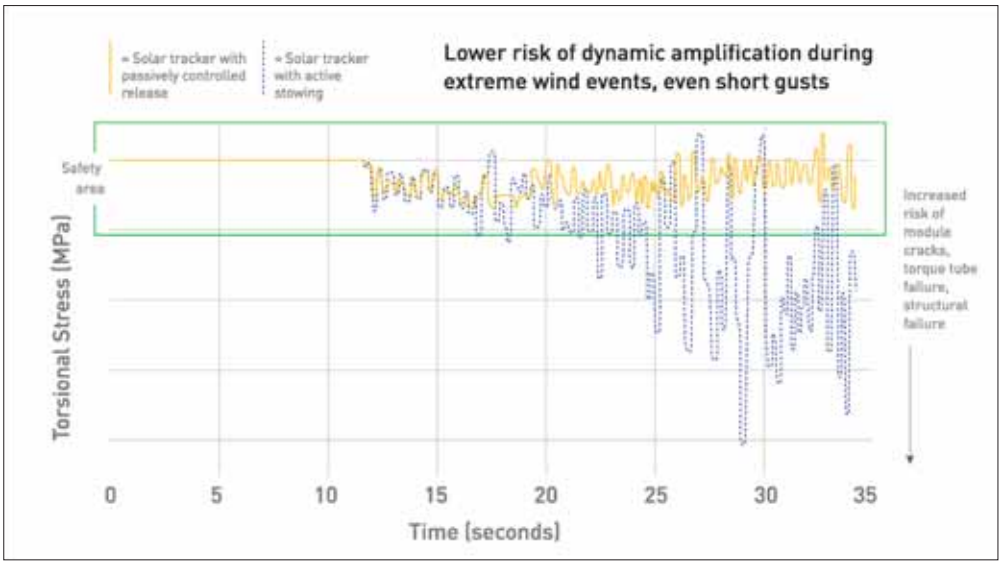

Figure 6. Tracker simulation performed by Array Technologies using multi-body dynamics software and wind tunnel data provided by industry leading wind consultants

Low wind speed response

Array trackers implement a patented, passively controlled mechanical release that activates automatically if the wind load exceeds the safety threshold established by engineers, where galloping and oscillation can occur.

The release allows a single row of trackers affected by wind of enough force, or wind from just the right angle, to rotate to a higher tilt. When this happens, the wind vortices are disrupted. The exterior row diverts the impact, protecting the rows behind it from unsafe wind levels and from the need to tilt themselves.

This automatic response by the tracker limits the harmonic wind forces, and the resulting torsional oscillations are reduced to an acceptable level that will not cause damage to the structure.

The chart in Figure 5 shows actual wind tunnel-derived loads applied to a full tracker system simulation model during low wind speed events. Array's DuraTrack HZ v3 passive stow is shown in yellow. Trackers with active stow are shown in blue.

High wind speed response

In the case of a sudden high wind event, such as a gust enduring for less than a minute, Array's DuraTrack HZ v3 reduces torsional galloping and stress via the same passively managed system. The impact on solar equipment is minimal compared with the impact on equipment in systems that stow at lower angles.

In the chart shown in Figure 6, Array's passive system response to dynamic amplification during extreme or high wind events is shown in yellow. The response of active trackers is shown in blue.

DuraTrack HZ v3 prevents torsional galloping on all rows in the full solar plant individually. This is important because there will be times when modules are flat due to the location of the sun in the sky. For example, if heavy wind picks up at noon, the modules will be parallel to the ground in order to collect light energy from the sun directly above.

When the load threshold of the passive wind mitigation system is exceeded at this angle, the affected row of modules naturally and passively rotates. This disrupts the flow of wind and puts an end to galloping. If the wind changes direction or suddenly comes from another angle, it is possible that oscillation and the galloping response could activate again. However, the system would allow this to occur only

up to a certain level before the tracker would passively cause another rotation, moving the tracker system once again to a safe position.

To be sure the wind mitigation issues were addressed in a comprehensive way, Array's engineers also designed the system for full wind loads occurring at full tilt angles. This ensures that the trackers are structurally sound and meet applicable structural design codes regardless of the tilt position of the modules and the wind speed.

More uptime and productivity with passive wind management

As previously mentioned, the exterior tracker rows generally take the brunt of high-wind events. This is an advantage for passive wind management systems, because usually only one or two exterior rows manage most of the force from the wind. The result is that the rest of the trackers remain at optimal operational tilt, reducing the impact on energy production even during a powerful wind event.

This works because the first two rows create a buffer zone to protect interior rows and prevent them from adjusting as well. Of course, winds can shift unpredictably, and sudden bursts may come from unexpected angles. There may be times when interior rows may need to adjust as well in order to protect the trackers from torsional galloping. However, the system automatically recalibrates twice daily at certain times, whether wind events take place or not. This resets the rows and positions them for maximum power production once the threat from any wind event has subsided.

With Array's passive wind mitigation system, there is still the possibility of some production loss in a wind event. However, the alternative with active sensing systems is to force the entire site into a nonoptimal position. In that case, no part of the site is producing power.

With Array's wind mitigation system, generally only a small percentage of the site's power production is reduced during a wind event. Any decrease in power production is corrected as soon as possible and without any exterior monitoring or intervention.

Financial implications with reduced project complexity, O&M cost, and risk

When site owners and developers are assessing potential trackers for resilience and sustained operation during wind events, levelised cost of energy (LCOE) and minimal investment risk are paramount for ensuring a profitable and successful solar site.

Wind mitigation is one of the most essential ways to protect assets in the form of people on the job, hardware in the field, and time and money invested in the project. It's undeniable that solar sites are often complex operations, from the first proposal through the commissioning ceremony and beyond.

However, we believe that reducing or eliminating the extraneous variables that leave room for error and increasing the integrity of single-axis tracker systems themselves are the answer to successfully mitigating wind effects long-term. This makes single-axis tracker sites more viable, more powerful, and more capable of withstanding anything Mother Nature forces on them over time.

Simple, intuitive, self-managed wind mitigation is the best way to diminish risk and maximise power production and cost savings. A passive wind management system reduces overall project complexity and operations and maintenance (O&M) costs, as well as the risk of failure and possibility of damage and downtime.

Reliability and the reduced need for maintenance create an opportunity for significant cost savings and boost profitability for key stakeholders, leading to a more financially successful solar project over time. ■

Author

Todd Andersen is chief engineer at Array Technologies. He is responsible for leading engineering efforts to study the dynamic behaviour of single-axis solar tracker systems while driving the continued reliability of Array Technologies' best-in-class solar tracker products. Todd brings over a decade of renewable experience to Array, drawing upon his years of experience in wind turbine support with GE Renewables. Todd holds a Master's Degree in mechanical engineering from Brigham Young University, with an emphasis in non-linear finite element simulation and structural dynamics.

Bifacial can smash its own glass ceiling

Bifacial | Having suffered from a chicken and egg status, bifacial solar is making ground and the advent of single-glass modules could lower costs and tip the odds in 2019. John Parnell reports

Credit: NexTracker

Nothing becomes mainstream while it's trapped in a niche. Saying a product or service is mainly targeting early adopters is effectively a polite way of saying 'this isn't commercially viable yet'. When technology surpasses this inflection point growth can be rapid. It's a familiar path already trodden by polycrystalline solar, First Solar's CdTe recipe thin-film modules and now monocrystalline panels too.

Bifacial solar has had a slightly more unusual path so far. As many a keen-eyed reader has pointed out to PV Tech, to call it new is something of a misnomer. The basic technology has been in the lab for 20 years. In the field though, the journey has been slightly tougher.

The aforementioned rise of mono-PERC modules and glass-glass modules opened the door. The price premium is fairly nominal, especially given the fall in module prices witnessed in 2018. With returns from the rear-side quoted from a conservative 5% to as high as 30% additional power, that price premium is surely easy to make back.

It's been obvious to all parties that the real issue with bifacial solar's slow take-up has been the lack of real-world data.

There are strong signs in 2019 that something has changed. A shift in the approach to project financing has undoubtedly helped (see box). An emerging technology trend could be set to improve the access and levelised cost of electricity (LCOE) for projects too, especially those with high labour costs. Typically, such markets also have better access to finance (think Western Europe, the United States, Australia, Japan, South Korea). These would have been many people's pick as the early adopters for bifacial solar and that trend may well now playout through 2019 and into next year.

Bifacial is beginning to make the transition from niche to mainstream technology

Through the looking glass

Bifacial modules have thus far been exclusively the domain of glass-glass modules. DuPont's development of a transparent backsheet provides the opportunity to change that.

"The clear backsheet is actually 18 years old," explains Mark Ma, global marketing manager for PV at DuPont. "This is not something we have developed from scratch. It was developed for use in BIPV markets. The new interest is driven by mono-PERC bifacial cells. Most module firms are going glass-glass because it is the only choice they have. What Mike [Demko] and his team have been doing is lowering the cost and improving the performance."

Demko is principal investigator at DuPont Photovoltaic and Advanced Materials and leads on new product development using DuPont's Tedlar films.

"We have a pre-existing field benchmark for the improvements that we have made. We are holding it to the same standards as our other Tedlar backsheets," Demko says. "We have improved the photostability of the transparent PVF film and it provides more permanent protection to the PET [polyethylene terephthalate] core."

The competition for the use of a transparent backsheet is obviously the use of dual-glass modules and that offers another benchmark for comparison.

"We are targeting a 30-year guarantee to match glass-glass modules. That is what is required in the market. To be honest, I'm not sure that glass-glass can actually last that long. The transparent backsheet has a higher requirement on both inner layer and outer layer for 30 years," says Ma.

Demko says the interest from manufacturers is clear. "They understand the benefits and it is something they want as an option. They want to see the data around the 30-year reliability. We have a lot of discussions about the test conditions," he says.

JinkoSolar is the first manufacturer to take a transparent bifacial module to the market with a soft-launch at the World Future Energy Summit in Abu Dhabi earlier this year. DuPont's Ma expects more to follow.

"At the moment, there is still more glass-glass bifacial modules. But in the long run we think glass-transparent backsheet structure will be the norm, just like mono-facial modules. A lot of the major manufacturers are testing transparent backsheet now and in H2 2019 we'll see more manufacturers using the transparent backsheet," he predicts.

"Different manufacturers have different opinions on the module construction. A lot have committed to glass-glass, even though there are issues. A lot are still building confidence in the new transparent backsheet.

"We are working on field data to show that there is an improvement. The power degradation rate might be lower and also the cell temperature compares favourably with some of the higher cell temperatures seen with dual-glass modules. That data set will be complete at the end of this year or early next year." Despite the wait for that data, Ma is bullish about how it will likely compare with dual glass.

"We're unconvinced by claims that glass-glass modules can last 30 years. We've seen field failure issues such as delamination and hot spots," he says.

First mover

Jinko's Swan range of bifacial modules use 158 half-cut cells offer both a glass-glass option and the transparent backsheet from DuPont in a standard aluminium frame.

"The main reason to choose a single-glass solution is based on the consideration of installation convenience," says Dany Qin, VP, JinkoSolar. "Some of our customers find glass-glass a little complex for installation, awkward, heavier etc. They have to use different mounting with clamps. It's a different approach than with conventional modules. As a result, it increases BOS cost particularly in the regions where the labour cost is relatively high."

Jinko already uses DuPont backsheets on 90% of its modules so the partnership on the transparent product was a comfortable decision says Qian.

Information on the comparative performance of the two Swan modules is not for public consumption but Qian says they are very similar.

"In terms of the LCOE and ROI, to some extent it depends on the cost gap between glass and transparent backsheet and which price comes down faster. If the cost of the single-glass module is similar to the dual glass, I think customers will prefer single glass. If the single glass is higher than the dual glass, the decision will come down to other factors influencing the customer's selection," she says adding that some may be more comfortable with one option, regardless of the fluctuating price of glass.

"For example, some EPCs are very familiar with working with dual glass so they will have no problems with that. But if an installer would have to put in additional effort through training, adding to their workforces, then they will be better with single glass."

