PV TECH POWER

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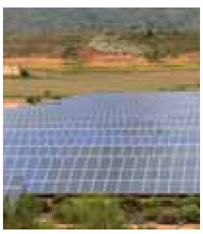
MAKING EVERY PHOTON COUNT

Repowering, retrofitting and the future of asset management

MARKET WATCH

High hopes of post-subsidy solar boom in Europe



SYSTEM INTEGRATION

A standardised approach to bifacial rating

DESIGN & BUILD

Harnessing the environmental benefits of floating solar

PLANT PERFORMANCE

On-site diagnosis of potential-induced degradation

About LONGi Solar

A world leading mono-crystalline solar module manufacturer for achieving best LCOE (levelized cost of electricity) solutions.

LONGi Solar is a world leading manufacturer of high-efficiency mono-crystalline solar cells and modules. LONGi Solar focused on MONO 18 years and is the largest supplier of mono-crystalline silicon wafers in the world, with total assets above $5.2 billion (2017). It also plans to have 45 GW of monocrystalline wafer production capacity by the year 2020.

Armed and powered by advanced technology and long standing experience in the field of mono-crystalline silicon, LONGi Solar shipped approximately 6.5GW products in 2017, with over 100% rate of growth in three consecutive years. The Company has its headquarters in Xi'an and branches in Japan, Europe, North America, India, Malaysia, Australia and Africa.

With strong focus on R&D, production and sales & marketing of mono-crystalline silicon products, LONGi Solar is committed to providing the better LCOE solutions as well as promoting the worldwide adoption of mono-crystalline technology.

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LONGi Solar

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Introduction

Welcome to the latest edition of *PV Tech Power*. Installed solar power capacity already rivals nuclear power and could well surpass it by the end of 2018. Rapid improvements in solar cell technology, module configuration, system design and financial innovation have been a big driver. Increasingly, we are seeing this mammoth legacy fleet continue to benefit from technical improvements ranging from intelligent monitoring to using machine learning and energy storage to predict when charging a battery offers a better return than feeding the grid. We'll explore a range of activities covering hardware and software, from module to market, that are helping asset owners maximise the value of solar (from page 16).

One such technical improvement that the industry is banking on for the future is bifacial modules. TÜV Rheinland's technical paper (p.64) examines how to test, measure and rate the electrical of bifacial modules given the vast number of factors that can affect the contribution from the back of the module.

A fresh resurgence for building-integrated PV (BIPV) is explored by the EU-funded PVSITES project team on page 50. The European market is increasingly embracing the technology, which has previously suffered a few false dawns, but the signs suggest a sustainable level of demand could be building. Fraunhofer ISE researchers meanwhile provide a technical paper on how to simulate BIPV systems given their bespoke nature (p.56).

With Intersolar Europe on the horizon at the time of writing, we thought it just to examine how one market could be set for a dramatic, subsidy-free return to form and whether this could be a pattern repeated across the continent (p.26).

Liam Stoker looks at the growing influence of the traditional oil and gas majors in the solar sector as they look to secure their seat at the table (p.32).

Tracker technology is evolving rapidly to meet new demands as PV applications diversify and projects are required to stand up to new rigours. Mark Osborne examines how the major manufacturers are addressing issues such as floating solar, 1,500V architecture and bifacial modules (p.72).

Our Storage and Smart Power section kicks off with an in-depth look at the opportunities presented for experimentation and innovation in providing power to the world's islands. David Pratt explores some of the ways smart grids and renewables are cutting costs and carbon for remote communities, and signposting the future for the rest of us (p.98).

Andy Colthorpe takes a deep dive into the world of flow batteries as they look to commercialise and secure their corner of the energy storage market with a very different proposition to the ubiquitous Lithium-ion (p.104).

We also have papers from Fraunhofer on PID (p.88), an examination of solar insurance issues on page 40 and the potential for green bonds to finance solar (p.46).

As ever, we hope the collective wisdom on these pages will help you navigate your way through solar's ever-evolving landscape and to make every photon count.

John Parnell
Head of content

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HUAWEI
Smarter Energy for a Better Life
Huawei FusionHome Smart Energy Solution, One-fits-all solution with battery ready
Net-zero energy living is something that we aspire to and Huawei is leading the way with its FusionHome Energy Solution, creating new ways for you to connect with and enjoy your home energy.
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REGULARS

EUROPE

Market

Inverter shipments hint at big 2018 for European solar

Inverter shipments in Europe suggest the continent is braced for another strong period of growth in 2018. GTM Research's global inverter report highlighted shipment growth of 34% in 2017 outstripping growth in European PV deployment of 8%. A spokesperson for Germany-based inverter manufacturer SMA said the GTM figures were in line with what it was experiencing – adding: "SMA experienced a positive development in the European business in 2017. Sales in the European, Middle East and African (EMEA) region increased by 40% compared to 2016. We agree as our outlook for the European and Asian solar markets is positive. In those regions we see a nice development for utility projects as well as a strong demand for our commercial and residential solutions. Key European markets for SMA were Germany, Italy, Benelux, France and Turkey."

Credit: SMA Technology

SMA said its own figures tallied with the forecast of GTM Research.

Acquisitions

Total to acquire Direct Energie

French power giant Total has signed an agreement with the controlling shareholders of another France-based power firm Direct Energie to acquire a 74.33% stake in the company for roughly €1.4 billion. In terms of power generation, Direct Energie has an installed base of 800MW in gas-fired power plants and 550MW of renewable energy. It is the parent company of Neoen, which has solar and wind assets across several countries including France, El Salvador and Australia among others. Last October, Direct Energie also completed its acquisition of Quadran, which has renewable energy assets predominantly in France. Moreover, Direct Energie has a 400MW gas-fired power plant under construction and a 2GW pipeline of renewable electricity projects in France, which will complement Total's own 900MW of installed power capacity.

Lightsource BP strengthens digital capabilities through IoT specialist acquisition

Lightsource BP, one of Europe's largest solar companies, has acquired Irish Internet of Things (IoT) specialist Ubiworx, in a bid to strengthen its digital capabilities. However, the firm's COO, Kareen Boutonnat, hinted that the deal was also part of Lightsource BP wanting to take advantage of a digitisation and decarbonisation of the energy sector that would require "reinvention" beyond just monitoring and consumption control. "This transformation is being led by innovation and market disruptors, like electric vehicles that will completely change the way household energy is used and stored. We cannot underestimate the 'power of the home' and its vital role in shaping this new energy future."

Projects and tenders

Solar notches up clean sweep in German renewable tender

All 200MW of Germany's latest wind and solar tender has been awarded to PV projects. The Bundesnetzagentur, the Federal Network Agency, said it received bids for a total of 395MW of capacity. The average successful tariff for projects was 4.67 euro cents per kWh (US$0.0467/kWh). Successful bids ranged from 3.96-5.76 euro cents. The average is slightly higher than the 4.33 euro cents recorded in the country's previous solar-only tender. Onshore wind prices in the dual tender averaged 7.23 euro cents per kWh.

Reden Solar acquires 50MW of solar projects in Portugal

French IPP Reden Solar has acquired several existing PV power plants in Portugal, representing a total capacity of 50MW. The firm also plans to develop new projects in Portugal. Thierry Carcel, president of Reden Solar, said: "The choice of Portugal is also part of the ambitious approach taken by the State in the promotion and development of the renewable energy sector. Where, following the 2008 crisis, other countries have retroactively challenged their tariffs and caused the long-term departure of investors, the Portuguese government has managed to cope with the extremely difficult economic situation, hence this current credibility." To date Reden Solar has developed 330MW of project capacity, including 180MW under its direct ownership. The company is involved in numerous projects at various stages of development or construction representing more than 350MW.

PPA signed for 170MW subsidy-free solar plant in Spain

BayWa r.e. and Statkraft signed a 15-year power purchase agreement for a subsidy-free, 170MW solar plant in southern Spain. The Don Rodrigo project, outside Seville, will be commissioned by the end of the year with work already underway. "The fact that we can implement such a project without state funding is largely thanks to the continual improvement of system design and building costs," said Benedikt Ortmann, managing director, BayWa r.e. Solar Projects GmbH. It is the first project in Spain for Norwegian power provider Statkraft, as it looks to build on its portfolio of 15GW. The plant will be based on 1500V architecture and will use Huawei string inverters.

Hanwha Q CELLS supplies Dutch floating PV plant

Hanwha Q CELLS said it would supply more than 6,100 'Q.PEAK-G4.1' 300Wp monocrystalline solar modules to a floating solar (FPV) plant in the Netherlands in 2018. The company noted that the FPV being developed by Tenten Solar Zonnepanelen B.V. on a freshwater reservoir in Lingewaard in central Netherlands would be constructed between April and June 2018 for Drijvend Zonnepark Lingewaard B.V., and be the largest of its kind so far built in the country. The FPV plant would also be equipped with FPV specialist Ciel et Terre's modular pontoon system and PV inverters and optimizers from SolarEdge.

AMERICAS

First Solar building new 1.2GW CdTe thin-film manufacturing plant in Perrysburg, Ohio

CdTe thin-film PV module manufacturer First Solar will build a new 1.2GW manufacturing plant near its existing flagship facility in Perrysburg, Ohio. The company said that the new production plant for its large-area Series 6 modules would require around US$400

SunPower

SunPower buys SolarWorld Americas

SunPower acquired Hillsboro, Oregon-based PV manufacturer, SolarWorld Americas. Financial details were not disclosed. SunPower said that it would invest capital into the manufacturing operations in Oregon to convert the production to its P-Series modules, which use monocrystalline PERC cells fabricated in China under a JV arrangement. "We are thrilled to announce this agreement to acquire SolarWorld Americas, one of the most respected manufacturers of high-quality solar panels for more than 40 years," said Tom Werner, SunPower CEO and chairman of the board. "The time is right for SunPower to invest in US manufacturing, and SolarWorld Americas provides a great platform for us to implement our advanced P-Series solar panel manufacturing technology right here in our home market. P-Series technology was invented and perfected in Silicon Valley, and will now be built in SolarWorld Americas' factory, helping to reshape solar manufacturing in America. SunPower's move to acquire SolarWorld Americas, which had a nameplate module capacity of around 500MW comes after the Section 201 trade case that imposed anti-dumping duties on almost all countries that have module production capacity.

Credit: SolarWorld Americas

The existing production lines will be upgraded to make SunPower's P-Series modules.

million in capital expenditure and create around 500 new jobs. The capacity expansion plan includes a 1 million square foot facility located in Lake Township, Ohio, a short distance from the Perrysburg facility, which is expected to start construction in mid-2018 and enter full production ramp in late 2019. As a result, First Solar will have a nameplate capacity in the US of 1.8GW of Series 6 modules and clearly be the largest PV manufacturer in the US. "Strong demand in the US for advanced solar technology, along with recent changes in US corporate tax policies, have encouraged our decision to grow First Solar's US production operations," said Mike Koralewski, First Solar's senior VP of global manufacturing.

Tracker deals

NEXTracker providing trackers for 634MW of First Solar Series 6 modules in the US

Tracker supplier NEXTracker will provide trackers for 634MW of First Solar projects using its Series 6 modules in the US. The company will provide its NX Horizon trackers for the plants in southwestern US, including a 312MW installation in Phoebe, Texas, and two California projects - 193MW in Rosamond and 129MW in Willow. NEXTracker will also provide a new racking technology for First Solar's Series 6 PV module, which includes new panel clamps for rail alignment and rapid module installation.

Array Technologies secures major long-term tracker supply deal with sPower

Independent Power Producer sPower entered into a strategic solar tracker supply deal with Array Technologies for multi-gigawatts of planned PV power plants, cementing a business relationship established over the last four years, according to Array Technologies. "The newly created partnership between Array Technologies and sPower is a testament to the strength and success of a mature US solar market," said Jeff Krantz, senior vice president at Array Technologies. "This deal represents a significant milestone for our company's continued robust growth throughout the nation."

Corporates

Apple hits 100% renewables goal

Just a few days after Google announced that it had officially hit its 100% renewable energy goal, rival tech giant Apple has now made the same claim. Apple's global facilities, including retail stores, offices, data centres and co-located facilities in 43 countries are now powered completely with clean energy. The company has also announced that nine more of its manufacturing partners have committed to power all of their Apple production with 100% clean energy, bringing the total number of supplier commitments to 23.

Intel Corp touts scale of carport solar installations

Intel highlighted that its electricity consumption across its manufacturing operations in the US and Europe have reached the milestone of obtaining all electricity needs from renewable resources such as solar PV, hydro-electric and wind. Intel noted in its latest 2017-2018 "Intel Corporate Responsibility Report" that its major manufacturing and R&D campus in Ocotillo, Arizona utilises PV carports extensively onsite and has installed more than 8,000 solar parking spots worldwide to date.

Walt Disney plans another 50MW solar project to power two theme parks

Walt Disney World Resort has partnered with Origis Energy USA and the Reedy Creek Improvement District for another 50MW solar project that will power two of its four theme parks in Central Florida. Spread over 109 hectares of land, the PV system is due to come online by the end of 2018. It will include half a million solar panels. The Walt Disney Company has a 2020 goal of reducing net greenhouse gas emissions by 50% compared to 2012.

Brazil

Latest auction in numbers

Brazil's 'A-4' power auction has seen energy agency EPE allocate 806.6MW of solar at the lowest ever price in the country.

29 ▶ Number of projects awarded capacity

118.07 ▶ The average price of winning projects in Brazilian Reals per MWh (Around US$35.25 per MWh)

145.68 ▶ The average price from the previous auction

2GW ▶ The expected installed capacity in Brazil by the end of 2018

US$2.2 billion ▶ The estimated investment created by the winning projects

MIDDLE EAST & AFRICA

Africa tenders

Engie and Meridiam win 60MW of Senegal solar projects with prices below €4 cents

French power giant Engie and investment firm Meridiam were awarded two solar PV projects totalling 60MW in Senegal with record low prices ranging between Euro cents 3.80-3.98/kWh. Senegal's Electricity Sector Regulatory Commission (CRSE) announced the results of the tender under the Scaling Solar program, which is supported by the World Bank. CRSE had received 14 bids from 8 of the 13 qualified bidders for both locations. The awarded solar plant, located in Kahone, will have a tariff of Euro

South Africa

South Africa's delayed PPAs finally signed

The South African government signed 27 power purchase agreements (PPAs) after resolving the latest twist in the long-running saga. Utility firm Eskom had delayed the contracts claiming that they were no longer in the interest of the company. In March, the impasse appeared to be resolved until two labour unions intervened at the courts, claiming the projects would cost jobs at existing, fossil fuel power plants. At that time, energy minister Jeff Radebe said that despite the court being unable to raise a legal reason why the contracts could not be signed on 13 March, the signing would be postponed until the legal process had run its course. The court chose not to uphold the complaint on 29 March. The 27 contracts represent R56 billion (US$4.7 billion) of investment and, according to the Department of Energy will create more than 58,000 jobs for South Africans. A number of developers were caught up in the delays including Scatec Solar, which was awarded 258MW of solar capacity in the fourth round of the country's tender process.

cents 3.80/kWh, while another plant located in Touba will have a tariff of Euro cents 3.98/kWh.

Zambia issues RfQ for 100MW of solar under GET FiT programme

The government of Zambia has issued a Request for Qualification (RfQ) for up to 100MW of solar under the first round of the GET FiT Zambia programme. German development bank KfW, which is representing the Zambian government, is implementing the tender on behalf of the Ministry of Energy. The capacity will become available via a reverse bid, competitive auction process. The maximum project size will be 20MW and each applicant can apply for up to two projects. A maximum of 20 projects and bidders will be shortlisted and invited to submit full technical and financial Bids during a Request for Proposal (RfP) stage.

Ethiopian utility pre-qualifies 12 bidders for 250MW Scaling Solar tender

State-run utility Ethiopian Electric Power (EEP) has announced the list of pre-qualified bidders for the country's 250MW Scaling Solar tender. In total, 28 developers submitted their applications, of which 12 have been pre-qualified to submit a proposal in the bidding process. The shortlisted developers will receive a formal invite to access the project's data room to submit their final proposal for the two PV projects, each with a capacity of up to 125MW. The winning bidders will be selected primarily on the basis of the lowest proposed tariff.

Six developers pre-qualified for 25MW Scaling Solar tender with storage in Madagascar

Madagascar's Ministry of Water, Energy and Hydrocarbons (MEEH) has released a list of six pre-qualified bidders for the country's 25MW Scaling Solar tender. This is the first Scaling Solar project to be tendered that includes battery storage requirements in addition to PV generation. The World Bank, which oversees the programme, had already contracted Italian advisory firm RINA to help structure a new version of the programme that would make energy storage an essential part of the tenders. This scheme, yet to be formerly announced, will be called the Scaling Solar Storage (SSS) programme.

Middle East projects

Softbank Vision Fund to seed investment in 200GW of Saudi Arabian solar

The Softbank Vision Fund has signed an MoU begin with Saudi Arabia that could see 200GW of solar generation capacity installed. Softbank chief Masayoshi Son said the first phase would involve the development of 7.2GW of solar. Softbank's Vision Fund will provide US$1 billion of the total US$5 billion required. Project finance will be sought for the remainder. By 2030 the collaboration could yield 200GW of generation capacity including energy storage and Saudi-based manufacturing for PV modules.

Dubai ruler flicks switch on first 200MW of mega-project's third phase

The first 200MW block of the latest phase of Dubai's Mohammed bin Rashid Al Maktoum Solar Park has been inaugurated. The third phase, totalling 800MW, was awarded in a competitive tender to Abu Dhabi's Masdar and French utility EDF. Two 300MW stages will be completed in 2019 and 2020. The power purchase agreement for the third phase was signed in 2016 at a rate of 2.99 US cents per kWh. Work on the park began in 2012 with a smaller 13MW installation before the programme was ramped up towards its multi-GW objectives. The completed park will include PV and multiple concentrated solar power arrays.

TSK and Environmena commission Jordan's largest solar project

A joint venture between Enviromena Power Systems and Spanish firm TSK commissioned a 105MW solar PV project in Jordan, having received financing from the Abu Dhabi Fund for Development (ADFD). The Quweira Solar Power Plant, the largest in Jordan to date, cost AED550 million (US$150 million). Hani Fawzi Al-Mulki, prime minister of Jordan, inaugurated the project, located in the southern part of Jordan.

Acciona, Swicorp start construction on 150MW PV project in Egypt

Acciona Energia, the renewables subsidiary of ACCIONA Group, and Enara - the renewable energy platform of Saudi company Swicorp - have started construction on three PV projects totaling 150MW in Egypt. The installations, which will be owned at 50% by both companies once completed, stand as an investment of around US$180 million and are located in the Benban complex - established by the Egyptian Government in the Aswan region. These three projects are Acciona Energia's first renewable projects in Egypt.

ASIA-PACIFIC

India

Indian solar bidding 'irrationally aggressive' say majority of CEOs

Bidding in the Indian solar industry has been deemed irrationally aggressive by 70% of CEOs responding to a survey from consultancy firm Bridge to India, however, sentiment remains upbeat about growth prospects and the overall industry. The 'India RE CEO Survey 2018' found company heads expect India to reach 66GW of installed solar capacity by March 2022, well short of the original 100GW target set under the National Solar Mission (NSM). Just 7% of respondents believe the 100GW target will be surpassed on time.

Hero launches India's first solar-wind hybrid project

Delhi-headquartered renewable energy firm Hero Future Energies has completed India's first large-scale solar and wind energy hybrid project in the state of Karnataka. The project at Kavithal, Raichur District, which included an existing 50MW wind farm, now has a neighbouring 28.8MW solar PV site to form a hybrid system. India has also launched a new Wind-Solar hybrid policy but Bridge to India said the policy was missing key incentives.

Indian Tariffs likely to stay between 2.65-3 rupees per unit

Indian solar tariffs are likely to remain between INR 2.65-3/kWh until either a safeguard or anti-dumping duty is imposed or module prices decrease, according to Mudit Jain, consultant at Bridge to India. Softbank's JV, SB Energy won all 200MW available in the latest solar auction in the Indian state of Karnataka with a tariff of INR 2.82/kWh (US$0.041). Maharashtra's latest 1GW auction attracted lower winning bids of between INR 2.71-2.72/kWh (US$.0.04), while Andhra Pradesh drew bids between INR2.72-2.73/kWh.

Uncertainty lingers over 'Change in Law' clarification for Indian solar but modules free of customs tax

India's Ministry of New and Renewable Energy (MNRE) has issued a clarification in its guidelines for tariff-based competitive solar procurement implying that a change in duties will henceforth be covered as a 'Change in Law', which would give developers protection in case a safeguard, anti-dumping or any other duty is imposed, but analysts said uncertainty remains. Meanwhile, one of the other major causes of uncertainty for India's solar sector has been put to rest after the Central Board of Indirect Taxes and Customs (CBITC) clarified that most PV modules will not be subject to customs duty.

India's Gujarat approves 5GW solar park

The Indian state of Gujarat has approved what could be the world's largest solar park once completed, standing at 5GW capacity in Dholera Special Investment Region (DSIR). The project would be spread across 11,000 hectares of land along the Gulf of Khambhat in DSIR, and would attract investment of INR250 billion (US$3.84 billion) while generating employment for more than 20,000 people.

Australia

Sunshine Energy Australia applies for 1.5GW Queensland solar farm

A council in the Australian state of Queensland has confirmed receipt of a planning application for a 1.5GW solar farm, with provision for battery energy storage, from Sunshine Energy Australia. Somerset Regional Council said the plant would be spread across 2,055 hectares east of Harlin along the D'Aguilar Highway. The site would be close to an existing high-voltage power network, which is also close to the city of Brisbane. It is also one hour from a 570MW pumped storage plant at Splityard Creek.

Australia's NEG would 'trash' renewable energy pipeline

Australia's National Energy Guarantee (NEG), which has been waived through for a final decision in August, would significantly harm the country's large-scale renewables pipeline, with just 1.5GW expected to be completed by 2025 despite the current 16GW pipeline, according to John Grimes, CEO of the Smart Energy Council. Moreover, uncertainty around the NEG has already started hitting funding parameters and therefore it has had an immediate impact on all players in the large-scale renewables field.

China

Chinese solar market strength supports IHS Markit forecast of 113GW of global installs in 2018

China will lead the industry again in 2018, reaching the record 53GW set in 2017 with an upside potential of 60GW in 2018, according to market research firm IHS Markit. "This latest forecast is close to the global polysilicon limit manufacturers can supply," said Edurne Zoco, research and analysis director for IHS Markit. "Tight supply and stable prices will continue throughout the year. Our forecast assumes manufacturers can further ramp up production, to meet demand, in the second half of the year. Demand in China will once again shape the global PV market. This year China will have feed-in tariff deadlines in the second and fourth quarters, which will create two sharp installation peaks." IHS Markit said that India would overtake the US as the second largest PV market in 2018, while emerging solar markets Mexico and Egypt will make up 1.8% and 1.3% of the solar market, respectively.


Credit: United PV

Southeast Asia

Sunseap JV gets green light for 168MW solar project in Vietnam

A joint venture between Sunseap, InfraCo Asia and CMX Renewable Energy Canada has received the green light for a 168MW solar PV project in the Ninh Thuan province of Vietnam, which will be the largest in the country. The US$150 million solar farm has received a Decision on Land Handover and an Investment Registration Certificate, which involved approval from the prime minister's office – necessary for all projects above 50MW capacity. The project is expected to break ground in mid-2018 before going into commercial operation by June 2019.

TNB signs 30MW solar PPA with Majulia and Greencells

Malaysian utility Tenaga Nasional Berhad (TNB) has signed 21-year power purchase agreements (PPAs) with a long list of developers for many 30MW solar projects across Malaysia. News of the signings came steadily throughout the recent months, after the second Large-Scale Solar (LSS) auction was held last year.

Emergence

Mongolia's largest solar project gets EBRD backing

The European Bank for Reconstruction and Development (EBRD) together with Triodos Investment Management and FMO are providing a US$31.6 million syndicated loan to Desert Solar Power One (DSPO) to build the largest solar plant in Mongolia, standing at 30MW. This will be its first utility-scale PV project to get financing in Mongolia, claimed the bank.

Construction starts on Nepal's first large-scale solar project

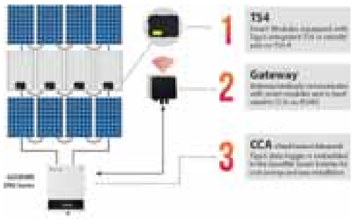
Construction has started on a 25MW solar PV project in Nepal, the largest ever in the country. Minister for Energy, Water Resources and Irrigation Barsha Man Pun laid the foundation stone at Devighat in Nuwakot. This is the first large-scale solar project in Nepal and it is hoped that collaboration between Nepal Electricity Authority (NEA), AEPC and the private sector will help to drive further sustainability and replication of such large-scale projects throughout the country.

Product reviews

Inverter | GoodWe launches smart solution for module-level monitoring, rapid shutdown and optimisation

Product Outline: Following last year's announced cooperation with Tigo, PV inverter manufacturer GoodWe is now launching the DNS and SDT rapid shutdown inverter series with MLPE functionalities, a streamlined solution for the optimisation of energy yields on the module level.

Problem: When a shadow is cast on a solar panel the power output of the whole system heavily decreases if even just a single module is shaded. Although there are a number of different approaches to reducing shading losses, most of them require full deployment on the modules which leads to higher investment. An ideal solution is to solve only the problem of shaded modules, optimising where needed.



Solution: Compared to other traditional optimisation systems in the market which require MLPEs on every module even when it is not necessary, GoodWe offers a highly efficient solution with fewer balance-of-system components, which lowers the overall cost of the system and is easier to install.

Applications: GoodWe DNS and SDT series smart inverters can offer a cost effective and reliable solution that matches perfectly with smart modules. This enables end users to harness more system data for valuable insights about real-time analysis in both Tigo and GoodWe's monitoring platforms and also enables cost-effective datalogging to collect operating information from the inverters as well as each smart module.

Platform: The TS4 platform uses two key components that are compatible with any PV module: a base that is integrated into the module, and five separate detachable covers housing varied levels of MLPE functionalities. Customers can mix and match TS4 covers according to their ideal budget and system requirements. The TS4 platform offers the option to selectively deploy the exact functionality needed to maximize system performance.

Availability: Available since May 2018.

Tracker | HeliosLite's 1.5-axis PV tracker provides 31% more energy and is bifacial ready

Product Outline: HeliosLite's 1.5-axis tracker captures more energy than single-axis horizontal trackers without sacrificing cost effectiveness.

Problem: Dual-axis trackers and inclined single-axis trackers increase output with much lower power density (MWp/hectare), but do not always decrease LCOE due to the marginal cost increase. Furthermore, decentralised PV plants and difficult project sites do not have access to modular and cost-effective tracking solutions.

Solution: HeliosLite has developed a disruptive PV tracker based on a patent-pending 1.5-axis kinetic capturing more energy than single-axis horizontal trackers without sacrificing cost effectiveness. The self-powered controller includes a power sensor, battery back-up and wireless communication to enhance the solution's simplicity and ruggedness. The tracking algorithm uses input from power sensors to achieve maximum energy output. As measured in a pilot project near Dubai, HeliosLite's 1.5-axis trackers have produced 31% more energy during the first year of operations versus the on-site east-west structures with seasonal variation decreased twofold.

Applications: HeliosLite's 1.5 axis PV tracker solution addresses market segments starting from 4kWp to multi-MWp projects where maximum energy output counts most (off-grid, hybrid, solar pumps, rural electrification, self-consumption projects with or without storage) and where current single-axis horizontal tracking solutions are less cost effective or not suitable (slopes, landfills, sandy soils, uneven terrains etc).

Platform: Wind tunnel-tested and pre-certified under Eurocodes, each HeliosLite 1.5-axis tracker carries 12 72-cell, PV panels driven independently or mechanically linked together in rows. The tilt angle can be optimised based on the project's latitude by adjusting a single component. The open back design and maximum power tracking algorithm make HeliosLite's 1.5 axis tracker a perfect match with bifacial modules.

Availability: Ready for delivery and can begin with benchmark trial projects from 24kWp upwards.

Inverter | KACO offering three-phase inverters from 3 kilowatts to meet European specs on larger systems

Product Outline: KACO new energy has made available two blueplanet three-phase PV inverters from 3 kilowatts up to 4 kilowatts. Up until now, the blueplanet 5.0 TL3 was entry inverter from the company into the world of three-phase devices. Now the blueplanet 3.0 TL3 and blueplanet 4.0 TL3 provides installers operating in markets where photovoltaic systems of this performance class and above that have to be connected in three phases, such as Switzer-land or Austria to better size inverters to the PV system

Problem: The growing grid penetration of decentralised solar power has increased the pressure for three-phase feed in for reliable load distribution. In Germany, this is now compulsory from 4.6kVA upwards. Countries such as Austria or Switzerland have also decided to adopt the same requirements but at 3.0kVA.

Solution: The new blueplanet 3.0 TL3 and blueplanet 4.0 TL3 inverters come with "full performance" in terms of equipment features: both have two MPP trackers, each of which can process the full DC power; they start from 200 volts of applied voltage; and they operate stable up to 950 volts. These features allow optimal PV system design with these inverters and rank them among the most flexible three-phase inverters of their performance class on the market.

Applications: Residential PV systems requiring three-phase inverters in countries such as Germany, Austria and Switzerland

Platform: The new blueplanet 3.0 TL3 and blueplanet 4.0 TL3 inverters come with fast cabling of the DC and AC peripherals by means of plug connectors and quick menu selection via the graphic display. The data logger and web server are already integrated.

Availability: Available since February 2018.

Module | LG increases 'NeON 2' 72-cell solar module series performance to 390W-plus

Product Outline: LG Electronics has introduced a higher performance version of its 'NeON 2' 72-cell solar modules using its n-type monocrystalline double-sided 'CELLO' cell architecture with 390W-plus performance.

Problem: Commercial and utility-scale PV markets are increasingly turning to 72-cell module configurations that reduce balance-of-system costs by requiring fewer modules and less racking to meet project electricity output requirements.

Solution: The CELLO technology, based on 12-wire cell connectors, reduces electrical losses and allows the module to produce

up to 30% more energy than modules without bifaciality. In regions where it snows heavily in winter, the module can also generate electricity through the active back of the module, even if the front is covered with snow. Studies have shown that bifacial modules, especially in snowy regions, show a significant increase in yield compared to normal modules.

Applications: Commercial- and utility-scale PV power plants.

Platform: For the LG Neon 2 BiFacial module, LG now offers a product warranty of 15 instead of 12 years. LG warrants an effective output of 98% for one year from the start of the warranty. From the second year, the actual average annual output for the remaining 24 years will not decrease by more than 0.5%, so that by the end of the 25th operational year, an actual output of at least 86% is guaranteed.

Availability: Available since March 2018.

Module | Sharp raises performance of 48-cell mono c-Si modules for European market

Product Outline: Sharp Energy Solutions is offering its most efficient 48-cell PV module to date for the European market. The NQ-R258H (258W) is a new addition to its NQ-R product family of highly efficient back contact monocrystalline PV modules for residential and commercial applications.

Problem: With conventional technology the solar cells have the electrical contact wires on the front side, blocking the sunlight that enters into the cell, and approximately 6% of received light remains unused. Often, standard 60-cell formatted modules limit the ability to maximize rooftop space due to size and roofing obstructions, reducing the opportunity to maximize system yield.

Solution: The NQ-R258H (258W) monocrystalline PV module incorporates

Sharp's back contact technology with efficiency of 20%. The large number of contacts on the back of the cell ensures an even and efficient energy dissipation. On hot summer days, a temperature coefficient of -0.377%/°C ensures the highest yields. The modules therefore maximise the amount of sunlight that can be used and ensure better power output for minimum roof space. On the same surface area, the 48 cell modules can generate more power than with conventional 60 cell modules, according to the company.

Applications: Small-area residential rooftops.

Platform: Due to its size – 1,318 x 980 x 46 millimeters and weighing only 17 kilograms – the module is easy to install, especially in difficult installation conditions. The corresponding IEC certifications (IEC/EN 61215 and IEC/EN 61730) confirm the module's safety, quality and long service life; the module has also been tested according to IEC 61215 for a snow load test exerting 5,400 Pa.

Availability: March 2018 onwards in Europe.

Design | Sistine Solar offers design studio software for customised solar panel appearance

Product Outline: Sistine Solar, the maker of 'SolarSkin' has launch its 'SolarSkin Design Studio', an online platform that allows homeowners to customise the look and feel of their solar installation.

Problem: Homeowners have had few options when selecting PV panels as they typically only come in either black or various shades of blue. Secondly, it can takes multiple phone calls and in-person appointments just to get an estimate.

Solution: Sistine Solar's SolarSkin Design Studio software allows homeowners to customise the design of their solar installation. Homeowners will also be able to see real-time pricing information as they

customize their order and choose from a variety of recommended equipment options, monitoring solutions and warranty packages.

Applications: Residential rooftops in the US.

Platform: SolarSkin Design Studio allows homeowners located anywhere in the US to design their system and compare the cost of going solar to their current energy bill. Sistine Solar hopes that, by offering a unique experience and custom aesthetic solutions, more homeowners will be encouraged to switch to solar. The software allows homeowners to design and order their system from a desktop computer or mobile phone.

Availability: March 2018 onwards in the US.