The weight reduction alone offers the potential for great savings. The 9kg saving makes each module a one-person lift. The regular frame can be used with the entire universe of mounting and, significantly, tracking hardware. The potential for breakages is reduced as well.

At the moment the potential scale of LCOE savings has not been quantified. Not publicly at least. For now individual customers will need to discuss those figures with a prospective module supplier.

"One thing is for sure, bifacial generation modules, no matter with dual glass or single glass, will be the future. The cost is approaching that of monofacial and as that gap closes then everyone will choose bifacial because of its additional generation capacity.

"We need more data to prove the technology, especially bifacial plus trackers. We are collecting more data to demonstrate to the financial sector that this is a very strong solution. It is enough already to show the benefit, but we plan to track all the established project field performance with our Swan panels and establish a databank that we can use to show that Swan is one of the best solutions." ■

Credit: DuPont

Transparent backsheets offer a promising alternative to the typical glass-glass construction of bifacial modules

How to finance bifacial power – don't

In theory, a project expecting, say, 10% more power generation, courtesy of the rear side, should be able to trade that greater yield for more favourable financing conditions. Any sensible financier is going to look for guarantees on that power ideally from field data. This is where bifacial solar has run into problems in the past.

Competitive projects have been sidelined from tenders for not using "proven" technology. In the absence of an open access data bank demonstrating bifacial performance in a variety of settings and configurations, how can projects capture the added value of rear side power? An emerging pattern suggests the key is actually not to bother.

PV Tech understands that the 160MW Southern Oak bifacial project in the US state of Georgia, is not initially financed against rearside power. Once a few years of site-specific performance data is available the project can be refinanced on better terms. The European Bank for Reconstruction and Development (EBRD) has confirmed that it is taking a "very similar" approach for 400MW of bifacial solar it is co-financing in Egypt. GRIDSERVE's 37.4MW bifacial project in the UK is using a conservative contribution for its financing model. All three of these projects transpired in the first three months of this year. The stars are aligning.

Credit: Enel Green Power

Enel Green Power began installing bifacial modules at the Magdalena II plant in Mexico in April

Project briefing

EUROPE'S FLAGSHIP POST-SUBSIDY PROJECT UP CLOSE

Project name: Don Rodrigo
Location: Near Seville, Andalusia, Spain
Capacity: 175MW

It is ironic that Spain, whose government is infamous for its history of damaging PV policy U-turns, is also now home to the figurehead project of large-scale solar's return in Europe after years of hiatus. The Don Rodrigo project in the southern region of Andalusia is the first mega-scale PV system to go without subsidies on the continent, standing at 175MW capacity. Ever since Spain retroactively dumped feed-in tariff support for solar projects in 2012, investors have turned away from the prospect of Spanish solar, which was further tarred by the infamous, but now withdrawn 'Sun Tax' on self-consumption of PV generation. This meant that only solar without subsidy would offer freedom from the whims of government. It would take a culmination of loosened EU trade restrictions, technological advances and some adept forward planning to make this a reality in Europe. The head of solar at Germany-based company BayWa r.e., which delivered the Don Rodrigo project, believes that the plant is a huge milestone in solar fast becoming the cheapest source of electricity, with projections for it to be significantly cheaper overall than not just conventional sources of power but even wind energy in the near future.

Notably, Don Rodrigo is BayWa's largest project to date, is said have the longest power purchase agreement (PPA) of its kind in Europe and was sold to one of Germany's top four largest asset managers. This stamp of approval from the big league of the investment community – MEAG Munich, the asset management division of insurer Munich Re and ERGO – would have helped to quell any fears about the viability of Baywa's project. The acquisition went through in December last year although this is not the first instance of such a transaction, since MEAG bought UK-located solar parks from BayWa in 2014 and 2015.

At first, investors had said the company was crazy going into Spain after the tariff cuts, but the unsubsidised model meant the project had an independence that was largely free from government interference.

"We said, in fact, it's not a feature of Spain to have government support; it's a feature to not have it, to have the least to do with the government as possible," says Benedikt Ortmann, managing director of BayWa r.e. Solar Projects.

It is this independence created by no subsidy support that allowed BayWa to go back into Spain as a bright land of opportunity rather than seeing it as a graveyard for solar. And the Don Rodrigo project's significance, of course, extends beyond Spain into the whole European continent as a result of this new model, because wherever solar can go without subsidy the final hurdle of economics has also been cleared.

The time is right

An unsubsidised project means there is no tax incentive or FiT, says Ortmann, who is keen to stress that this is separate from a merchant project that does not have a long-term PPA and is exposed to the spot price market.

Ultimately, the project's lack of subsidies demonstrates that it is not only possible to operate a large solar plant on the grid in Europe, but that PV power can be cheaper than that of coal-fired power plants. It symbolises the first nail in the coffin for coal and the first step towards this solar model becoming plausible in other parts of the continent, even further to the north.

BayWa was wondering back in 2012 where post-subsidy PV would first become a reality in Europe, if at all, says Ortmann, but it earmarked the areas of highest irradiation including Southern Spain, Italy, parts of Greece and Turkey. The decision was soon narrowed to Spain and Italy before political and economic situations, grid availability, land costs and the sheer size of BayWa's planned plant meant that Spain was chosen. There was no special technique being applied to the project, rather a focused investigation into where grid parity could happen first.

Timing the project with the downward trajectory of solar module prices was key, given that panels have historically accounted for around 50% of the cost of a PV project, says Ortmann. It was widely accepted back in planning stages that prices would continue to fall and that industry-wide belief could be seen played out in real time by the record solar tariffs being set in auctions across the globe. In each case there was still at least a year longer timeframe to complete projects so those low bids were dependent on prices continuing to lower during the period before purchasing the modules, or the developer would come unstuck. The beauty of the solar is of course that, once installed, it becomes totally independent of the oil price and interest rate fluctuations over a couple of decades or as long as the plant remains active.

However, much of the Don Rodrigo project relies on Chinese-made equipment. Intrinsic to the reliance on module price, therefore, was the long-awaited removal of the Minimum Import Price (MIP) on Chinese imports of solar panels to Europe in September 2018.

"With MIP it would have been impossible," says Ortmann. "So that's the reason why we always said the MIP is a damage to the European economy as 80% of the value added on a PV system is not coming from the panels, but from all other parts like BOS, construction, project development, O&M etc., so making panels artificially high or costly is actually a measurement against solar in Europe."

Most of the industry is now using China not just for cost, but even for the quality of panels, adds Ortmann – noting that almost all of the top 10 manufacturers come from China.

Off-take first

Electricity generated by Don Rodrigo will be sold via a 15-year PPA with the heavyweight Norwegian hydropower company Statkraft. A fixed price for five years was put in place to ease the worries of investors, with a floor price scheme brought in for the remaining 10 years.

"In Europe PPAs of length beyond even five years are completely unusual, because we have the liquid market there, you have the stock exchange," says Ortmann. "There's also a huge counterparty risk associated with that.

By Tom Kenning

"This is why when we were approaching the market, nobody was willing to go for 15 years' duration, but on the other side we had interviews with banks and they were of course more cautious about long-term risks regarding the merchant exposure."

This caution led to the banks asking for a long-term PPA for the first time, so there was a three-party approach between BayWa, the banks and potential off-takers.

Building Don Rodrigo

BayWa r.e. has already commissioned 2GW and manages more than 5GW of plant output, so it was well versed in solar and Don Rodrigo turned out to be a relatively straightforward development.

"It was very easy, because, at the time, nobody else was there, so the government as a municipality, the landowner, literally everybody was very keen to attract us. It was very good," says Ortmann. "It was agricultural, but very rough agricultural land. Down there in southern Andalusia it's very dry so you have to really water everything, so it was more or less abandoned and it was next to a huge waste disposal site, so not really attractive from others' points of view."

For equipment, BayWa decided to do a 50:50 between its two most favoured module suppliers, Astronergy and GCL, to avoid exposure to delivery risks from only having one supplier. Don Rodrigo also uses Chinese inverter firm Huawei's 'smart' technology to optimise the plant through data-driven monitoring opportunities.

The BayWa r.e. service team will also be responsible for the ongoing operations and maintenance (O&M) of the plant, which was completed without any delays or complications, except for a port incident that made site access difficult.

The modules were first to be brought in through Spanish harbours, but a combination of inexperience and confusion over the MIP meant that the harbours blocked BayWa's transportation, says Ortmann, so the company had to shift the load to Amsterdam before transporting the panels overland back to Spain.

How to clean the panels is still under discussion. Water could be used from a nearby reservoir that was used for farming originally, but the possibility of using robotic cleaners is still in play.

"It's a question of cost and efficiencies and maintenance of those robotics," adds Ortmann.

Stamp of approval

BayWa's quick sale of the project to MEAG was a great success. The price of the sale has not been disclosed, but German commercial bank Norddeutsche Landesbank (NORD/LB) had provided a construction bridge loan of €100 million in August 2018.

Discussing the sale, Ortmann says it "is clearly a signal from investors that they now are overcoming the feed-in tariff times and seeing that unsubsidised solar is a viable business case for them. Having the Statkraft PPA as a potential counterpart, Nord/LB was actually very happy to provide a long-term facility, however Munich RE was acquiring the project and they preferred to buy full equity so we had to give the loan back to the bank."

A subsidy-free future

The Don Rodrigo project will be the marker for when people look back to see at what point European solar's shift to an unsubsidised model became reality for the largest-scale plants, but there are several smaller subsidy-free projects operating in Italy, Portugal and even in the UK where the local firm Anesco has combined batteries with solar.

Furthering the model within Spain, X-ELIO has signed a 15-year PPA with Nexus Energía for 100MW in Murcia, and Luxcara has signed a PPA with Alpiq for a 45MW project in Espejo.

BayWa itself is working on Don Rodrigo II, which will be constructed this year and there are several projects in the pipeline with 1-2GW in Spain up to 2022-23 as well as projects in Italy, France and most other countries in Europe.

Ortmann is optimistic about the chances of subsidy-free solar proliferating across the continent, adding that it is hard to see it going any other way unless there is a major hindrance to Chinese supply:

"As panels are getting even cheaper nowadays, we can extend the area where subsidy-free solar is possible further north, even in countries like UK people are talking about unsubsidised solar, which if you had asked me five years ago I would never have expected.

"That's now the ultimate tipping point we reached, that solar energy is cheaper than any other conventional energy source and that's actually good news for climate change and good news for our society." ■

Don Rodrigo key facts

- Modules: >500,000 Astronergy and GCL polycrystalline modules with maximum efficiency of 17.6%
- Site: 265 hectares
- Balance-of-system: fixed-tilt on 1,500V(DC) architecture
- Annual generation: 300GWh
- Completion time: 10 months to complete
- Cabling: 3,000 kilometres
- Inverters: HUAWEI String inverters SUN2000-60/100 KTL

Reflecting on ways to boost module output

Module coating | Anti-reflective coatings have been a standard technology on solar modules for some time, but several companies are now targeting the market for older solar farms. Sara Verbruggen reports on the promising early results from trials of these performance-boosting technologies

Credit: Pellucere

Anti-reflective coatings retrofitted to untreated PV modules are offering a new option for boosting performance

While the majority of installed solar capacity globally comprises modules with anti-reflective (AR) properties, applied during production, coatings producers are working with the solar industry to target the aftermarket opportunity.

Many photovoltaic (PV) installations built before 2012 would have used panels without any AR coating applied during production. While the share of installed PV capacity comprising modules with pre-applied AR properties is much greater than the share of panels without any such coating, there is still a substantial capacity of uncoated modules – tens of gigawatts, some estimate – concentrated mainly in Europe's mature solar markets, such as Germany, Italy, Spain and Greece.

As these established markets host substantial amounts of solar capacity receiving high feed-in tariff (FiT) payments, the pre-2012 solar market in Europe is a lucrative opportunity for AR coatings since even incremental output improvements can result in significant additional value for owners and operators of solar asset portfolios.

AR coatings and how they work

According to trade body SolarPower Europe, reflection losses are one of the first loss factors that occur in the energy flow when PV plants convert sunlight to electricity.

AR coatings, usually based on a silica gel solution applied to the glass face of the module, work by creating a gradual transition from air to glass for incoming photons. The result is a reduction in the amount of light that is reflected off the glass, allowing more light to reach the PV cells in the module, which is converted into energy.

AR coatings do this by varying the porosity of the material from very high at the coating-to-air interface through to very low at the coating-to-glass interface.

AR coatings are very thin, 150 nanometres in thickness, or less. They are applied to the module surface via techniques such as spraying. A process that can be highly controlled achieves a more uniform thickness, which can optimise the amount applied.

The coatings that are being developed for the solar aftermarket are based on the same technology platforms as the AR coatings applied in production technology for new modules, according to SolarPower Europe. However some companies are developing advanced coatings based on nanomaterials and are targeting solar with their technology.

Pellucere's MoreSun

AR coatings designed for retrospective application on installed PV modules are close to commercialisation as producers of these coatings collaborate with solar companies providing operations and maintenance (O&M) services for asset owners.

One product is Pellucere's MoreSun coating, which combines AR and anti-soiling properties, using what the company describes as a 'silica shield' technology. The coating, which is available on the market, is designed for solar modules that have not been supplied with a factory-applied AR coating. Pellucere is also working on a product for application during production by module manufacturers.

Pellucere's senior vice president, business development for Europe/MENA Peter Fuss says: "AR coating applied to new modules in production became established between 2012 and 2013. We

estimate there is an eligible installed base of 45-70GW worldwide, comprising crystalline silicon modules without an AR coating, which were installed mainly prior to 2011 and 2012 and almost all First Solar series 2 to 4 modules, except the series A modules."

According to Pellucere, MoreSun achieves higher gains in the evening when sunlight is falling on the module at an angle and also when the sunlight is more diffused, such as on cloudy days, when light is hitting the panel from multiple angles. Solar plants installed in coastal areas with more mist and in cloudy regions can achieve higher performance gains, compared with plants in very dry regions, with little cloud and lots of direct sun.

Pellucere has been working with Alectris, a European third-party O&M service provider, which has exclusive rights to install MoreSun in Italy and Greece.

To date Alectris has applied MoreSun on over 6MW of test arrays at 16 different locations across a variety of module technologies. Field-testing of modules has occurred in countries that include the US, China, Taiwan, Italy, Greece, UK and Germany. Most of the trials have been running since 2015 with results gathered so far validated with accelerated lifecycle laboratory testing.

MoreSun helps the solar module capture more light, increasing energy output from direct axis light by 3.4% to 3.8% and total energy output, modelled in PVSyst software, by up to 4.7%. These energy gain estimates are based on laboratory-certified energy gains applied to a specific solar farm using PVSyst, according to Pellucere.

According to Alectris, real-world field trials demonstrate energy gains of 3.4% to as much as 4.9%.

For example, results from trials where the coating was applied on modules in central Germany in May 2018 achieved power gains of 4.1% (AC) (Figure 1).

The cost of applying MoreSun depends on several factors, such as plant and module layout, with an expected payback period of between 1.5 and 3.5 years, depending on factors such as plant yield, which can depend on location, performance and the subsidy support mechanism in place.

According to Pellucere and Alectris, MoreSun's application can complement solar farm upgrades, such as replacing inverters and other repowering options.

"MoreSun can either be applied as a retrofit product on older PV plants. In such cases the boosted output would increase the plant performance therefore compensating for the natural degradation of the mature asset. Or it can be applied as an 'added value' product, providing a performance gain as additional revenue," says Fuss.

Depending on plant location, the cleaning cycles and environmental conditions, the coating is expected to last over 10 years. If and when it does begin to degrade, it can be reapplied, explains Fuss.

MoreSun's anti-soiling properties can lengthen cleaning cycles, reducing O&M costs associated with cleaning. The MoreSun coating incorporates Pellucere's proprietary Talus Dirt Rejection Technology (DRT). Talus DRT prevents build-up of dirt and other particulates. Unlike hydrophobic anti-soiling technologies, the Talus DRT's properties allow the coating to reject dirt without requiring rainfall.

Fuss says the primary function of MoreSun is to provide anti-reflective properties. "The anti-soiling is an added value. However, our technology roadmap includes developing an anti-soiling coating for modules that is highly effective in regions where water is scarce and which can make panel cleaning challenging, as part of O&M activity," says Fuss.

Pellucere has developed the MoreSun package to be a comprehensive offering for both independent solar O&M service providers as well as solar asset owners that manage their own O&M activity, and is in discussions with companies in various European markets as well as in the US, according to Fuss.

"We see lots of potential in markets such as Italy, Greece, France, Spain and Germany as well as the US, where in certain regions there are some very large solar parks, built pre-2011. Coating season runs from May to October, so we are hoping to announce some customers in the next few months," says Fuss.

The package includes the coating as well as two types of application tools. For smaller solar parks, the backpack tool (pictured, main image), which workers wears on their back and apply to each panel, is suitable. For larger solar parks, the company provides an application system that a human operator sets up to apply the coating to several panels in a row.

Fuss says Pellucere is continuing to focus on application tool development to enable more efficient application of the coating. "The MoreSun package also includes insurance, quality control and measurement devices. The aim is to provide a standardised product across the industry that is very simple and straightforward to apply," he says.

Alectris is promoting the AR coating to PV plant owners that the company already provides O&M services to and has begun marketing it to the wider industry, offering the coating as an added value product and a point of differentiation to other O&M service providers.

In Italy and Greece, where the company has been testing the coating among solar asset owners, it expects to capture the largest share of the potential market for retrospectively applied solar AR coatings.

In addition to its discussions and customer trials with existing and potential new clients Alectris says it is working on optimising operations and reducing the labour costs associated with applying the coating in situ by training dedicated teams and project managers.

Fuss says one of the benefits of working with Alectris is the feedback Pellucere has been able to gain from the practical application of MoreSun on PV modules within solar farms. "The cooperation has helped us to refine the offering," he says.

MoreSun Field Trial Energy Gains		
Location	**Date applied**	**Power gain**
Germany		
Central	May 2018	4.1% AC
Southern	Nov 2017	4.0% AC
Central	Jul 2018	3.7% AC
United Kingdom		
Central	Nov 2017	3.6% DC
Italy		
Central	Sep 2018	3.8% DC

Source: Pellucere

Figure 1. Power gains in trial modules treated with MoreSun AR coating

DSM

DSM has spent over two years testing its AR solar module coating in the lab and, more recently, in the field to optimise the product ahead of its commercialisation, working in cooperation with German solar EPC company Enerparc.

According to an official at Enerparc, the company sees greatest potential for the coating in Europe, which has the highest proportion of older solar parks, installed before 2011, and also with the highest FiT rates.

The retrofit AR coating has no other functions, though DSM does produce a coating combining anti-soiling properties with anti-reflective properties, which is applied by the glass producer. However future solar coatings for retrofit applications may comprise AR and anti-soiling properties or contain anti-soiling properties only, according to Paolo Tusa, commercial director at DSM.

The retrofit AR coating is based on DSM's existing technology, which is applied during solar panel production. The company estimates the technology has been used within the production process of over 70GW-worth of modules since 2011/12.

The retrofit AR coating is produced in DSM's coating plant and production can be scaled rapidly to meet demand, according to Tusa.

The retrofit AR coating will be launched in the first half of 2019 and the company expects it to be used in a significant amount of PV plant repowering projects this year, starting in Europe and then rolling out into other, undisclosed markets, from 2020.

DSM has conducted 10 trials of the coating in Italy and in Germany since 2017, while Enerparc is testing the coating on a subfield of panels within a 27MW solar park.

Enerparc's first trial began in September 2017, followed by further trials in 2018. Results in field trials show a 2-3% increase in output. The coating can achieve a payback in under three years, according to DSM.

Enerparc has been interested in the potential for retrofit AR coatings for a number of years, according to the company however, since there were no references of performance that Enerparc could rely on the company and DSM cooperated on pilots. Enerparc says this was so that it could establish trust in the product and the team that developed it.

The partnership is not exclusive, however.

Following on from the field trials, the next stage is to scale up the coatings application on several megawatts of capacity, within Enerparc's portfolio.

For the retrofit market the only pre-requisite is that the coating is applied to PV modules where the glass does not have an existing AR coating and the sooner it is applied the sooner the solar farm can achieve increased output.

DSM is also working to enhance the commercial coating offering with a tool that can apply the coating in a highly controlled manner and at high speed, which will help reduce cost and enable more efficient application and is targeting commercialisation of the tool by the end of 2019.

Opus Materials

UK-based start-up Opus Materials has developed a coating, called Solar Sharc, which combines anti-reflective and anti-soiling properties.

The core technology is based on nanostructured particles, functionalised to provide different attributes within a base matrix, to create a coating with different properties, such as anti-soiling and anti-reflective properties.

Target markets for the coating include the Middle East, Sub-Saharan Africa and India.

"In these markets, particularly, we see great potential for the coating because of water scarcity, so a coating that combines these various functions, not just AR, but also anti-soiling, will reduce O&M costs by minimising water consumption needed to keep PV modules and solar thermal tubes clean from dust, while also optimising output," says company co-founder Russell Banks.

In India, Opus Materials is working with a UK company called Solar Polar, to trial the coating on solar thermal panels. Opus Materials has been trialling the coating in several other countries, including the UK, Denmark and, most recently, locations across Saudi Arabia.

According to Banks: "The field trials are important because they will enable us to finesse the coating formulation as we prepare for commercial launch in late 2019/early 2020," adding: "The ultimate objective is to develop a 'tuneable' coating, where we take the base matrix and adapt the formulation for different regions, as environmental conditions change."

Ultimately Opus Materials wants to produce the coating adapted for different regions, to optimise performance, particularly in terms of its anti-soiling properties, according to Banks.

"For example, for solar farms nearer the coast, salt and sand is a problem whereas in other regions sand and humidity is more of an issue," he says.

According to Opus Materials, the coating's production process deploys a "materials by design" approach, so that the composition can be fine-tuned according to geographical location or climatic conditions.

The coating can be applied by spraying, dip coating or it can also be wiped on. Under accelerated testing, based on the IEC 61215 standard for outdoor testing PV modules, Solar Sharc has proven its performance so far.

Banks says the company is also investigating a prototype able to apply the coating via an automated application tool, for large multi-megawatt solar farms.

To raise funds to commercialise its technology, Opus Materials is in talks with potential investors.

Over the next 12-18 months owners of solar PV assets and O&M contractors should benefit from an array of AR coatings for retrofit application designed to improve returns from existing PV farms. The development potentially paves the way for advanced coatings that combine AR properties and the latest in anti-soiling functionality, opening up new opportunities for slashing O&M costs whilst enhancing the performance of assets across global markets. ■

Solar Sharc trials around the world

Opus Materials is working with an undisclosed solar research and development (R&D) facility in Saudi Arabia, which began trialling the Solar Sharc coating two to three months ago on installed solar panels in eight locations throughout the country.

Co-founder Russell Banks says: "The trials will last for about a year so we can gather results on how the coating performs in different seasonal weather conditions, as well as in different locations throughout the country."

The company also has field trials ongoing in the UK, including London and Ipswich, which both started in late 2018. In Ipswich the coating is being trialled on panels equivalent to multiple kilowatts within an operational PV farm. Even from early results the coating has initially increased output by 3.8%, due to the easy cleaning and anti-reflective properties.

Through its academic partner Crest, Opus Materials is also trialling its coating and is awaiting results from an initial weathering period.

The field trials are a critical step as they will enable us to finesse the coating formulation in preparation for commercialising it in the solar industry.

Solar asset management: why it needs to evolve

Asset management | Asset management practices must mature and standardise to keep pace with the rapidly accelerating deployment of solar. Ypatios Moysiadis, vice-chair of an industry group tasked with drawing up new best practice guidelines, explains how

Credit: Getty Images

Asset management approaches must mature in response to the rapid pace of change in the solar industry

The solar industry has entered a new age of maturity. New opportunities and challenges are knocking on our door. Conventional oil companies are racing to become the world's biggest power firms. All the while utilities are looking to diversify their assets away from fossil fuels to cleaner and easily deployed renewable energy assets. Infrastructure funds are investing in solar and larger institutional investors want a slice of the market as it offers a predictable income for the long-term future.