Product reviews

Inverter | SMA Solar's next-gen MLPE solution offers lower component count and faster commissioning

Product Outline: SMA Solar's 'Power+ Solution' is the next generation of optimised residential systems, now with fewer components and simpler commissioning.

Problem: PV rooftop installers often have to compensate for shading and multiple roofing orientations that can limit space for module installations reducing electricity production, compared to an optimised system design.

Solution: Greater integration within the inverter now only requires a single plug-and-play connection, eliminating additional labour and balance-of-system costs. The Power+ Solution is claimed to deliver the fastest installation possible without sacrificing the energy yield or investment security. The system combines SMA inverter performance and

intelligent DC module-level electronics in one package, meaning maximum solar power production as well as significant installation savings as maximum production with partial shading or with multiple module orientations can be accommodated, according to SMA. A single plug-and-play communication connection speeds installation and reduces labour. The new Power+ Solution offers 50% faster commissioning within Sunny Portal

Applications: Residential rooftop PV systems.

Platform: Tool-free installation is claimed to save 75-90 minutes per system compared to other brands. Selective deployment can eliminate up to 72 minutes per system compared to other solutions. The Power+ Solution now also features SMA Smart Connected, a proactive service solution that can decrease truck rolls, lengthy service calls and system downtime, saving installers time and money and maximising a homeowner's power production.

Availability: Available since February 2018.

O&M | SMA Solar offers component and work solutions for PV system repowering and modernisation

Product Outline: SMA Solar is offering solutions to comprehensively and sustainably modernise solar PV systems. The solution packages range from the replacement of components such as inverters, to the expansion of the solar system with modern energy management functions and storage solutions.

Problem: In the event of a PV system suffering significant under-performance due to faults, options can include a major retrofit or repowering of the system that could restore or actually improve overall performance and still achieve required ROI.

Solution: 'SMA Repowering' enables PV plant

operators to obtain higher yields, the advantages of new technologies and the new start of a five-year SMA factory warranty.

In addition, operators and installers of solar systems can use SMA's newly developed SMA Repowering App. In the run-up to a system's modernisation, this provides all the information about the appropriate replacement devices and will soon be available for free in the various App Stores.

Applications: Repowering of PV systems from residential to utility scale.

Platform: SMA repowering packages offer new inverters in the event of warranty expiry, failure and obsolescence, while providing plant modernisation, modern energy management and the integration of storage solutions where applicable. The SMA Repowering App provides a three step process from data entry, request offer to installation completion.

Availability: March 2018 onwards. From the middle of the year, solutions for the project business and for PV power plants will be added.

Inverter | SolarEdge's most powerful PV inverter means large scale meets easy installation

Product Outline: SolarEdge will soon be shipping its most powerful inverter product to date– the SE100KUS inverter for 277/480Vac commercial gridsSolarEdge will also be offering a 66.6kW (277/480Vac) and a 43.2kW (208Vac) invertern, as well as a 30kW (277/480Vac) inverter based on the standard architecture.

Problem: Both central and string inverters have their own individual limitations and benefits. SolarEdge wanted to create an inverter that eliminated the drawbacks of both systems, yet provides the benefits of each. SolarEdge's inverters with synergy technology enable PV systems to be designed and wired as if with a central inverter, but installed and serviced as if with string inverters.

Solution: The SE100KUS inverter can be

installed by as few as two technicians. The inverter ships with all required cables and connectors and supports nine separate DC string inputs and a single AC output. After on-site assembly, each unit maintains its functional integrity while bundling them together on the AC side for easy commissioning and less cabling. The individual units are managed and interact with the grid as a single inverter, while acting independently for DC-AC conversion. This allows for higher system uptime and decreased maintenance costs.

Applications: Commercial and utility-scale PV power plants.

Platform: The SE100KUS introduces the SolarEdge Inverter SetApp, a new, smartphone-enabled commissioning system. Installers can now commission and configure up to 32 inverters simultaneously (up to 3.2MWac) from a single main inverter using a smartphone app and a local WiFi connection. The inverter ships with the latest in code and compliance with out-of-the-box support for Rapid Shutdown (NEC 2017) and is UL1741 SA certified for CPUC Rule 21 grid compliance.

Availability: Second quarter of 2018.

Module | Solaria launches AC solar module using Enphase IQ 7+ microinverter

Product Outline: Enphase Energy and Solaria Corporation have announced the introduction of an AC solar module, the Solaria 'PowerXT'-AC, combining the Enphase IQ 7+ Microinverter with Solaria's proprietary module technology.

Problem: AC modules based on Enphase IQ microinverters meet or exceed regulatory requirements set by the National Electrical Code (NEC) and individual states and are certified compliant with NEC 2014 and 2017 rapid shutdown requirements. Unlike string inverters, Enphase IQ microinverters have rapid shutdown built in, with no additional equipment necessary.

Solution: The PowerXT-AC will integrate Enphase IQ 7+ Microinverters with Solaria's high-output PowerXT 355W (60-cell equivalent) modules. Enphase Energized AC Modules allow installers to be more competitive through improved capital management, reduced labour costs and accelerated design and installation times. The PowerXT-AC can help ensure that solar installers maximise power deployment on customer roofs, which accelerates payback timelines for customers and increases profitability for installers.

Applications: Residential and commercial rooftop PV systems.

Platform: The Solaria PowerXT-AC is based on Solaria's all-black, high output PowerXT 60-cell equivalent module and features a black backsheet. The proprietary PowerXT platform uses Solaria's advanced cell interconnect and module production processes. The IQ 7+ Micro supports 60- and 72-cell PV modules up to 440W with peak AC output power of 295VA and a Maximum Power Point (MPP) tracking range of 27V - 45V.

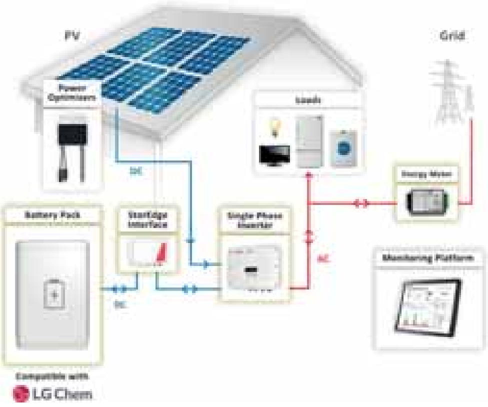
Availability: The PowerXT-AC will be available from distributor Soligent at locations around the US, starting June 2018.

Inverter | SolarEdge provides 'StorEdge' with power backup in European markets

Product Outline: SolarEdge Technologies 'StorEdge' solution with power backup has been launched in European markets. SolarEdge's StorEdge is a DC coupled storage solution that allows home owners to gain energy independence and stay powered even when grid power is down.

Problem: The majority of installed residential and commercial rooftop PV systems remain grid connected, meaning they will not operate independently during electric/grid outages.

Solution: With StorEdge, unused solar energy is stored in a battery and used when needed to maximise self-consumption and reduce electricity bills. StorEdge also supports time-of-use management, which promotes energy consumption when electric demand from the grid is low (off-peak rates) and lower consumption when demand is high (peak rates). The backup function allows homeowners to store solar energy and use it during electric outages to power pre-selected devices.



Applications: Residential PV systems in European markets.

Platform: The SolarEdge single phase inverter with HD-Wave technology manages battery and system energy, in addition to its functionality as a DC-optimised PV inverter. Existing SolarEdge single phase systems can be upgraded to StorEdge. To add StorEdge to PV systems using the SolarEdge three-phase inverter or a non-SolarEdge inverter, the StorEdge AC coupled single-phase inverter may be used. The StorEdge interface is required in order to connect the high-voltage storage battery to the SolarEdge inverter.

Availability: Available since March 2018.

Balance of system | Trina Solar's smart PV power plant solution aims at lower capex and opex

Product Outline: Trina Solar has launched a new smart PV solution, 'TrinaPro' an optimised combination of its PV module product range, state-of-the-art solar tracker systems or floating systems, and world-class inverters.

Problem: The ongoing need to reduce capex and opex costs of PV power plants requires greater attention to be given to maximising the efficiency and utilisation of the system, irrespective of being a ground-mount or floating solar system. The development of bifacial modules has also required new system solutions to harness the superior potential yield of double-sided cells.

Solution: The ground-mounted solution features a state-of-the-art solar tracker system, which will help improve energy gain by 10-30%. The floating solution will cover several application scenarios such as reservoirs and lakes. With the optimised matching among components and "Edge Computing" algorithm integration, TrinaPro can improve system stability with higher power generation and lower BOS cost in order to reduce system LCOE. With the interconnection between the 'Edge Computing' algorithm and a smart O&M system on a cloud platform, TrinaPro is empowered to analyse and process data from the cloud, to optimise the system's operational model and ensure the system runs smoothly and efficiently.

Applications: TrinaPro is designed for utility-scale ground mounted and floating PV power plant systems.

Platform: TrinaPro is the result of Trina Solar's full cooperation agreement with Huawei Technologies and Sungrow Power Supply, as well as its strategic cooperation agreement with Nclave Renewable. TrinaPro is characterised by premium components, optimised system integration and smart O&M interconnection.

Availability: Available since March 2018.

Making every photon count

Plant management | The technologies and methods used to extract the maximum value from PV power plants are rapidly evolving. Ben Willis and Liam Stoker look at some of the latest developments in PV system repowering and asset management

Credit SecondSol

The booming trade in second-hand modules in Germany is a sign of increased plant repowering

While solar's global expansion continues apace, as important as the deployment of new capacity is the question of how best to manage what's already been built. A multitude of factors can affect how efficiently and profitably a plant will perform, and of course we should not forget that in a still-young industry, some PV power plants are getting positively long in the tooth, having been built 10 years ago or more – a lifetime in the context of the speed at which the industry and its technological capabilities have developed over that period.

This reality is bringing the range of activities that fall under the banners of operations and maintenance (O&M) and asset management increasingly to the fore. A study published by US market analysts GTM Research in December last year put the total addressable market for solar PV O&M at the end of 2017 at 395GW and estimated that figure would increase to 900GW worldwide by 2022.

The overriding objective of this fast-emerging offshoot of the solar industry is to ensure a PV power plant operates as expected over its anticipated 20-25-year lifetime, netting as much profit for the owner/investor as possible along the way. That is not always a given, as everything from the age of a PV plant and the local conditions it operates in, to the equipment with which it was first built and the quality of its design and execution, can impact on performance. Added to this is the desire among some investors to wring more yield from a plant than it was originally built to produce.

As the industry gets to grips with these and the many other issues that can befall a PV system over its lifetime, a tension emerges. Cedric Brehaut, author of the GTM report cited above, alluded to this in a recent blog post highlighting how, with the basic elements of the O&M business not getting any cheaper in a market so focused on driving down costs, the question must inevitably arise: "How can O&M providers resolve the head-scratching equation of continuously reducing costs when the main resources they tap (people, vehicles and tools) are becoming more expensive?"

New technologies

The answer, as it so often is in the solar industry, is technology. Labour is not getting any cheaper, nor are the tools for the job. But plant components are becoming more powerful, reliable and efficient, as is the industry's general level of sophistication in putting a PV project together. And alongside that, new technologies are emerging all the time that have the potential to significantly speed up certain aspects of the O&M/asset management process.

One rapidly growing area is in so-called PV plant repowering, a label that encompasses a suite of activities aimed at revamping PV systems either where they are falling short of projected performance or where the owner wants to go beyond the originally envisaged expectations of the plant and achieve asset 'overperformance'.

That trend appears to be particularly pronounced in Germany, home to some of the world's oldest PV power plants. It would seem logical that some of those plants might not still be working at their best, and indeed the second-hand solar component platform SecondSol has witnessed an uptick in the trading of used PV modules, a trend it ascribes to repowering activity.

"Second-hand module trading at SecondSol increased by 30% in the third quarter of 2017 compared to the previous year," the company said in a recent statement. "Although the cold winter months significantly reduced activity, a general upward trend in repowering is clearly evident."

The company's managing director Frank Feldman added: "Many wholesalers, traders and project developers use SecondSol to sell the used modules after the repowering of PV power plants. Looking at the number of used modules traded, we can see that the repowering of German PV systems is increasing significantly. The repowering market is still in an early stage, but it is currently at a turning point. It will continue to increase."

The typical approach to repowering a plant involves replacing old components such as modules or inverters with newer, better ones, correcting supporting structures such as trackers or changing the plant's electrical configuration to boost performance. Another approach is to retrofit plants with new technologies that enable them to perform beyond their original design. Some of these measures are outlined in the Technical Briefing article on pages 18 to 23.

Digital O&M

Another evolving area is the set of activities and practices that have collectively earned the label 'digital O&M'. Put simply, this means using technologies such as remote monitoring sensors, wireless communications and advanced software to generate and analyse plant and other data, and thus improve the operation, maintenance and management of solar assets in the most cost-effective way.

Many of these are already in use, particularly in the operation and management of large-scale PV power plants and geographically dispersed fleets. But with the rapid development of technology in fields such as computing and robotics, it seems likely that the digitalisation of the O&M and asset management fields still has some distance to run. Some of the possible future innovations in digital O&M were rounded up in a recent study by trade body SolarPower Europe [1], a few highlights from which are outlined as follows:

Drones: These are already being widely used to monitor PV plants from the sky, providing visual imaging of modules and other components, and infrared thermal imaging of modules to monitor faults. According to SPE a possible innovation would be for drones to have their own on-board data analytics capabilities to detect patterns and changes in plants.

3D printing: According to SPE 3D printing could in the future reduce spare parts management costs by reducing the number of spare parts in storage, decrease lead times and manufacture spare parts closer to site.

Satellite forecasting: This is already considered best practice for irradiance measurements and remote sensing, and also allows for better scheduling of maintenance. Looking ahead, SPE predicts better granularity in satellite data, for example allowing forecasting at 15-minute intervals.

Artificial intelligence: Sitting behind many of these innovations are the possibilities offered by 'big data', and advances in machine learning and artificial intelligence to mine that data for the purposes of enhanced asset management. The jury still seems to be out on the extent to which the solar industry can best take advantage of these technologies (see box above), but it seems almost certain that they will have a bigger future role to play.

What is also certain is that the business of managing PV power plants will continue to grow both in importance and sophistication as technology evolves. Looking at how the solar industry as a whole has advanced over the past decade, nothing should be considered off the cards in terms of how the industry will adapt to make sure its prized assets are well looked after. ■

The future of asset management technology

While asset managers have spent time and consideration getting to grips with their respective portfolios, many have also cast at least one eye to the future to assess which emerging technologies or principles may make their jobs easier and their assets more productive.

Two such fields are artificial intelligence and machine learning, which, as a panel heard at this year's Solar Finance & Investment Europe event, organised by *PV Tech Power* publisher Solar Media, could play useful, albeit possibly limited roles in the future of solar asset management.

Declan O'Halloran, chief executive at asset management firm Quintas Energy, said his firm had worked hard in identifying solutions that could be employed in these areas with the overall aim of keeping performance ratios high. But, he stressed, Quintas had been eager to ensure that any new initiatives launched by the company "wouldn't just keep people with PhDs in mathematics with job satisfaction", but would make money through real-world applications.

One such area is using AI and machine learning principles to more accurately predict use of system charges within 24 or 48 hours. In the UK, entities that use the country's transmission system pay to do so through Transmission Network Use of System (TNUoS) and Balancing Services Use of System (BSUoS) charges that are owed to the system operator, National Grid.

These charges fluctuate owing to various market factors, and by being able to predict them with some degree of accuracy would feasibly allow asset managers to make more informed decisions about what to do with the power a solar farm may generate. For example, if a site has a battery storage facility connected, charging during periods of high system charges will be more beneficial than simply exporting to the grid.

"At that point you at least know what your balancing charges are going to be and you can make decisions about the solutions around the PV generation, [and] it can make a difference to a hybrid solution. Those are areas which are exciting for the future of asset management," he said.

Francesco Girardi, chief executive at Bluefield Services, added that his firm had also been investigating the use of data and machine learning-based algorithms to expand on its predictive maintenance capabilities, helping plant owners and operators better understand how plants and individual components are ageing.

The prospect of using enhanced predictive maintenance principles becomes particularly interesting when taking account some of the issues felt with spare components and supply chains. One asset manager in the UK in 2017 suffered at the hands of a lightning strike which damaged equipment that then took weeks to replace. While lightning strikes are of course unpredictable events, using predictive maintenance to prepare for eventual component failure by knowing how many replacements to order and when to do so holds the potential to drastically reduce downtime.

O'Halloran concluded that ultimately, an asset manager's role is to maximise the return for owners; the application of new trends like standardisation, machine learning and AI therefore need to be viewed from a purely financial perspective, he said: "Business intelligence and machine learning have a role to play in the future, but I question all the time whether it makes any money for anybody. You've got to be careful about that."

By Liam Stoker

References

[1] SolarPower Europe, 2017, "Digitalisation and solar", www.solarpowereurope.org/reports/digitalisation-solar

Turn to p.18 to learn more about the latest in PV plant repowering

Retrofit technical approaches to maximise PV plant returns

Operations and maintenance | Repowering, revamping and new technologies to retrofit existing solar PV plants offer owners, operators and investors increased energy generation. Antonio Bilella provides a view of each approach to maximise return on investment

Deep into over a decade of serious PV plant deployment worldwide, the industry is dealing with ageing solar installations. Business drivers including maximising return on investment (ROI) and shortcomings in the original construction may cause owners, operators and investors to consider technical solutions to increase site performance. Options available for such consideration are outlined here along with examples to help guide retrofit technical approaches.

Underperforming plants. Retrofit solutions include the interventions and measures implemented to an underperforming PV plant. Underperformance factors can be tracked to the components of a system including physiological degradation or poor quality of installed components, modules subject to potential-induced degradation (PID), degraded inverters and distressed tracking systems with unreliable mechanical systems. Subpar engineering also affects long-term performance. These issues can include but are not limited to incorrect DC/AC ratio or cabling sizing causing overstressed equipment. The aim is to bring the solar asset to its planned performance capability and reliability.

Asset overperformance. Alternatively, an investor's objective may be to achieve overperformance compared with the actual and/or planned baseline in order to maximise the ROI and IRR of the investment, thus increasing the profitability of the investment.

For both the above-mentioned reasons, investors are faced with a key question: what can I do in order to bring my asset back to an acceptable performance and/or boost it to a higher level?

The answer lies in one of three options: "repowering", "revamping", or the application of new technologies. Repowering is applied to existing plants and can be utilised for recovering from an underperforming condition or for extending the life at the end of its initial design life, projected at about 20 to 25 years. Revamping applies to distressed PV plants, those underperforming compared with the planned baseline. A third option is boosting plant performance through retrofit solutions with new technologies.

With specific reference to underperforming PV plants, it is possible to come up with a traditional approach that identifies the technology that will specifically address what is causing the underperformance. The PV plant can essentially be brought back up to what it originally was through the replacement of aged or degraded components (repowering and revamping). It is also possible to boost the current underperformance through a specific technology that compensates for the plant deficiency; such solutions are commonly indicated as retrofit with "new technologies" and have appeared on the market in recent years.

The common approach of investors and operators remains the traditional one and the implementation of such new technologies is still seen as a second-step solution that can boost the plant performance beyond what it was originally designed for by providing an "added value".

Moreover, like any other innovation, these technologies need to overcome customers' scepticism, gain market share and become cost-efficient – and, in some cases, bankable – products before being considered by investors for large-scale deployments. Currently, some of these new technologies are already in an advanced stage as market products, others are in the process of getting there.

Revamping and repowering as a traditional approach

Solar plant repowering and revamping services are tailored to the needs of the solar asset owner. In both cases, the general approach for the implementation of such a project includes several steps:

- Initial project analysis and recommendations;
- Review and correction of displaced or degraded photovoltaic modules;
- Replacement, removal and reinstallation of the main components including, mainly, modules and inverters as part of the balance of system (BOS);
- Eventual modification of the distribution system in the energy/ grid network;
- Eventual changing the system connection point to the grid network, where this is allowed.

Maintenance and technological upgrading to BOS components can typically include:

- Correction or regeneration of malfunctioning or aged inverters;
- Replacement, removal or re-installation of smaller electrical components if the operation does not cause changes in the distribution system in the power grid produced by the plant;
- Corrections to supporting structures of the modules or building structures on which the plant has been installed; this can include replacement of structure components or change of the tilt in mono-axial trackers in order to optimise irradiation level;
- Correction to the electrical configuration of the plant where such changes can improve plant performances.

New technologies offer a new approach to PV plant optimisation

PV plant performance can also be increased through the installation of additional devices (hardware/software) that can optimise and increase the current plant performance beyond the planned baseline or compensate actual underperformances. This approach can commonly be defined as retrofitting with new technologies.

Increasing the energy production and performance of the installed solar capacity

Repowering and optimisation in action

Foresight is one UK's most prominent solar investors and comfortably sits inside the top three asset holders, with assets spread across a number of funds. But its status has not made it immune to performance-related issues that have required rectification.

Foresight's annual report for the year ended 31 December 2017 perhaps best evidenced the extent of the work required by its asset manager. Of the 18 operational assets owned by Foresight Solar Fund, six required what it terms as "significant levels of remedial work and interventions".

Of those, four were acquired from now defunct solar developer SunEdison, having been built during the UK market's Renewables Obligation rush of 2013-2015. Castle Eaton (18MW), High Penn (10MW), Highfields (12MW) and Pitworthy (16MW) were expected to return to full availability and performance in early 2018 following those extensive works, which were conducted by Foresight's in-house O&M provider Brighter Green Engineering (BGE).

In 2017 alone Castle Eaton performed nearly 8% below expectation, while High Penn and Highfields generated 19% and 14% less power than expected respectively. Pitworthy was the principal offender however, generating more than one-third (35.8%) less power than anticipated over the course of that year.

Throughout 2017, Foresight requested in-depth investigations to be carried out in collaboration with technical advisors, equipment manufacturers and BGE, which resulted in an "extensive list of defects" being uncovered. On top of performance-related problems, potential health and safety risks and site security issues were also discovered.

Among the technical issues discovered at the sites were problems with inverter modules and combiner boxes, which required upgrades in Q1 2018. Indeed, the parties tasked with the investigations also found that the combiner boxes were unlikely to last the full lifetime of the projects and were particularly susceptible to damage from events such as lightning strikes. Additional surge protection was installed to protect these sites from such issues.

Moreover, new commercial agreements with the inverter manufacturer and inverter maintenance provider were agreed to help improve performance and allow faults to be resolved more efficiently in the future.

Other sites to have been impacted by issues include the 12MW Spriggs Farm array, which was affected by potential-induced degradation (PID) before Foresight's asset manager intervened, and the 35MW Port Farm site, which suffered from slow response times from the original O&M contractor to minor failures. Port Farm has subsequently been brought under BGE management.

In response to the issues, Foresight claimed more than £3.5 million in liquidated damages (LDs), plus the cost of rectifying defects identified within the sites. Total revenue lost to date as a result of poor performance and downtime as a result of works amounted to £950,000, with Foresight not expecting any material loss in the long term.

It led Foresight to conclude that LDs received by the firm to date were "substantially more" than the value of lost revenue as a result of ongoing works and performance. Over the years since the sites' acquisition, more than £13 million – £5.9 million worth of which was attributed to LDs – of financial compensation has been recouped by Foresight as a result of poor performance.

By Liam Stoker

of clients' portfolios is a compelling vision but, in all cases, since we are talking about "new technologies", the implementation on a large scale requires a necessary transition from lab testing to large-scale pilot testing. For this purpose, a well-structured process adds field results to the test data of the technology providers and, once a new technology fulfils the performance envisioned, it will be ready for market adoption.

The successful outcome of a pilot test gives investors confidence in the technology and the willingness to afford an investment that, long term, will be successful in terms of ROI/IRR and project profitability over the remaining lifetime of the asset.

A typical new technology evaluation goes through a well-structured process that includes:

1. Market potential evaluation: A careful selection of the best solutions in order to bring them fully vetted to the international market of large PV systems. The goal is to address and resolve performance problems including return expectations, regulatory compliance, financial covenants and constraints, O&M issues and clear measurements of the overperformance thus limiting the risks for participating customers.

2. Technologies screening process: Potential new technologies for testing must meet a set of minimum requirements including:

- Investor return expectations
- Regulatory compliance
- Financial covenants and constraints
- Warranties on equipment in place
- O&M proper execution
- Clear measurement of the overperformances

3. Pilot testing phase: Once a technology has cleared initial screening hurdles, it must then go through a set of installation and testing procedures (i.e. at a pilot test). Sites for testing are equipped with the Alectris solar ERP (Enterprise Resource Planning) software tool, called ACTIS, to benchmark and measure increases in energy output and performance.

Within these technical solutions we can refer to the installation of energy storage systems, string optimisers that work on the MPPT string optimisation, reflective foil systems that increase the incident light on the module surface through the utilisation of the albedo, as well as anti-reflective coating (ARC), which modifies the reflection properties of the module surface by capturing more light. In all the cases the final result is a plant performance improvement and higher yield.

In the case of the ARC, the treatment of the modules provides also an anti-soiling effect that leads to reduced cleaning cycles with operational expenditure reduction of the O&M activities for the investor.

The PV market shows a great potential for retrofit solutions and Alectris has been cooperating for their evaluation with market leading vendors, Alencon Systems LLC (SPOT) for the string optimisers, New Power Systems GmbH for the reflective foil technology (CONFLECTOR) and CSD Nano Inc. for the anti-reflective-coating technology (MoreSun).

Each of the above-mentioned technologies is expected to provide different performance gain and currently, based on executed pilot tests and/or already deployed large-scale installation, the results are encouraging and show potential overperformance in the range of 5-7% for string optimisers, 10-15% for the reflection systems and 3-6% for the anti-reflective coating.

Italy PV plant revamping case study

In its capacity as O&M and asset management service provider, Alectris has executed several repowering projects over the past years gaining both a deep know-how and the proper experience for a customer-tailored approach. The result is to find and supply the best solution for the current plant issues.

A representative case is the revamping of a portfolio of seven PV plants with distressed biaxial trackers in Apulia (south Italy). All PV plants were built between 2009 and 2010 and the project owner is a reputable and specialised investor in large-scale PV projects.

The whole portfolio was experiencing severe underperformance and safety issues, where the underperformance of the plants was ascribed to bad system design, lack of proper maintenance, complete absence of adequate monitoring and inappropriate identification of root causes.

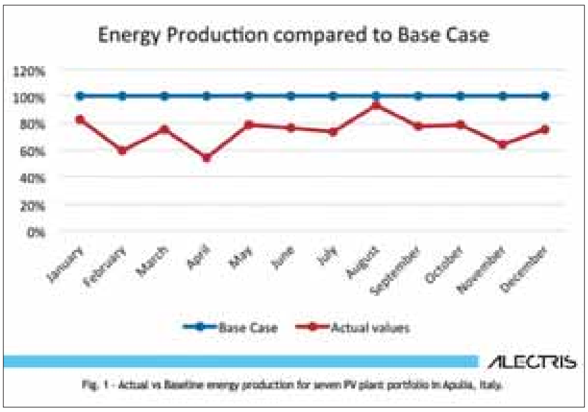


Figure 1. Actual vs. baseline energy production for seven PV plant portfolio in Apulia, Italy

Deliverables provided by for this revamping project included:

- Plant check-up and diagnostic
- Engineering
- ACTIS implementation (web-based platform)
- Trackers re-engineering
- Plant Turnaround
- Solar operations and maintenance

Due to the deeply distressed tracking system, the plants were underperforming and producing well below the base case scenario leading to severe cash-flow issues with an overall financial performance of the investment below budgeted values (Figure 1. The underperformance was around 25% with an average yearly loss of revenue of €150,000/MW. Additionally, huge costs were incurred to preserve even the suboptimal operational status of the plants.

Alectris provided an integrated care approach to solar photovoltaic (PV) energy assets. This holistic, step-by -step process helped to identify the main causes of the performance issues and ensured the corrections would create the desired performance results.

The PV plant revamping process was implemented through three steps:

Step 1 – in-depth analysis of the tracker design

Alectris stepped into this portfolio as the solar O&M manager starting in late 2013. The company conducted an in-depth study of the existing trackers implementation to identify the bottlenecks and deficiencies of the system, paying special attention to the safety mechanisms incorporated. The structural issues affecting the biaxial trackers were identified and summarised for the client.

Step 2 – implement ACTIS for holistic control of trackers and plant performance

Plant monitoring via ACTIS, the Alectris Solar ERP Platform, and analysis of the portfolio's performance and availability revealed severe underperformance. The performance was aggravated by structural issues including: manageability (proprietary protocols bottleneck, inefficient and unreliable hardware, difficult and prolonged (re) start-up, unreliable tracker positioning) and safety (lack of general alarms, inefficient tracker movement, high consumptions, no alarm positions). ACTIS alerted the team to the range of issues involved and allowed fixes to be adapted readily.

Step 3 – trackers re-engineered

Major modifications of the existing biaxial tracker control system were required:

- Identification of proper hardware PLC upgrades
- Correction of any malfunctions of the existing firmware
- Enhancement of alarms, parameters and settings to maximise proper operations and remote control via ACTIS
- ACTIS customisation according to trackers requirements

The outcome of the revamping was a dramatic increase of the solar portfolio's profitability. The new configuration resolved the underperformance and safety issues. The first month of operation showed additionally generated revenue of 15% if compared to the same prior year, resulting in a payback period of the new tracking system installation of few months. Moreover, thanks to the close monitoring reached via ACTIS no manual intervention is required and reliable predictive maintenance can be achieved. Additionally, extra yield can easily reach 33% thanks to further optimisation of the backtracking capabilities of the installed firmware.

New technology case study using anti-reflective coating by MoreSun®

Within the retrofitting of new technologies, Alectris has been working closely since 2015 with the USA-based CSD Nano Inc. company, owner of the ARC MoreSun technology.

As said by Mr. Paul Ahrens, president and CEO of CSD Nano, the MoreSun technology can be summarised with the

Distressed biaxial trackers before revamping

Reconfigured trackers in Apulia, Italy

Independent Supply Chain Management.

Controlling performance and quality of PV system components.

Why PV Supply Chain Management Services?
You want to mitigate risks and make your PV power plant project attractive for lenders and investors. They want to be sure that the PV modules and PV inverters perform and last as expected. Independent supply chain management services create such certainty for you and your investors, e.g. by carrying out in-line but also pre-shipment inspections, verifying power yields pre and also post shipment and managing risks throughout the supply chain.

Why TÜV Rheinland?
With more than 35 years in Photovoltaics, we provide all-round risk management throughout the supply chain: finding reliable suppliers, conducting tests before and after shipping and monitoring the installation. We offer sound and cost-efficient solution packages worldwide that go hand in hand with our independent engineering services. Take advantage of our global network of PV laboratories and PV experts. Make your PV project a success with TÜV Rheinland.

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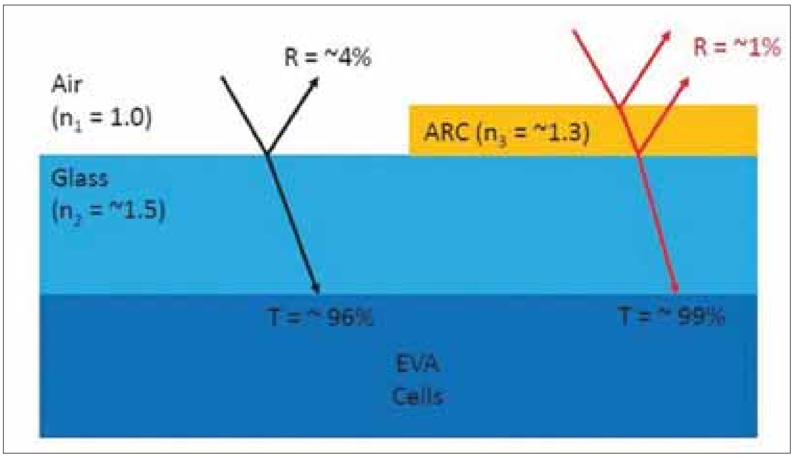

Figure 2. ARC effect on glass-air layer

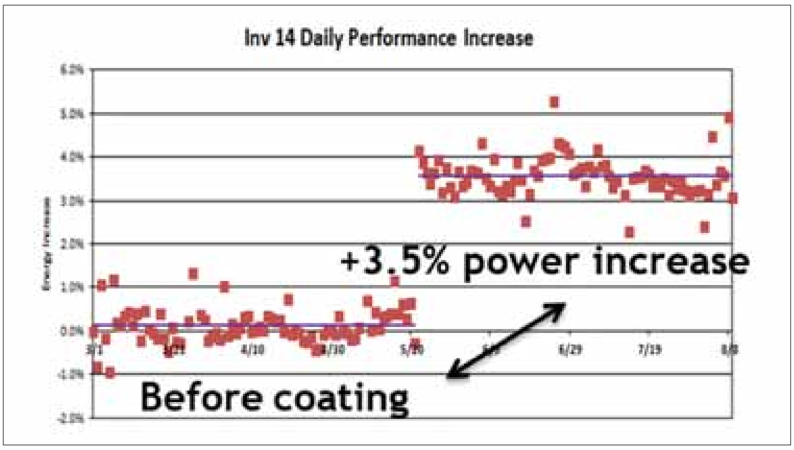

Figure 3. ARC effect on PV plant performance

motto: "More photons in means more electrons out."