With the massive reduction in solar project expenditure, we see new countries investing in solar and rejuvenated markets in Europe such as Spain, Italy and France. Asset owners are now faced with the new challenge of managing assets across different geographies, with different regulatory and environmental challenges, not to mention different business models (subsidised, power purchase agreements (PPAs), pure merchant, etc.).

This creates a perplexing scenario for service companies and, in particular, solar asset managers. In order to assist service companies and asset managers' transition to this new solar reality, asset management needs to evolve.

Moving towards 'Solar Asset Management 2.0'

Before we start elaborating on how asset management should evolve, we should outline the basics. Arguably there are seven main points that we should take into consideration when we discuss managing an energy-generating asset:

1. We are managing an investment: a company – not just a plant.
2. Markets constantly evolve where new possibilities and threats emerge.
3. Long asset life cycles (30+ years) demand a long-term planning approach.
4. "One size does not fit all". Every asset has unique attributes and requirements, which may require a different management approach.
5. Performance Optimisation and Value Increase comes from focused information-driven decision making.
6. It is vital to make sure that business stakeholders, and especially people working on the assets, remain engaged and incentivised.
7. Tested management practices should form the basis of the asset management framework which should be implemented across portfolios with the necessary adaptations.

Taking the above points into consideration, we need to develop the right "incubating" environment for asset management to evolve. How could we take the traditional technical and commercial asset management functions to the next level?

The first step of this evolution is to recognise that the current linear management approach, with its linear flow of information and decision making, is not efficient. This linear approach prevents the flow of data and information from the asset to the asset owner and also limits and filters the information that the asset managers receive, which may create mistrust and a lack of transparency between the parties (Figure 1).

We need to transition to an asset-centric information-based management approach, where data capture and analysis will drive overall performance optimisation (Figure 2). This will enable the three main stakeholders to view the same set of data and make decisions based on pragmatic, valid information and not on unwritten rules.

Figure 1. A linear approach in asset management is not efficient

Credit: Greensolver © 2019

Credit: Greensolver © 2019

Figure 2. Data capture and analysis will drive overall performance optimisation

This new approach will enable asset managers to address three key problems:

1. Loss of generation and income.
2. Loss of time.
3. Lack of transparency.

The transition to Asset Management 2.0 should provide a holistic approach to how we view and manage assets. Apart from the adaptation of information systems and digitalisation, the development of continuous improvement processes is just as important.

Real value is created through proactive management

To put it simply, asset managers should increase the revenue (Alpha – α) through production improvements, revenue stream optimisation, innovation adaptation and at the same time reduce the cost (Theta – θ) through service optimisation, contract renegotiation, financial instrumentation and people management.

Through industry experience, we can identify six key processes that asset managers should effectively use to achieve continuous improvement and performance optimisation:

1. Plant performance.
2. Operation cost reduction.
3. Financial restructuring/reengineering.
4. Legal and contractual renegotiation.
5. Technology adaptation and upgrades.
6. People management.

These processes also form the asset optimisation cycle, which is the level that the asset manager should strive to operate at.

Quality systems and digital tools

An integral part of the asset management evolution is the adoption of quality systems and digital tools.

The first key element is the ISO 55001 standard on asset management which was published in 2014. However, there are very few asset management service providers that have been certified with ISO 55001.

Quality systems will provide the backbone of any standardisation for our sector and will indicate the internal transformational changes that service providers will have to undertake to improve their own organisations and deliver constant quality of service.

The second key element towards evolution is the adaptation of digital tools and information management systems. Even today, despite the multiple well-designed digital tools and platforms that exist, most asset management functions are performed on spreadsheets and communicated by email.

As a result, the asset owners and the industry are missing out on the historical value of information that derives from the assets and consequently have information gaps, which restrain their capability of strategic, long-term asset management planning. The industry will need to make a significant effort to adopt these quality systems and digital tools.

For asset management companies these two elements are critical and will help them stay competitive and deliver value to their clients. It is not a matter of choice but rather a matter of survival.

Asset management standardisation: introducing best practices guidelines

The need for asset management to evolve is unquestionable. However, a second challenge remains. How are we going to deliver service standardisation especially in a fiercely competitive, price-driven environment? Can we create a level playing field where asset owners know what to ask and service providers understand what they need to deliver?

Some sceptics would argue that process standardisation and scaling should be the responsibility of individual companies, which grants them a competitive advantage. Fortunately, industry experience has proven that this is not the case, especially when a whole industry is growing at an accelerated pace.

We have multiple examples from the IT and communication industries where standardisation helps to accelerate market adaptation and technology deployment, driving down operational expenditure and raising standards.

Within our industry, we already have successful examples of industry associations, corporates and governing bodies coming together to establish standards and best practices for solar operation and maintenance (O&M).

A very successful example is the solar O&M Best Practices Guidelines, which were created by SolarPower Europe, the European solar energy association. Currently, version 4.0 of the guidelines is being developed and now, the SolarPower Europe O&M and Asset Management Task Force, led by over 50 companies, has started a new endeavour – the development of the Solar Asset Management Best Practices Guidelines. These guidelines will be launched at the O&M and Asset Management event in London in December 2019.

Final thought – the social environmental aspect

It is yet to be determined at what speed the solar industry will progress. According to a new study by Energy Watch Group and LUT University of Finland, 100% renewable energy across all sectors is possible by 2050 with solar leading the way. In fact, the study finds that solar could become the largest and most affordable energy source, meeting up to 69% of global energy demand. The choices we make today as an industry will be instrumental in realising this huge potential. As an industry we are at the forefront of the energy transition and electrification of our societies. More importantly we are spearheading the fight against climate change. Solar cannot operate without the key service functions. Therefore, as solar is a key solution against climate change, our responsibility to evolve and adapt is even more critical. The Solar Asset Management Best Practices Guidelines are another step towards this aim.

Further information on the task force's work can be found at www.solarpowereurope.org/priorities/operations-maintenance/ ■

Author

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Presented to you by: Energy Storage NEWS

STORAGE & SMART POWER

Introduction

Welcome to 'Storage & Smart Power', brought to you once again by Energy-Storage.news. Dark times as yet more warnings are sounded on global emissions and pollution. The Extinction Rebellion brings some of central London to a halt, as hundreds of protestors express the frustrations of many more worldwide that climate change still isn't being properly dealt with.

Extinction Rebellion? Yes, unfortunately. But the more appealing flipside, 'survival together', could be the story that our industry will be able to tell in years to come. Whether you like them or not, the activists' direct actions have the intention of bringing awareness of the grave mistake that inaction would be to the wider world. But it's down to all of us, especially those already in the relevant industries, to make the clean energy future a reality for every day rather than for days of protest.

While the likes of Shell and other oil super-major companies might be the focus of activists at shareholder and street level, they are also the ones that could hold the keys to the energy market post-carbon too, if they play their cards right. Our feature, "Corporate takeover: the end of independence?" (p.100) looks at Shell's acquisition of battery storage player Sonnen, as well as the new ownership of Greensmith and Younicos by Wartsila and Aggreko respectively. We ask what makes an energy storage company an attractive target, whether these mission-driven companies can retain their commitment to their original aims and if corporate involvement is vital to roll out clean energy technologies at scale.

Complementary to that piece in some ways is the feature, "Power to the People" by Liam Stoker, Solar Media's UK editor (p.106). It looks at how control of Britain's domestic energy market, traditionally held by the 'Big Six' group of utilities, is now a hotly contest prize. From big players from other industries taking a sideways step, to start-ups that claim to have cracked the grid's complex combination safe of stacked revenues, an energy market revolution is happening as the energy transition accelerates.

We're also privileged that this edition of Storage & Smart Power includes a contributed piece on DNV GL's Battery Module Scorecard, through which the accreditation, certification and testing house explains the importance of comparing and accurately assessing the capabilities of different lithium modules used for energy storage (p.96).

We are collectively correct in fearing climate change and ordinary people are right to demand action. Whatever form that action takes will ultimately determine the outcome. It's time to shine a light in the darkness.

Andy Colthorpe
Solar Media

Philippines' Department of Energy issues regulatory framework

Credit: Solar Philippines

Questions around who should own, operate and ultimately benefit from the deployment of energy storage systems could soon be resolved in the Philippines after the government Department of Energy (DoE) issued a set of draft guidelines in April.

In order to accommodate energy storage as an enabler for the modernisation of its electricity networks, the Philippines' Department of Energy (DoE) has issued a circular, "Providing a framework for energy storage system [sic] in the electric power industry".

Internationally, the department said, energy storage systems are in use for a variety of applications relating to the transmission, distribution and generation of energy. Domestically however, various stakeholders have raised concerns that there is a "lack of governing policy framework for its regulation and operation".

The Philippines DoE is hoping to improve regulations and address ongoing questions about energy storage's role in the network

Siemens launches own 'Junelight' lithium home energy storage systems

German engineering giant Siemens has furthered its involvement in the stationary energy storage industry, becoming the latest 'big player' to launch a range of home battery energy storage systems.

The company already provides its Siestorage brand of containerised energy storage and since just over a year ago has been a partner in Fluence, providing energy storage technology and services as a joint venture with AES Corporation.

In February the company unveiled Junelight Smart Battery, lithium-ion battery-based energy storage systems for private households, aimed primarily at maximising the use and integration of onsite-generated solar energy, dubbed 'self-consumption' in many markets.

The battery has been launched initially in Germany, with a launch imminent in Austria in April. Siemens said the battery system's predictive charging and discharging procedures are coordinated in line with forecasted weather patterns and expected energy demand.

India takes more big steps forward

India has launched its first grid-scale energy storage project, a 10MW/10MWh lithium-ion battery at a substation in Delhi owned by Tata Power Distribution, the grids and networks business of India's mammoth Tata Group.

Other big events during a huge amount of activity across the solar and renewables sector in the past the quarter included the country's first tenders for floating solar, while a 200MW/300MWh solar-plus-storage tender was launched in the state of Andra Pradesh.

The Solar Energy Corporation of India (SECI) announced three huge tenders across the country with various combinations of solar, energy storage, wind and hybrid concepts, to be connected to the Interstate Transmission System (ISTS). Among these was a tender for 1.2GW of solar PV combined with 3,600MWh of energy storage in a country aiming for hundreds of gigawatts of solar capacity deployments.

Portugal to hold 50-100MW energy storage auction in 2020

Portugal is to kick-start its energy storage sector by arranging its first dedicated auction next year. João Galamba, secretary of state of energy, told Energy-Storage.news of plans to put forward 50-100MW worth of capacity for dispatchable renewables in 2020, at a date that has yet to be decided.

"It could be batteries, it could be anything else, as long as it's renewable and dispatchable – we will let the market decide what the best solution is," Galamba said.

His statement follows recent calls by experts for Portugal to "urgently" move towards storage technologies, to help manage the annual 800-1,200GWh surplus in renewable production expected by 2020; power-to-gas options are seen by researchers as particularly promising.

Florida utility plans world's largest battery combined with solar

Major US utility Florida Power & Light Company (FPL) is planning to build the world's largest battery energy storage system adjacent to an existing solar power plant, with plans to roll out multiple other storage systems across the state.

With the key proposed battery standing at 409MW capacity, the Florida energy company claims it will be four times larger than the largest battery currently operating worldwide. Furthermore, the system will help reduce fossil fuel usage and thereby accelerate the decommissioning of two neighbouring, 1970s-era natural gas power units.

The FPL Manatee Energy Storage Center will be powered by an existing PV plant in Parrish, Manatee County, and capable of distributing 900MWh of electricity. It will start serving customers in 2021, with the batteries being used particularly during peak demand periods, thereby reducing the requirement for electricity from other power plants.

Arizona utility's 950MW solar-plus-storage plan

Arizona Public Service (APS) has announced a plan to make solar energy dispatchable into the evening using batteries, calling for the deployment of 850MW of energy storage by 2025.

The utility's "major clean energy initiatives", include adding batteries to its existing fleet of solar plants, add new solar-plus-storage plants and use energy storage to help deliver an increased proportion of grid energy at times of peak demand. APS, the utility for 2.7 million people in the southwest US state, said it will add 850MW of energy storage and 100MW of new solar by 2025.

Partly due to abundant sunshine, Arizona's utilities have been able to embrace low-cost solar-plus-storage solutions early. APS, as well as Salt River Project and Tucson Electric Power have all been behind recent big projects to combine solar and storage to provide energy and power into the evenings and other peak times. Meanwhile, the state is considering a 'Clean Peak' standard which could include a 3GW energy storage target.

Easing the risks of battery investment

Battery performance | As the building blocks of energy storage systems, batteries have a key role in influencing system design and economics. Davion Hill of DNV GL explores the importance of testing the performance of individual battery cells in minimising the exposure of battery buyers to technical risks

Credit: NY-BEST

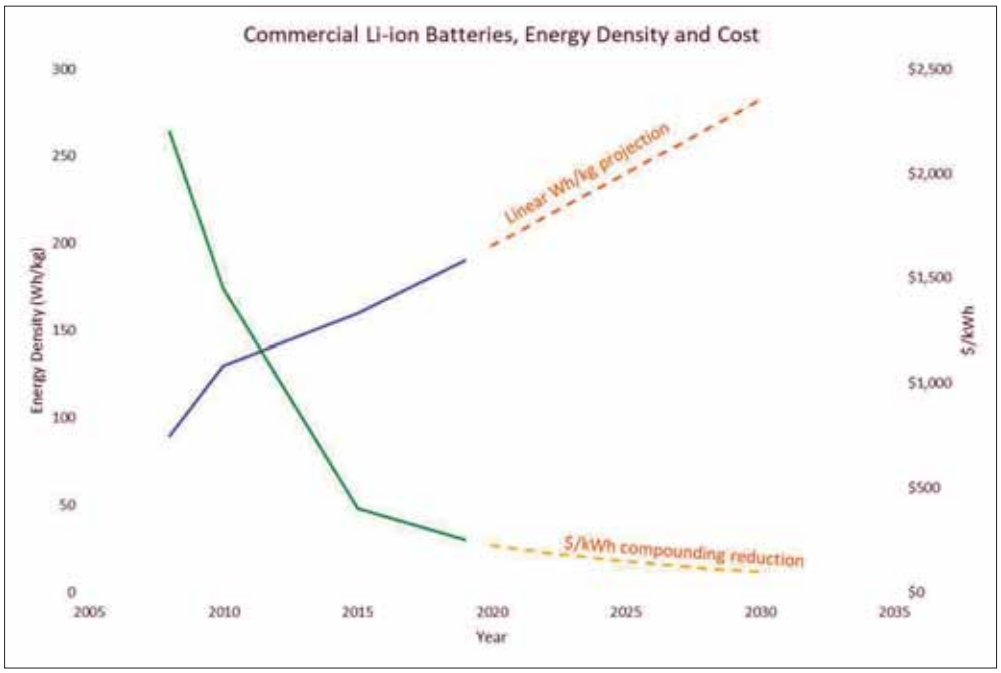
Energy storage deployments are growing, with markets opening across the globe. These markets are recognising the value of storing energy at one point in time and dispatching it later. This is especially true in markets where solar energy is increasingly part of the grid and, due to its intermittent nature, can be disruptive. On a short time scale, storage can provide frequency regulation to balance the grid. But on long time scales it has a larger role, providing peaking capacity that can defer other more expensive investments such as distribution, transmission, or generation upgrades.

Both storage and solar have experienced significant declines in price over the last decade. Many markets are now observing that capacity bids from renewables are undercutting conventional fossil and nuclear generation. Not long ago it was thought that renewable energy was too expensive, and now fossil energy is too expensive.

Together, solar and storage are uniquely suited to provide energy to the grid and replace the function of gas generation plants. With tangibly lower capital costs, compared to just a few years ago, and no fuel cost over the life of the project, solar now offers a cost of energy that undercuts conventional energy. When coupled with storage, this energy can be dispatched at targeted times, and the instant response rate of the battery enables the entire plant to be flexibly designed for energy, capacity, or ancillary markets.

Testing battery cells is a key aspect of technical due diligence

The energy storage market has slowly become dominated by now-incumbent Li-ion batteries based on nickel cobalt manganese (NCM)/nickel cobalt aluminum (NCA) chemistries. Today, these batteries have achieved low cost



Source: DNV GL

Figure 1. Li-ion batteries have achieved low cost and increasing energy density through simple and persistent engineering optimisation

and increasing energy density—not by leap-frogging their competition with technological breakthroughs, but with simple and persistent engineering optimisation of their production methods, tooling, speeds and efficiency (Figure 1).

At the present rate, NCM/NCA Li-ion batteries will achieve US$100/kWh at the DC level before 2030 and will likely achieve 300Wh/kg. These rates appear linear; if greater compounding occurs, these metrics will be met much earlier. The main driver for this advancement is the increasing volumes of production driven by the automotive sector.

What to consider for storage

There are a number of considerations required when designing energy storage systems. The power and duration of the battery are determined by its purpose in the project. The purpose in the project is determined by the economic value. The economic value is determined by the market in which it will participate. That market ultimately determines how the battery will dispatch—what power, charge or discharge and for how long. The power and duration not only determine the capital cost, but also the lifetime.

In some markets, the storage system will get paid to charge and discharge. In others, it will just get paid to discharge, and the charging cost is a cost of doing business. The number of opportunities to charge and the rate of charge may be different from the discharge. For example, in a utility-scale solar + storage scenario, or in a behind-the-meter application with solar, the battery is creating value by charging while the solar is active, such that it qualifies its portion of the capital cost for the investment tax credit (ITC). This concept of storage getting "paid" to charge has nuanced differences from the way storage would get paid to charge for frequency regulation in a regional transmission organisation (RTO), like PJM, for example. In the ITC instance, the storage increased the tax equity value of the project and therefore the internal rate of return for the owner. In the PJM instance, the storage is getting paid for both charging and discharging and its compensation is therefore proportional to its throughput.

It may seem counterintuitive to state that the power and duration of the battery determines its lifetime. The intertwining factors in power, duration, and lifetime are what makes energy storage different than any other energy technology. At its core, the battery system is an electrochemical device. Like PV, its materials degrade over time, diminishing performance. PV panels lose power output and efficiency. Batteries lose their ability to store energy. While PV systems can be expected to last 20-25 years, energy storage systems typically last only 10-15 years.

Replacement cost should be considered for any project. A risk-based evaluation of replacement should be part of any solar + storage pro-forma. The probability of replacement is dependent on the project throughput and the conditions related to its operation.

The four main factors that contribute to battery degradation are:

1. temperature at which the battery operates
2. currents which the battery experiences
3. average state of charge (SOC) the battery experiences, and
4. SOC "swing", or the interval of the SOC where the battery spends most of its time. The factors in #3 and #4 are related.

There are two tactics to manage battery life in the project. If the project revenue can support it, the battery size can be minimised and a planned future replacement cost can be built into the pro-forma. There are many markets where the revenue of the project can support a future replacement cost. It is usually the case that the estimation of future replacement cost includes a price reduction going into the future consistent with what has been witnessed in the last 10 years of the market. The second tactic is to oversize the battery such that its overall current (or C-rate, defined simplistically as charges or discharges per hour) is minimised by paralleling batteries. Lower currents tend to produce lower temperatures due to the exothermic nature of charging and discharging. Having excess usable energy in the battery system, and using less of this energy overall, reduces the throughput of the battery and makes it live longer.

Throughput is a key term. The legacy of the automotive industry has encouraged the use of "cycles" as a measurement of lifetime. In stationary storage applications, a battery system is more likely to experience partial cycles, or a series of partial charges and discharges, each of which do not fully consume the available battery energy. The sum of the partial operations may be equal to less than one cycle per day, or they may exceed that metric, depending on the market. This throughput should be assessed to determine how long the battery may live.

Storage lifetime and validation

Testing the energy storage system requires two elements. First, testing at

the cell level is critical to evaluating system lifetime. Testing at the cell level uncovers the strengths and weaknesses of the cell, and helps inform an owner about how the cell should have been integrated into the system, and whether the integration practices were adequate.

a total of 10W. This increases system life by reducing the current (and therefore the throughput) per cell, but it also leads to twice as many cells which increases the cost. This is the overbuild scenario discussed previously. In either configuration, individual cells can be monitored

"The testing compares battery performance against its series-parallel architecture, the system limits, the charge/discharge behaviour in the market, and the market functions. This unique service independently verifies whether the manufacturer responsibly and correctly estimated their warranty"

It helps to understand the implications of system design by imagining series and parallel battery cell configurations. Battery cells in series are voltage-additive, meaning that a "system" with several batteries in series will have a system voltage equal to the battery voltage multiplied by the number of batteries. Highly serialised architectures have cost advantages; however, they also have some disadvantages. When in series, the cell current is the same as the system current. For example, if a cell has a maximum voltage of 1V and a maximum current of 1A, a string of 10 cells will have a max voltage of 10V but still only a max current of 1A, for a total power of 10V*1A = 10W. When strung together in series, battery systems have voltage monitoring challenges. To reduce cost, the entire string of series cells may be monitored for voltage, but this bulk monitoring will obscure whether a single cell is drifting out of specification.

On the other hand, battery cells in parallel are current-additive, meaning that a system with parallel battery cells will have a system voltage equal to the battery voltage, but a system current equal to the battery current multiplied times the number of batteries in parallel. For example, if the same 1V 1A cell is considered, the same 10W power is required, two cells can be wired in parallel to decrease the current per cell by half for the same total current per cell pair of 1A, and then 10 pairs can be stacked in series to achieve 10V at 1A for

for voltage, current and temperature, but this is more common in the parallel configuration.

This series-parallel distinction is important when the battery capacity guarantee or warranty is considered. The following factors flow down through a hierarchy that ultimately influences battery life: market function → charge/discharge behaviour → system limits → cell series-parallel architecture. Therefore, the nameplate capacity, which is what the system can do *after* the system architecture and system limit layers, is not indicative of how much overbuild may be in the system. The overbuild is important for warranty considerations, as it determines the current at the battery cell, the battery cell temperatures, which SOC ranges the battery cells dwell in, and therefore, whether they are designed to exist inside or outside abusive conditions.

System testing is complementary for battery cell testing and is often more applicable to project requirements that certify that the system is operational and meeting its contractual obligations. Manufacturers often have factory or field commissioning test protocols that verify the function of systems and subsystems, but they may not adequately address the risk of system performance over project life. A common area of discussion around field commissioning is the conditions for the capacity test, and whether they are relevant to the actual market in which the system ultimately participates.

The importance of battery testing

DNV GL tests battery cells and ranks them in its annual Battery Performance Scorecard, which provides independent data to battery system buyers. The Scorecard demonstrates how battery cells respond to the four categories of abuse: temperature, current, average SOC and SOC swing.

This testing compares battery performance against its series-parallel architecture, the system limits, the charge/discharge behaviour in the market, and the market functions, and determines if the warranty is valid. This unique service independently verifies whether the manufacturer responsibly and correctly estimated their warranty such that the owner can make an educated assessment of its exposure to technical risk.

This validation is one of several required in technical due diligence. The other factors of assuring that the project is built and designed as intended, on schedule, on budget, and with reasonable guarantees and appropriate equipment, are common to technical due diligence processes across the energy sector. ■

DNV GL's 2018 Battery Performance Scorecard can be downloaded at www.dnvgl.com/BatteryScorecard. The 2019 report will be published later this year.