An anti-reflective coating works by providing an incoming photon with a very gradual transition from air to glass. It does this by varying the porosity of the material from very high at the coating-air interface to very low at the coating-glass interface. The result is a reduction of reflected light which means more absorbed light by the PV module and higher energy output (Fig. 2 and 3).

Since any new technology needs to go through a testing and validation phase before being ready for the market and accepted by investors and financial institutes as a "bankable" product, CSD Nano and Alectris have been jointly working for the development of this technology.

The ARC is now a product ready for the market, and looking at the whole installed gigawatts, every increase of percent in terms of overproduction leads to huge values of additional green energy and reduction of CO2 emission and also a significant increase in returns for asset owners.

In a typical ARC installation Alectris follows a specific process based of three main phases:

1. *Pre-coating phase* for the site evaluation and the PV module eligibility analysis. This is needed because only PV modules without ARC can be treated with MoreSun ARC.
2. *Coating-phase* where the ARC is physically installed on the modules surface.
3. *Post-coating* with the performance evaluation and proper site management.

All the activities carried out during the coating phases are based on specific standard operating procedures (SOP) developed jointly by the companies.

The MoreSun ARC provides overperformance in the range of 3-6%, depending on different variables such as plant location, irradiation level, design factors (e.g. shadowing), BOS efficiency.

By the end of 2017 Alectris has performed two additional pilot tests on two different projects: a ground-mounted PV plant in the UK and a rooftop installation in Germany. The UK plant is equipped with FS-480 modules, SMA Sunny Central inverters and has a tilt of 25° with azimuth south, meanwhile the German plant is equipped with FS-262, SMA Sunny Mini Central inverters and has a tilt of 2° NW-NE.

Coating was executed between October and November 2017. In both cases, the installation of ARC showed overperformance between 4-5% (Figure 7). The benefits of an ARC installation are seen in figures 5 and 6, which compare two typical daily performance metrics before and after coating. Beside the average daily overperformance as a global behaviour of the plant, it is shown that the ARC provides high benefits in the early morning and late afternoon of the day, when the light incidence on the module surface has a low angle.

Both PV plants are currently overperforming more than 4%, which is a value higher than the expected minimum 3.5%. Figure 7 shows a typical "step" in the energy production diagram before and after the ARC installation.

As mentioned, a PV plant treated with anti-reflective-coating (ARC) benefits from additional revenues due to the increased plant performance; the order of magnitude of additional revenues depends on the plant location (i.e. energy yield) as well as granted feed-in tariff (FiT). For a typical 5MW PV plant located in Germany with 11 years of FiT period still left, based on an average energy yield of 980kWh/kW and a FiT of €0.35/kW, a 3.5% overperformance due to ARC ranslates into a total additional revenue of €675,000 over the remaining FiT period. Payback time for such investments is expected to be within three to four years.

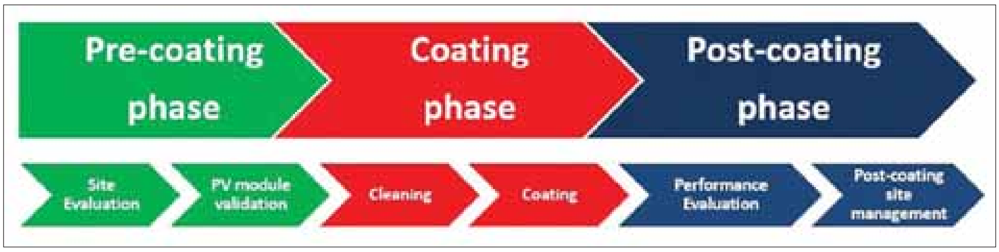

Figure 4. Coating process flowchart

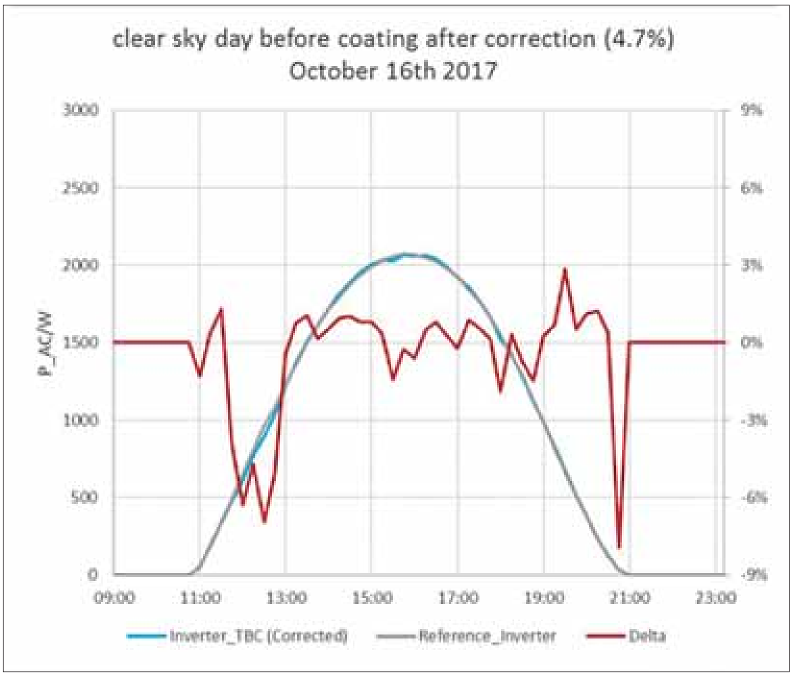

Figure 5. Daily performance before coating

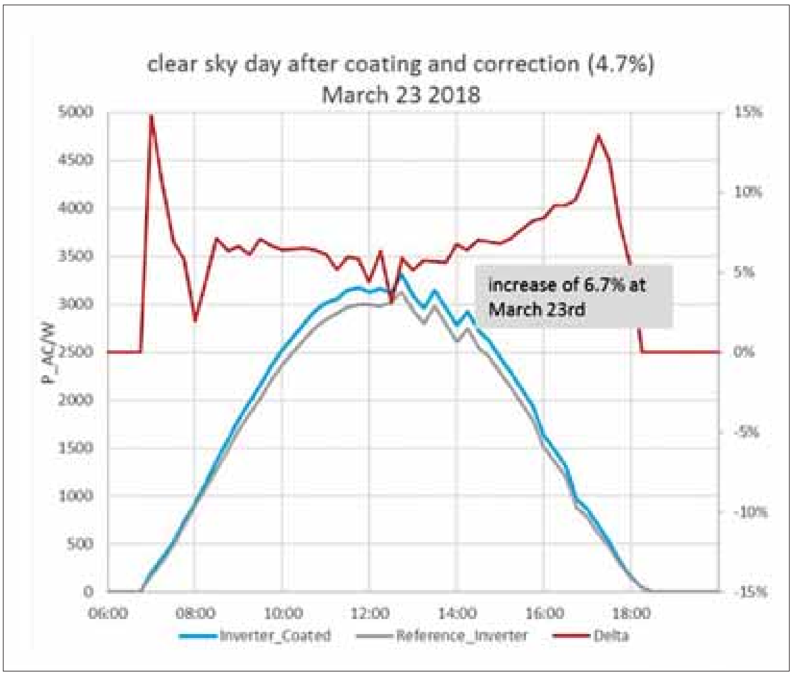

Figure 6. Daily performance after coating

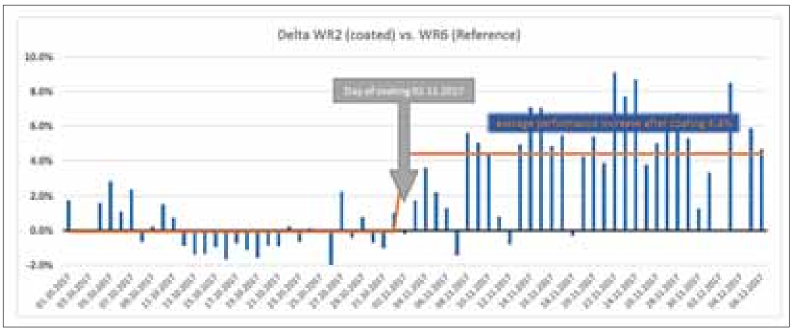

Figure 7. Production diagram before and after MoreSun coating. PV data from ACTIS, the Alectris solar ERP platform

General Information	
Average energy yield Germany per year / kWh / kWp	980
Solar Plant Specs	
Nominal output / kWp	5000
Value Feed In Tarif (FIT) / €	0.3579
Remaining time (FIT) / Years	11
MoreSun Additional Performance / %	3.50
Plant performance	
yield / Year old / €	1,753,710
yield / remaining time old / €	19,290,810
yield / Year new / €	1,815,090
yield / remaining time new / €	19,965,988
additional yield / Year / €	61,380
additional yield / remaining time / €	675,178

Table 1. Economic analysis of MoreSun coating

Outlook for repowering

Looking at the development of the current market, revamping and repowering have become important activities in the past years and the trend is still positive due to the natural ageing and degradation of PV assets. Often, for an investor, this is not an option since the asset is still in the payback period and the maintenance of good level of performance is compulsory in order to generate an appropriate level of cash-flow according to the planned business model.

In other cases, and this might be more related to the deployment of the so-called "new-technologies", the asset owner is willing to put an additional investment on top of the one already made in order to increase ROI/IRR of the asset(s).

With specific reference to the new technologies, we have seen a lot of interest coming up from many investors/asset owners, especially for the anti-reflective-coating technology. Alectris and CSD Nano currently have ongoing pilot-tests and new opportunities are going to be executed within the end of this summer in Italy, Germany and UK. Alectris sees great potential and interesting business opportunities for solar owner, operators and investors from these activities in the years ahead. ■

Author

As innovation & project manager for O&M specialist, Alectris, Antonio Bilella manages the New Technologies division and supports operations and maintenance services for the Italy office. Bilella's solar credentials include nearly a decade of development and operational work involving over 110MWp in Europe, Asia, Latin America and the Middle East.

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Hoymiles was founded in 2008 by 3 post-doctors operating as an R&D team in China' s National Power Electronics Laboratory, based at Zhejiang University, one of the top 3 universities in China and one of the top 60 in the world.

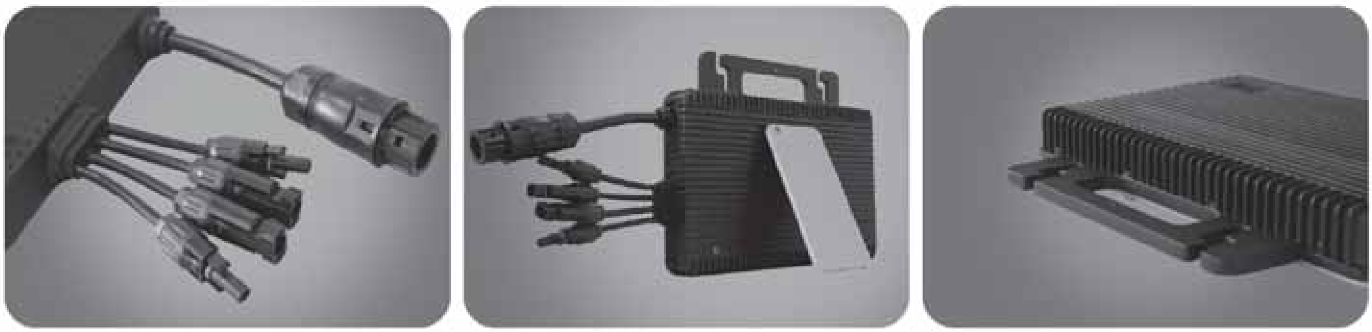
In 2015, the Hoymiles microinverter achieved the world' s highest CEC peak efficiency - 96.7% in California, US, which ranked it as the most efficient microinverter globally when compared with other well known brands.

An interview-based article in 2017 by PV-Tech, the leading professional solar media organisation, entitled "The Biggest Microinverter Firm You Have Never Heard of", spread the Hoymiles name around the world as the "Invisible Champion" of microinverters in the Chinese PV market, now supplying over 50% of the world' s solar installations with 53GW in 2017.

Today, 10,000+ commercial & residential rooftop installations (the biggest one 3.6MW) are built annually using different types of Hoymiles microinverter: single panel unit (MI-250/300), 2 in 1 unit (MI-500/600/700) & 4 in 1 unit (MI-1000/1200).

Thanks to the constant efforts of Hoymiles' 500+ staff, together with distribution and service partners all over the world, the company has established local logistics & service networks in over 20 countries, including Germany, the Netherlands, Poland, Estonia, Brazil, Mexico, South Africa, the U.S., Canada, Korea & India.

Localisation is the key to the company' s ongoing success – the combination of local warehouses, local training and local service centres keeps Hoymiles together with its local customers 24/7, 365 days a year.



MI-1000/MI-1200
Unique design for 4 solar panels

How Spain's post-subsidy surge is a sign of things to come for Europe

Europe | Subsidy-free solar is changing the fortunes of the Spanish solar market, which had experienced the deepest of slumps. All the signs suggest the rest of Europe will be next, regardless of how the trade row plays out, writes John Parnell

Credit: Getty/jjnogueron

The boom-bust cycles of solar have arguably been demonstrated most violently in Spain. In the space of a few years the government went from taking out newspaper adverts encouraging people to invest their pension pot in solar, to effectively criminalising self-consumption.

Feed-in tariffs were ditched retroactively, investors large and small were left stranded. The big beasts, including Masdar, E.On and RWE, went to the courts; the little guy went to the wall.

The investor and owner of one commercial rooftop plant famously ran the numbers, and sent the keys back to the bank, abandoning and literally stranding their asset.

The major utilities in the country were mothballing gas generators and were owed billions by the Madrid government. The global economic downturn had strangled growth and cut power demand forecasts. Jettisoning solar capacity helped to maximise the number of kWhs the incumbent utilities would need to sell.

After the dark days of the so-called sun tax, of protesters in prison stripes opposing fines capped at €60 million for self-consumption of PV, of levies designed to make systems not just unprofitable but unaffordable, now Spanish solar has something to cheer about.

But Spain remains a cautionary tale and the reaction to its recent revival speaks volumes about the direction solar is moving in more generally.

The government turned Spain's solar landscape upside down and its recovery is largely in spite of rather than because of the authorities in Madrid

Barge poles

On the sidelines of Solar & Storage Live, organised by *PV Tech Power*'s publisher Solar Media, a panel of infrastructure investors were chatting about their approach to European markets.

Spain had announced a round of gigawatt-scale tenders, keen to take advantage of the low power prices being realised elsewhere while also ensuring its commitments to Brussels would remain on track. A total of 3.9GW of solar was awarded a contract.

So would these London-based investors be keen to get involved with the tenders? 'We'll definitely be investing in Spain next year but we won't have anything to do with the tenders. We won't touch them,' was the message that very strongly came through.

The Spanish government's track record for flip-flopping from advocate to executioner has not been forgotten. It was between a rock and a hard place, tough decisions were required but the breadth and depth of the cuts, plus the hefty fines, have left a bad taste in the mouth.

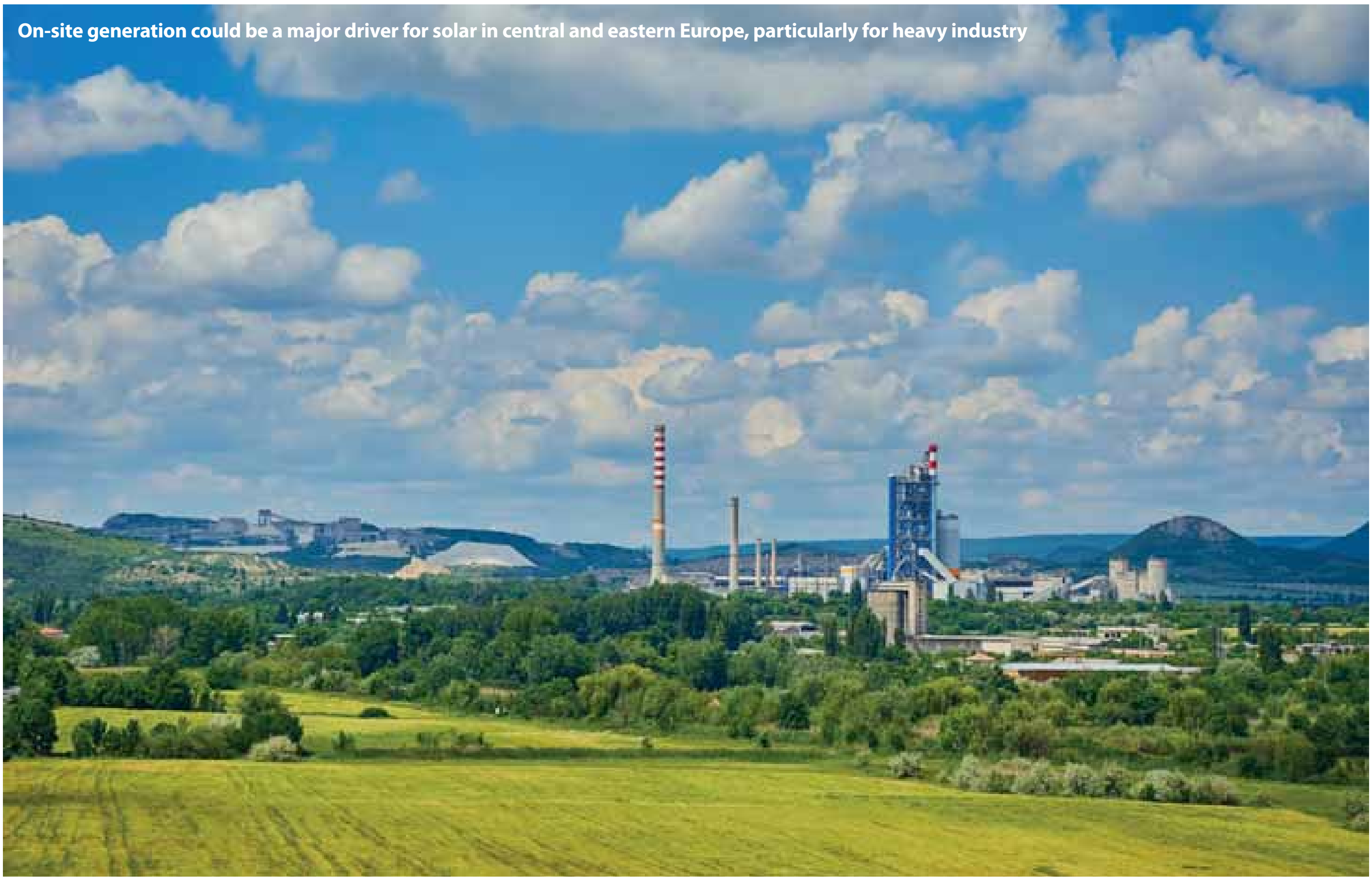
In the intervening years, solar has been chipping away at cost, improving efficiency and getting access to cheaper finance. With sufficient irradiation it is the cheapest power source and these iterative cost improvements are lowering the bar for grid parity. We've India, the Middle East, Portugal, Spain.

While the government's change in appetite for solar is welcome, the real driver of optimism is simple economics. Subsidy-free economics.

Pipeline

The scale of the opportunity is summed up by Jose Donoso, head of UNEF, Spain's PV trade association.

"The market has realised that they can expect very little from the government and



On-site generation could be a major driver for solar in central and eastern Europe, particularly for heavy industry

Credit: Rocter

they aren't going to wait around for a new support scheme," says Donoso. "The tender only gives the winners a floor price of €28.30MWh. With the degree of competiveness that solar has, we can go straight to the market on a merchant basis or we can look for PPAs [power purchase agreements], without any need for input from the government and this opens a new era in Spain when all the major players will start developing new installations.

"At this moment in Spain there are 29GW of solar projects in the planning process. One year ago we had no PPAs and now we have a PPA signed every week with big companies. All the major off-takers are in talks with different developers," adds Donoso.

If the numbers seem too large, consider the stream of deals announced in 2018 so far. Eco Energy World plans to develop 600MW. In April, BayWa r.e. and Statkraft signed a PPA for 170MW. Solar Ventures is planning 1GW of projects across in Spain and Italy, the UK-based developer Hive Energy has agreed a deal for 45MW with another 20 in the pipeline. Donoso's figures do not seem so unreasonable.

Spain developed an ecosystem of solar engineering and manufacturing, from modules and trackers to EPCs, many of which have carved out success overseas.

"Between direct and indirect employment we have around 12,000 people employed in solar with the market orientated to export. Now with a domestic market we expect to have a significant increase in the number of jobs and more importantly, stable jobs. We could have several thousand more jobs next year but without stability they could be lost again by 2020. We are not interested in that. We want an established market with stable jobs," says Donoso.

Spain and beyond

The happy ending for Spain, that appears to be approaching, is unlikely to be unique. The same conditions apply globally. In Europe, there is hope that the economics are now beginning to resonate with heavy industrial users who are free to build their own generation assets independently of the host nation's subsidy structure, or lack of.

"Companies will do business in Spain because they can get grid parity, not because they can get a small premium from the Spanish government, which it might change its mind about in a year," says James Watson, CEO of SolarPower Europe.

"It all comes down to grid parity and being able to get that PPA, a long-term contract with a guaranteed off-taker. This will be big for a lot of the southern European countries," he says adding that on-site generation is a second market that grid parity, or even near grid parity, will open up.

"One of our members, ENI, is planning to install 230MW of PV to power its refineries in Italy. That is half of what the entire country installed last year," he points out.

Using solar to power oil refineries might be ironic but it's not counter-productive. The refinery will run anyway to tease petrol and other chemicals from the black stuff. Solar might be helping an oil major to trim its costs but based on the growing tendency of the big traditional energy companies investing in power, especially solar (see p.34), the old viewpoint of 'us and them' is slowly eroding.

Watson points out that in Italy's case, another commitment of that scale would put the country back on the brink of being a gigawatt market.

In Europe's industrial heartlands, the case of on-site solar is strengthening too. Energy intensive industry such as cement production and iron and steel could be the next area of growth. Bulgaria's cement industry is known to be keen to cut its production costs with the addition of on-site, directly connected solar power.

"In central and eastern Europe where we

have very large industrial complexes we could see the market for on-site generation increase as quickly as PPAs do in other parts of Europe," adds Watson.

Looking at all of this, the number of gigawatt-scale markets in central and southern Europe could easily creep up.

Northern lights

In Europe's higher latitudes, subsidy-free solar requires a little more work. In the UK, which has a number of revenue streams open for energy storage, the key to grid parity is co-location. It's not subsidy-free solar in the purest sense but it's getting projects built and financed at a time when government support is in name only.

The UK's Contracts for Difference (CfD) programme has not been kind to solar thus far. Competition with onshore wind saw just five projects make it through the first round back in 2015. Of those, only two have been built. Solar would undoubtedly be more competitive now than in 2015 with most in the PV industry favouring a technology-neutral auction.

Fears that a rush of subsidy-free renewable projects could drive down wholesale power prices, cannibalising their own revenue in the process, are gaining more traction – another example of the increasing importance of intelligent regulation not legislation, for the future prospects of large-scale solar. It also reinforces the benefits of projects diversifying where that revenue is coming from by co-locating with energy storage.

"Nearly every planning application for new-build solar in the UK includes the possibility of including an element of energy storage at the time of construction but often, in the early stages of a proposal the details are not refined," says Finlay Colville, head of market research at Solar Media.

"At the moment we are seeing new screening applications being submitted for solar projects of 20-50MW with an element of storage included, which we would expect to turn into full planning applications later this year," says Colville. "If successful, these projects would make up the next wave of solar installations in the UK from 2019 onwards. Many of the prominent UK solar developers are also focussing on international projects or pure energy storage projects and it's not yet clear when they will return to UK solar," he adds.

Larger projects, including one of 350MW being developed by Hive Energy and Wirsol, are also in the works. The latter has its own 150MW pipeline of subsidy-free projects.

As the cost of solar falls and its competitiveness improves, PV reaches more northern latitudes. The boundary of viability for subsidy-free solar is chasing behind. In markets such as Sweden, lessons are being learned from the boom bust cycles of other markets. In July 2017, the trade association there urged the government not to increase the size of financial support for PV systems in order to avoid the "risk of a significant market crash". With subsidy-free markets a reality, it instead asked the government to focus on simplifying access to solar and opening the market up and putting the right tools in place to support organic growth.

> "It all comes down to grid parity and being able to get that PPA, a long-term contract with a guaranteed off-taker. This will be big for a lot of the southern European countries"

Minimum import price

The issue of the presence or removal of trade barriers could be a little clearer by the time the industry gathers in Munich for Intersolar Europe.

In the run up to previous editions of the exhibition, we have been anticipating milestones in the trade case on Chinese imports of solar cells and modules. Having extended the initial duties and the conditional price undertaking deal that goes along with them, the European Commission indicated that it was time to wind down the measures.

The minimum import price (MIP) on cells and modules is lowered each quarter and that direction of travel appears to have the support of the bureaucrats in Brussels. This was the first public indication from the Commission that it could make a political decision on the measures. Till that point it had either ploddingly followed procedure, or its hands were tied by European trade law. It depends who you ask.

By 3 June, EU ProSun, the SolarWorld-backed trade group that brought the request, will have to lodge a request for the Commission to review an extension of the measures. By 3 September the Commission has to decide whether to open a review or let the tariffs, and the price undertaking lapse.

The review is likely to take around a year. The tariffs and so the price undertaking would remain in place throughout. The quarterly degression of the MIP price would be on hold freezing prices at their July 2018 levels and locking the EU out of the benefits of any subsequent fall in the price of cells and modules.

With one expiry review already out of the way, a misconception remains among many in the industry who believe September 2018 marks the end of the European solar trade spat. Watson warns opponents of the tariffs not to get complacent.

"It is only formally over if there is no expiry review request by 3 June or the Commission rejects a request by 3 September," he stresses.

SolarWorld's second dip into administration in as many years does not impact its ability to represent the manufacturing industry. As Watson says, the closure of Jabil's facility in Poland back in February means the German company represents more than a quarter of all European solar manufacturing on its own.

In order to retain its legal standing as a European solar manufacturer in the eyes of the Commission, it must continue producing, its financial footing is of no concern.

"So as long as they keep turning out a few panels here and there they have the legal standing that they need," says Watson.

What is less clear, is how keenly an extension of the MIP would bite. Merchant and PPA projects are being built at existing prices and we still have one more downward adjustment to come before the potential expiry review locks in prices.

Happily, the loss of the MIP would be a bonus for the downstream sector and its continuation would be less keenly felt than its introduction was. The severity of its impact is now greatly diminished. This puts European solar developers in the enviable position of knowing that the economic case for solar appears strong enough to negate trade rows and subsidy u-turns.

US-based consultancy GTM Research recently pointed to an upturn in Europe's fortunes indicated by inverter shipments. These are growing at a faster pace than deployment in the continent signalling further good times ahead.

The wave of subsidy-free solar is washing across Europe and it is hard to envisage the good ship solar getting caught on those particular rocky outcrops once again. ■

Tongwei drives adoption of large-scale smart manufacturing in the solar industry

Since entering the PV industry just over ten years ago, the Tongwei Group has consistently made huge advances in its development and has now built arguably one of global PV's most complete vertically integrated supply chains.

Tongwei Solar is heavily involved in the R&D and manufacture of core solar products from its two Chinese bases in Hefei and Chengdu. The Hefei centre became operational on 18th Nov. 2013, and already has a multicrystalline cell capacity of 2.4GW and a module capacity of 350MW, the combination of which ranks it among the top manufacturing sites in the photovoltaic industry.

Tongwei's Chengdu base now has a mono cell capacity of 3GW, of which 1GW from its 'Phase I' was completed and put into operation on 30th June, 2016. The construction of the plant took only seven months and was widely recognised by mainstream media as "Tongwei Speed", "Shuangliu Speed" and "Chengdu Speed". It has since become a demonstration project for rapid construction, production, operation, and profitability for the global photovoltaic industry. The 2GW capacity of Phase II was completed and entered into operation on 20th Sep., 2017. This 2GW high-efficiency c-si solar cell production line also took seven months to build, the same period as that for the first phase, although production capacity and project volume were doubled, reflecting a further acceleration in construction speed. All Phase II production lines were upgraded to handle fully automated unmanned manufacturing, thus becoming Chengdu's "Smart Manufacturing" model project and the first to incorporate both digital workshops and smart factories. "Made in Chengdu" has become established as a leading brand for clean energy, becoming the largest manufacturing base for monocrystalline silicon solar cells in the world. A national 'smart manufacturing' demonstration base is currently being built here.

Tongwei Solar currently employs more than 4,700 staff. Its Deputy General Managers Zhang Zhongwen and Zhang Guanlun are both outstanding experts in PV technology, with almost 20 years experience in R&D. They are now leading a professional R&D team, consisting of more than 800 technical engineers, to continuously research and develop products with competitive advantages in the PV market in order to meet ever growing client demand.

Since its foundation, Tongwei Solar has been recognised with awards for the 'World's Best Supplier of Solar Cells' and the 'Exemption to Cell Inspection' for three consecutive years, along with the best quality for cells in the world, also for three consecutive years. After reaching its full manufacturing capacity in 2014, as of this April, the company has successfully achieved profitability, full scale manufacturing and 100% utilisation rate for 43 consecutive months, making it an enterprise of "Five Consecutives". The company's annual cell capacity only accounts for 4% of global cell capacity, but its profits account for more than 80% of that of the global industry, reaching Apple's level in the mobile phone industry at its peak period, and maintaining its status as a company with "Four Top Ones" – top one profits, top one market share, top one manufacturing indicator standards and top one construction speed in the global cell industry.

In November 2017, the company launched 10GW high-efficiency c-si solar cell projects at its Hefei and Chengdu bases. In 2020, Tongwei Solar will have a cell production capacity of over 30 GW, and its output value will reach 30-50 billion RMB (USD 4.71 – 7.84 billion), making it one of the largest and most influential clean energy companies in the world.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Black to gold: The oil & gas majors plotting a solar revolution

Business | The global decarbonisation agenda and still-tumbling costs are sending oil and gas giants and traditional energy majors into the PV market, and in a big way. Liam Stoker investigates what that means for the international solar market

Credit: Lightsource Renewable Energy

An unavoidable transition towards cleaner power solutions is occurring. And as that transition accelerates, the companies that have historically dominated global energy markets through fossil fuel exploration and extraction are having to move with it.

This has led to something of a tectonic shift, with solar now a priority destination for investment. Both Shell and BP have re-entered international solar markets after lengthy hiatuses and Statoil and DONG have been so reluctant to remain affiliated to oil and gas (O&G) that they've undergone significant rebrands.

Those changes have not gone unnoticed. EY's most recent Renewable Energy Country Attractiveness Index published in May 2018 sought to narrow in on why O&G majors were so keen to turn back to solar and it's a subject explored at many an industry event. Speakers at February's Solar Finance & Investment London conference, organised by PV Tech Power publisher Solar Media, concluded that there was only one direction for investment to flow, and that direction stands to change the course of the solar industry forever.

Ed Pitt Ford, investment manager at Octopus Investments, the UK's largest solar asset owner with more than 1GW in its portfolio, said that there would be major opportunities for solar firms to work hand in hand with big oil giants. This view was endorsed by Abid Kazim of NextEnergy Capital, another of the UK's largest asset owners. "When they come into this space they will buy wholesale… there will still be all sizes of business [and the] opportunity for us across the spectrum is to continue to disrupt," he said.

Early signs indicate that this may well be the case, with O&G majors in an acquisitive mood.

BP's acquisition of a stake in Lightsource is one of a number of moves by oil and gas and other energy majors into solar

A very British investment

BP has something of a chequered relationship with solar, one which ultimately resulted in the shuttering of its BP Solar business unit in December 2011. More than 30 years after its first foray into solar as a technology – which began with the purchase of a 50% stake in Lucas Energy Systems – the fossil fuel powerhouse disregarded the 'Beyond Petroleum' tagline it had dreamt up and drew a line under it entirely.

In truth, BP had been scaling back its solar position for a few years before then, a victim of overcapacity and frequently cheaper variants emerging from China. While the preceding six years saw the firm investigate alternative fuels and wind, solar PV remained just outside of BP's list of interests.

All that changed in December 2017, when BP announced that it was to pay US$200 million to acquire a 43% stake in British solar giants Lightsource. The London-based developer, one of Europe's largest, has brought more than 1GW of utility-scale solar to fruition since its formation in 2009. Since then it has established interests in the US, India and other emerging markets, set up a thriving O&M division and secured a domestic solar-and-storage partnership with utility giant EDF. If BP wanted a foothold in the downstream solar market, there were few entities better placed.

Speaking at the time of the acquisition, Dev Sanyal, chief executive at BP's alternative energy division, said the company had maintained a watching brief of the solar industry for some time, before striking while the iron was hot.

"From our vantage point we'd been looking at the developments in the solar energy industry for some years, and effectively what we are seeing are fundamentals that are really important. Growth has been around 10-15% per annum, we've seen a trebling of solar installed capacity over the last four years, and you see business models that are actually now being developed and are in places that are very attractive," he said.

What made the Lightsource deal attractive to BP was the fact that in the Nick Boyle-led company they had found not just an investment, but a seasoned pair of hands that could furrow their own path, one that BP could offer assistance with when and wherever possible.

"It's about bringing together complementary skills and abilities to create not just a great solar company, but a great solar company which operates on a global platform. That's what we're trying to do and we believe the partnership element is really important. It's bringing together the best of both companies," Sanyal said, adding that one of the most attractive qualities the company saw in Lightsource was a "culture of entrepreneurship [and] innovation, but also disciplined execution".

But of broader significance, BP's move was fuelled by an internal belief that solar was worth investing in as a technology of the new energy age, one which could see it deploy the world over. "Quite candidly, we see great opportunity in the solar business globally given the fundamentals of the sector. I don't think we'll be starved of opportunities, the question is being disciplined in which choices we pursue," Sanyal said.

His sentiments were reinforced in April 2018 when BP published a new report detailing its decarbonisation efforts. Dubbed 'Advancing the Energy Transition', the report cited three core tenets of "reduce, improve, create", the latter of which is a key commitment to building low carbon business under the BP moniker.

> "It seems to be the time is right now with subsidy-free on the horizon; I see solar as a new backbone of the energy industry"

The off-grid opportunity

While Europe and the Americas represent possibly the most significant opportunities for O&G majors and utilities, many companies have spied the potential within a solar revolution throughout Africa, mainly in the off-grid or pay as you go (PAYG) solar markets.

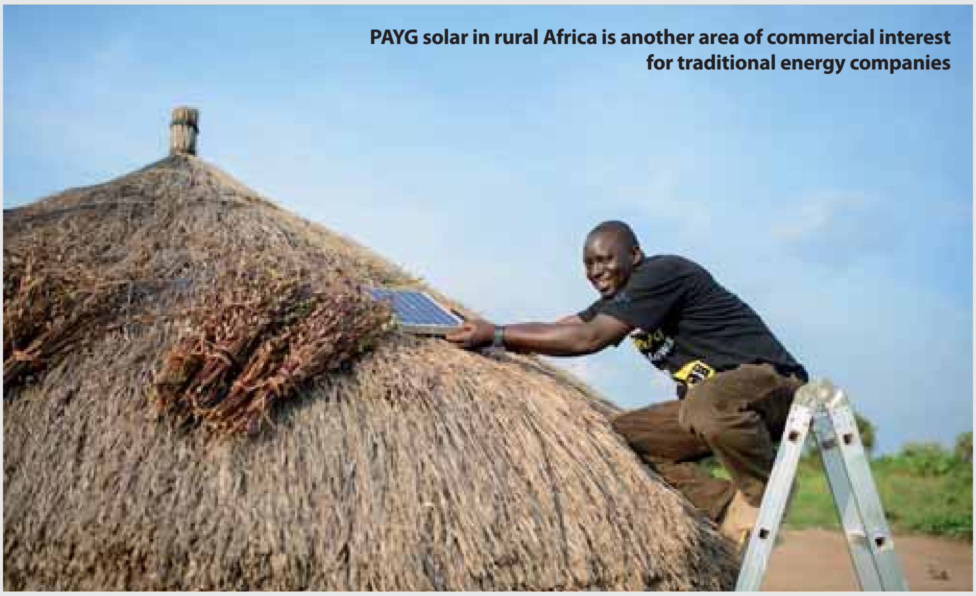
The likes of E.On, Enel and EDF have all invested in companies within that sphere in recent years, the latest of which is Engie. The French energy giant acquired PAYG PV specialist Fenix International in a move which was finalised in April 2018.

Bruno Bensasson, chief executive at Engie Africa, described Fenix as the "agile growth engine" that would help it expand its footprint in Africa's solar home system business. Engie's interest in Fenix stemmed from an initial interest in investing but, having liked what it saw and identified a more "general alignment", according to Fenix's Chris Bagnall, it took the plunge and acquired the firm outright.

"What it fundamentally meant for them is they were looking to divest out from traditional centralised power and move into decentralised power within Africa, and that really spoke to us," Bagnall says.

With Engie's more significant capital and people power alongside Fenix's expertise and experience in the market, both parties expect to overcome the more prevalent hurdles in the PAYG market and deploy solar quicker than before. But, Bagnall says, the key to the Engie deal is Fenix being largely allowed to operate as it has done before.

"The ability to… retain our culture, retain the management team was also a key influencer in making that decision," Bagnall says, adding that Fenix is predominantly left to its own devices day-to-day.



PAYG solar in rural Africa is another area of commercial interest for traditional energy companies

Credit: Fenix International

Bob Dudley, BP's group chief executive, has made it clear that the company, with its history and legacy steeped in fossil fuels, now wants to pick up where it previously left off with regards to solar. "Two decades ago, BP was one of the first energy companies to address the threat of climate change, pioneering alternatives like wind, solar and biofuels. We invested billions of dollars to make renewable energy a genuine alternative," he said.

"Some of our investments worked out – others did not. We were early, but I don't think we were wrong, because we learned valuable lessons along the way." It's Dudley's job to ensure those lessons are remembered.

BP has ambitious investment plans in the field, with plans to allocate at least US$500 million per year for low carbon activities. Those commitments, BP argues in the report, have the potential to "make a real contribution" to the company's future. Quite what those commitments entail remains to be seen, but there have been subtle nods that solar and storage are high on the agenda.

BP has partnered with storage giant Tesla for a pilot project at its 25MW Titan 1 Wind Farm in the US state of South Dakota. A 212kW/840kWh battery unit is to be installed alongside the wind turbines as what the two companies have described as a "potential step forward in the performance and reliability of wind energy". Moreover, the pilot's success would seemingly pave the way for battery storage to be deployed elsewhere on BP's estate, with the findings of the project to be used to garner "valuable insights" as it evaluates and develops further battery storage installs in the future.

While the finer details of BP's post-oil and gas plan take shape, there is one certainty. In gearing for the future, BP is setting itself on a slightly different course, one that its great rival – Shell – is also plotting.

Shelling out on renewables

For evidence of Shell's developing approach to renewables, look no further than its Energy Transition Report, published in April 2018. Designed as a follow-up to Shell's transitions and portfolio resilience report published two years prior, the document provides a glimpse of the company's climate and energy forecasts and details how it intends to navigate the energy transition.

Within the report Chad Holliday, chairman at Shell, stresses the importance of the energy major learning "new skills" as the world increasingly moves to lower carbon energy, a matter which would place greater importance on its New Energies division. "I like to think that our New Energies business is sowing different seeds in different places. Over time, we will see where the best and most profitable crops start to grow. Then we will give the winners all the nourishment they need to flourish," he said.

Shell's movement into renewables will be largely driven by its New Energies division, which is to invest between US$1-2 billion each year until 2020. That is between two and four-times larger than investments outlined by BP, perhaps indicating the sheer scale of the opportunity in renewables Shell has identified.

"This is a long-term journey. There are tough challenges ahead that society will need to address because the transition will require enormous levels of investment, and profound changes in consumer behaviour. Shell is also on a journey. We cannot know exactly how this transition will play out, or how long it will take. But it could mean significant changes for Shell in the long term. We will learn, and adapt our approach over time," Ben van Beurden, chief executive at Shell, explains in the report.

Shell is remaining prudent. It will only seek to invest in projects that are financially viable today (as in, unsubsidised) due to potential regulatory uncertainty, and by stating that it normally seeks equity returns of 8-12% for investments in power.

But it's not just the O&G majors spying on opportunity. Other major energy companies are also launching major solar investment plans as the paradigm begins to tilt in PV's favour.

Upstream or downstream

O&G investments in solar have become more frequent as these giants look to enter, or indeed re-enter, the fray as the technology becomes more mainstream, but are upstream or downstream moves the best bet?

BP & Lightsource: In paying US$200 million for a 43% stake in Lightsource, one of Europe's largest solar developers, BP's play is very much a downstream one. The investment will be used to "supercharge" Lightsource's bid to build out a multi-gigawatt pipeline of plants in multiple continents.

Shell & Silicon Ranch: In January 2018 Shell ventured back into the solar market, paying US$217 million for a 43.86% stake in Silicon Ranch. The Tennessee-based firm is a developer, owner and operator of solar projects in the US, making the deal markedly similar in both size and intention to that of BP's. Shell said the deal would expand its 'New Energies' footprint across the globe.

Total & SunPower: Both deals pale in comparison to Total's purchase of a 60% stake in SunPower, the cell and panel manufacturer, for US$1.38 billion seven years ago. The parties said at the time the deal would create a "new global leader" in the solar industry, with SunPower brandished as the "centrepiece" of Total's solar activities. SunPower's recent move to snap up SolarWorld Americas will be one to watch as Section 201 bites.

Energy's new backbone

For Claus Wattendrup, vice president of solar and batteries at state-owned Swedish utility Vattenfall, the desire to turn to solar has been one driven by simple market factors. "If you look at it globally, solar is the dominant new-build generation technology. I would say you can't afford to ignore solar, which we have done unfortunately for too long. And that's why we are stepping in now, although a bit later," he says.

Vattenfall are ignoring it no longer. Earlier this year the company announced that it would be investing €100 million in solar over the next two years, predominantly at the utility scale and often co-located with wind and/or battery storage. Those investments will also fall predominantly in Europe, but will not be restricted to any particular market. Wattendrup insists that the potential for solar to complement wind – and vice versa – in terms of generation portfolios make them a perfect match.

But why now? Why is Vattenfall, a company with an established and thriving wind portfolio, on top of successful utility divisions throughout Europe, embracing a generation technology at this stage? Wattendrup says Vattenfall is well aware it is a late mover in solar but is keen to embrace it because of the role it stands to have in future energy systems. "It seems to be the time is right now with subsidy-free, and in the end, I see solar as a new backbone of the energy industry," he says.

> "We've seen a trebling of solar installed capacity over the last four years, and you see business models that are actually now being developed and are in places that are very attractive"

For Vattenfall, the technology's maturation and decline in costs has made it, and other incumbents, sit up and take notice. "It's the price level, it has been quite expensive and it has been small – just a few megawatts – and in the past our companies have thought mainly in gigawatts of conventional capacity. This paradigm was based on a mix of all kinds of different reasons," Wattendrup adds.

But the bigger entities would appear to be better suited to the next stage in solar's deployment, at least certainly in Europe. Certain markets have had their subsidy-backed boom cycles – the UK between 2014 and 2016, Germany before that, the likes of Spain and Italy prior to those countries – are examples that will immediately spring to mind. Smaller, more nimble players have moved quickly, but Wattendrup believes this era is now ending and resulting in a "different ballgame now". It is hard not to escape the thought that different players will be required too.

In the absence of such support mechanisms, meaningful solar deployment requires a different set of skills and scale that traditional, smaller players may find beyond them. Wattendrup says the incumbent utilities and other energy majors can bring those in abundance.

Now you need all kinds of different competencies. This is why I see such a big chance for us because the integration of our capabilities – having a large customer portfolio, having a trading desk, doing PPAs – this is what we've been doing for decades. It's good to link this with renewable production in wind and solar – even with batteries – to make a combined offer to customers and we can serve you with whatever you want."

It is undeniable then that solar is not only a destination for significant levels of investment from energy giants of every kind, but also one of – if not the – pivotal energy technology of the coming decades. Solar now stands at the forefront of the energy transition and looks set to be the most competitive generation landscape. If you're not in solar, at least according to Wattendrup, you aren't a serious player.

"If you don't manage this as a serious player, you're doing something wrong. Therefore everyone's moving into this in a serious manner. There's no greenwashing, this is serious," Wattendrup says. And the oil and gas majors certainly appear to be in agreement. ■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Emerging market briefing

Tom Kenning and Ben Willis look at the latest developments in some of the most promising emerging PV markets worldwide. This issue features Pakistan, Tunisia and Uzbekistan

Pakistan's Sindh details 400MW solar parks and 250,000 solar homes plan

The government of the Pakistani state of Sindh has made clear its intentions to boost solar by launching a framework to address the potential environmental, resettlement, and social impacts associated with its major solar initiative, for which it is seeking World Bank funding.

The Sindh Solar Energy Programme (SSEP), a pioneering scheme in Pakistan, aims to support solar deployment in the province across utility-scale, distributed generation and residential segments.

This includes up to 400MW of solar park capacity (50-200MW per park), starting with 50MW that will see the first competitive tariff-based auctions in Pakistan – the plans for which were announced last December. The Solar Park concept aims to help to reduce the risk profile for private sector developers by ensuring that land is secured, permits obtained and power off-take is pre-arranged.

The first 50MW site near Manjhand, Jamshoro District, has already been identified with land secured, and the aim is to complete this pilot solar auction by the end of 2018, allowing the project to be operational by 2020. When first announced, a formal procurement process was scheduled to take place in Q2 this year.

The progamme also aims for 15MW of distributed PV on rooftops of public sector buildings and others in the cities of Karachi and Hyderabad as well as a target of bringing solar home systems to a quarter of a million households in areas of Sindh with poor access to electricity.

Electricity generated from distributed solar in Sindh is expected to have tariffs of around US$0.06-0.10/kWh, lower than the retail tariff charged by utilities.

The project is not entirely Sindh focused as the aim is to spur on other Pakistani provinces through example. With this in mind, Pakistan could soon see a widespread focus on PV as long as other states take note and start to implement their own policies.

The new 'Environmental and Social Management Framework' (ESMF) released by the Sindh government is in line with the national and provincial regulatory as well as World Bank safeguard requirements. While the location of most projects under the solar programme are yet to be decided, the ESMF aims to identify generic environmental and social impacts of the projects.

The 209-page document details how to mitigate these impacts and details a Grievance Address Mechanism, consultations and a host of other processes. The main concerns for the three segments, which were all deemed 'low to moderate' in significance, were also laid out in detail.

Also this year, another solar firm Siachen Energy has submitted a tariff petition for a 100MW solar project at Gharo, District Thatta, Sindh, with another tariff well below grid parity (US$6.2939), but the developer must now wait for the regulator to respond with its tariff determination.

In separate news, EcoEnergy, a solar energy provider in Pakistan, has secured US$600,000 in debt finance to help it provide off-grid solar energy to 10,000 of the poorest rural households in the country.

EcoEnergy struck the deal with SIMA, a social investment advisor and manager backed by the Dutch and Belgian government development banks, AXA, MetLife, USAID and the pension fund of the Episcopalian and Lutheran churches.

EcoEnergy will use the capital to purchase products, technology and services from UK-based BBOXX, which is active in off-grid services in Africa among other destinations. BBOXX will provide its cloud-based task management software, Pulse. EcoEnergy will then scale up its operations and extend distribution of smart solar home systems across the country, having been constrained until now by a lack of access to working capital.

The state of Sindh is leading the way on solar deployment in Pakistan

Credit: Paul Keller/Flickr


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Tunisia eyes 1GW solar and wind

Tunisia has its eye on 1GW of solar and wind projects worth US$1 billion in investment, and has now released a tender for 500MW in each technology.

Prime Minister Youssef Chahed announced the news at an energy conference in April.

The Tunisian Ministry of Energy, Mines and Renewable Energy later issued the tender for 500MW of PV projects within the country in May. Within this tender, the Tunisian government plans to develop five different projects, headlined by a 200MW power station that will be developed in the Tataouine governorate. Other planned projects include 100MW PV projects in the governorates of Kaiouran and Gafsca, along with 50MW projects in Tozeur and Sidi Bouzid governorates.

These five projects will all be developed under a build, own and operate (BOO) model, with interested developers now asked to issue pre-qualification applications as part of the tender.

The country is close to building a 2.25GW concentrated solar power (CSP) export project in the Sahara Desert in south-west Tunisia, which is believed to be the largest solar power plant in the world. The aim is to provide power to Europe. British company Nur Energie is waiting for an authorisation approval from the Tunisian Ministry of Energy, Mines and Renewable Energy, before it can start exporting electricity to major European markets.

Tunisia's Ministry of Energy, Mines and Renewable Energies has also recently published the list of the winning projects selected in the 70 MW solar tender it issued in May. It awarded capacity mainly to local firms or consortia involving both domestic and international companies.

The projects, which were preliminarily approved by the Tunisian government at the beginning of May, include six 10MW solar parks and four 1MW ground-mount PV systems. This left 6MW unallocated.

Other news includes the Tunisian power state-owned utility, Société Tunisienne de l'Electricité et du Gaz (STEG), issuing a tender for the construction of a second 10MW solar park in Tozeur, in the south of the country.

Uzbekistan calls on IFC to push forward solar plans

Uzbekistan has sought assistance from the International Finance Corporation (IFC), part of the World Bank Group, to drive forward its solar plans. In mid-May the Central Asian state announced that the IFC would help it realise its solar ambitions by encouraging private sector investment in its nascent renewable energy sector.

The IFC will operate as 'transaction adviser' to the government Uzbekistan, supporting the state-owned national power utility, Uzbekenergo, on structuring a public-private partnership aimed at bringing private sector experience and capital to construct a 100MW solar plant. This project will form part of a larger programme that ultimately aims to see up to 1GW of solar installed in the country.

"Developing renewable energy in Uzbekistan is crucial to diversify our power supply," said Sukhrob Kholmuradov, Uzbekistan's deputy prime minister. "The joint work of IFC, the State Investment Committee and Uzbekenergo could bring up to US$1 billion in private investment to develop solar photovoltaic plants that will not only improve the supply, but also create a transparent mechanism to attract more private sector investment, which could be successfully replicated in other energy spheres."

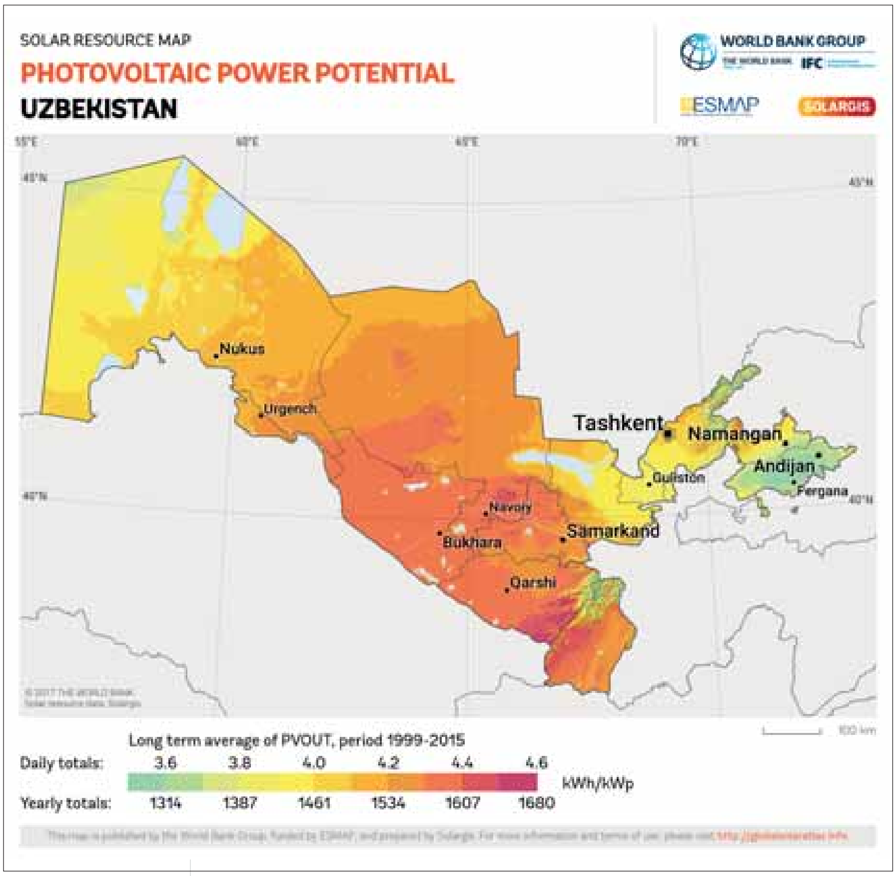
Uzbekistan currently relies largely on fossil fuels, notably natural gas, to meet its energy needs, with hydropower – currently the country's only source of renewable energy – accounting for only around 2% of primary energy supply. But with significant solar resources at its disposal, the Uzbek government is looking to develop the renewable energy sector to diversify the country's energy mix and attract private investment.

"The agreement demonstrates the strong partnership between IFC and Uzbekistan," said Georgina Baker, IFC Vice President for Latin America and the Caribbean, Europe, and Central Asia. "We are committed to creating markets and crowding-in private investment to help unlock and scale up renewable energy in Uzbekistan, and provide clean, reliable energy to its citizens."

It is unclear how – or if – Uzbekistan's tie-up with the IFC and ambitions for 1GW of solar relate to plans unveiled earlier in May by the Canadian solar developer SkyPower. On 7 May the company released a statement saying it had signed a power purchase agreement with the government of Uzbekistan for 1GW of PV, a deal it claimed to be both the largest foreign direct investment ever made in Uzbekistan and the country's first independent power producer project.

Commenting on the estimated US$1.3 billion deal, SkyPower's CEO Kerry Adler, said: "This is a historic partnership that will benefit both the Government of Uzbekistan and SkyPower, and we are happy to be building Uzbekistan's first solar power installation."

However, no further details were provided on the location or estimated timeline for building out this capacity. In 2015 SkyPower announced plans to build 1GW of PV in Kenya over five years, but has since made no further public statements on how these proposals will be executed.



Credit: Solargis

Uzbekistan is targeting its first solar projects


THE POWER OF RISING VALUE
risen
solar technology
6.6GW/year
Bloomberg
TIER 1
25
years
25 Years Linear Power Warranty
$
Average Debt Ratio(2010-2017)50%

Credit: Jp Marquis/Commons Wikimedia

Perspectives on risk mitigation measures for PV power plants: insurance and quality assurance

Risk | In the previous issue of *PV Tech Power*, quality assurance was considered as a key measure in maximising PV power plant performance and ensuring safety. Building on this train of thought, Thomas Sauer and Georg Fischer from EXXERGY examine insurance as a risk mitigation measure, based on analysis of more than 3,600 insurance claim cases

When it comes to managing PV power plant risks, on the one side, quality assurance is a viable mitigation measure. However, even with quality assurance measures implemented, there are limitations when it comes to backstopping financial losses in the event that the performance deteriorates more than predicted and warranted by the manufacturers, or if at the time of incidental power degradation beyond calculated limits, the manufacturers or EPCs are no longer in business.

In such instances, insurance solutions seem to provide an additional risk mitigation measure. Most insurance solutions on the market, however, cover only against externally induced risk exposures, e. g. severe weather, theft. Most of these insurance solutions follow a certain minimum standard. A few insurance products offer performance insurances where general cover is less standardised. All this triggers the question of how to look at insurance solutions. The interests of an insurance company are generally different than those of the insured stakeholders.

This article will consider these different viewpoints and discuss selected warranty and insurance aspects. Recently, more than 3,600 insurance claim cases have been statistically analysed. Selected results of this analysis will be discussed. The article closes with an outlook of how insurances can likewise mitigate their risk exposure – at last, insurances are just as good as the balance of the solvency resulting from their business model, or in the terminology of the insurance sector, the loss ratio must be at an acceptable level.

General thoughts on risk mitigation measures

In a recent article published in PV Tech Power [1], failure assessments of actual PV systems were discussed in detail. There are various factors explaining why a PV power plant can underperform or completely fail for technical reasons. Besides the technical effects, most importantly, underperformance of a PV power plant negatively influences the equity side in the very first place. Hence, the investors are first in the queue to suffer financially from underperforming assets. In some cases, technical performance deteriorations are so severe that even the debt side of the financing scheme is negatively affected to the extent that the redemption of the loan and part of the interest payment can no longer be serviced. As a result of such a situation, the bank typically holds a strong position to exploit the asset if taking recourse from the senior lender is not an option. When it comes to performance deterioration, the main questions are whether the quality assurance measures – if any – have been sufficient and, more importantly, whether the gap between planned performance and current performance are covered, either by any warranty claim or by an insurance wrap that can legitimately be expected to cover most part of the financial consequences resulting from underperformance.

Lightning is just one of a range of risks for which PV plant owners may use insurance to safeguard against financial losses

Insurances differentiate greatly between externally and internally induced damages that cause underperformance or other losses. Externally induced damages are related to events that are not caused by the PV power plant itself, examples are damages resulting from severe weather conditions (e. g. hail, thunderstrikes, storm), natural disasters (e. g. earthquakes) or from unexpected human intervention (e. g. theft). Internally induced damages are related to events that are caused by defects resulting from insufficiencies during component manufacturing, PV power plant design, construction, and/or operation.

Regardless, in the given damage event, the key question remains whether compensation for performance losses can be claimed or not.

Risk mitigation I: Considerations on quality assurance measures

As part of an overall PV power plant project due diligence, the financial sector currently bases its investment decisions, lending commitments etc. on technical assessment reports. These assessment reports also outline all measures that have been taken during the project execution to assure the quality of the end product. Up to now, no encompassing international standards existed, neither when it comes to the quality assurance nor to the assessment report itself. Depending on the assessor, these reports vary significantly in terms of thoroughness, accurateness, completeness, reliability, validity, transparency etc.

Two important consequences derive from this situation. (1) The quality assurance measures may or may not be sufficient to ensure that the planned performance will actually materialise throughout the planning horizon of typically 20 and more years. Especially when it comes to the re-sale of the asset in the secondary market, the originally applied quality measures are an important factor for the fungibility of an asset as available documentation may be partly missing. (2) The diversity of technical assessment reports (lacking any standards) results in a high workload on the receiving side (e.g. banks), and more importantly, in uncertainties evaluating the true risk exposure of a PV power plant project.

Other aspects indirectly related to quality assurance are: (1) The lack of consistency of tenders among government bodies and other institutions inviting to participate in tenders – oftentimes, the quality requirements per se as well as the quality assurance measures are not precisely specified; and (2) the untapped potential of optimised PV power plant performance resulting from inaccurate work results.

This status quo motivated the member bodies of the International Electrotechnical Commission (IEC) to create an **IEC** conformity assessment system for certification to standards relating to equipment for use in **R**enewable **E**nergy applications, in brief, IECRE. While for wind, first projects have already been certified, the IECRE certification system for PV power plants is on the verge of entering the market. With the adoption of the IECRE certification system, quality assurance is given a common platform, a minimum standard, to enable fair and efficient competition. These minimum standards are supplemented by IECRE plans to develop a technical rating system for PV power plants. This rating system will be essential to enable financial stakeholders to get a nuanced picture of the quality of a PV power plant beyond minimum requirements, a complimentary grading system similar to those common in the financial realm. The IECRE will soon publish the first draft documents outlining scope and intend.

Risk mitigation II: Insurance solutions

In the context of analysing insurance claim cases, various insurance solutions related to PV power plants have been looked at to understand which insurances have an immediate relation to quality requirements. Initially, the identified insurance solutions have been systemised in two ways, (1) by phases in the lifecycle and (2) by purpose.

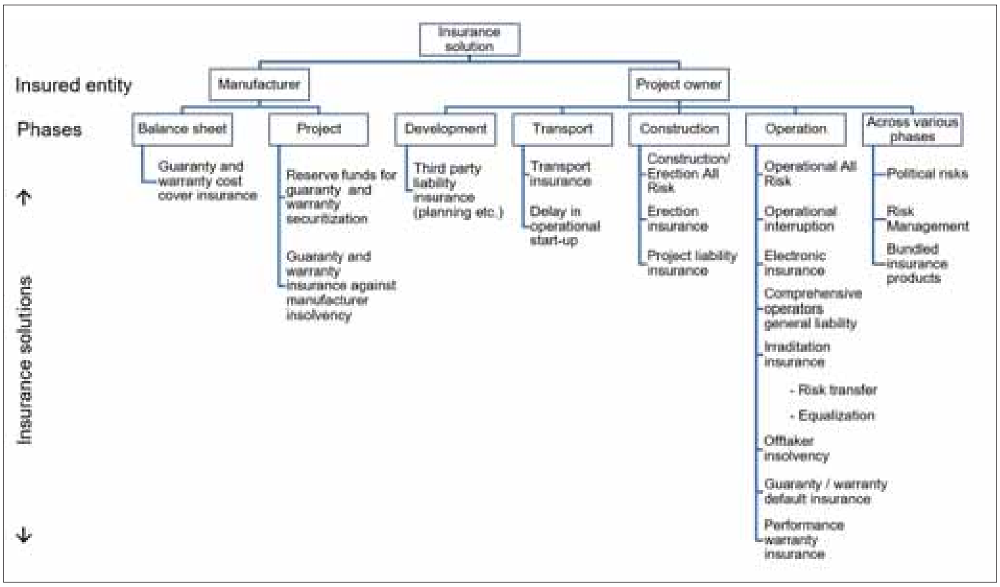


Figure 1. Systematisation of insurance solutions by lifecycle phases

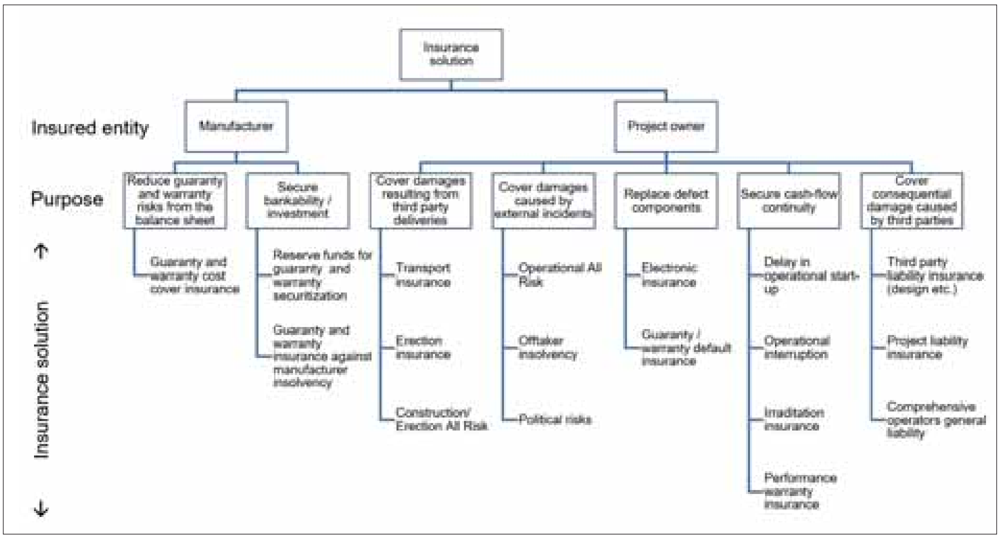


Figure 2. Systematisation of insurance solutions by purpose

Insurance solutions by risks and phases (insurer's point of view)

Figure 1 illustrates the systematisation of insurance solutions by lifecycle phase on the horizontal axis and the attributed insurance solution on the vertical axis. This system may serve as the reflection of the natural interest of the insurance company.

Insurance solutions by business risks and insurance purposes (operators point of view)

Figure 2 illustrates the systematisation of insurance solutions by purpose on the horizontal axis and again the attributed insurance solutions on the vertical axis. This system may serve as reflection of the natural interest of the insured entity.

Considerations on selected warranty insurance aspects

Insurers who cover the risk of inherent technical defects and their economic consequences should most likely have an interest in good quality assurance. This is especially applicable for insurers offering performance warranty insurance solutions. Generally, two models are supposedly available on the market to secure a minimum yield of a PV power plant:

- Component manufacturer related: the insurance covers the manufacturer's warranty services (e. g. replacement of inherently defective components) in the event of the insured manufacturer's insolvency. Some insurance solutions offer as well a warranty cover for the event that the manufacturer rejects the warranty service or disputes the obligation to perform in whole or in part (warranty failure insurance). The warranty failure insurance typically compensates the (re-) purchase value or the book value of the defect components plus in some instances the replacement costs and/or loss of revenue.
- Project related: depending on the scope of the insurance, (partial) compensation for losses can be covered, such losses deriving either from technical issues (e. g. excessive performance degradation) or from radiation-related losses. . The performance warranty insurance typically compensates for an inferior energy yield caused by inherent module defects. The trigger for the insurance to become liable varies. As an example, manufacturer insolvency and an inherent defect-related performance shortfall of at least 10% are basic triggers. In addition, a maximum limit of cover is typically provided. The cover payout can be provided in cash (loss of revenue) or in kind (replacement of defect components) or by a combination of both.

Regardless of the insurance solution, it is important to understand the limitations, exclusions or pre-requisites to be met as well as other relevant insurance terms and conditions in detail. These details are relevant for the assessment of the actual effectiveness of this risk mitigation tool and hence, viably concluding whether a tangible risk transfer is taking place in the perceived insured event.

Insurance claim cases – selected insights

A study of analysing the root causes of insurance claim cases has been conducted. Four of 13 invited insurance companies have responded to an inquiry providing information and data related to claim cases. As a result, 3,666 insurance claim cases have been analyzed in this study, all of which were occurring in the northern hemisphere at latitudes north of 35°. The following outlines an excerpt of a much more detailed study.

The insurance claim records date from the time span between January 2012 and June 2017 so that a history of 5.5 years of insurance claim cases was covered in the study. First commercial operation dates of the PV power plants in the study ranged from 1997 until 2017 offering a time span of up to 20 operational years. However, because of the very limited number of claim cases related to PV power plants having a service life of more than 13 years, only claim cases with maximum 13 years of service lifetime have been analysed in greater detail. The average amount of loss was 2.6% of the investment, or €26 (US$30.7) per €1,000 investment.