Authors

Dr. Davion Hill is an energy storage expert managing DNV GL's energy storage business for the Americas region and is currently also serving as the interim global energy storage segment leader. He is an executive board member for NAATBatt International, former president (2015) and chairman (2016), and also serves on the Board of Directors for NYBEST. As an energy storage expert serving the energy project development and energy finance communities, Dr. Hill has been principle investigator for R&D programmes with ARPA-e, NYSERDA, the US Department of Transportation, the Federal Aviation Administration, and the California Energy Commission, Dr. Hill also led DNV GL's North American joint industry guidelines for energy storage on hybrid vessels in the oil & gas sector, and was one of several authors for DNV GL's GRIDSTOR RP-0043. As primary author on the Consolidated Edison Battery Energy Storage Safety report, Dr. Hill led an industry-wide conversation in 2016-2017 to address fire safety issues in energy storage. Dr. Hill's expertise spans energy storage business models and project development, safety issues and integration, and long term performance to support warranties. In 2011 Dr. Hill was a co-awardee of the TechColumbus Innovation award for DNV's analysis of grid scale energy storage via CO2 conversion, and also chaired panels for the National Academy of Engineers on energy storage across scales. He is an accomplished author with over 30+ peer reviewed publications and articles and acquired his PhD in applied materials physics from The Ohio State University in 2006.

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Corporate takeover: the end of independence?

M&A | The growth potential of energy storage has drawn interest from some of the biggest names in the power business and beyond. With the trend set to continue, Andy Colthorpe explores how three of the recent targets are faring under new ownership

Credit: Flickr/tom jervis

The urgency of the need to act on climate change grows in tandem with the modernisation of the energy industry and is also taking renewables and therefore energy storage – into the mainstream. Over the past couple of years, this has manifested itself primarily as growth in investment into the sector and big players now wanting to own significant pieces of the market as it rapidly develops.

It will be interesting to see if they've got it right in terms of the types of energy storage companies they target, with many expecting widespread consolidation to obliterate all but the best – or biggest – in the industry. It will also be interesting to see if the acquired companies are well-positioned to succeed as part of a bigger corporation or if they'll continue to do what they've always done – only bigger.

We've spoken with three energy storage companies that have in the past couple of years been the object of that intensifying interest. Sonnen, which was recently acquired by Shell, Greensmith Energy Management Systems, owned since 2017 by gas engine manufacturer and power producer Wartsila, and Younicos, which is now part of portable energy solutions company Aggreko.

To be prepared is to survive

Florian Mayr of consultancy Apricum says that Shell is "seeing the overall trend that the world has made the choice: to decarbonise, to do something against climate change", through electrification of the power, heat and transport sectors. Mayr points out that it's "not a given" that fossil fuel companies will prepare for the long-term future in this way, with Chevron and Exxon seemingly doubling down on their ambitions to lead the planet to disaster while lining their pockets.

"Shell is saying that they want to prepare for this time and feel it is also a means to ensure their long-term survival. Shell claims to create a 'utility of the future' covering all relevant end user demands looking forward," Mayr says, with the company on a current wave of acquisitions.

Among others, it has already hoovered up UK-based companies Limejump, an aggregator, energy supplier First Utility – and its 750,000 customers – and Dutch EV charge solutions company New Motion as well as Sonnen. While it's still early days, joining the dots between those different segments appears the obvious way forward in creating a behemoth of the energy transition.

A drop in the ocean? While the likes of Shell have invested big in the clean energy sector, for now, much of their main business remains unchanged

Sonnen CEO Christoph Ostermann says that there's scope for partnering what Sonnen does with those other acquisitions. To use an old phrase, the combination could represent a greater value than the sum of its parts.

"Shell is already present in more than 140 countries around the world and some of them are already interesting as markets for Sonnen as of today, some of them will become interesting in the future," Ostermann says.

"So I think one-plus-one is not two in this case, it is more. Simply because there are synergies and we can also leverage existing businesses within the Shell Group. The equipment we provide is a solution for residential customers. A customer can supply themselves with self-generated solar power on the one hand, on the other hand, in the bundle with First Utility, First Utility (now rebranded as Shell Energy) could provide that customer with the remaining grid power that they still need."

As opposed to that long-term strategic decision from Shell, for Aggreko and Wartsila, "energy storage is a natural extension of their core business and current product portfolio which can help their customers to save money today", Apricum's Florian Mayr says. Aggreko's mobile (yet sizeable) solutions power everything from gold mines in Australia to the Olympics around the world, while Wartsila supplies gas engines in 170 countries.

"By adding storage and PV to existing fossil generation, for example, you reduce the run time of the fossil generation assets

and thereby save fuel, you also save fuel by being able to run the gensets more efficiently because you can then do fossil firming – to make a firm output profile and keeping the genset at a high utilisation which improves efficiency. You also save Capex because you don't need spinning reserve if you're adding energy storage," Mayr says.

At one such project, Granny Smith's gold mine in Australia, the addition of Younicos' battery system and battery management to existing power solutions expects to make fuel savings of 13%. The economic value of that is obvious but the sector is very conservative on operational risk. The endeavour is something of a gamble to begin with; that they bought a solution from a company started by self-confessed "solar hippies from Berlin" is all the more surprising.

Similarly, the addition of battery storage to Wartsila engines, either existing or new, can have a dramatic impact on ROI, with payback of two years modelled at some of the company's newest projects. Using technology and staff gained since the addition of Greensmith for around US$170 million in 2017, a range of battery-backed hybrid engine solutions was launched as this edition of *PV Tech Power: Smart Power & Storage* went to press.

100% renewable? Really?

Although it may sound at odds for a gas engine company like Wartsila to claim a mission towards 100% renewable energy and for Greensmith, Younicos and Sonnen – all from a background almost entirely rooted in renewables – now to be owned by companies that have an undeniable stake in the fossil fuel game, it is to be hoped that the combination of different energy system stakeholders' interests will give the best outcome for everyone.

Warstila's Andy Tang, himself a Greensmith alumnus and renewable energy advocate, is bullish that, whatever our collective best efforts, natural gas is not going to go away just yet. Equally, he says, that does not need to be at odds with a vision of a world powered by renewables, nor does it needlessly endanger the survival of a species already locked in a race against time to decarbonise.

"I'm all for 100% renewables, I see that you can get to that on the capacity side but on the true energy side: you don't have wind everywhere, right? And solar power is an eight to 12-hour resource, depending on where you are. Are you really going to massively overbuild the solar power system by x2 and have batteries of 12-hour duration to be able to store all of that excess solar power and run it at night? I don't think so.

"I don't think that's the cost-effective power system and I don't think that's the carbon neutral solution or the best carbon mitigated solution. When you look at the price tag on that I don't think that our ratepayers, citizens of the world are going to be willing to pay for that," Tang says.

While the renewables community has, out of necessity, always viewed a push to majority renewable energy as an incremental process, the increases are now getting so big that the industry has a responsibility to ensure it can keep adding clean capacity without the system breaking down. Reaching a kind of capacity addition stasis on reaching 20% penetration of renewables in a typical grid scenario, Tang says that the only answer is to add "flexible power resources that can turn on and off really quickly". While a Wartsila gas engine can be switched on and running in five minutes,

Credit: Sonnen.

Sonnen has heavily emphasised not only the sales of its battery units, but also the networked grid services and energy trading aspects of its business model

a battery-Wartsila engine hybrid "can be ramped up immediately", providing fuel and carbon savings and ensuring reliability and quality of power.

"We have a path mapped out," Tang says. "We think that there's this interim period where you're getting from 20% to 60-80% renewables during which you need this flexible fuel source. Maybe I'm a little bit different [to some 100% renewables advocates], but I look at the 100% renewables and I'm not convinced that the most efficient way to do that is renewables plus massive batteries."

Carrying on the theme, Tang's colleague Magnus Miemois says that according to the "number crunching we have done in creating our energy vision and our perspectives: there is a clear correlation that the more renewables you put into a system the more flexibility you are going to need. Decarbonisation is obviously one objective, but you have the objective of grid reliability to attend to at the same time.

"Some of the traditional forms of generation are simply way too inflexible for existing assets to perform that role. You add energy storage to thermal [generation], you get a better performance and minimise the carbon emissions. So it is a necessary element of future energy systems. You might have various existing assets, CCGT, they might prove to be not able to provide the flexibility in an economical sense." Framed in this context, the acquisition of a battery system integrator sounds a necessity for the Finland-headquartered gas (and latterly wind turbine) company.

Business models and scalability

Taken at face value, these are acquisitions in the truest sense. Large companies have spotted that rather than force their way up a steep learning curve by trying to do it all themselves in-house, it is better in some cases to acquire expertise and technology that fits into their plans. Whether that's today's plans in the case of Wartsila and Aggreko, or from a longer-term play perspective in the case of Shell and Sonnen. Big players are seeking not only expertise and technology, but those things have to fit into scalable and viable business models.

Aggreko's Dan Ibbetson, says that post-acquisition, it wants to use Younicos' decade of experience with battery systems to deliver complete bundled solutions, in this case for commercial and industrial (C&I) customers. He also cites the mining sector, data centres and cheap LNG-powered Caribbean Islands as huge segments of market potential perhaps previously not readily accessible to Younicos. Aggreko's business model of renting equipment and solutions to customers is a perfect fit for the 'energy storage as-a-service' offerings that Younicos was already delivering to its customers, Ibbetson says. It has also enabled Aggreko to tout new product lines including mobile containerised solar-plus-storage, also for rent.

"You come to us, you want energy, we'll have a discussion about the right mix of solar and thermal and then the kind of batteries that you need to integrate those two and then it's all in one contract. You don't have three different suppliers. Then all the kit is designed in a way that it fits really well together."

The all-in-one rental model can potentially work well for both energy system provider and customer. The customer is no longer burdened with a high Capex, while what was formerly known as Younicos is able to leverage the balance sheet of its new parent to execute projects on an ongoing and presumably increasingly ambitious basis. Apricum consultant Florian Mayr cites the example of an energy intensive but temporary mining site which might be in operation for less than 10 years. The owners of that site need power, but they don't need to buy a system.

"Having a storage solution which is more energy as a service and not being sold and needs to be amortised over 20 years but can also be moved to a different mining location, that could help a lot [in persuading customers to try it]," Mayr says.

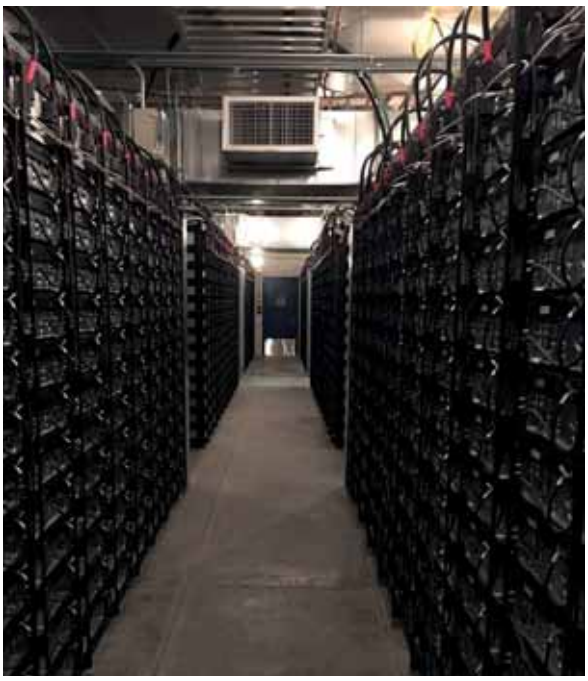
The role technology plays

A couple of years ago, as the importance of battery and energy management and control software became clear, Younicos, Greensmith and others were selling their software platforms as a kind of side-line to their more complete system integration businesses. For both companies, this has changed, not inspired by their respective takeovers but coinciding with a wider market shift. That shift being a recognition that the system integrators' core expertise is in delivering a complete, working system.

"I don't believe that in this industry, there's a strong case for a software-only business model," Greensmith alumnus and now Wartsila's Andy Tang says.

"The biggest challenge you run into as a software-only business is that the solution the customer is looking at is a system: it's the total thing that's working and any time there's any problem, whether it be a hardware or software problem, it's on the software vendor. A hardware problem shouldn't be, but because it's viewed as a system, the hardware problem becomes the responsibility of the software vendor. You don't really have control over having specified the equipment and if you don't have control over having the commercial relationship with the hardware equipment provider, you have no leverage to help fix the situation."