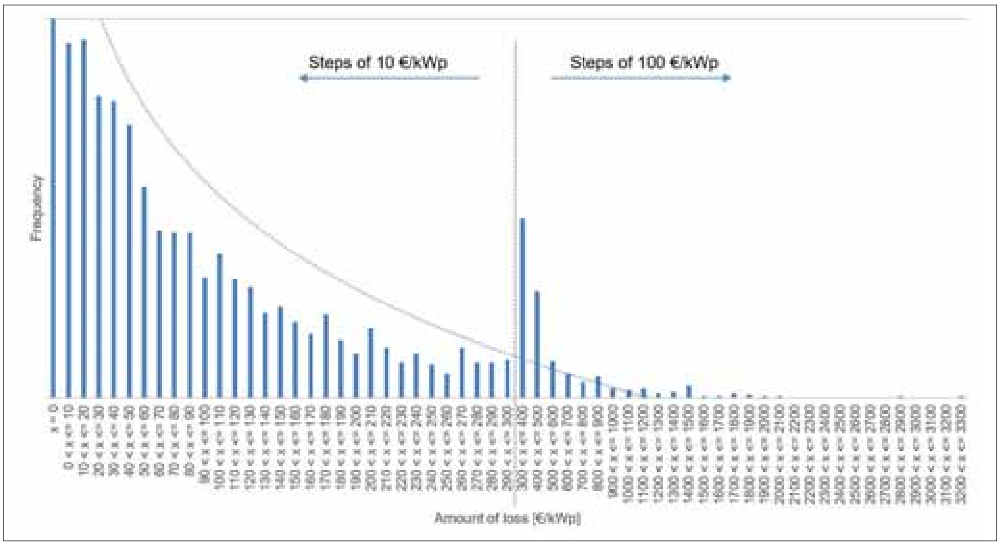


Figure 3. Distribution of amount of loss classification

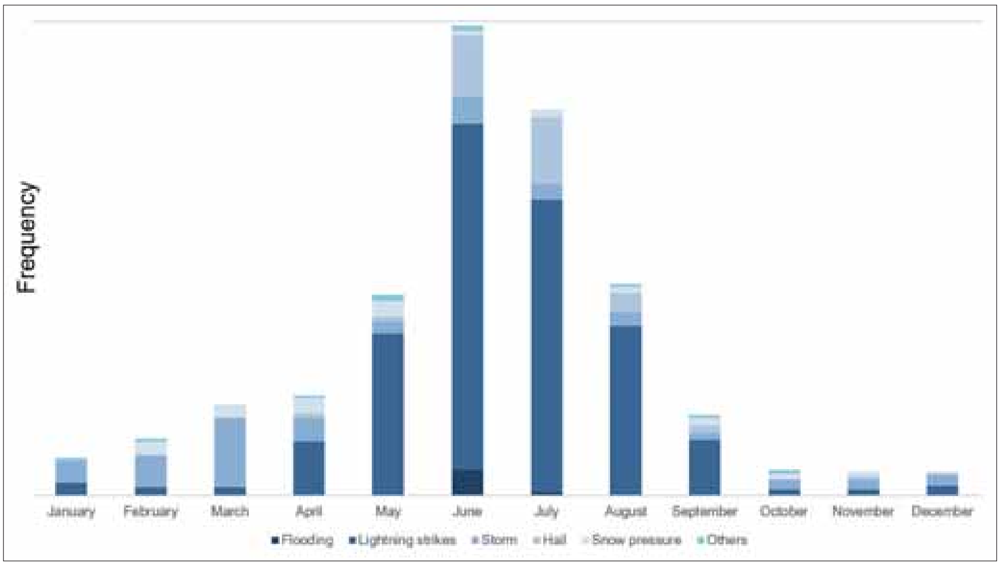


Figure 4. Frequency of weather related causes of damage across seasons

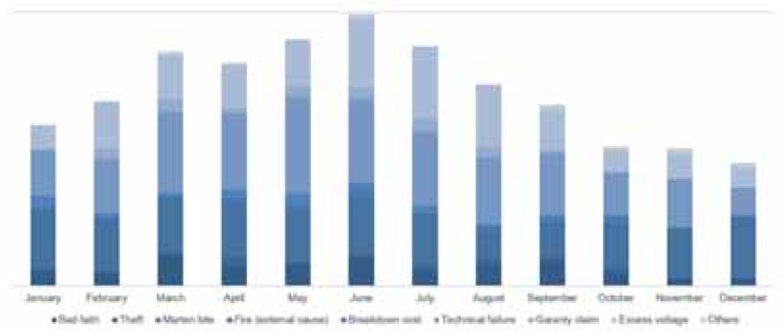


Figure 5. Frequency of weather-unrelated damage causes across seasons

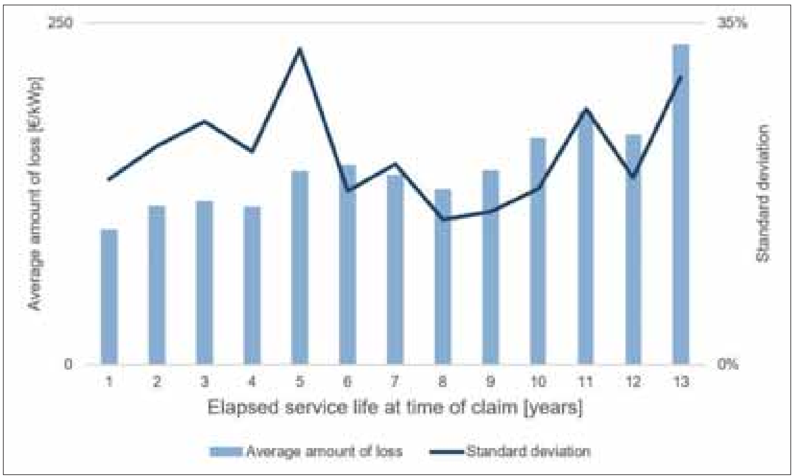


Figure 6. Average amount of loss as a function of service life (all analysed claim cases)

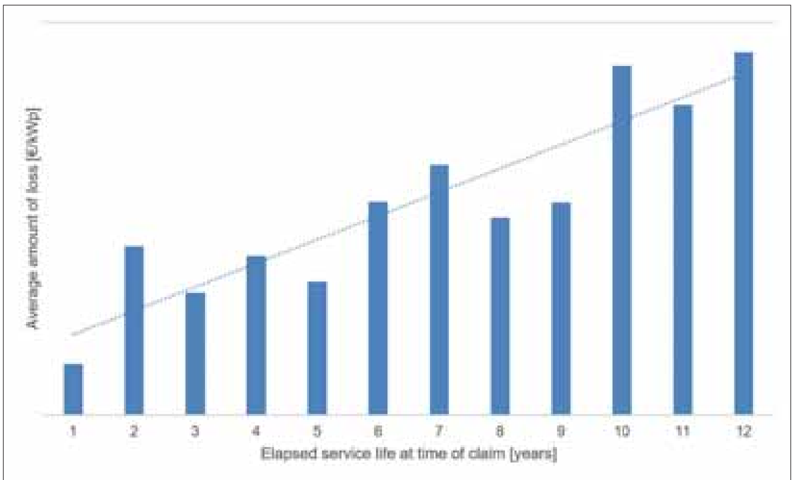


Figure 7. Average amount of loss as a function of service life (internal defects)

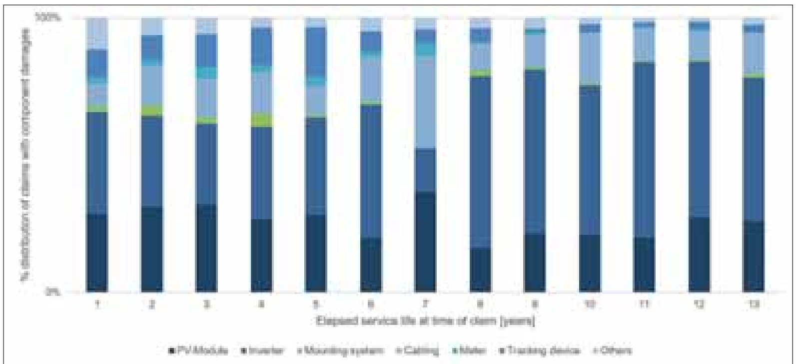


Figure 8. Damaged components in % of all damages as a function of service life

The spread, however, is significant with a peak value of more than 110% relative to investment (>€1,100 per €1,000 investment). Looking at the relation of damage to nameplate power, the maximum damage was €3,250/kWp installed capacity. Note that the maximum numbers originate from different claim cases. Not surprisingly, for neither relation, neither for the damage amount versus investment nor for the damage amount versus the installed capacity, could a linear correlation be drawn. The decline in frequency of claimed damages over the amount of loss nearly follows a logarithmic relationship: damage cases with high amounts of loss are rare whereas minor damage cases occur more frequently. Figure 3 shows the frequency of damage claim cases as a distribution of the amount of loss data in €/kWp for those approximately 3,600 claim cases for which the amount of loss data has been available.

Going into more detail of the analysis, 24% of the insurance claim cases could not be analysed by IT tools in terms of root cause analysis since the information available did not contain a taxonomy that could be IT evaluable with reasonable effort. Nearly 3% of the insurance claim cases had multiple causes, and because of the relatively small relevance will not be discussed here in further detail. Some 6.7% of the claim cases neither had a time stamp for the time of incident nor for the time of claim. Including cases with no time stamp (2,676 = 73% of all cases), 20% have been caused by internal defects, 65% by external causes. Nearly 12% have been caused by excess voltage excluding lightning strikes. The analysis was inconclusive as to whether cases of excess voltage without proven lightning strikes have been caused by lightning strikes or by internal defects or by grid instabilities. The remaining 3% of the claim cases have been caused by other causes that are not reviewed in more detail.

Analysing insurance claim cases that are caused by weather phenomena, the frequency of damages increase significantly in the months of May through August showing a significant peak in June (see figure 4). This can commonly be explained by increased occurrence of convective weather activity and the resulting thunderstorms during the summer time.

Other causes of damages, outlined in figure 5, show that the distribution across seasons is more spread out, with excess voltage showing a significant increase in the summer months. This phenomenon can be attributed to the fact that records were inconclusive as to whether the excess voltage came from the grid (cause may be lightning strikes as well) or from the system. Remarkable is the relatively high percentage of technical failures that can be attributed largely to internal defects of the system.

This conclusion leads to analysing the amounts of loss propagation over the service life of a PV power plant. A view on Figure 6 clearly evidences that, while standard deviation varies between 14.8% and 32.5%, the average amount of loss significantly increases with service lifetime of a PV power plant.

This conclusion is even more evident when damages resulting from internal defects are analysed. The trend is clear with average amounts of loss for damages from internal defects being in the same range as the overall average amount of loss across all damage causes.

Analysing the breakdown of components affected, as outlined in Figure 8, reveals that inverters and modules are the most prominent to be affected by damages, another significantly affected component is the cabling.

Looking into more detail related to the main damage causes by component (as far as specified), the following results have been elaborated:

- For modules in particular, external causes for damage were found to be malevolence as the most frequent cause (21.6%), followed by storm (18.6%), and hail (16.9%) while as an internal defect cause, technical failures account for a remarkable 18.4% of all cases.
- For inverters in particular, overvoltage is the most frequent cause of damage (60.8%), 30.5% of which have not been associated to lightning strikes. Technical failures accounted for 31.9% of all specified damages.
- 80.9% of all cabling damage results from marten bites.
- 93.4% of damage to communication equipment results from overvoltage, 20.6% of which has not been caused by lightning strikes. For damage cases to AC protective devices, the relative shares are 58.9% and 63.6%, respectively.

Regarding the documentation of insurance claim cases, the effort of documentation increases with the amount of loss. The mostly used documentation classifications are (%-numbers relative to the total number of claim cases n = 3,666):

- Evidence of insurance policy (98%)
- Insurance claim report (71%)
- Quotation/invoice (44%)
- Photography (28%)
- Severe weather reports (18%)

Other documentation includes expert opinions, particularly for cases with large amounts of loss. Naturally, the extent of documentation typically increases significantly with the average amount of damage. For amounts of more than €250/kWp, mostly five or more documentation classifications have been provided.

Finally, the correlation between component manufacturers and damages has been studied by analysing the quota of damage cases where devices have been affected by internal defects and by externally caused damages (where component quality had an influence on the damage) relative to the total volume components involved in damages by the respective manufacturer. Depending on the manufacturer, internal defects range from 0% to 90% for modules, and 25% to 100% for inverters. However, it is important to note that this analysis only allows a first insight as it is not statistically conclusive. Nevertheless, it is obvious that quality assurance measures in the past have seemingly been insufficient, or else such a high quota would not become evident.

Concluding thoughts on risk mitigation and on PV power plant economics

While most insurance solutions covering externally caused defects are relatively well standardised, guarantee and performance warranty insurances vary significantly in terms of their concept and cover principles. Relevant factors to look at have already been discussed in [1].

Truly understanding and aligning the interests of the insurance with the interests of the investors is crucial going forward. This train of thought as well as the fact that 20% of all damage cases have been caused by internal defects trigger the authors' concluding remarks:

While having experienced an incredible dynamic growth over the last 20 years, the solar sector currently still represents only approximately 2% of worldwide annual electricity production. To push the energy transition to the next level, it is important to enable the PV sector to push the electricity share generated by PV power plants towards 20% and beyond. At least evenly important, it is of the essence to enhance the profitability for all stakeholders in the PV sector. The relatively low contribution to the electricity generation share means that the PV sector is yet far from maturing. Still today, deploying PV power plants goes along with relatively high soft costs for engineering, due diligence etc. At the same time, the race to reduce the levelised cost of electricity (LCOE) continues; the current benchmark is to deliver electricity from PV power for less than US$18/MWh. The only way to establish profitable business for all stakeholders at such levels of LCOE is to continue reducing costs. One important lever in this race to drive cost down is to establish standards that are valid across the industry, including quality assurance standards. Minimum standards are about to be published by IECRE, and a rating system is being developed helping to assess the risk exposure that goes along with a PV power plant investment in a more effective and uniform way.

The authors therefore recommend insurances (and financing institutions) to request a higher degree of quality assurance – ideally following internationally accepted standards - throughout the lifetime of the PV power plant, and investors to apply more diligence when it comes to quality assurance.

Finally, in mature markets, standardisation has proven to enlarge market potentials that would have been impossible to address without having established standards – for example the market penetration of IT or mobile telecommunication. ■

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The rise of green solar bonds?

Solar financing | Banks will be unable to fully finance solar on the scale envisaged in the transition to a low-carbon economy. Vicky Münzer-Jones and Stacey Giunta look at the role of solar bonds in bringing much needed capital to the sector

Credit: Scatec Solar

The commercial use of solar cells began in the 1970s and it was not until the late 1990s that efficiency levels have led to greater commercial use. Since then, the speed at which the technology has developed has made it difficult for some to keep up. Government regulators determining how to regulate a power generation revolution which is turning the old-fashioned, centralised power grid on its head; urban planners racing to adapt planning laws to rooftop solar systems; and (on a slightly smaller scale) my parents trying to choose which solar panels to cover the field next to my childhood home. Subsidies have come and, in some cases, gone or been cut as the price of the technology has shrunk. Solar is the cheapest, fastest-growing source of electricity in the world, with more money invested in new solar energy plants last year than in any other power source. Perhaps, in part, this is due to its flexibility in being able to solve the energy consumption concerns of the masses...and my parents.

Against this fast-moving backdrop, the financial sector is also struggling to keep up as the types of solar installation they are requested to finance change in size, complexity, geography and infrastructure. So far, banks have picked up the largest proportion of the financing opportunities through loans, mainly secured. But banks will not be able to meet the funding requirements in the longer term and we are now starting to see greater use of solar bonds as a sub-set of the broader excitement being stirred up by green bonds.

SolarCity (now part of Tesla) has been amongst the biggest repeat issuers of solar bonds over the past four years and in 2017/18 significant issues of solar bonds have occurred across the world. For example, by Grupo T-Solar (Spain), China Singyes Solar Technologies (China – USD420m equivalent), Scatec Solar (Norway, but producing solar power in Europe, Africa, the Americas, Asia and the Middle-East), Azure Power (Mauritius, but funding projects in India – US$500 million) and Sindicatum (Singapore, but funding projects in India – the first masala green bond and guaranteed by GuarantCo).

Scatec Solar has used green bonds to fund its international IPP activities

Bond investors tend to be more risk averse than banks, so it helps that solar seems to be 'coming of age'. The technologies have been tried and tested and the longer tenors of the guarantees afforded to the technology give greater confidence in the reliability of the projects.

Ratings agencies such as Standard & Poor's have also recognised lower risks associated with the performance of solar assets as compared to other renewable energy assets [1]. However, not all of the bond issues listed above were labelled as "green bonds". This article looks at the characteristics of green bond transactions and whether the opportunities offered by them make a green label a worthwhile investment for a solar company.

Green bonds

Green bonds are any type of bond issued with the purpose of financing or refinancing green projects, including solar energy projects. As such, they offer the usual advantages of straight bonds, i.e. diversification of investor base, publicity, opportunity to structure innovative structures and solutions, improved liquidity, arbitrage of regulatory and tax treatment versus loans, etc. In order to be considered a green bond, an issuer simply has to label them as such. This self-labelling is usually (but not always) supported by an opinion of an independent third party which will look at the issuer and the bond against a set of green bond criteria. Bonds issued by companies whose sole business is solar energy generation (i.e. "pureplay" solar issuers) can fit within green solar bond eligibility criteria and therefore qualify as a green bond. It is also possible for green bonds to be issued by companies where only a part of their business is green and those involved in the solar supply chain, if such companies can link the proceeds to their green/solar product divisions.

As with straight bonds, there are different types of green bonds, any of which could be used to finance companies involved in solar power generation. These range from straight corporate bonds (the majority of solar bonds issued so far) through to green securitised bonds (issued by SolarCity/Tesla, Mosaic and Sunnova) and green sukuk (the first issued in 2017 by Tadau Energy).

Understandably, the development of green bonds as an investment category is coupled with the development of the green investor community, which has become more discerning and prescriptive. Self-labelling for some green investors can be problematic. In order to bring some certainty to the green bond market, the International Capital Markets Association published the Green Bond Principles (the GBP), last updated in June 2017.

The GBP are a set of voluntary guidelines "that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the approach for issuance of a Green Bond" [2]. Since their publication, governments (e.g. China and Indonesia) and bodies such as the Association of South East Asian Nations (ASEAN) have issued their own green bond guidelines along similar lines. An issuer wishing to issue a bond which is independently verified as green will need to select a set of guidelines to follow. The four core components of the GBP are use of proceeds, a process for project evaluation and selection of projects, management of proceeds and reporting.

"There may come a time when green bonds will not be required because all companies and projects have become green, but until then solar companies are well placed to obtain a green label with little additional expense or effort"

The GBPs state that the proceeds of a green bond issue are used for green projects. Solar energy projects are eligible for classification as "green projects", so this component of the GBP should be handled easily by scrupulous solar issuers. A more rigorous requirement, however, is the tracking of proceeds while the green bonds are outstanding. Until the proceeds can be fully deployed in the financing of a solar project, the issuer must outline the investment decision-making process it follows in managing the undeployed funds. Investors may be updated (typically annually), by independent third parties where possible, as to how the proceeds are being used and managed until full allocation is reached, and as necessary thereafter in the event of material developments. The Azure Power bonds went as far as saying they might be redeemed if the proceeds were not spent on solar financing or refinancing within six months.

Second opinions given by an external, independent consultant or assessor can provide an additional level of comfort to investors who invest in green bonds. Various new companies have entered this business (e.g. Vigeo, DNV-GL, Sustainalytics, CICERO, Climate Bonds Initiative) as have some of the big four accountancy firms. These companies give an opinion that compliant bonds meet the particular green bond criteria the issuer has chosen to follow and are aligned with the definition of green bonds within those criteria. Different third-party entities can also provide other services to assist issuers, such as acting as a consultant to advise on the establishment of a green bond framework for a company; providing verification of a company's alignment with internal standards or claims made by it; or providing a green bond rating.

The providers of these services will charge fees based on commercial negotiations and there will be internal costs incurred by an issuer in establishing and complying with procedures designed to ensure that it meets its new green bond obligations. In addition, the Climate Bonds certification process incurs a certification fee equivalent to one tenth of a basis point of the bond principal (e.g. US$5,000 on a US$500 million issue). However, while not negligible, we would argue that issuers of solar bonds should not be put off by a perception that arranging for a bond to be labelled green is prohibitively expensive.

In terms of any additional effort incurred in adhering to the GBP, or other guidelines, in the bond documentation an issuer expects to enter, there is little extra work it will need to do other than with respect to disclosure. The issuer will need to state in its disclosure document for a public green bond issue to which green bond guidelines it will be aligned and draft a green bond framework which is appropriate for that issuer. In typical green bond issues, the joint lead managers support the company in designing its green bond framework in collaboration with the external consultants. It will set out what "green" means to the issuer (i.e. solar energy projects in this context) and measurable green targets and goals for how the money will be used and managed which can then be checked and/or monitored by the independent evaluator of the issue. Issuers often opt to include the framework as an annex to their public offer document and the GBP recommend public disclosure of external reviews as well, or at least an executive summary. These tend to be accessible via external websites, such as the Climate Bond Initiative's labelled green bond database, rather than being attached to the offering document.

Market practice has been not to include covenants in green bond documentation which would penalise an issuer for failing to use the proceeds of its green bond issue for green purposes. So, even if a company fails to meet the criteria for its use of proceeds it will not be a direct default. The level of disclosure in offer documents as to the green use of proceeds has therefore tended to be limited or broad in order to prevent indirect events of default as a result of misrepresentation. The non-prescriptive nature also helps to reduce the risk of reputational damage. However, it is difficult to imagine that a reputation could remain intact if an issuer were to be found spending the proceeds of its green bond on non-green projects, even if it publicly announced the change in its business.

As an example of the above light touch approach to disclosure, the Greenko prospectus gives reasonable detail as to the categories for which the proceeds will be used (refinancing existing indebtedness, paying transaction expenses and meeting operating and working capital requirements) and promises disclosure within a year as to the split of funds between those headings, but it finishes with a statement that there can be no assurance as to whether the proceeds will be used for eligible green projects or the characteristics of those projects.

As mentioned above, an advantage of a bond is a diversified investor pool. By labelling a bond green that potential pool broadens even further as another category of environmental, social and governance (ESG) investors becomes able to buy the bonds. The green label immediately attracts investors with an interest in green investments, including an increasing number that are limited by their investment criteria to being able to invest in green investment products only. Unique to green bonds are philanthropic investors, whose presence can reduce some of the commercial issues which might otherwise arise with respect to solar companies, such as a short business history. Green solar bonds tick a big green box on the investment criteria for many pension funds holding the money from environmentally conscious baby boomers (taking us back to my parents again).

There is also credit enhancement available to issuers of green bonds via guarantees supplied by multilateral financial institutions (e.g. the Credit Guarantee and Investment Facility established by ASEAN members, China, Japan, South Korea and the Asian Development Bank) or quasi-multilateral (e.g. GuarantCo sponsored by development banks and agencies in the UK, Australia, the Netherlands, Sweden and Switzerland). These help to mitigate the impact which low credit ratings given to solar issuers with short business histories and operating in new markets can have on the interest rates payable by an issuer and the size of the issue.

The emergence of solar regulations and the positive influence of governments further support the development of green solar bonds. The Indian regulator has issued green bond requirements to help in raising funds in the renewable energy space [3] and the EU High-Level Expert Group on Sustainable Finance has released its Sustainability Taxonomy as a first attempt to provide a shared EU classification of sustainable activities applicable to all types of assets and capital allocation, including bonds [4] The Chinese Green Financial Task Force has published various suggestions for promoting green bonds, including possible regulatory capital and tax incentives. The Monetary Authority of Singapore has launched an incentive under which it agrees to pay up to S$100,000 of the costs of obtaining an independent review (although the conditions imposed means that it is difficult, if not impossible, to claim).

However, despite the above factors, there has been little, if any, evidence that green bonds enjoy better pricing than equivalent straight bonds. Although there has been some indication that secondary market pricing and liquidity has been stronger. Recent research published by NN Investment Partners [5] has shown that the average yield of green bonds is lower than non-green bonds. On average and over time, a green bond yield is 1.1 basis points lower than a non-green bond yield. The researchers put this down to several factors, including the dramatic increase in investor demand for green bonds over the last three years, but a limited number of issues; and green bonds being less volatile because ESG investors tend to buy to hold due to longer-term horizons and again a lack of alternative green bonds in the market.

If these trends continue, the pricing benefits for issuers must translate to the primary markets, thus cementing the appeal of a green label.

Outlook

The developed world is becoming greener by the day and the developing world is trying to put the brakes on the devastating environmental damage being caused by polluting industries and energy production. Governments, corporates, financial institutions and multilateral organisations, partnered by pressure groups such as the Climate Bonds Initiative, see green bonds as a public means of showing support for combatting climate change.

There may come a time when green bonds will not be required because all companies and projects have become green, but until then solar companies are well placed to obtain a green label with little additional expense or effort. Green solar bonds may not appear to be the most appealing financing mechanism in the immediate term, but longer term the striking development of the green solar bond market (which trends predict) will improve pricing in favour of issuers and do away with the need to artificially incentivise green bonds, in the same way as solar subsidies are increasingly unnecessary. ■

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Advancing BIPV in Europe

BIPV | The EU-funded PVSITES project is working on a number of initiatives aimed at accelerating the roll-out of building-integrated PV across the continent. Members involved in the initiative outline some of the efforts being made to unleash BIPV's as-yet untapped potential

Credit: ONYX Solar

Figure 1. Internal view of ONYX Solar's photovoltaic glass-glass curtain wall at Balenciaga storefront (Miami, USA). The BIPV laminates include crystalline silicon technology and blue tinted glass, one of the products developed and tested within PVSITES project

Over the past decade, the expansion of the building-integrated photovoltaic (BIPV) market predicted by analysts bumped into a context that combined a lack of regulatory and standardisation framework, political support and cost-competitiveness. As a consequence, market forecasts were overestimated, and BIPV installations were mainly limited to niche flagship construction projects. Despite that adverse scenario, the BIPV sector has managed to evolve and has steadily consolidated its presence, proving that the bright future depicted by market experts is about to blossom. BCC Research estimated the worldwide installed BIPV capacity during 2016 to nearly 2GW, confirming the growing trend, increasing by 12.6% compared to 2015, when 1.78GW of capacity was installed [1].

The BIPV sector has also faced the difficulties derived from merging two different sectors: the photovoltaic sector, thoroughly focused on the manufacturing of standard PV modules and the implementation of economies of scale; and the construction sector, demanding aesthetics, customisation, freedom in terms of design, and in general terms reluctant to the introduction of novel active solutions.

During the past few years, the understanding of both sectors has significantly progressed, especially due to the irruption of new BIPV companies providing solutions that met the features demanded by architects and building owners: customised solutions, adequate aesthetics and, in certain cases, even cost-competitiveness when tailored business models were applicable.

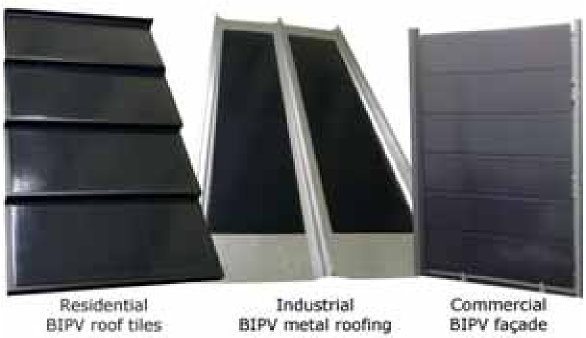
In Europe, the so-called Winter Package evidenced the clear bet made by the European Union towards the decarbonisation of the economy and the building sector. Although no clear binding measures are specifically defined for BIPV technology, the framework drawn up by the latest recast of the Energy Performance of Building Directive (EPBD) expects a prominent role for BIPV, implicit in the low primary energy consumption allowed for nearly-Zero Energy Buildings (nZEBs) by most Member States' transposition of the Directive, requiring renewable on-site generation to comply with the regulation.

The global context seems finally appropriate for the mass deployment of BIPV technology. This will require further progress in overcoming the traditional barriers of the technology, such as the lack of awareness or confidence in BIPV technologies among key stakeholders, the difficulties in the technical and aesthetical integration of BIPV systems in the building skin and, most importantly, the final cost of BIPV. Mastering these key market drivers will help unleash the great and still untapped potential of BIPV.

Towards cost reduction

The European PVSITES project [2] has been conceived as an industrial joint approach to provide robust BIPV technology solutions to comply with market needs. The ultimate goal is to significantly enhance BIPV market deployment in the short and medium term. Clearly one of the main challenges faced by the BIPV sector is to demonstrate significant cost reductions that can lead to large market uptake, moving from exclusive projects

Figure 2. Several CIGS on metal designs for BIPV integration by FLISOM



Credit: Flisom

		Single House	Educational building	Carports	Industrial building	Apartment building	Office building
Responsible partner		FormatD2	Flisom	Flisom	Cricursa	Vilogia	Tecnalia
Location		Stambruges Belgium	Geneva Switzerland	Zürich Switzerland	Barcelona Spain	Wattignies France	San Sebastián Spain
BIPV	Product(s)	Roofing shingles (CIGS on steel)	Large tiles on façade (CIGS on metal substrate)	Roof tiles (CIGS on metal sheets)	Large roofing shingles (CIGS on metal substrate)	Ventilated façade (c-Si modules with hidden bus bars)	Ventilated façade (Glass-glass back contact c-Si cells)
	Manufacturer	Flisom	Flisom	Flisom	Flisom	Onyx Solar	Onyx Solar
	Orientation	SSW	E + W	Horizontal	Horizontal	SSE	SSE
	Surface	75 m²	136 m²	145 m²	225 m²	130 m²	170 m²
	Installed power	8 kWp	4 + 8 kWp	7 + 7 kWp	19 kWp	20 kWp	10 + 10 kWp
	Use for electricity	Self-consumption + Grid	Self-consumption + Grid	EV chargers + Grid	Grid	Self-consumption + Grid	Self-consumption + Grid

Figure 3. Overview of the main PVSITES products and demonstration sites. The market-ready products developed in the project are being implemented in a variety of existing buildings throughout Europe

towards a mass market including the ordinary built stock. European policies are aligned with this objective, as clearly stated in the "SET Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics"[3]. The ambitious targets in the Declaration point to a 50% reduction of additional costs for BIPV modules in 2020 and to a 75% reduction in 2030, with respect to the reference costs in 2015.

PVSITES partner ONYX Solar, manufacturer of BIPV glass laminated products, is deeply invested in the achievement of this cost reduction roadmap. Glass-based BIPV products must compete directly with the traditional architectural glass industry, in which high aesthetic standards are imposed. ONYX Solar has worked in recent years in a large portfolio of crystalline and amorphous silicon glass-based solutions with high aesthetic levels and attractive ROI values for the final user. The company's strategy towards 2020 and beyond includes a further automation of its manufacturing lines and quality control processes, materials-related innovation and further economies of scale (Figure 1).

Flisom, manufacturer of CIGS solar modules in the PVSITES project, has also defined a clear roadmap for cost reduction with a focus on two main factors:

- An overall module efficiency improvement from 10 to 14%, at the same time decreasing the cost per Watt.
- An increased annual production capacity from 15 MW to 100 MW, bringing significant economies of scale.

Combining these two aspects, production costs below €0.5/Wp are realistically achievable.

Cost reductions are also achievable for balance-of-system components and grid interface electronics as evidenced in the PVSITES project. On the one hand, low-cost conversion technologies removing unnecessary power stages are proposed, with target prices of €0.12/W for a 5kW Silicon Carbide (SiC) based inverter and €0.16/W for a 10kW PV storage inverter, developed by CEA INES and TECNALIA respectively.

All the BIPV modules and inverter solutions developed within PVSITES are being demonstrated through integration in seven installations in Europe, as detailed in Figure 3.

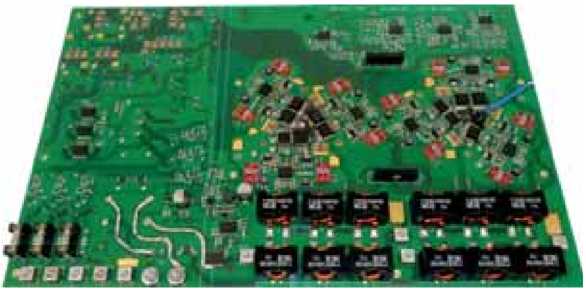
Aesthetics and multifunctionality

Another main driver to enhance the fast adoption of BIPV by the construction sector lies in the aesthetic value of the integration and the ability of BIPV products to provide additional functionalities to the building, at the same or superior level than traditional construction materials. BIPV systems are construction products, and as such provide weather protection, thermal control and aesthetics in addition to on-site electricity generation, among other features. Novel multifunctional BIPV products are giving place to large product portfolios based on different PV technologies, material substrates, transparency degrees, colours, etc.

A relevant challenge for the development of the BIPV market is the possible overheating of PV modules after building integration. A performance loss of nearly 0.4%/°C is observed for crystalline silicon PV modules, decreasing their electrical performance as well as their lifetime compared to traditional rack-mounted PV modules. This effect could be reduced using PV technologies less sensitive to temperature (CIGS, amorphous silicon, bifacial cells…), or through thermal management based on passive solutions such as natural convection through the air gap between the roof and the PV modules (e.g., the CIGS shingles designed by FLISOM for industrial buildings in the PVSITES project), phase change materials or active cooling methods (e.g., forced

Credit: ONYX Solar

Figure 4. San Antón market (Madrid, Spain) amorphous silicon transparent skylight by ONYX Solar.



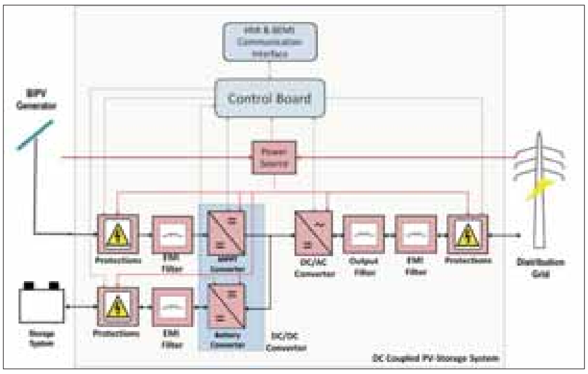


Figure 5. (Above) Power Board of the SiC current source inverter designed (soft and hard) by CEA-LITEN-INES (width 390mm x depth 245mm). (Below) Block diagram of the 10 kW three-phase DC-coupled PV storage system developed by TECNALIA

convection in hybrid BIPV/thermal solar collectors), with an opportunity for heat recovery and valorisation.

Enhanced grid integration

Progressing towards a more manageable, grid-friendly and profitable generation in terms of energy savings in buildings remains a challenge. As part of the PVSITES project, TECNALIA and CEA INES are aiming at improving the integration of the electricity generated by the PV panels in the grid.

The CEA INES Photovoltaic Systems Laboratory is working on a new inverter technology that simplifies the chain of conversion of electrical energy: the three-phase current switch. This type of inverter allows the direct injection of electrical energy from a PV array to the network in a single conversion stage. This new inverter topology is simpler and does not require any capacitance hence will be cheaper and more robust. This evolution is made possible by the emergence of silicon carbide semiconductors offering compact and high efficiency conversion solutions. The CEA INES team has fully designed the hardware and software of this three-phase current source inverter and has manufactured a first 5kW inverter prototype (Figure 5) for full validation prior to launching the industrialization of a pilot series of eight 5kW inverters. These will be installed on two demonstration sites in Spain: the ventilated façade of an office building and an industrial roof (Figure 3).

A high-efficiency, low-cost and flexible 10kW three-phase DC-coupled PV storage inverter has furthermore been developed by the Solar Energy Group at TECNALIA Research & Innovation. This system is proposed in order to cope with different storage requirements and operating modes. The 10kW inverter can be easily parallelized to make larger systems up to hundreds of kW, being suitable for the residential, commercial and industrial markets. DC coupling is achieved by means of multilevel DC-DC converters for the PV generator and batteries, and a high-voltage DC link, increasing the conversion efficiency of the whole system. These inverters will be demonstrated at a residential roof in Belgium and at the ventilated façade of a multifamily building in France (Figure 3).

Additionally, an advanced Building Energy Management System (BEMS) has

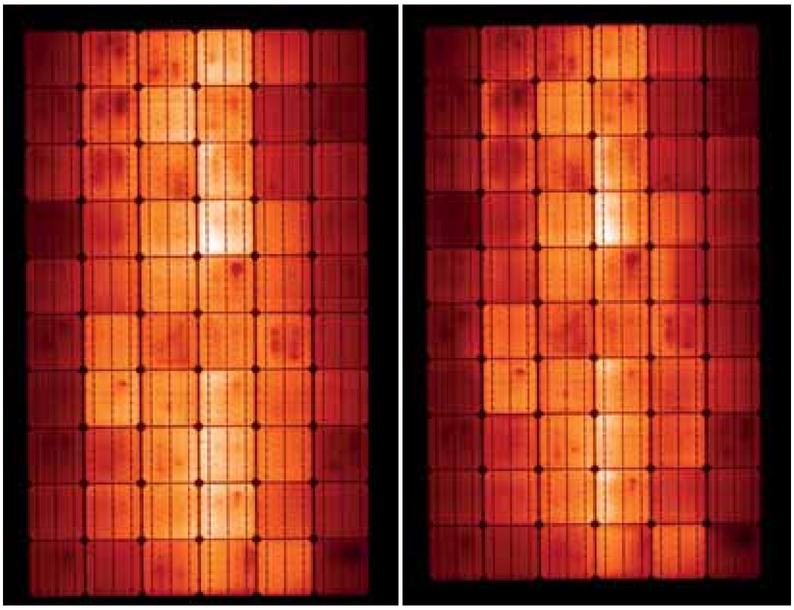


Figure 6. Electroluminescence imaging of ONYX Solar 60 cell glass-glass BIPV modules with a black rear glazing: before (left) and after (right) 100 thermal cycles

been developed by TECNALIA within the PVSITES project for different building typologies. The BEMS optimises energy flows between the building and the grid and increases overall energy performance. Economic benefits come from a better utilization of the produced electricity for peak-shaving and self-consumption maximisation at the most profitable time, taking advantage of known daily evolution of electricity tariffs in each country. The developed BEMS smartens the interface between the prosumer and the rest of the electricity system, exchanging information about anticipated performance.

Progress in standardisation

The still ongoing development of a specific and complete standardization framework for BIPV is a main barrier affecting the market deployment of the technology. In order to be suitable for building integration, a BIPV product has to demonstrate compliance with the Low Voltage Directive as electrical equipment, and the Construction Products Directive as building component. Additionally, as elements contributing to energy performance of buildings, BIPV systems are subjected to the EPBD and the Energy Efficiency Directive. The recent European standard EN50583, "Photovoltaics in buildings", parts 1 and 2, gathers these requirements. National building codes and regional/local regulations also apply on BIPV elements. A complete analysis of the BIPV standardisation framework has been made in the PVSITES and Construct PV [4] projects.

One of the first applications of EN 50583 standard in Europe has taken place within the PVSITES project. For each BIPV c-Si glass-glass and CIGS-on-metal-based product developed within the project, an in-depth analysis of the standard was made and a test sequence was defined and executed by project partners, with the final goal of ensuring long term performance and increased reliability.

Within the complex standardisation framework described above there are still gaps in how the different functionalities of BIPV systems are addressed. In general terms, it is clear that performance in operational BIPV conditions can be significantly different from that of traditional photovoltaics, building-attached systems, or non-photovoltaic construction materials. Another issue is that, given the large variety of module configurations, testing is performed almost on a single project-basis, which increases the final costs. Therefore, significant progress regarding BIPV systems qualification is still key to support cost reduction and market development. Several related initiatives such as the IEA PVPS Task 15, "Enabling framework for BIPV acceleration" [5], or the new IEC Technical Committee 82 PT 63092 [6] are currently under way.

Developing new skills

Even with an increasingly favourable regulatory framework and technical solutions in place, a key factor in the deployment of BIPV systems remains the know-how of designers and installers at the end of the value chain. Specific efforts are needed at different levels to make integrated solar energy a standard practice in the construction sector.

Architects need to be familiar with up-to-date solar architecture concepts and associated benefits in terms of indoor comfort and energy savings, as well as with the possibilities offered by the broad range of BIPV products available on the market. Initiatives are ongoing to make this knowledge and skills part of the main curriculum in the education of building designers. For instance, the European project Dem4BIPV [7] is developing a course to be implemented in a number of leading universities.

New building design practices also require adapted tools. The advent of Building Information Modeling (BIM) as the new paradigm for the conception of construction projects is a significant breakthrough in this direction. BIM platforms allow building designers to integrate BIPV elements from the very early conceptual

Credit: CADCAMation

Figure 7. Visualisation of a BIPV project with the PVSITES software tool (CADCAMation). The user is guided through the different project steps, from the computation of solar irradiance on all model surfaces to the system's economic assessment

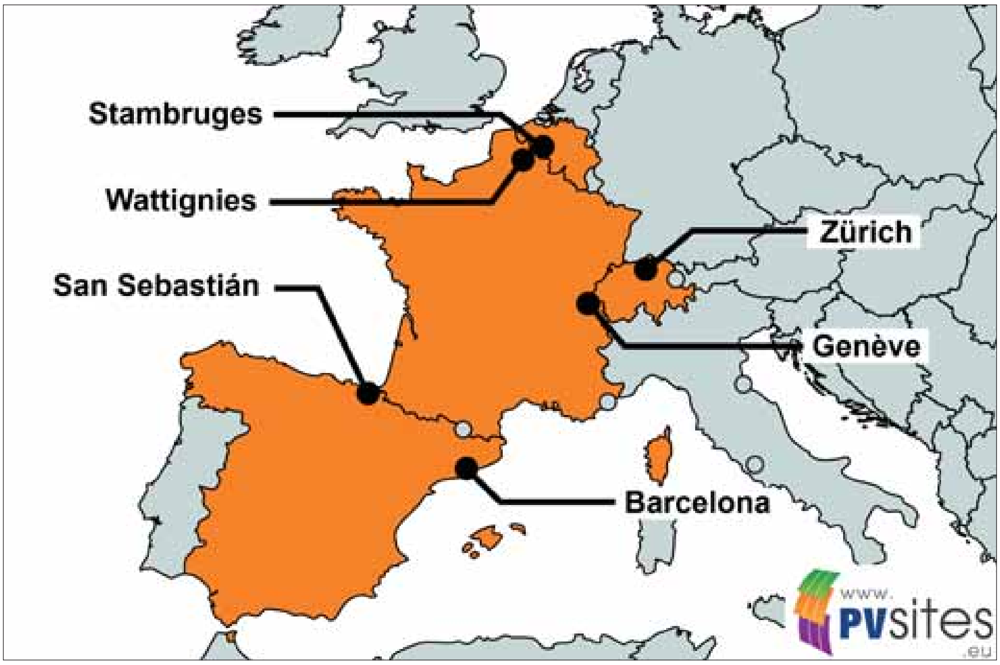


Figure 8. Location of the main PVSITES demonstration sites. Training courses for installers and guided visits will be organised in local languages in late 2018 and early 2019

stage and to simulate their effects in terms of electricity production, light transmission and thermal performance. To this effect, a user-friendly and BIM-compatible tool allowing designers to model and assess BIPV installations is being developed by PVSITES partner CADCAMation, as illustrated in Figure 7. Early versions of the software can be downloaded for free on the project website [2].

Lastly, the large-scale deployment of BIPV is entirely dependent on the availability of a skilled workforce of installers. Installers of traditional PV systems are already qualified regarding electrical aspects of BIPV systems, but typically lack experience regarding constructive aspects (structural assembly, thermal insulation, and air and water tightness). Conversely, roofing, façade and glazing professionals are fully qualified regarding constructive aspects of BIPV but may lack the necessary electrical know-how. There is therefore a need to train expert BIPV installers with knowledge in both trades. As a pilot action, PVSITES partners will organise free half-day practical training sessions at the demonstration sites in Spain, France, Belgium and Switzerland during autumn 2018 (see Figure 8). Information and registration will be made available through the project website [2].

Outlook for BIPV

Building-integrated photovoltaics is reaching commercial maturity, with the availability of a large diversity of reliable products and a steady reduction in costs. But despite being boosted by a favourable regulatory context, the large-scale implementation of BIPV systems in Europe still requires a number of obstacles to be overcome. Besides costs, these are currently mostly related to standardisation issues and to the slow spreading of new practices amongst construction professionals. Overall, the photovoltaic and building sectors need to work closer together to accelerate the deployment of BIPV in the near-future.

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Turn to p.58 to learn more about BIPV system modelling

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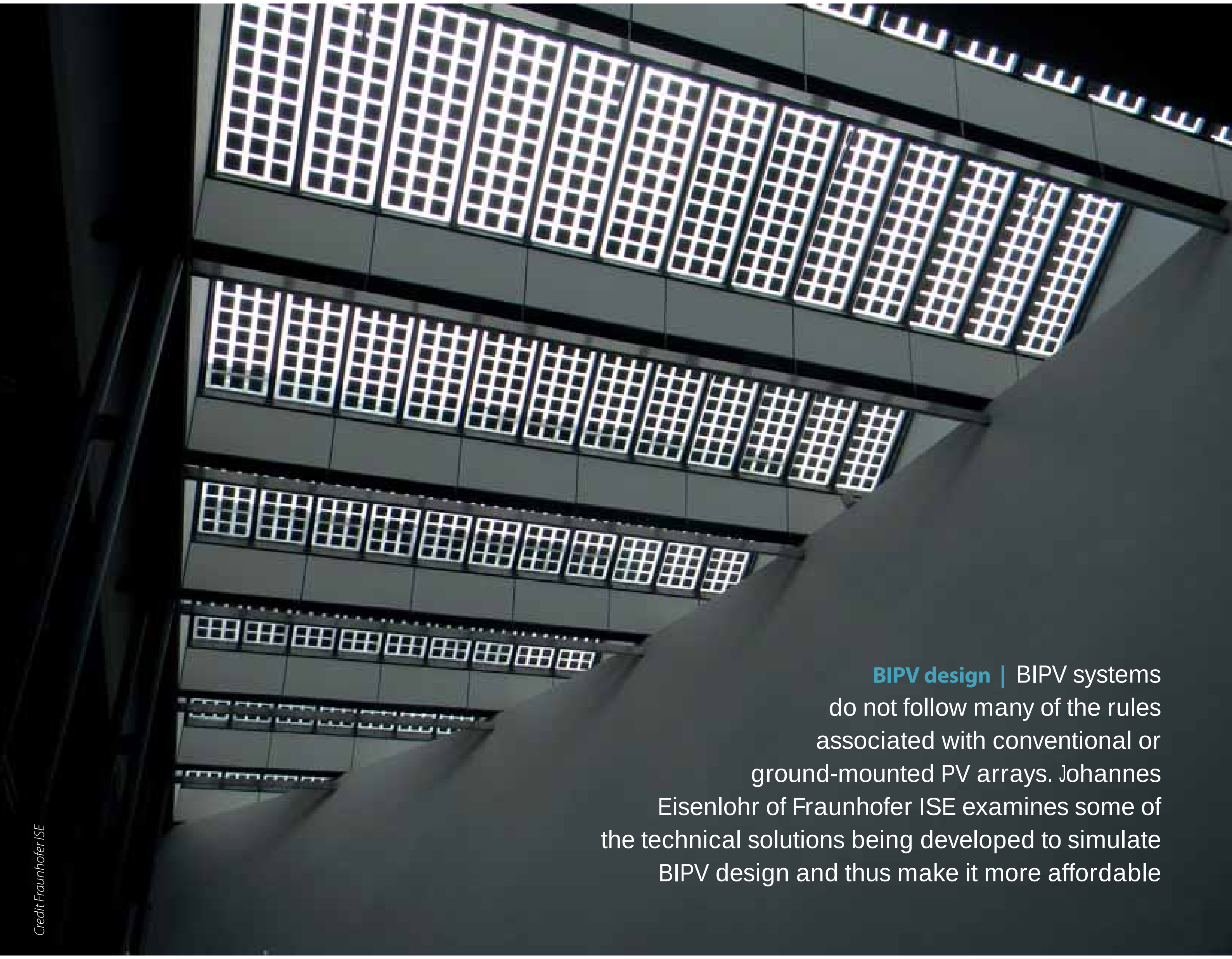
Detailed yield analysis and optimisation of BIPV systems by simulation



BIPV design | BIPV systems do not follow many of the rules associated with conventional or ground-mounted PV arrays. Johannes Eisenlohr of Fraunhofer ISE examines some of the technical solutions being developed to simulate BIPV design and thus make it more affordable

Figure 1. BIVP system in the atrium of Fraunhofer ISE main building with semitransparent glass-glass-modules as an example of one specific form of BIPV. Other BIPV systems look completely different and have different requirements

A significant amount of the global energy consumption is caused in and by buildings. In Germany, for example, the building stock is responsible for 35-40 % of the final energy consumption. Generating electric power directly on site is one promising approach to realise buildings with a low net consumption and consequently low CO2 emissions. Due to the massive price reduction over the last decade, PV became an obvious choice to generate renewable energy directly at the building level. In many cases, it is economically beneficial for building owners to harvest the energy the sun sends to their building skin.

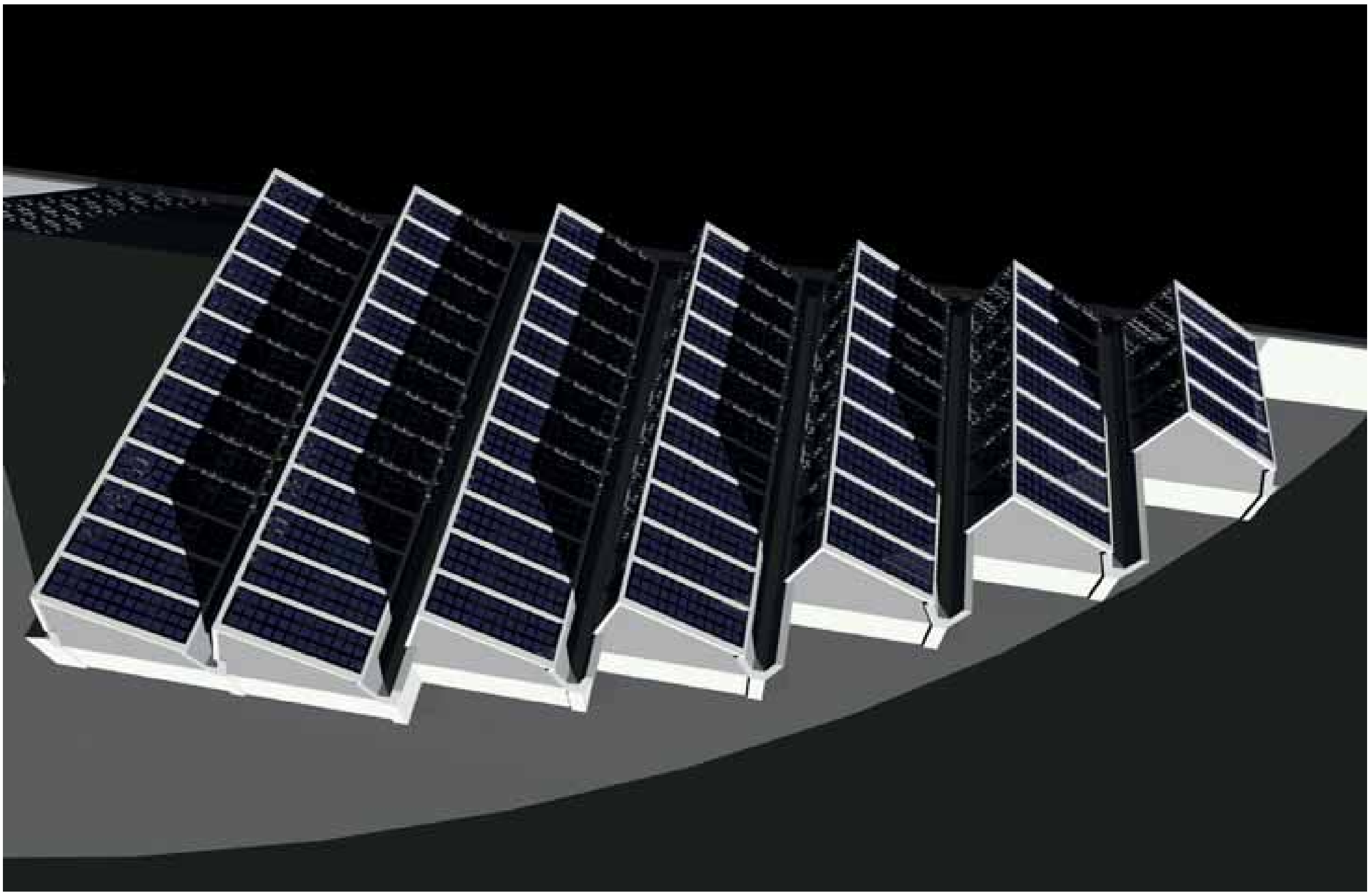


Figure 2. A rendered image of the BIPV system shown in Fig. 1 based on a RADIANCE model. Partial shading of the system at this specific time step is clearly visible [3]

While for small single-family houses, the roof area is often large enough to cover a significant share of the energy demand, for higher buildings also the façade gains in importance. Either way, on the roof or in the façade, active PV-elements can replace conventional building materials and fulfill conventional functions of the building skin, in addition to the PV functionality. So from the perspective of a single building, BIPV is a promising approach. But there is another perspective: For overall renewable energy systems, we need large areas for PV. Especially in densely populated regions, the area available on buildings can contribute a significant share to that. According to recent studies in Germany [1], the available technical and even economic potential on building skins exceeds the area required for PV in a 100% renewable energy scenario by far.

One of the challenges to overcome on the path to more BIPV in the market is to handle the complex planning process. If you look at many different BIPV projects, you will notice that each one is different and unique. Most obvious, the geometric situation of each building and its surroundings is different, which leads to different and often inhomogeneous irradiance levels. The degree of standardisation, which massively contributed to the success of conventional PV in the last decade, is significantly lower for BIPV. This makes also each planning process unique and complex. The following article will give a short overview of what has to be considered in such a planning process to result in an efficiently and safely working BIPV system, in the end focusing on a simulation-based approach.

What is important for planning and simulating BIPV systems?

Before focusing on BIPV simulations, it is essential to keep in mind that BIPV components are multifunctional building elements, where the PV functionality is only one amongst many. From mechanical resistance over safety in case of fire to aesthetic demands, there are lots of further aspects to consider and requirements to fulfill. The European standard EN50583 [2] provides the normative framework for BIPV – including the PV functionality as well as all other building-related requirements. The standard is divided into two levels: modules and systems. For both levels, different mounting categories are defined. BIPV can be roof- or façade-integrated and accessible from the inside or externally mounted. Corresponding to the category, a different set of standards applies. On the basis of EN50583, an IEC standard is currently in preparation (IEC TC 82 PT 63092). Everybody who realises a BIPV system should consider this normative framework.

Beyond the multifunctionality, the electrical system design is a challenging task for BIPV. While for the design of PV systems in typical plant or rooftop configurations a lot of simple design rules and specialised software tools exist, the electrical system design for each BIPV system is different, complex and less standardised. To design a yield-optimised BIPV system, one has to understand the behaviour of each solar cell for all the operating conditions occurring in reality in advance. To approach such a detailed understanding, several aspects have to be considered. We presented a BIPV simulation tool suite elsewhere [3–5], which covers all the following aspects, and at some points I refer to this tool suite. The five main aspects are summarised in Figure 3.

Irradiance (1)

Investigating the irradiance situation for a planned BIPV system is the first step. Analysing the partial shading due to topography, neighbouring buildings, trees, features of the building itself or the mounting system is mandatory. There are simple tables or tools to calculate the annual irradiance on an area depending on the geographical position and the orientation and slope of the area. This can give a very first basis to decide if a BIPV system comes into consideration.

To plan and optimise a system, however, a more detailed analysis is required. As shading of single cells can have a strong influence on the performance of the complete system, a high spatial resolution is required. Via ray-tracing, the irradiance on each solar cell for each time step can be calculated. RADIANCE (www.radiance-online.org/), for example, is an open-source ray-tracing tool that can be used for this task. As input for such a ray-tracing calculation, the following data is required: the 3D-geometry of the building and the relevant surroundings, including the optical properties of the materials and meteorological data containing the direct and diffuse part of solar radiation. The meteorological data is used to generate a sky model, e.g. the one by Perez et al., that is used as light source in the ray-tracing calculation.

At the position of all solar cells, the irradiance is calculated, typically with a time resolution of 1-15 minutes. The hourly data often used for standard PV installations do not reveal all partial shading effects. The shadow of a simple antenna, for example, can move over many cells during one hour, which would not be covered by hourly calculations. The time-resolved irradiance data can already be used to identify suitable strings and sub-systems or to narrow down the needs for power electronics. Already at this level, it is possible to get an impression of whether one large inverter, several small inverters or module level power electronics like DC-DC power optimisers might be suitable. Figure 2 shows an exemplary 3D-model of the BIPV system installed in the atrium of Fraunhofer ISE.

Temperature (2)

The second aspect to investigate is the temperature of all solar cells for each time step. The temperature is relevant for two reasons: First, maximum and minimum temperatures as well as quick changes are important for all materials in a BIPV module. Especially encapsulant materials might only be suitable for certain temperature ranges. As BIPV systems quite often are weakly ventilated, higher temperatures can occur. Second, the efficiency of solar cells depends on temperature. For crystalline silicon solar cells, typical relative temperature coefficients are about -0.3%/K. Depending on the ambient air temperature, the irradiance, the layer structure of the module and its mounting, the temperature can be calculated. There is a variety of methods; a good overview is given, for example, in [6]. Some models also take into account the wind speed, but the actual wind speed at building surfaces can vary strongly over short distances and, thus, is an input parameter difficult to determine precisely.

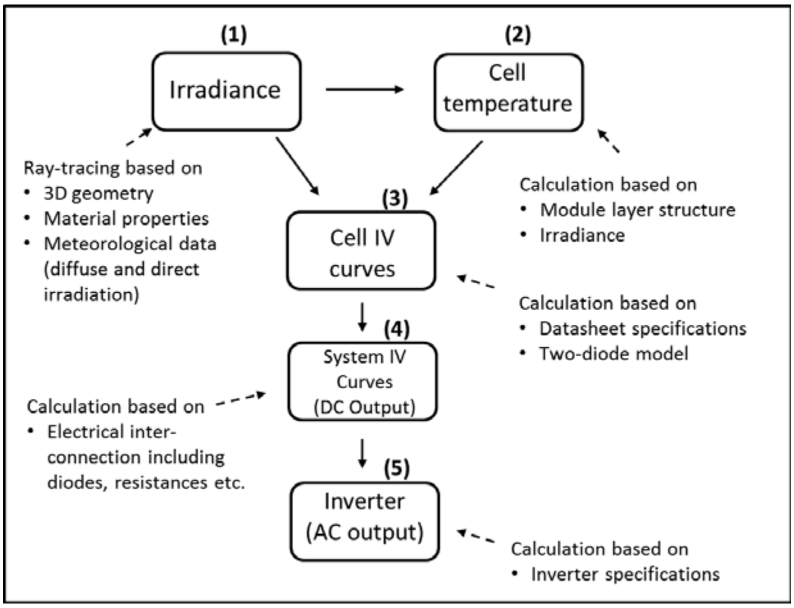


Figure 3. Summary of the five main steps of a detailed BIPV simulation with the major input required.

Electrical model of individual solar cells (3)

To understand a complete BIPV system, an equivalent circuit model of the individual solar cell is needed. In these models, the electric behaviour of a PV cell is represented by an equivalent circuit consisting of one or more diodes, series and shunt resistance. The simplest version would be the ideal single diode model with only three parameters: photocurrent I_{pv}, saturation current I_0 and ideality factor a. However, the practical relevance of the ideal single diode model is low, as at least an additional series resistance has to be considered to describe a real device. Therefore, the single diode R_s-model, also known as four-parameter model, has been introduced [7]. Adding also a parallel shunt resistance leads to the single diode R_p-model, also known as five-parameter model (e.g. [8]). All single diode models inherently neglect the recombination losses in the depletion region. These can be included by extending the equivalent circuit by an additional diode leading to the two-diode model with two additional parameters: saturation current I_{02} and ideality factor a_2 of the second diode. With these seven parameters, the two-diode model gets computationally demanding, but also results in a high accuracy especially at low irradiance conditions, which often occur in the case of BIPV.

For all equivalent circuit models, a precise extraction of the parameters from typically available data sheet information or IV measurements can be challenging and a lot of algorithms have been presented. A good overview about equivalent circuit models and corresponding algorithms can be found in [9]. With an equivalent circuit model, the electrical behaviour under all operating conditions (irradiance and temperature) can be predicted. Note that the diode models originate from the description of a solar cell as a plane pn-junction of differently doped semiconductor layers and their validity for different cell technologies has to be rechecked. Furthermore, the reverse bias behavior has to be modeled. Especially the breakdown voltage is important to understand the systems behavior in the next step when partial shading occurs. An equivalent circuit model can be set up for a complete module, but as already mentioned in (1), it is required to understand the system not only on module level, but on cell level. Thus, the parameters should be extracted for each individual solar cell.

Electrical model of interconnected cells and modules (4)

Knowing the irradiance, temperature and the equivalent circuit model of each solar cell for each time step, everything can be combined according to the electrical interconnection of cells. Additionally, bypass diodes have to be included in this step, as they play a key role when some of the cells in the system are shaded and delivering a lower current. Series and/or parallel interconnections have to be considered and all IV curves have to be added up according to Kirchhoff's laws resulting in an IV-curve of the complete (sub-) system that will be connected to power electronics components, typically an inverter. Also DC-DC power optimisers can be applied to BIPV systems to attenuate the losses due to partial shading. We recently extended the BIPV simulation framework at Fraunhofer ISE for optimisers. There are optimisers with different typologies and control strategies. Either buck- or buck-boost-converters are typically used. Depending on the actual optimiser used, this step (4) has to be adjusted. The MPP-tracking has to be performed for each unit connected to a power optimiser (typically a single module) and the output of these units has to be connected according to the control strategy of the optimiser system. As DC-DC power optimisers also lead to some additional conversion losses, the benefits have to be quantified for each specific system and balanced with the losses. Besides the system IV curve, in this step also the operation points of all individual components of the electric circuit can be checked. Especially the question of whether are cells in the systems that are strongly reverse-biased at certain time steps should be answered due to the risk of hot spots.

Step (4) is the central step of the BIPV simulation and allows for a detailed optimisation. The use of bypass diodes, the connection to strings and the division into sub-systems can be varied here and optimised with respect to yield maximisation and a fail-safe operation. As BIPV modules and systems are customised very often, the simulation tool in this step needs to be very flexible and should not only be able to handle standard PV modules with 60 cells and three bypass diodes.

Electrical model of inverter (5)

Finally, an electric model for the inverter is needed. Depending on the DC output of the system and the inverter data sheet specifications, the AC output can be calculated. We use a parametric model for the inverter according to [10]. In the first part of this step, the MPP tracking can be performed (if not already done in step (4) in case of DC-DC-optimisers) and in the second step the inverter model applied resulting in the time-resolved AC output of the BIPV system. Step (5) allows for choosing a suitable inverter or combination of inverters for a specific system. As low irradiance conditions occur more often in BIPV applications, the inverter layout might differ from the simple rules well-known for standard PV applications.

From BIM to BIPV

The detailed simulation steps (1) to (5) require a detailed input. Results can only be reliable and precise if the input is correct. The input described above has to be collected from various sources, and for different projects, it might be available in a different structure and different formats. As Building Information Modelling (BIM) is more and more used in the construction industry, a direct and automated link from a BIM model to a BIPV simulation is a promising approach. Collecting all the input data by hand is time consuming and error-prone. It makes detailed BIPV planning processes expensive. If there is already a 3D model of the building and its surroundings, it is obvious to use this model for the irradiance calculation in step (1). Therefore, a colleague at Fraunhofer ISE developed a tool that filters and wraps IFC data to RADIANCE files. IFC (Industry Foundation Classes) is a neutral data format to describe, exchange and share information related to buildings, including the 3D geometry.

Also product-related data like the electrical cell properties for step (3) or the inverter properties for step (5) could be automatically extracted from digital product databases instead of transferring information of PDF data sheets manually. This, however, requires flexible and parametric product data modules, as BIPV modules are not only available in one specific size and layout. We are working on the holistic integration of BIPV components into construction processes in the project SolConPro [11][12]. Also other research projects like PVSites (www.pvsites.eu) aim at the connection of BIM to BIPV modelling. Including BIPV into BIM offers many further advantages for the whole lifecycle, not only for the planning stage but also for operation and maintenance until deconstruction.

Conclusion

With a detailed simulation like the one described above in the steps (1) to (5) and a flexible and versatile link from BIM to BIPV, BIPV can become cheaper, more efficient and more reliable. It can be ensured that BIPV systems work safely and contribute a significant share to energy-efficient and CO2-neutral buildings.

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Investigating the impacts of floating solar on the water environment

Floating PV | Despite the growing popularity of floating solar installations, relatively little is known about their environmental impacts on water bodies. Ian Jones and Alona Armstrong are leading a research progamme to understand more about how the environmental benefits of floating PV can be harnessed and the downsides minimised

Credit Lightsource

We are aware that as energy needs escalate alongside the simultaneous pressure to de-carbonise supply, the world has increasingly been exploring alternative means of low carbon electricity production. This has led to fast-paced deployment of solar photovoltaics (PV), a large proportion of which has been ground-mounted. Land, however, is useful for many things, so ground-mounted PV systems need to compete against economic gains which could be generated by other land-uses. The Far Niente Winery in California, for example, realised that deploying solar panels on their land would displace vines, resulting in a revenue loss of US$150,000 annually [1]. They hit on the idea that the pond on their land was a fallow area of no use for growing vines, but which could, nevertheless, be used for electricity production by using floating solar panels.

Thus, the first commercial 'floatovoltaic' array was deployed. From this expedient beginning floatovoltaic deployments have gathered pace across the world. Capacity doubled from 2016 to 2017, and now exceeds 198MW world-wide, with individual installation capacities of up to tens of MW [2]. Floatovoltaics have been deployed in several countries, not only in sunny locations such as arid California, but also in temperate regions such as the cloudy, drizzle-soaked, north-west of England.