While Greensmith had a hand in a third of all US installations in the 2014 mini-boom, the company was cautious not to overextend itself pre-takeover



Credit: Greensmith Energy

Not only that but with Greensmith's GEMS software platform, and those made by rivals, if deployed to manage energy storage's operation and performance at the heart of the energy system, it is better for the software platform to run the overall system itself.

De-emphasising certain aspects of their existing strategies and in Younicos' case making several pivots over time have been key to the survival of all of the companies pre-acquisition. Tang says that in addition to the decisions around software, Greensmith also had to know not to get too hungry for new projects during the early 'mini-boom' in energy storage projects from 2013 to 2015, although the company's software ended up in around 30% of projects deployed the US that year.

In the meantime Sonnen is given scope to expand the existing base of sales of its systems and subscriptions to its services in Germany, as well as the US and particularly Australia, where the company just prior to acquisition announced the construction of a local factory to enter domestic content eligibility for South Australia's Home Battery Scheme.

The appeal of the Australian market is something of a no-brainer at the moment, with Sonnen's German domestic rival Senec also launching its Australian division (with Senec also in post-takeover mode after a 2018 buyout by utility EnBW) this year. But in terms of manufacturing, does the backing of a fossil fuel supermajor give Sonnen aspirations to fully vertically integrate into battery manufacturing as well? While Ostermann says system assembly and manufacturing could continue to be integrated, he is highly doubtful on the latter point.

The core focus is on the battery and energy management and control software and hardware in terms of creating a self-contained home energy system. Then, as the company has shown in becoming the first home storage participant in Germany's Primary Control Reserve (PCR) ancillary services market, turning that into something that can become part of an orchestra of virtual power plants (VPPs) and communities of energy sharers and traders on the grid. That's not to say the choice of battery is not important.

"Sonnen decided in the beginning of the company history in 2010 to focus on lithium iron phosphate (LFP) chemistry for two simple reasons: the first is that being a residential player, safety was extremely important for us and LFP is the safest cell chemistry you can find within the lithium-ion cell family, regarding thermal runaway – no smoke, no fire, no explosions, no crazy stuff like that, and that was key for us," Ostermann says.

"Secondly, lithium iron phosphate has the highest cycle life. Always given that you use a decent quality [cell] of course. This choice has set us a little bit apart from other players in this industry, whereas now we recognise that more and more of our competitors, laughing at us in the past about this choice, are now also orienting themselves toward LFP, which I find interesting!"

Ostermann also says that not using higher energy density nickel manganese cobalt (NMC) cells also frees Sonnen from some of the supply chain issues which struck energy storage companies reliant on the same cells used in electric vehicles last year.

All roads lead to home

There's an understandable excitement at these previously almost 'alien' and futuristic

companies being taken over by such significant names, but why these three? And why now? And can being part of a much larger 'mothership', as one interviewee described it, bring the scale and reach our industry needs – that our planet needs – to truly play a key role in effecting the global energy transition?

Sonnen's Christoph Ostermann certainly thinks so. Back when Shell led an investment round in the Bavaria-headquartered start-up in mid-2018, Ostermann told me that the involvement of the world's major energy companies was a positive for the "clean energy future", a view that he stands behind even more emphatically since the company became a part of the Royal Dutch Shell Group.

It's a little surreal to think of a company many of whose employees still live in a renewable energy-powered village in the remote southern German countryside, that touted energy independence from the big utilities as its selling point to many of its customers, is now dependent – in the long-term at least – on the utility ambitions of an oil company. As Ostermann reels off a list of geographies that could open beyond the company's core territories in Europe, the US and Australia in the near future, it might almost be easier to compile a much shorter list of territories, which the Sonnen CEO does not think will have a residential energy storage market before long.

"Japan is a market we will look into closely in the near future. We're also looking at other geographies in Asia, such as the Philippines, which we will look at more intensively in the future. There are a couple of countries in Africa, so, just to give some examples, there's Nigeria or South Africa, where we have preliminary plans to enter these markets. Then you have new markets in Latin America, where we're looking at the moment. At the end of the day, due to the fact that renewable energy generation is already price competitive all over the world, and storage prices come down more and more, I deeply believe that we will see a lot more geographies in the future that turn out to be residential storage markets."

Greensmith Energy's systems on the other hand have been supplied in eight countries to date (80 systems) and Andy Tang predicts that in a year's time the number of countries will have more than doubled.

"The growth we're seeing because of Wartsila's sales organisation selling our energy storage, we expect that to really, really, grow incredibly. Energy storage I think is still in its infancy as a market but I think now is the time to enter these new geographic markets that are opening up," Tang says.

It isn't just the geographies; it's also the range of projects and systems the company is now integrating batteries with that's increasing. In tandem with that, the number of different applications the systems perform increases and so too does the complexity of managing the entire energy system that is created.

"If you think about how people are beginning to use energy storage, there's a lot of single-application deployments around the world, where energy storage is thought of as one or two things: peak shifting or smoothing out renewables. A lot of our customers are applying four or five different applications out of our software to get the maximum outcome. Not just from storage, but from software," Tang says.

Commitments not compromises

Whether their takeovers are judged a success will all come down to the value each of these companies can provide to their new owners, although obviously they will be judged on other metrics too, such as their contribution to decarbonisation. Apricum's Florian Mayr says that with US$1-2 billion invested per year through Shell's New Energy Ventures VC wing the company's "magnitude of investment is too much to be considered 'greenwash'". However, to put it in context, Shell is nonetheless spending perhaps tenfold that amount on oil exploration activities still and is "definitely not exiting the oil business today", Mayr says.

The flexibility energy storage can bring to the renewable energy transition is critical on both an environment and long-term economically sustainable level. Whether that means the continued acquisition of smart new companies or the development of their own products, big players are swooping.

As Mayr says, it's likely that for costs associated with residential storage to continue falling and "a widespread, globally applied business model" to be feasible a mass market is needed and big balance sheets and a recognition of the need to change will play a big part in that. As the examples of Aggreko and Wartsila also show, albeit from other angles, non-residential storage is also in the sights of those big players. Let's hope it's not too bumpy a road. ■

Credit: Flickr/Tony Webster

Aggreko's history of powering major events and industrial operations around the world using containerised solutions includes sports and stadiums: the LA 2024 Olympic Games are pledged to be carbon neutral

A needs-led, thematic approach to investment: A quick look at one big player's approach

Centrica, the global energy giant behind British Gas, launched an innovation fund two years ago, seeking to plough some £100 million in tech start-ups that could help it navigate the energy transition.

In its first two years it has backed the likes of New York-based blockchain start-up LO3, Israeli EV software firm Driivz and a host of other companies operating at the grid edge.

Sam Salisbury, director at Centrica Innovations Labs, says the division starts by being led by a need, indicating that two of Centrica's present themes are driven by societal issues, namely mobility and 'active ageing', or making people feel more comfortable in their homes.

"We try to have a bigger vision of what we're trying to achieve and then look at who can contribute to that vision and who we can assemble together to create a big solution for our customers," he says.

Plugging capability gaps with a well-timed, strategic investment stands to be significantly cheaper than ploughing resource into an in-house R&D department like other industries can, and is often the only option in an energy retail sector famed for its slim margins.

But Centrica's activity is becoming increasingly consumer-led, a notion backed by the company's work in establishing a peer-to-peer renewable trading network in Cornwall, one of the UK's most sun-drenched areas, which is to feature a heady mix of solar, various storage technologies and blockchain.

"Certainly my view is we need to find out how to make the homes more self-sufficient… as an energy supplier we have to be developing more solutions for our customers," Salisbury says.

Author: Liam Stoker

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Power to the people

Markets | The UK's energy retail market is witnessing an exodus of customers leaving the so-called Big Six for independent suppliers, who are attracting them with home solar systems and a battery to match. Liam Stoker uncovers what's behind the trend for new energy suppliers taking to domestic PV

Credit: Shell Energy

The UK's energy retail market is, slowly but surely, changing beyond recognition. Ever since the market was privatised in 1990, it has been dominated by a select handful of companies whose combined share of the market has at times topped 99%.

Now, nearly 30 years later, that status is changing and their footing is being eroded by an influx of independent operators with a stated aim of giving power back to the people. Increasingly, they are turning to solar and storage to do that.

The heavy hitters of the UK retail market, dubbed The Big Six, are British Gas (parent: Centrica), E.On, EDF Energy, npower (parent: innogy/RWE), ScottishPower (parent: Iberdrola) and SSE. Although historically they have enjoyed an oligopoly over UK homes, a government-backed drive to encourage switching, political uproar over increasing bills and heightened consumer engagement with their energy supply has turned the market on its head.

Ofgem, the UK energy regulator, charts the market share of all suppliers over a certain threshold and its most recent dataset, for Q3 2018, places the collective Big Six market share at 75%, indicating the sheer level at which consumers have started to vote with their feet.

Solar and storage systems, so adept at handing power back to the people, are causing a shift in market share towards independent suppliers.

Empowering software

Social Energy, one such independent new entrant, launched with much fanfare earlier this year. While technically an energy supplier – it holds a supply licence – its chief executive Ryan Gill describes the company as "more Microsoft than Apple" by the way it has developed bespoke software which is then added to third-party equipment.

Shell rebranded its First Utility supply business as Shell Energy in March 2019, before promising to offer its 700,000 customers battery storage

And it's that software which has enabled Social Energy to lay claim to kick-starting a revolution in home solar in the UK.

It uses artificial intelligence techniques to educate an algorithm which effectively assesses and manages individual home solar and storage systems every five minutes, meaning the company engages with its customer more than 100,000 times each year. To put that figure into context, during a recent trial of its system with National Grid to qualify it to be used in grid balancing services, Gill says the company delivered 11.2 billion pieces of data to the system operator.

Gill says this level of engagement allows the company to radically enhance the effectiveness of the systems it manages, taking them into revenue streams and balancing markets which are uncharted territory for domestic solar. Homes will be capable of providing their flexibility into frequency response

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markets, with ambitions to enter the Capacity and Balancing Markets in the future. Social's supply licence also allows homes to subvert network charges at times they are most costly. When combined with more standard self-consumption and spot trading benefits, batteries featuring Social's software are almost supercharged.

"What this allows us to do is deliver a return on investment that's actually better than solar tariffs at their peak," Gill says, referring to the UK's feed-in tariff which, once upon a time, stood at a richly rewarding 43.3p/kWh. At that time a standard 4kW system returned an ROI figure of around 348%. Social's heady mix of revenue streams, certainly aided by cost reductions which place a standard 4kW PV system plus 4kWh battery at circa £8,500, means that Social boasts a ROI figure of 365%.

Put bluntly, Social Energy's combination of self-generation and storage benefits professes to render solar and storage systems so economical they'd essentially pay for themselves significantly quicker than they could otherwise.

But they're not alone. Another independent supplier, Resilience Energy, caught attention earlier this year with a similar model and the bold intention of establishing itself as the "Uber of Electricity" and "future proofing" homes with energy saving – and generating – technologies.

Loic Hares, founder and chief executive at Resilience, says the company's bespoke platform would not only trade surplus power more efficiently and provide flexibility services to network operators, but allow Resilience to autonomously predict when system faults are likely to occur.

Both models are reflective of a growing trend in global power markets, with 'prosumers' replacing consumers. Hares says this is particularly true in a UK sector where the public has grown frustrated with years of neglect.

The virtual challenge

Another such challenge could emerge from a range of projects unveiled by the UK government in early April, combining not just solar and storage but a raft of other smart technologies to deliver tangible benefits to consumers.

One of those, dubbed the Smart Local Energy System (SLES) project on the UK's south coast, is to effectively link solar panels, batteries and electric vehicles across hundreds of homes, schools and council buildings – alongside a marine source heat pump, a grid-scale battery and a hybrid, electric/hydrogen fuel cell vehicle refuelling station – throughout West Sussex.