The deployment of a floatovoltaic system in the north-west of England stimulated us, scientists at Lancaster University and at the Centre for Ecology & Hydrology, to think whether there were other impacts to floatovoltaics beyond the direct benefits of low carbon energy provision and averted land-use change. In terms of energy system benefits, judicious siting of deployments can enable electricity production to be co-located with demand, such as at reservoir water treatment plants. Similarly, co-locating on hydroelectric power reservoirs would enable the use of the same grid connection, potentially enabling a better power curve [3, 4]. There are efficiency benefits to floating PV panels on water too, as the cooler environment of the water surface increases electricity production [3]. What, though, would the impacts be on the water body itself?

Understanding any beneficial or detrimental environmental impacts is crucial as water bodies are vital ecosystems and provide many essential goods, for example drinking water, and services, such as playing a role in the global carbon cycle, on which societies rely for their financial prosperity and wellbeing. Placing floatovoltaics on water bodies may alter fundamental physical, chemical and biological properties and processes. Installation, for example, effectively puts a lid on the water body and will, therefore, inhibit evaporation of the water, making floatovoltaics particularly attractive in regions of restricted water availability. Other effects could include changes to water temperature, nutrient concentrations and algal populations.

Research is underway to understand more about the positive and negative environmental impacts of floating PV

The significant uncertainty associated with the likelihood and extent of beneficial and detrimental water quality effects gives pause for thought, lest an unwanted impact proves more economically or environmentally costly than the benefits gained. A full understanding of the ramifications of deployment on the water body could, though, enable promotion of a range of costless additional benefits. Currently, little research has been carried out on the impact of floatovoltaics to the water environment, prompting the need for researchers, regulators and industry to collaborate to develop industry standards

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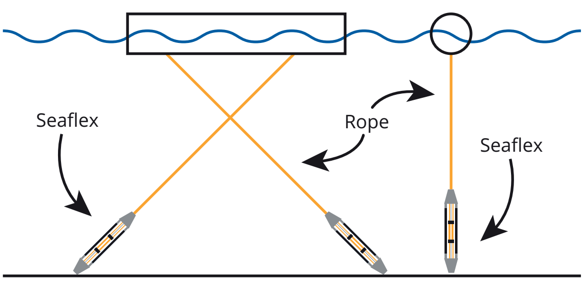

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Why are water bodies important?

Water bodies – lakes, ponds and reservoirs – are hugely interesting, ever-changing parts of our planet, with every one unique. For many people, a water body is just a water body; a feature in the landscape. Water bodies are, though, much, much more, providing public goods and services with resulting economic benefits. They provide drinking water, a fundamental need for our existence. In many places fisheries on water bodies are key sources of food. Some water bodies are used for electricity or heat production through hydroelectric schemes or heat pumps. Others contribute to flood control. Many are go-to places for recreation and have considerable economic potential to the tourist industry. They are inspirations for swathes of artists and poets such as Wordsworth and Coleridge who drew on the natural beauty of the English Lake District to create lasting pieces of verse. They are a source of biodiversity containing countless types of fish, macroinvertebrates, zooplankton, phytoplankton, macrophytes, bacteria and more. A lesser known service that water bodies supply, of particular relevance to those interested in low carbon electricity production, is climate change regulation through processing of the carbon which enters a lake from inflowing streams or from the atmosphere. In order for this vast array of benefits from water bodies to be realised it is of critical importance that we understand the changes that the deployment of floatovoltaics could impose on our water bodies.

Will floatovoltaics be good or bad for the water environment?

Simply put, we do not know, but we do need to know. The technology is so recent and the deployments so new that very little research work has been carried out. That said, research starts with theory and it is possible to hypothesise how floatovoltaics might influence the functioning of the water body and the benefits that it provides to society (Figure 1). As a water body is heavily influenced by the weather at the surface we can be confident that interfering with the air-water interface (as deploying a floatovoltaic would do) will have a large impact on the water body, and the greater the proportion of surface covered, the greater the influence.

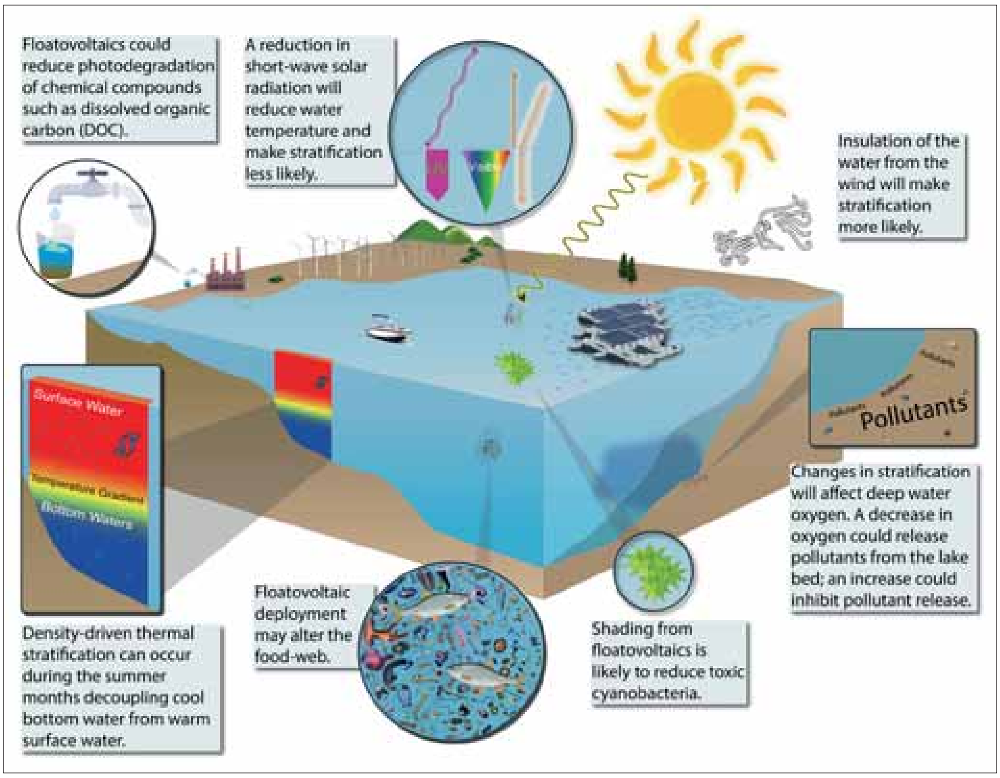

Figure 1. Schematic diagram of the range of impacts floatovoltaics may have on the water body. Figure courtesy of Giles Exley, PhD student at Lancaster University and the Centre for Ecology & Hydrology

Understanding effects of floatovoltaics on water temperature, stratification, oxygen content and sunlight receipts is fundamental in determining the impacts on key environmental aspects such as water quality, species diversity and nutrient status. Water temperature, which affects the rate of many important chemical and biological processes, is determined by several surface processes by which water bodies are heated and cooled. These processes are surprisingly complex, each varying differently through the day, through the seasons and with the location of the water body. Wind speed, air temperature, humidity and cloud cover all play a role. We would, though, expect that the presence of floatovoltaics will generally reduce water body temperature, primarily by reducing the heating effect of the sun. This will slow the rate of many fundamental water body processes, such as productivity. To corroborate this and to determine the conditions in which this does or does not occur and the scale of effect, requires data collection and scientific analysis.

During colder periods of the year it is common for water bodies to have the same temperature throughout, enabling the water to freely circulate from top to bottom under the influence of the wind. For some water bodies, though, summertime heating leads to water nearer the surface warming substantially whilst the bottom waters remain cool, the accompanying density difference inhibiting vertical mixing of water. Arguably the extent to which this stratification occurs is even more important to the water body environment than the temperature itself. The depth of stratification, the strength of the variation in temperature with depth, and the duration of the stratification all significantly impact the way a water body functions. While the likely impact of floatovoltaics is to reduce the heat coming into a water body, and thereby make stratification less likely, the expected effect on the wind is to reduce mixing, making stratification more likely. Consequently, it is difficult a priori to unpick the net impact of floatovoltaics on stratification. Almost certainly the answer will also depend on other factors, such as where the water body is located, the size of the water body, and the percentage of floatovoltaic coverage on the water body, as all these influences will shift the odds for or against stratification becoming more or less likely.

When a water body stratifies, the top and bottom become very different as nutrients, microscopic algae, and gases, such as oxygen, can no longer be mixed. Oxygen plays a crucial role in the water body, entering from the atmosphere or through photosynthesis from algae and other aquatic plants near the surface and being consumed by biological and chemical activity. From an anthropogenic viewpoint, oxygen is good: the more of it that gets into the deep waters of a water body the better. Without oxygen, fish habitats will shrink, nutrients and heavy metals will be released from the bed sediment and more of the potent greenhouse gas, methane, will be produced. If floatovoltaic deployment leads to an increase in stratification and a reduction in oxygen at depth, the environmental consequences could be severe and costly. Conversely, if natural stratification is reduced, then floatovoltaics could provide the happy side-effect of offsetting some of the predicted unfavourable impacts of global warming on water bodies.

A further, predictable consequence of capping a reservoir with floatovoltaics will be the reduction in the wavelengths of sunlight which aquatic plants use to grow, particularly the microscopic phytoplankton which form the base of the food-web. If the primary concern is producing clear, clean water this could be a positive impact, but if there was more interest in food supply or biodiversity this could be a negative impact.

More subtly, but no less important, would be the different impact on the many varied types of phytoplankton. Typically toxic cyanobacteria thrive in warm, sunlit waters, so floatovoltaic deployment could be a neat way of reducing this costly environmental problem. Other types of phytoplankton, such as silica-rich diatoms, however, thrive in lower light and the associated cooler and well-mixed waters. Many of these diatoms are noted for their filamentous structure, useful for absorbing dwindling light but also capable of clogging up filters used on reservoir intakes, adding substantial costs to treatment. Currently, we do not know how floatovoltaic deployment would impact the phytoplankton community, so whether the costs of maintaining water quality after deployment, either through treatment processes or reservoir management, would go up or down remains an unknown. Where they are deployed and which designs are chosen will likely influence the net outcome on water quality and treatment costs as well as which water quality management strategies are most appropriate.

Floatovoltaics may alter the chemical composition of the water as sunlight can break down compounds such as dissolved organic carbon (DOC), a key concern for some water companies. By reducing the sunlight reaching the water, floatovoltaics may, therefore, inhibit a free service, with implications for water treatability and cost. Intriguingly, water bodies also play a part in the global carbon cycle and there are several ways in which floatovoltaics could impact how much carbon the water body stores and releases. Deployments may therefore alter the extent the water body contributes to, or mitigates, climate change. If floatovoltaic deployment can be undertaken in a way which leads to increases in water body storage of carbon rather than release, this would increase their appeal over other means of PV deployment.

How can the full environmental benefits of floatovoltaics be realised?

There remains enormous scope for choice in the deployment of floatovoltaics. How can they be deployed in a way which maximises the myriad potential benefits to the water body while simultaneously removing or minimising any disadvantages? How much of a water body should be covered? Where on the water body should they be put? What size of water body should they be deployed on? Which geographical locations are best? How should the floats and the PV panels be designed for maximum environmental benefit?

Questions such as these were raised at a recent floatovoltaic stakeholder workshop, and are the focus of preliminary research at Lancaster University and at the Centre for Ecology & Hydrology (Figure 1). Answering these questions is the key to understanding how floatovoltaics can be best deployed to increase any beneficial impacts and reduce any detrimental impacts. Demonstrating robust additional benefits beyond low carbon electricity provision will enhance opportunities and support business cases.

Fortunately, although the deployment of floatovoltaics is new, scientists have been studying water bodies for years and have developed numerous tools which will aid answering these questions. These range from the ability to deploy automated in situ sensors collecting data on unprecedented scales, to the development of computer models capable of simulating the water body environment.

The vast array of factors which are likely to affect exactly how floatovoltaic deployment impacts water bodies should be seen as a boon. The range of possible positive and negative environmental impacts means that there is much potential for optimising deployments for additive environmental benefits. Situations which could have net uneconomic or unpleasant environmental consequences can be avoided while those replete with additional environmental benefits can be identified. The key to unlocking this potential is the understanding which scientific research can provide; research which will have global relevance given the increasing number of countries investing in floatovoltaics.

The joint pressures of increasing energy usage, increasing pressure on land and the need to mitigate climate change are driving the desire for inventive and environmentally friendly solutions to electricity production to be found. Stakeholders in the community now have the opportunity to demonstrate how floatovoltaics can be one of these solutions. Researchers, regulators and industry share a common goal of developing industry standards which maximise the additional benefits of floatovoltaic deployment. The beauty or ugliness of floatovoltaics is all in the eye of the beholder, but whether they are good or bad for the water environment is within our gift to determine. ■

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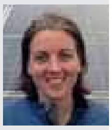

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Power rating and qualification of bifacial PV modules

Bifacial | The question of how to define, measure and rate the electrical output from bifacial modules is a hotly debated topic, given the extent to which the rear-side contribution is dependent on a range of variable factors relating to local environmental conditions and system configurations. Xiaoyu Zhang, Christos Monokroussos, Markus Schweiger and Matthias Heinze of TÜV Rheinland explore the power rating issue for bifacial devices, examining the definitions of rear irradiance, measurement test method, power stabilisation and verification for type approval

The global PV industry is experiencing a boom in bifacial PV modules. Coming with extra energy gain from the rear side, bifacial PV modules are finding themselves with versatile and promising application possibilities in many fields, from building-integrated photovoltaics to utility-scale power plants. These application advantages are reflected in the forecasts of bifacial technology development in the market: according to the recently released international technology roadmap for photovoltaics (ITRPV) 2017 results [1], the world market share of bifacial PV modules will steadily increase to about 35% by 2028. Compared with monofacial PV modules, energy yields of around 10% higher (or even more) from bifacial modules in the field have been consistently reported by various parties [2,3]. Such increases in yield can considerably reduce the levelised cost of energy.

Bifacial PV technology is not a new concept in the PV community. As early as 1966, a US patent regarding an n-type bifacial solar cell with a p^+np^+ structure was granted to a Japanese researcher [4]. Nowadays, passivated emitter rear totally diffused (PERT), passivated emitter rear cell (PERC) and heterojunction (HJT) are the three mainstream technologies for bifacial PV devices [5]. It is feasible to increase the competitiveness of PV manufacturers through a transformation from the production of traditional monofacial PV modules to bifacial ones with little additional cost.

The most important reference in setting the price of PV modules is still the power rating under *standard test conditions* (STC), defined as follows: a device temperature of 25ºC, and an incident irradiance of 1,000W/m^2 with the spectral distribution AM1.5G. This leads to the first technology-related problem of how to define, measure and rate the electrical output power of bifacial PV modules, taking into consideration the rear-side power contribution. These tasks also stir up heated arguments in the PV industry, because the rear-side irradiance is highly dependent on environmental factors and installation configurations. The fact is that the ground albedo, installation location, tilt angle, ground clearance, shading (including self-shading) and other elements can all affect the rear-side irradiance and energy yield of a bifacial PV module.

In response to the strong demand for an appropriate power rating method for bifacial PV modules, the international standard IEC 60904-1-2 has been proposed, which describes the test methods and additional requirements for the *I–V* characterisation. Since there is still no standard definition of rear irradiance under AM1.5G conditions, it is proposed that the measurement results for the bifacial device under test with a front irradiance of 1,000W/m^2, along with different levels of rear irradiance (namely 100W/m^2, 200W/m^2 and a third undefined level), be reported in accordance with the IEC standard [6]. Much as the standard is trying to give a solution for *I–V* measurement, the power rating issue for bifacial PV modules remains unresolved. The manufacturers and PV product buyers are confused by so many power results, and cannot find common ground on which the bifacial devices can be priced and on how the quality of different bifacial products can be evaluated and compared. To look into the power rating problem associated with bifacial PV devices, it helps to break it down into the following issues: 1) definition of rear irradiance; 2) test method of measurement; 3) power stabilisation; and 4)

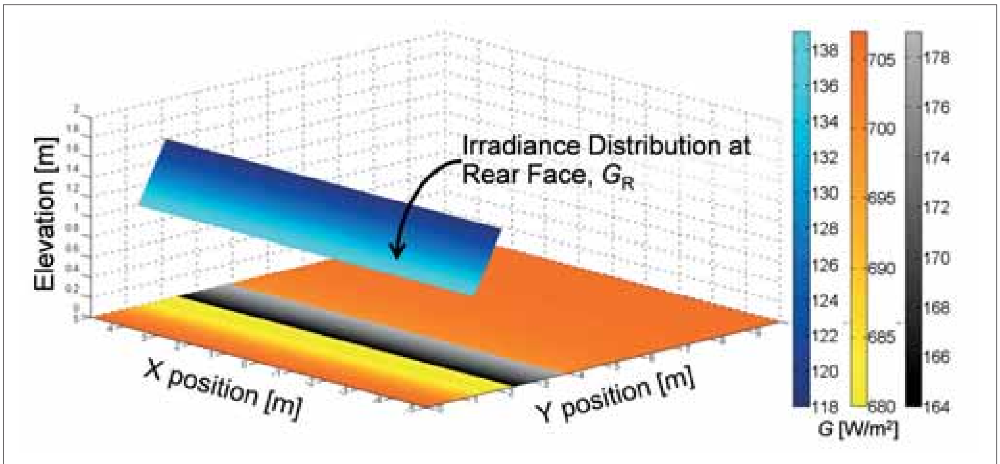

Figure 1. Irradiance distribution for a single-row bifacial PV array simulated in the conditions shown in Table 1, without taking into consideration the influence of the racks. The blue bar represents the distribution of irradiance G_R at the module's rear face (shown here facing the front). The orange and black bars represent horizontal ground irradiance: black signifies the area shaded by the modules, and orange the area which is not shaded

Modelled parameter	Bifacial reference condition
Air mass	1.5G
Beam and circumsolar irradiance	As defined in IEC 60904-3
Diffuse irradiance	As defined in IEC 60904-3 Isotropic diffuse
Ground albedo	Lambertian diffuse reflector Light sandy soil with spectral albedo as given in SMART
Inclination angle	37 degrees
Shading	PV array self-shading on the ground No near-object shading
Module transmittance	Spectral transmittance data for glass/EVA/glass and glass/POE/glass structures of bifacial modules

Table 1. Summary of the parameters used in the simulation.

Front irradiance	1,000W/m^2
Rear irradiance	135W/m^2
Equivalent irradiance	1,000W/m^2 + φ·135W/m^2
Module temperature	25°C
Angle of incidence	0 degrees
Irradiance spectrum	AM1.5G

Table 2. Parameter definitions for BSTC

verification for type approval.

The reliability and safety issues with bifacial PV modules come next in line. Because of the rear contribution to energy generation, bifacial PV modules in the field often operate at higher currents, which may impact the reliability of PV systems. In addition, to maximise the bifacial gain, special mounting designs for bifacial PV modules are often used to reduce the shading caused by racks. The test conditions for IEC 61215-2 and IEC 61730-2 may need to be modified accordingly in order to encompass the potential reliability and safety issues.

Definition of rear irradiance

From an objective standpoint, in-house computer coding has been developed by TÜV Rheinland to model and simulate the expected rear irradiance under the environmental conditions defined in IEC 60904-3, with additional ground clearance of the PV module (details in Table 1) [7]; the simulation results are presented in Fig. 1. The higher end of the PV array receives slightly less irradiance than the lower end when the bifacial modules are installed at a tilted angle of 37 degrees and with a ground clearance of 1m. According to TÜV Rheinland's simulation, the rear irradiance on the PV array varies in the range 118–138W/m^2 with a spatial non-uniformity of 7.8%, which is in good agreement with other published research [8]. This theoretical work has laid a solid foundation for bifacial standard test conditions and the TÜV Rheinland internal standard 2PfG 2645/11.17, which defines requirements for supplementary power rating and label verification of bifacial PV modules.

Bifacial standard test conditions (BSTC) are defined by a rear irradiance of 135W/m^2, corresponding to the 1m ground clearance of a bifacial module in the same environment as that specified in IEC 60904-3. The equivalent irradiance for bifacial PV devices can therefore be calculated using the formula (as shown in Table 2):

$$G_E = (1{,}000 + \varphi \cdot 135)\text{W/m}^2 \qquad (1)$$

where φ is the smaller of the two values of the bifaciality coefficients φ_{Isc} and φ_{Pmax} for I_{sc} and P_{max}. The benefits of BSTC are not only the compatibility with STC and IEC 60904-3, but also the direct comparability of the PV performance between bifacial and monofacial PV modules under the same conditions. Furthermore, the photovoltaic performance data under BSTC could provide useful information for PV installation and power plant design.

Test method of measurement

The TÜV Rheinland internal standard 2PfG 2645/11.17 allows both single-side illumination and double-side illumination test methods as defined in IEC 60904-1-2, although the single-side version is currently used in the TÜV Rheinland laboratories. Regardless of the stipulation of BSTC, the *I–V* measurement results with a rear irradiance (G_r) of 100W/m^2 and 200W/m^2 can also be provided as supplementary information in the test report. As shown in Fig. 2, the bifaciality is determined first by measuring the front and rear sides of a bifacial PV module separately under STC. Next, the bifacial module is measured again on just the front side with an equivalent irradiance (G_{Ei}), which is calculated using the equation:

$$G_{Ei} = 1{,}000\text{W/m}^2 + \varphi \cdot G_{ri} \qquad (2)$$

where $\varphi = \text{Min}(\varphi_{Isc}, \varphi_{Pmax})$ and G_{ri} = 135W/m^2, 100W/m^2, 200W/m^2, …

Power stabilisation

In accordance with IEC 61215-1,-1-1,-2 standards, PV modules should be electrically stabilised before any further measurement. As bifacial PV devices are mostly PERT, PERC and HJT technology based, issues such as light-induced degradation (LID) exist and should not be neglected.

LID is a phenomenon whereby PV modules undergo a performance and power degradation as a result of illumination exposure; this deterioration is related to various factors such as the cell technology, wafer quality and manufacturing processes [9]. Several degradation mechanisms have been reported: boron–oxygen complex activation (B-LID), for example, is the most commonly known LID mechanism in boron-doped Czochralski-grown c-Si devices, and has been under investigation since the 1970s [10]. Recently, light- and elevated-temperature-induced degradation (LeTID) was reported initially in rear-passivated mc-Si solar cells; it is more severe in PERC devices and can lead to an efficiency loss of up to 10% [11].

Most industrial crystalline silicon solar cells and modules suffer from some type of LID. A drop in power of even 1% could result in considerable energy and capital losses; an initial stabilisation is therefore essential in order to accurately specify the power rating for a bifacial PV device. However, whether both sides of a bifacial

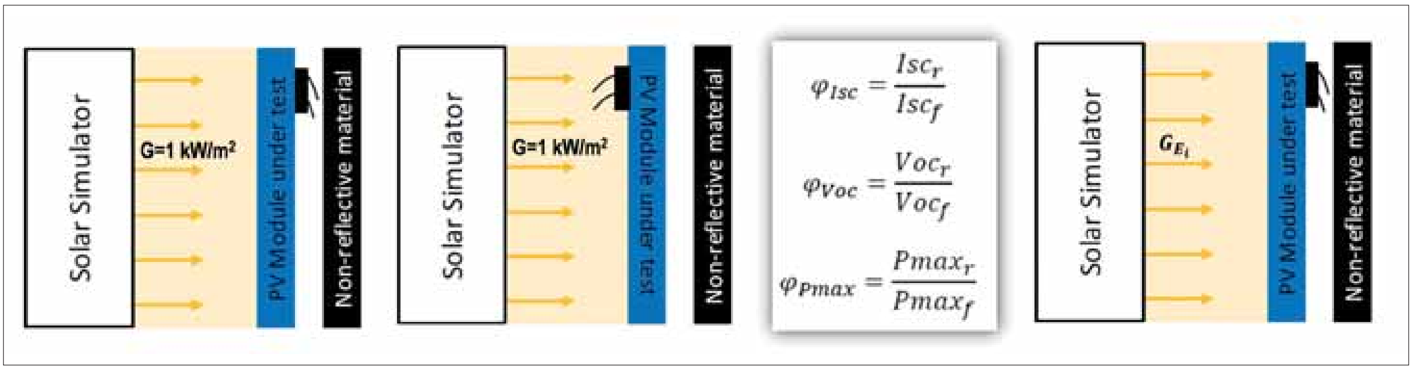

Figure 2. Schematic of the single-side illumination test method for bifacial PV modules

module need to fulfil the requirement of initial electrical stabilisation is still under investigation.

Verification for type approval

Variations in the bifaciality coefficients have been observed on the production lines of different bifacial PV technologies (see Fig. 3); therefore, the verification of rated values is necessary for the labelling of modules under BSTC. The TÜV Rheinland 2PfG 2645/11.17 standard establishes a label verification system for photovoltaic data under BSTC, with the same requirements for measured P_{max}, mean P_{max}, V_{oc} and I_{sc} as defined in IEC 61215-1:2016 [12]. An additional requirement of P_{max} under BSTC for the minimum power class is particularly enforced in order to guarantee the quality of PV modules, even at the lower end power class:

$$P_{\max(\mathrm{BSTC})}(\mathrm{Lab}) \cdot \left(1-\frac{|m_{1(\mathrm{BSTC})}|[\%]}{100}\right) \leq P_{\max(\mathrm{BSTC})}(\mathrm{NP}) \cdot \left(1+\frac{|t_{1(\mathrm{BSTC})}|[\%]}{100}\right) \quad (3)$$

where $m_{1(BSTC)}$ and $t_{1(BSTC)}$ are respectively the measurement uncertainty of the laboratory and the manufacturer's rated upper production tolerance for $P_{max(BSTC)}$ in per cent (NP = name plate).

Module reliability and qualification

Bifacial PV modules in the field are observed to continuously operate at higher currents than their monofacial counterparts because of the power contribution from the rear side. Higher currents can cause higher localised temperatures in PV modules, especially in areas where current crowding might occur; this may impact the reliability of PV systems, in particular with regard to solder bond fatigue and bypass diode endurance. Thus, the relevant test conditions in IEC 61215-2 and IEC 61730-2 should be modified in order to reflect the higher current flows observed for bifacial modules in the field.

Bifacial modules experience significantly higher total irradiances at higher albedos compared with monofacial samples, as highlighted in the modelling results (Fig. 4), under the conditions given in IEC 60904-3. The current stringency definition used in this work derives from irradiances corresponding to reflective ground conditions (1,300W/m² at 0.51 albedo). A rear irradiance of 300W/m² is considered to be a typical irradiance which represents the worst scenario in field operation. Thus, the affected test items in IEC 61215-2 and IEC 61730-2 are updated with additional requirements to account for the higher equivalent irradiance G_E = 1,000W/m² + φ·300W/m².

Table 3 lists the revised test conditions for bifacial PV modules, based on the original procedures for monofacial PV modules in the IEC standards. The applied currents, I_{mpp} or I_{sc}, are enhanced to their corresponding I_{mpp} or I_{sc} values under an irradiance of (1,000 + φ·300)W/m² in the temperature test (MST 21), thermal-cycling test (MQT 11/MST 51), hot-spot endurance test (MQT 09/MST 22) and bypass diode test (MQT 18/MST 25). As regards the current for the reverse-current overload test, it is recommended to use in the calculation the higher of:

- the module's overcurrent protection rating provided by the manufacturer;
- the maximum reverse current that could be reached ((n–1) × I_{sc}@G_E ×1.25, where n is the maximum allowable string number in parallel, and 1.25 is the safety factor).

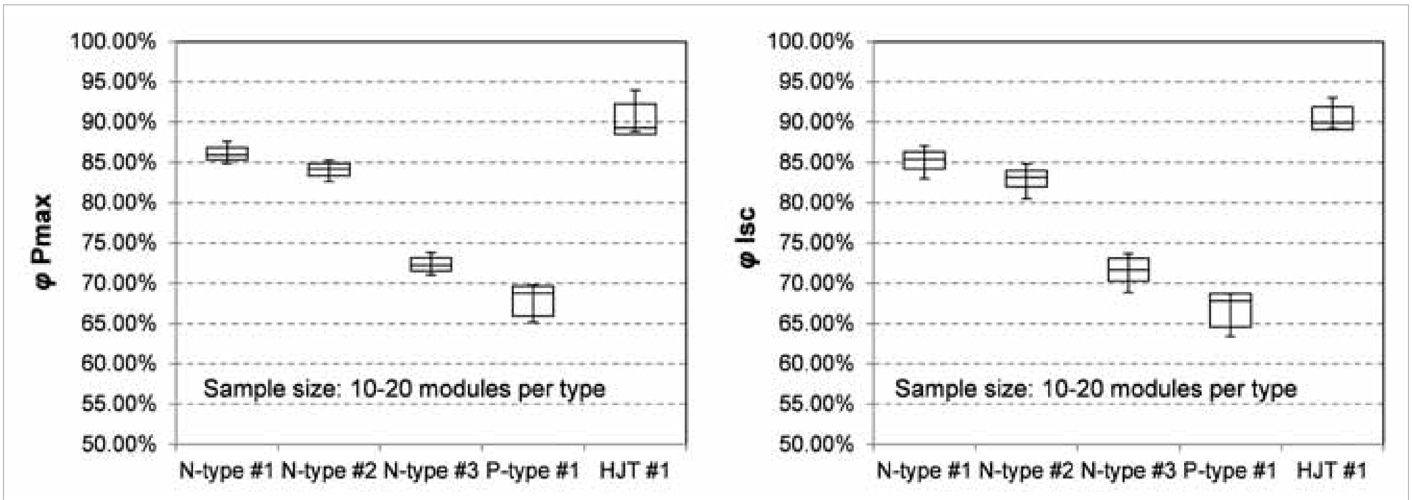

Figure 3. Variations in bifaciality coefficients (φ) of P_{max} and I_{sc}, evaluated by measuring modules in production from different manufacturers

Bespoke steel for world's largest solar power plant

German solar EPC firm Greencells has been active in the European PV market for a decade, but three years ago it set its sights on the global stage, including the Middle East, Africa, US and the APAC regions, and it has now introduced its own steel mounting product service. Ric Hallikeri, managing director of Middle East and Africa, discusses the firm's landmark achievements at the world's largest solar project.

What led you to initiate your offer of bespoke steel structures for fixed-tilt mounting?

Ric Hallikeri: We found we could have a lot more control over projects, because there are a lot of projects where you've got to be very tough on timelines and steel can be one of the tricky items. It was a good opportunity for us to vertically integrate our products as an EPC and bring in at least one part that we could control ourselves.

Steel price fluctuation is always going to happen, however it's more about having a competitive edge against other EPCs If we can save one cent on an EPC project that can make all the difference.

How was it providing services to perhaps the world's largest solar plant at Sweihan in Abu Dhabi?

RH: We are constructing 300MW of the 1,177MW and we have supplied the steel structure for the full 1,177MW. We have product coming from Switzerland as well as a small portion from India, so logistics and ensuring the supply was always on site intime for the installation was always at the forefront of our planning. Overall it has been a fantastic experience, we have learned a lot where it comes to clever design and using automotive industry led engineering.

What are your plans at Intersolar Europe this year?

RH: There are a lot of exciting changes happening at Greencells; we are now active in more far reaching areas of the globe. Project Development in emerging markets and being creative with solar hybrid solutions which really make a difference is a definite focus for the coming years.

Test	Monofacial PV	Bifacial PV
I_{mpp} applied → I_{mpp}@G_E		
MST 21 – Temperature	Near I_{mpp} applied during the test	Near I_{mpp}@G_E applied during the test
MQT 11 / MST 51 – Thermal cycling	I_{mpp} applied in sequences	I_{mpp}@G_E applied in sequences
MQT 09 / MST 22 – Hot-spot endurance	I_{mpp} applied while finding the hot-spot-sensitive cells and the shading rate	I_{mpp}@G_E applied while finding the hot-spot-sensitive cells and the shading rate
I_{sc} applied → I_{sc}@G_E		
MQT 18 / MST 25 – Bypass diode	Applied current: • I_{sc} for first hour • I_{sc} × 1.25 for second hour	Applied current: • I_{sc}@G_E for first hour • I_{sc}@G_E × 1.25 for second hour
Relevant test		
MST 26 – Reverse-current overload	Declared I_R by manufacturer × 1.35	To consider: (n–1) × I_{sc}@G_E × 1.25 × 1.35 (if this value is higher), where n is the maximum allowable number of strings in parallel

Table 3. Supplementary test conditions on relevant test items in IEC 61215-2 and IEC 61730-2 for bifacial PV modules (G_E = 1,000W/m² + φ·300W/m²). (As specified in IEC 61730-2, the applied reverse current shall be equal to 135% of the PV module's over-current rating, hence the factor 1.35.)