Credit: Social Energy

Social Energy's platform allows users to see the performance of their solar and battery unit, displaying generation against savings

Moixa, the British battery storage company currently making waves in Japan, is to incorporate the technologies into a virtual power plant (VPP), which the firm's chief technology officer Chris Wright says will demonstrate the benefits of linking power, heat and transport in one local system.

The three-year pilot scheme is expected to cut energy costs by around 10% per user. With Ofgem placing the average UK dual-fuel energy bill at around £1,150 per year, combining solar and other technologies to save consumers more than £100 could be a winning formula. Moixa and its project partners are also backing the combination to hold the potential to save the UK some £32 billion on infrastructure spending by 2035 – harnessing more flexible power will reduce the need for costly network upgrades – which will again, in turn, come off the bills of consumers.

Ultimately, Moixa intends to install about 4MW of generation and 4.2MWh of battery storage, which is to be combined with other technologies to result in just over 7MW of generation and 17MWh of storage, all of which will be managed by Flexitricity.

But perhaps the biggest challenger to the Big Six's status will arise from a common household name not usually associated with renewables.

Shelling out

In 2018, O&G major Shell completed its acquisition of First Utility, a supplier sitting just outside the ranks of the Big Six with around 700,000 customers nationwide. Aside from positioning First Utility firmly within its New Energies unit, Shell remained coy on what, exactly, it wanted to do with the purchase. Until earlier this year.

In late March Shell tied its billion-dollar brand to the UK energy retail market by rebranding First Utility as Shell Energy and switching all of its customers to a renewables-only tariff overnight, at no extra cost. It also combined energy supply with broadband internet services – the kind of utility bundling many in the energy retail sector hope to accelerate rapidly in the coming years – and, crucially, introduce new domestic energy technologies to its offering.

Customers of Shell Energy receive discounted smart thermostats supplied by Nest and can pick up a domestic EV charger from NewMotion, the Dutch manufacturer Shell acquired in October 2017. That ability to dip into companies acquired and siloed within its New Energies division would become all the more relevant just a day later.

Colin Crooks, chief executive at Shell Energy, took to the stage at an industry event in London just over 24 hours later and detailed his company's strategy for tackling the Big Six's stranglehold on energy supply. Referring to the rebrand as a "line in the sand, a statement of intent" for Shell, he revealed that the company would indeed also be introducing sonnen batteries to customers imminently, leveraging the German battery storage manufacturer it acquired just a few months before.

Crooks described sonnen's offering as "the best home battery storage solution in the world" in what constitutes a fairly significant shot across the bows of Tesla et al. But the home battery itself may only be part of the solution. Crooks went on to discuss how other facets of Shell New Energies – London-based virtual power plant specialist Limejump, which it too acquired earlier this year, and billing app Wonderbill – could combine to create a supply revolution.

"What's exciting about this is that each part of the story is actually working somewhere in the world. We haven't had to invent it all from scratch… but while

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much of the world does some of this well, nowhere is pulling it all together.

"And that's the opportunity we see today, to find the best people, to invest in the best technologies and bring them together in ways which empower and excite our customers," Crooks said.

Shell's decision to place consumer-facing technologies such as battery storage firmly within their offering is down, Crooks adds, to a need to induce "enormous levels of investment and profound changes in consumer behaviour" in order to both transition away from fossil fuels and engage consumers with their energy supply.

It's something which sonnen chief executive Christoph Ostermann is also a huge advocate of. Speaking to sister publication Energy Storage News after his firm's acquisition was finalised, he said: "The equipment we provide is a solution for residential customers. A customer can supply themselves with self-generated solar power on the one hand, on the other hand, in the bundle with First Utility, First Utility could provide that customer with the remaining grid power that they still need. The customer could buy this as a package. It's a very nice opportunity to offer more complete packages to the residential customer."

Combining sonnen's product suite – the manufacturer's sonnencommunity virtual power plant has already been tried and tested in the UK – with Shell's 700,000-strong customer base could make for a potent mix, especially when you factor in the obvious synergies in introducing the aggregated capacity of those batteries, some of which could be coupled with solar, into grid balancing markets using Limejump's capabilities.

But as Crooks says, cracking the market will either require a sea change in consumer behaviour or an easier, more penetrative way for batteries to become more prevalent in consumer homes.

Enter the electric vehicle.

Driving change

The electrification of transport, specifically the personal vehicle, is driving car companies into the energy market at speed. Automotive giants have quickly come around to the concept that they will soon be purveyors of batteries on wheels, embracing the change that comes with it.

As has been identified by Moixa, the average electric vehicle's battery is six-times the size of its domestic counterpart at ~30kWh, making them an ideal resource to pull from. This proved to be a significant contributing factor to Honda saddling up to Moixa earlier this year in a partnership designed to strengthen the duo's collaboration in the energy sphere moving forward.

This, too, is forcing them to at least consider bolting on additional services. Last year Nissan partnered with UK PV firm Solarcentury to launch a domestic solar-plus-storage offering, making full use of the second-life battery partnership it has with Eaton, while earlier this year Volkswagen – perhaps still conscious of the reputational hit it suffered via 'Dieselgate' – announced the launch of a 100% renewable supply arm dubbed Elli. Buying an electric VW? The dealership will now be offering you a 100% green tariff to power it and a home charger install for the trouble.

Whether or not consumers will take to purchasing their home's energy from a car dealership remains to be seen. Trust has proven to be a significant hurdle for UK energy suppliers and, if anything, trust in car manufacturers is low post-Dieselgate. The same could be said for Shell and its renewable credentials, after its announcement was pilloried by eco groups in the UK.

But independents will face hurdles too as they attempt to get their fledgling models off the ground.

Trading places

Such is the pace of change within the UK's energy sector that fears remain that decentralised energy may be attempting to run before it can walk. When the UK government consulted on proposals for a replacement scheme for its feed-in tariffs for solar (p.44), the UK's Solar Trade Association raised a multitude of concerns on its reliance on technologies which just aren't ready for at-scale deployment. Smart meters, for example, are a technology crucial to everything working in tandem, but installations are considerably behind schedule.

One energy company questioned for this piece also raised serious concerns over using such systems to bid into flexibility markets and factoring these revenue streams into the economics of individual installations, suggesting that would-be installers could end up over-promising and under-delivering.

UK grid balancing markets are plentiful, but complicated. Entry barriers are high and often participating in one precludes you from opportunities in another, allowing network operators to guarantee that flexibility is available should they need to call on it. This extends into the battery's operation, meaning that if a VPP operator or aggregator has secured a contract, as long as it is participating in that market it cannot be utilised by its actual owner. "Try explaining to a customer they can't use their battery or car because their energy supplier is using it instead," the energy company representative said.

There are apparent workarounds. Moixa, for instance is only taking surplus capacity into flexibility markets to bolster its project economics and Social Energy packages homes in groups of 400 for flexibility provision, rather than the minimum necessary 330, to account for any connectivity issues or instances where devices are already in use.

Concerns over the financial benefits attached to flexibility markets have too been raised, particularly as competition for such payments stands to increase. Social's model has been backed by energy consultancy Baringa, lending it a considerable amount of authority in the market, but industry scepticism looks only set to continue until such a time that installs are demonstrably achieving what they've set out to.

Any apprehension would not appear to have extended as far as the consumer, however. Gill says Social Energy is preparing to install as many 1,000 domestic batteries per month by the summer, with a target of installing twice or three-times as many per month by the end of this year. Its software will soon be approved to be used in conjunction with a number of new batteries from an extended range of manufacturers, and the company has turned to renowned investment advisory Evercore to raise £90 million to fund an expansion into Australia, the US and, like Moixa before them, Japan, where the market for intelligent battery systems has exploded.

Fears of running before these systems can walk could be well founded, but there is most certainly appetite for solar and storage to be installed en masse and, although the likes of E.On and EDF have their own established offerings, the exodus of consumers from the Big Six is changing the face of the UK's energy retail market for good.

Intelligent solar and storage could prove to be the accelerant needed. ■

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Renewable rethink at Norway's oil fund sets scene for allocation swell

Finance | Norways US$1trn-plus sovereign wealth fund has already shown appetite for solar manufacturers. Does a new interest in unlisted infra herald a capital bonanza for downstream players, asks José Rojo

Credit: Graeme Maclean/Commons Wikimedia

Norway's vast oil fund has hinted at forthcoming downstream solar investments

It is hard to overstate the significance of the entity that lies behind the deceptively unexciting moniker of Government Pension Fund Global (GPFG).

Numbers alone make Norway's US$1 trillion-plus sovereign wealth fund a formidable financier, whose every move is followed by industries of all stripes. This correspondent remembers the shockwaves made by the entity last April as it contemplated – and then abandoned – plans to invest in lucrative-yet-risky private equity plays.

One year down the line, a new instalment of the GPFG saga touches directly on the PV ecosystem. The fund may already have worked up an appetite for listed solar manufacturers (see below) but what the government now says it will be allowed to do – backing unlisted renewable infrastructure – holds far-reaching implications for developers and investors on the downstream end of the chain.

Economics not ethics

A noteworthy element of Norway's move is that economics, and not ethics, appear to be the driver at play.

The GPFG – whose self-styled mission is to safeguard wealth for when the "oil runs out" – will tap into unlisted renewables strictly because of the "investment opportunities" they represent, the government said in its statement in early April. "[It] is not a climate policy measure, but is a part of the investment strategy for the fund," is how finance minister Siv Jensen chose to put it.

Exactly how this market-driven philosophy will work out in practice remains, at this stage, anybody's guess. PV Tech's questions – will the GPFG invest directly in projects or in developers, will there be any technological or geographic focus – were met by a resounding nei.

The answer from a GPFG spokesperson was that specifics on how unlisted renewables will be tapped into must wait until the government's regulation is rubberstamped by the Norwegian parliament. The MPs' decision, the spokesperson added, is expected before the summer.

Until then, a few information nuggets from the government can help fill some of the gaps. Based on what has emerged so far, the renewable investments will come under GPFG's separate environmental programme but face the same profitability requirements. To minimise risk, exposure will initially be limited to developed markets and subject to a cap equal to 2% of the fund's assets.

More trickle than flood

As speculation builds on where GPFG's trillion-worth eye will fall next, it pays to look at its past solar plays on the listed side.

Over the past decade, the fund has developed a taste for manufacturers such as SolarEdge (US$56.2 million invested as of December 2018), First Solar (US$54.2 million), Canadian Solar (US$17.9 million) and JinkoSolar (US$3.3 million); except for SolarEdge, exposure to all the aforementioned has declined to varying degrees throughout the late 2010s.

Downstream counterparts should likely not expect an overnight allocation surge going forward; the government's use last week of the words "gradual" and "caution" suggests the aperture to unlisted projects will be more trickle than flood.

However, PV developers may find room for hope in the consultant report that preceded this week's announcement, a 31-page document put together by McKinsey & Company for the Finance Ministry [1]. Published last December, the analysis found unlisted projects will represent 70% of the investable renewable market between 2018 and 2030; the vast majority of that unlisted opportunity will lie with solar and wind projects built after 2017, with Asia taking the lion's share.

McKinsey's report sheds some light on how risky a venture solar is seen to be in today's world. According to the firm, institutional investors will find PV can require significant land areas but tends to be reputationally and environmentally safer than other renewables. However, McKinsey continued, the decommissioning of panels with cadmium telluride – as well as policy U-turns and power price shifts – means risks do exist.

How the GPFG will ultimately move on PV assets is a question only its investment teams in Oslo can answer; time will tell whether the sense of opportunities ends up prevailing over that of risks. The oil giant is hardly the only institutional investor circling the industry at present. Its sheer size, however, means such a journey will leave far more ripples in its wake than others – definitely one to watch in 2019 and beyond. ■

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[1] "The Market for Unlisted Renewable Energy Infrastructure External perspective developed for the Norwegian Ministry of Finance" https://www.regjeringen.no/contentassets/7fb88d969ba34ea6a0cd9225b28711a9/20181219-the-market-for-unlisted-renewable-energy-infrastructure_final.pdf

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