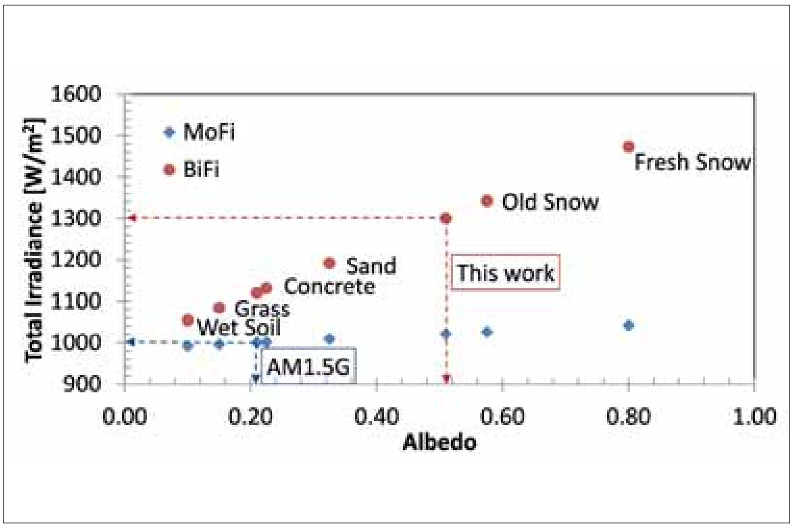

Figure 4. Analysis of the albedo sensitivity of total irradiance received by bifacial and monofacial PV modules. The simulation was carried out using the environmental conditions as defined in IEC 60904-3

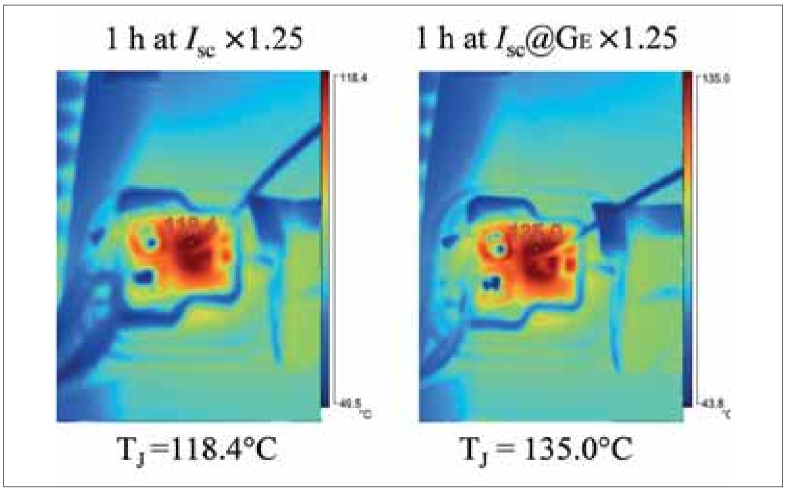

Figure 5. Example of elevated diode junction temperature observed by the TÜV Rheinland laboratory during the bypass diode thermal test with enhanced test current

The adapted test sequences for bifacial PV modules are undergoing a verification process in the laboratory at TÜV Rheinland to prepare the 2PfG standard regarding the reliability test for bifacial PV modules. Several module types from different manufacturers are being tested under the new test sequences; so far, no bifacial module failures in the above-mentioned tests have been encountered. The preliminary test results, however, have shown that module components, especially bypass diodes, can operate at 10–30°C higher temperatures with the enhanced test currents (Fig. 5), which could critically test the endurance of the materials involved. Other bifacial PV module failures in tests such as the module breakage test (MST 32) have been observed; these failures were mainly caused by the particular mounting design without supporting bars at the back (see Fig. 6). For safety reasons, this type of failure warrants more attention from constructors and end-users.

Another issue regarding the reliability of bifacial PV modules is potential-induced degradation (PID). In the field, PV modules are connected together in the form of a string to achieve a certain high voltage; at the same time, this string needs to be grounded for safety reasons. As a consequence, modules at either end of a string suffer from large electrical potential stresses between the frame and the solar cells, which can lead to severe performance degradation, referred to as *PID*. For crystalline silicon PV modules, there are two common *PID* mechanisms. The first of these is known as Na^+ *migration* in the high electric field between the

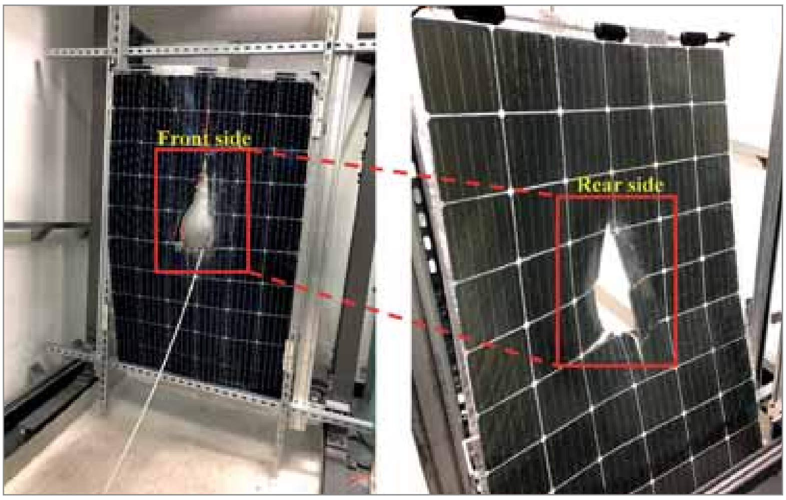

Figure 6. Examples of module breakage test failures of bifacial PV modules observed at the TÜV Rheinland laboratory

glass and the solar cell, which results in significant shunts; these *PID* shunts are often observed in p-type c-Si technologies. As regards n-type c-Si PV technologies, *surface polarisation*, the second PID mechanism, can be mainly responsible for the increased surface recombination and power drop [13].

IEC TS 62804-1:2015 provides indoor test methods for the detection of PID. The modules can be tested with a high voltage, either in damp heat using a climate chamber for 96h, or by contacting the surfaces with a conductive electrode for 168h. The test requires four representative and identical samples, two for the positive voltage bias test and two for the negative voltage bias test [14]. Thus, IEC TS 62804-1:2015 is currently capable of handling the PID test for bifacial PV modules.

Summary

Driven by the strong demand for reducing the levelised cost of energy, the market share of bifacial PV modules has increased rapidly in recent years because of the extra energy gain contributed by the rear side. The complexity of the technical problems with bifacial PV modules requires modifications and updates in respect of the current power rating and qualification standards. TÜV Rheinland has published its internal standard 2PfG 2645/11.17, which addresses the power rating issue for bifacial modules; it defines BSTC with a front-side irradiance of 1,000W/m^2 and a rear-side irradiance of 135W/m^2 in accordance with the 1m ground clearance for bifacial modules in the same environment as defined in IEC 60904-3.

Supplementary reliability tests are proposed, with enhanced test conditions reflecting the worst scenario in field operation, for which a rear irradiance of 300W/m^2 is chosen. Laboratory verification is ongoing at TÜV Rheinland; the internal standard 2PfG concerning the reliability and safety tests in liaison with IEC 61215-2 and IEC 61730-2 will soon be published to assure the quality of bifacial PV modules for better and safer operation. ■

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Tracker technology continues to advance as applications diversify

Balance of system | The worldwide market for trackers is developing rapidly and so too are the technologies they use. Mark Osborne reports on some of the latest design innovatoins that are helping drive trackers into new markets and applications

Credit: Array Technologies

PV tracker technology and designs have advanced in recent years, notably with the increasing adoption of the technology for utility-scale PV power plants. Further market penetration of tracker systems, notably single-axis trackers is expected in 2018.

However, innovation in tracker design is not being dictated by cost reduction strategies alone; emerging markets and new solar cell technologies such as bifacial, which promise higher yields than conventional monofacial modules, are demanding attention and provide tracker manufacturers with new market opportunities.

According to a new report from market research firm GTM Research, the solar tracker systems market in 2017 increased by 32% to a record 14.5GW, while global PV installations reached around 98GW in 2017, dominated by China, which installed over 53GW. GTM Research noted that the rapid pace of solar installations in Mexico and Brazil were behind the region beating the US for PV power plants using trackers as both countries deployed over 1.5GW of tracking systems in 2017.

Scott Moskowitz, senior analyst at GTM Research and author of the study said: "Mexico and Brazil are two of the fastest growing solar markets in the world, each accounting for over 1.5 gigawatts of tracker shipments in 2017. The US utility-scale market was significantly stunted last year due to tariff uncertainty, so it took a backseat to Latin America."

Innovation in tracker design is helping the technology reach new markets and applications

NEXTracker, which has manufacturing facilities in Brazil and Mexico, solidified its market share leadership, accounting for 33% of all trackers installed, with its nearest rival, Array Technologies accounting for 14% of installations.

The leadership position held by NEXTracker was further highlighted by the fact that after Array Technologies none of the other top 10 ranked tracker suppliers came close to a 10% market share, according to GTM Research.

"Fundamentals in the global utility-scale solar industry are excellent, and trackers are an obvious choice in most developing solar markets," added Moskowitz. "We expect 30% growth in 2018, with shipments approaching 20GW."

Tracker benefits and developments

One of the key drivers in the adoption of trackers in markets such as Mexico and Brazil has been the competitive project auctions that have created the need to maximise internal rate of return (IRR), while reducing the levelised cost of electricity (LCOE) to make projects in these countries viable to develop.

The adoption of tracker systems over fixed-mount systems seems to be in contradiction to LCOE and IRR metrics, yet the high irradiance allows PV modules to reach their highest potential output (yield) with single-axis trackers that is around 20% higher than when using fixed mounting.

In 2017, an independent study by TÜV Rheinland on Array Technologies's flagship tracker, the 'DuraTrack' HZ v3, was reported to have delivered US$0.04/WDC higher Net Present Value (NPV) and 6.7% lower LCOE, driven by 37% lower lifetime O&M


Credit: Soltec

Soltec has innovated in the supply logistics of its tracker products

costs to a typical PV power plant project.

It also deserves mentioning that the project of MecaSolar in Kortuteli, Antalya Turkey (4.6MWp with Hyperion-MR trackers) rated 1,962.34kWh/kWp in 2017, almost 7% higher than the expected figures and an estimated extra 22% yield compared to a fixed mounting structure.

However, the electricity output gain from using trackers in high irradiance regions is not the only consideration. In regions such as the northern Chile's Atacama Desert, access to remote areas and the scale of projects being developed can have a key bearing on tracker selection.

A good example was the recent supply win by single-axis solar tracker firm, Soltec that used its horizontal independent-row tracker 'SF Utility' on four different plants totalling around 46MW in the Atacama Desert as the tracker design is not only supply chain friendly but Soltec has innovated in the logistics of tracker supply.

The projects were said to have benefited from Soltec's 'Solhub' warehousing and logistics system that supplies unitised tracker components on site following the 'just-in-time' methodology without intermediary handling companies, and minimal additional on-site material handling. Soltec's stock inventory and shipping activity from five factory warehouse facilities across the globe are synchronised with regional operations and project schedules with the least on-site handling.

According to GTM Research Soltec, had an 8% global market share during 2017 with 1,097MW of trackers shipped. The company had stated that a key reason for its success was down to its SF7 tracker, which it claimed solved more project challenges with a set of standard features honed over years of field experience "to make shorter work of development and execution phases across variable situations and conditions".

The competitive tracker business landscape is not only leading to continued innovation in tracker design to reduce costs; new features are also being developed aimed at boosting system performance, a factor that becomes increasingly important when projects can incur lower than desired output due to losses from issues such as plant construction variabilities and terrain undulation as well as highly variable environmental conditions where plants can be sited.

In mid-2017, leading tracker firm NEXTracker launched its self-adjusting tracker control system for solar power plants. Its 'TrueCapture' technology is said to continuously refine the tracking algorithm of each individual solar array in direct response to existing site and weather conditions. As a result the company claimed that the technology delivering a 2-6% energy gain.

NEXTracker's also recently developed SCADA (Supervisory Control and Data Acquisition) system, which communicates bi-directionally with Flex's cyber-secure SmartNexus platform, accelerating tracker system commissioning by automating the tracker configuration steps.

The company highlighted recently that Enel Green Power's 754MW plant, located in Torreón, Mexico, achieved on-time delivery of 26,000 piers and 1,624 miles of torque tubes, enabling EPC firm, Swinerton to install at a rate of 100MW per-month.

The plant was said to have been able to start generating and selling electricity in December 2017, nine months ahead of schedule as each individual row could be commissioned sequentially as the project progressed.

Bifacial modules

Aside from the innovations tracker companies are driving themselves, technological developments in other parts of the industry are also keep them busy. One of these is in the emergence of a new breed of bifacial modules.

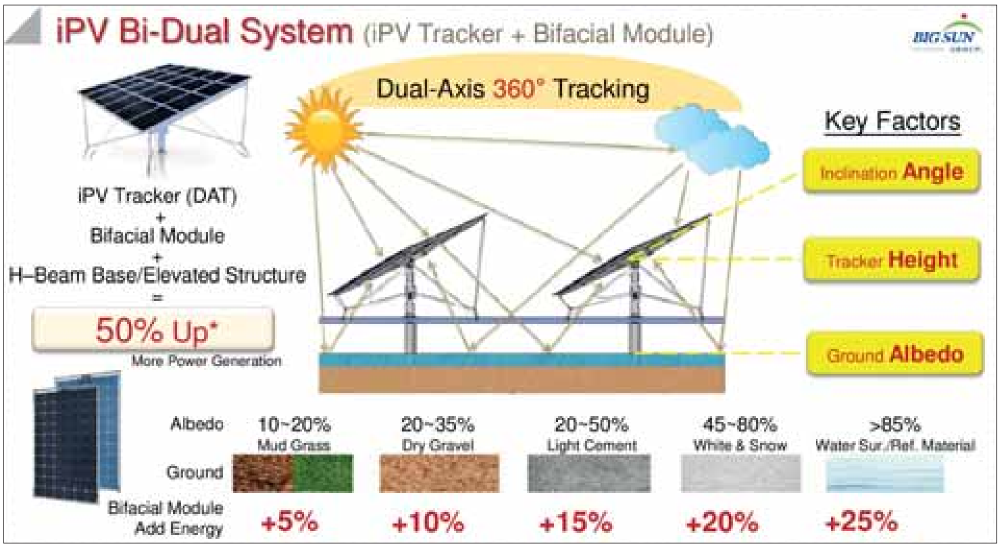
By gathering light on both sides of the module, bifacial devices can provide additional yields of up to 12%. However, bifacial modules demand unrestricted rear cell access to capture scattered light and so trackers have to be designed specifically for such modules.

Bifacial module experience in the field is still very limited and numerous demonstration projects are steadily providing real data on the both the challenges and benefits of bifacial modules in utility-scale PV power plants. Numerous module manufacturers are developing and testing bifacial technologies, while TÜV Rheinland has been leading a working to develop standardised testing methods for bifacial devices, with a draft of the testing method having recently been released for review (see p.64).

Not surprisingly, tracker designs for bifacial modules are being launched. At SPI 2017, Soltec demonstrated a modified version of its single-axis tracker for bifacial modules and later in the year, Arctech Solar launched its 'SkySmart' tracking system, claimed to be specifically


Credit: NEXTracker

NEXTracker has introduced its self-adjusting TrueCapture technology



Credit: BIG SUN

Taiwan's BIG SUN claims its iPV tracker achieves significant power gains when used with bifacial modules

designed for bifacial modules. BIG SUN Energy also introduced last year a dual-axis version of its iPV Tracker, designed for bifacial modules.

With major PV module manufacturers increasingly touting bifacial module performance gains and unique characteristics, tracker innovation is expected to be further pushed to maximise bifacial module performance.

1,500 volt

In the rapidly evolving large-scale PV power plant sector, higher-voltage systems have been making inroads at the gigawatt level in recent years, making the 1,500V system market highly desirable for PV plant owners, developers, EPC firms and component suppliers from inverters to PV panels.

A simple but key attraction is that 1,500V PV systems enable longer strings, which allow for fewer combiner boxes, less wiring and trenching, and therefore less labour, reducing capex and opex for lower LCOE and improved IRR.

Typically much of the world is 1,000Vdc (Europe set the trend) but the US solar utility sector was the first to bring to market 1,500Vdc systems, namely via First Solar (modules) and GE (inverters). Going to this maximum voltage allows for a considerable reduction in current, reducing the system losses on the DC side.

However, the adoption of 1,500Vdc technology means longer module rows and therefore trackers. MecaSolar tackled this issue with its 'Hyperion-SR' system, which offers extended trackers to accommodate up to 90 modules per row for 1,500Vdc systems, increasing land coverage up to 6%.

The company notes that the system uses self-powered actuators, which renders the AC power unnecessary. Each row integrates an advanced controller equipped with electrical devices such as UPS, inclinometer and motor current monitor sending its data through a wireless mesh network (zigbee).

Raising the system voltage to 1,500Vdc allows for 50% longer strings, thus reducing the number of strings for the same amount of power, which MecaSolar says eliminates almost 30% of the related cabling and combiner boxes and means fewer inverters per project.

The market is potentially growing for 1,500Vdc systems as bidding on utility-scale projects is replacing feed-in tariffs. Bids are getting lower and lower (kWh/$) so an increasing number of countries (where applicable) are looking for 1,500V (DC) systems such as India, MENA states and Brazil to meet low bids and still make a profit.

According to GTM Research, cumulative installations of 1,500Vdc solar now exceed 20GW, but still accounts for a minority of global utility-scale solar installations. GTM expects the share of 1,500Vdc installations to continue rising steadily. There is an obvious advantage to using these products, and those that are installing 1,000Vdc systems where 1,500V would be appropriate are essentially leaving money on the table, according to GTM.

Floating solar

Just to add to the list of demands being placed on tracker firms to innovate for new solar applications that hold gigawatts of potential across the globe is floating solar (FPV).

In May 2017 a global media frenzy was generated over a 40MW floating PV (FPV) power plant being completed and grid connected on a former flooded coal mining region in Huainan, south Anhui province, China, due to subsidence. This was the world's largest FPV plant ever built.

According to market research firm IHS Markit, China, Japan, and South Korea have deployed the majority of the more than 450MW of installed FPV power plant projects.

China is expected to consolidate its position as the world leader in 2018, due to plans to add a second 70MW and a third 150MW project Anhui province during the first quarter of 2018.

While China is set to stay at the forefront, new potential markets are also emerging, such as India with a 10GW tender, and the Netherlands with a 2.3GW plan by 2023.

Japan is expected to continue to adopt FPV and a growing list of new projects continues to gain momentum in France, Latin America and across Southeast Asia, notably countries such as Taiwan.

It is becoming increasingly likely that not only will FPV plants require tracking systems to maximise project returns but the use of bifacial modules will only enhance those returns, making tracker systems essential in the future for FPV to flourish.

Indeed, Taiwan's BIG SUN Energy has recently kick-started the FPV tracker market having launched a version of its iPV Tracker whether floating or water mounted that it claims to increase power gains by 50%.

"Two thirds of the earth is covered by water, by extending the application of iPV Trackers over water surfaces we will help increase power generating efficiency without impacting the local environment," noted Summer Lou, inventor of iPV Tracker and chairman of BIG SUN Energy. "iPV Trackers can be floating or mounted, when installed at a 3m height with 2.5m spacing, iPV Trackers are able to harvest 60% of light transmittance and increase power gains by 50%."

In shallow waters its 'Aqua Solar' solution is claimed to elevate the light transmittance 70-80%. By installing an iPV Tracker over a water surface using bi-facial modules, the increase in yields achieved can reach 60%, when compared to fixed tilt systems utilising mono-facial modules, according to the company.

MecaSolar interview and perspective on tracker innovation drivers

Spain-headquartered MecaSolar has been in the solar tracker market since 2005 and was one of the first companies to produce tracking systems. It has provided systems to projects in more than 45 countries over the last 15 years.

The company has worked with major global EPC companies such as IBERDROLA, Opde, TSK Group AMS–Aldesa, CELENIM and Tozzi Group among others over this period and garnered experience in many large-scale projects.

PV Tech Power spoke with Alexandros Giannis, CEO of MecaSolar on the topic of tracker design and innovation that remains a key business need for companies in the sector.

PV Tech Power: What currently are the key developments in trackers?

Alexandros Giannis: The tracker market has become increasingly price sensitive today, especially in the large 100MW plus utility-scale market. So the design has to be approached from a cost-competitive and economic perspective. But at the same time the technology has be state-of-the-art and always be innovative to support the market. This of course is a key challenge we have today, coupled with being on top of new product and market developments as well as market diversification. This requires a flexible and proactive approach to the market.

What demands are being placed on tracker suppliers today?

Nowadays, there is a lot of discussion surrounding storage, the same goes for bifacial [modules] and a lot on automation in order to optimise system operation. Similarly, although a number of technical challenges are posed, there is a lot of discussion going on for implementing tracker structures on floating surfaces. By nature, as a mounting structure provider, it is difficult to be proactive towards the market trends; however we always try to foresee the next challenges.

Although fixed-mount systems cost less than trackers and cost issues are so critical, why are trackers so popular?

The attraction of trackers comes from the ability to increase plant yield and the quality or consistency of the improved yield (performance). But the cost of the system remains a priority as well: a capex to opex debate. However, we see today that the capex increase is so low compared to a fixed mounting system, that it makes total sense on a yield, IRR and NPV basis to use the technology. In other words, going for a 20 to 22% performance gain with trackers, the small capex increase easily depreciates in a matter of a few months depending on the particulars of the project. It is estimated that the use of a tracker approximately delivers 3.5 €cents/WpDC higher NPV compared to a simple fixed mounting structure. The strength of the above financial benefits is illustrated clearly by the statistic that trackers make up the vast majority, in the range of 75% of utility-scale project in the US, for the year 2017.

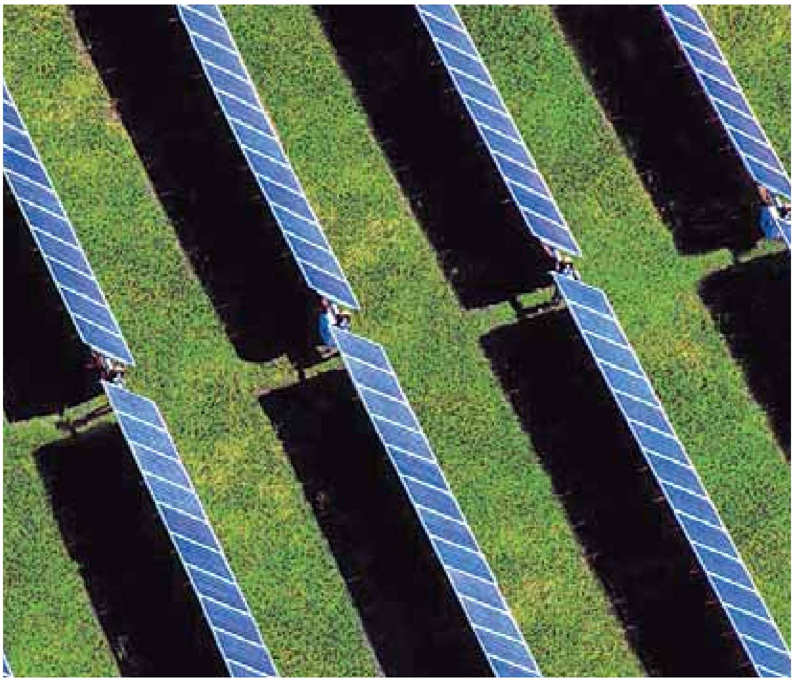
Alexandros Giannis, CEO of MecaSolar

In a market were supply is high, what distinguishes you from similar companies in the solar market?

Mecasolar is a pioneer tracker expert leveraging quality, performance, price competitiveness and history. Our mission is to meet customer's objective no matter how different and difficult those are. In addition the urgency of the market creates a necessity for continuing improvement and innovation. We stay alert to track the technological advances of module or inverter manufacturers and we constantly adapt to those evolutions. In our portfolio, we have both Hyperion-MR, a state-of-art block tracker and Hyperion-SR, a single-row, independent horizontal solution. Further to that, Hyperion-SR can be powered either with AC or DC (here we have the possibility of self-consumption). We provide almost any possible layout approach, 1V, 2V, 2H, 3H so the client can chose what is most adequate to his needs and its preferences. Engineering-wise, we provide support in many aspects like yield calculation (PV sys), design (cad), training, mechanical installation, commissioning and others. Ultimately, we recognise and respect the need for the presence of the local factor and we put a lot of effort to be present in the most active markets via local partners (Turkey, Mexico, India etc).

The emphasis on the yield capabilities of trackers must therefore be a key discussion point for developers and where the innovation in tracker design is being driven?

This is a very big discussion in the sense that the key inputs put into this equation can be defined by very diversified param-



Credit: MecaSolar

The Hyperion-SR, MecaSolar's single-row, horizontal tracker solution

eters. If we talk purely on the actual tracking technology for the strict case of the horizontal tracking movement being the prevailing current nowadays, there are not a lot of new innovations that can be made. However, if we extend the discussion on further optimisations on automations, module technologies such as bifacial, storage technology, stringing adaptations and other R&D optimisations, then yes, there are clearly a lot of improvements and innovations that can be made. New and exciting ideas pop up constantly and this is what constitutes our market as a truly exciting one to belong to!

So yield improvement opportunities exist in other emerging applications such as bifacial modules but are there still design and innovation opportunities in reducing the tracker BOS costs?
It is an undisputed fact that no other BOS component can increase the performance of a PV project like a tracker does. On the other hand as solar continues to globalise and new markets open up, we are trying to be more project oriented and to optimise the design and operating conditions of the system project by project. Trackers are significant capital investments and each feature has to show either a performance benefit or other advantages, for example O&M cost. We put a lot effort into R&D to provide superior value propositions both in cost and differentiation and I should mention here that from my experience the primary feature that buyers are looking for is just a very reliable product and a company they know will be there to service the product over its lifetime. I believe that our long history has proved in actions our trustworthiness.

One of hot topics and something you have already mentioned is bifacial modules. What challenges does this bring to trackers?
There is a lot of discussion and work being carried out on trackers for bifacial modules and there is some doubt over whether trackers are the best mounting solution for bifacial technology. If the yield makes sense to use trackers in order to provide extra performance to bifacial that meets the usual IRR parameters, then from a purely technical perspective, it is not difficult to design for bifacial modules. What is evident from a lot of research so far, however, is that many new parameters raised by bifacial module performance have to be taken into account to conclude whether tracking with bifacial modules makes sense. We are into it.

Larger modules with 72 cells and more are readily available and First Solar is migrating to its large-area thin-film modules. Is this a design challenge for trackers?
Large sized modules can be a great advantage for utility-scale projects in a number of regions especially for cases where land utilisation is of extreme importance. For instance, we just completed a project with high efficiency modules – a similar logic to the size efficiency achieved by large area modules – where in a land area of 20,000sqm we achieved the placement of 1.2MW DC. We have put a lot of effort on design efficiency and we are unique on the fact that we can provide flexible mounting solutions corresponding to 1V, 2V or even 3H, managing to achieve the maximum outcome per each case (in terms of allocation-design and power with respect to the project specifications). ■

Project briefing

HERO LAUNCHES INDIA'S FIRST SOLAR-WIND HYBRID PROJECT

Location: Raichur District, Karnataka
Project capacity: 282.8MW PV, 50MW wind

Delhi-headquartered renewable energy firm Hero Future Energies has completed India's first large-scale solar and wind energy hybrid project in the state of Karnataka.

The project at Kavithal, Raichur District, which included an existing 50MW wind farm, now has a neighbouring 28.8MW solar PV site to form a hybrid system. The project's evacuation capacity remains at 50MW since the primary aim is to address grid-integration concerns around variable power coming from renewable energy.

At the inauguration, Rahul Munjal, chairman and managing director, Hero Future Energies, told PV Tech that despite well-publicised government plans to introduce a wind and solar hybrid policy, none has been released yet due to uncertainty on how to price such technology combinations. Without adequate pricing, project developers would not be able to sell their power to a distribution company (Discom) or partake in an auction where prices are the cornerstone of the bidding.

However, Hero was able to go ahead with this pioneering hybrid, because it is a group captive project, where the off-takers are a number of unnamed private companies based in the state of Karnataka. This gave Hero the freedom to deliver the pricing on its own terms, while of course delivering cost savings to the consumers as compared to normal grid electricity.

Munjal said that, were the government to release a suitable hybrid policy, then it would make sense to move more of Hero's own existing sites into hybrid systems and he expects much of the rest of the industry to follow suit with this group captive model for hybrid systems.

Having been one of the first companies to try out a new length of wind turbine blade with Regen several years back, Munjal maintained that one of Hero's philosophies is to be first to market with new technologies and the firm is constantly looking at how to innovate. It is already a heavyweight in the industry with around 1.2GW installed renewables capacity, with another 500MW under construction and 300MW now ready for building.

Referring to another Spanish company that claimed its wind projects were working better today than they had originally forecast 25 years ago, Munjal said the next push in renewables creativity and R&D will be retrofitting existing sites and working out how to extract more energy from them.

Rural south India – approaching the site

Flying from Hyderabad in Telangana, towards Karnataka, several individual solar and wind projects – as well as the occasional thermal power plant – could be seen marking the flat plains of this part of central, southern India.

Overland, villagers dried red chillies in the sun, sat in the shade of the trees or played cricket in the cooler morning hours, while traffic waited for herds of goats, horses or sparring cattle to cross the roads.

Apart from green pockets of lush agriculture, formed through irrigation, the land was sparse, barren and sunburnt with temperatures regularly hovering around 40 degrees Celsius at this time of year.

Technology

At Kavithal, both the wind and solar plants were developed by Hero Future Energies and built by EPC contractor Siemens Gamesa.

The wind project uses Siemens Gamesa turbines and inverters, while the solar PV project uses Gamesa inverters and 320/325W modules from China-based manufacturer Suntech. Cables came from Hyderabad-based firm KEC International, and steel for mounting structures was sourced locally to Hero's specifications.

Beside some of the solar arrays lay a large assembly of boxes bearing the Suntech logo. These modules were resting in storage soon to be transported within the month to Hero's 400MW of other PV capacity being set up in the state.

Hybrid to grid

Perhaps the most significant offering of a hybrid renewables system is its beneficial

Credit: Tom Kenning

impact on the grid when compared to single technology renewables projects.

Munjal said that the wind tends to blow most early in the morning and in the evenings, while sunshine comes in the day, so the two sources of power generation are complementary. Not only does this smooth out the overall energy production over a 24-hour period, but it also increases the plant load factor (PLF).

Indeed, individually the wind PLF is 28%, while the solar PLF is 18.7%. This brings the total PLF for the whole project to 41.8%.

Looking seasonally, wind increases ahead of the Monsoon, said Munjal, but when the rains come, the wind does start to die down.

The hybrid element is extremely pertinent to India's renewable energy industry given the increasing penetration of renewables on the grid. Consistent forecasts from analysts suggest that the country will face major grid integration issues in the coming years if network infrastructure is not improved at the same rate as renewables capacity additions. Indeed both India's authorities and renewables industry have been accused of having their 'heads in the sand' over the grid integration issue in the past.

Moreover, the Green Energy Corridors, touted to help evacuate power from states rich in renewable energy resources (high irradiation and strong, consistent winds) to states with high power demand, have faced delays and by some reports have also faced a serious lack of funding.

Pricing

To calculate the hybrid pricing, Munjal said that using highly advanced, modern

By Tom Kenning

technologies and software, one can take an assumption of how much solar and wind will be generated separately, before taking a weighted average of the generation and price.

He said: "The beauty is the price for both gets lowered since the infrastructure is common. You are using the same evacuation, you are using the same substation etc."

Indeed, due to the existing wind site, almost all the necessary infrastructure for the solar plant was already available, and the project only required a few enhancements, such as updating the inverter technologies. Some extra land had to be purchased for the solar system, which is spread across 65 hectares, but Hero was already familiar with the location, the landscape and the local authorities, which made the process easier than developing a standard PV project from scratch.

Land headache relief

Karnataka itself is also particularly suited to renewable energy, because there is plenty of land, with strong winds and irradiation. Munjal said it will become the next big state for wind capacity after Tamil Nadu, and it is already a leading state for solar.

However, describing the process of delivering transmission to the project, he said: "When you are building that 20 kilometre [transmission line] the number of people that you have to encounter… I've always maintained the toughest thing about doing renewables in India is land."

Indian land records are not digitised so one has to deal with both a private surveyor and a government surveyor, and plots of land that are suitable for a project can be owned by hundreds of different people.

"Land is only 5-10% of our cost, but 95% of the problems are with land," said Munjal.

Thus, even though Hero had to purchase some extra land for the project, the hybrid element actually reduced the land requirement, particularly with transmission and this for Munjal is "going to be the biggest benefit" of hybrids.

Atul Raaizada, senior VP projects and O&M, large wind and solar farms at Hero Future Energies, said his team studied the wind project for three months before coming up with the hybrid concept, learning how to minimise energy wastage when combining both wind and solar at the right levels. Once the combination is understood, execution is easy, he said.

He also highlighted that this particular project location, which has consistently strong irradiation, is both on hilly land, which is conducive to wind, and on barren land, therefore not impacting agricultural production. This is "the best of everything", he said.

The specific generation capacities were chosen to find the most suitable balance and minimise the clipping (curtailment) of solar and wind, should their generation go above the 50MW evacuation limit, said Raaizada. Having to find that right balance stemmed from being unable to regulate wind generation due to the huge mechanical components in use.

Module performance

An unsung benefit of hybrid systems is that by choosing a location with naturally high wind resources, the temperature of the solar modules is also reduced by the breeze, increasing their generation, said Raaizada. Year-round lower temperatures on the solar panels from the wind also reduce the rate of degradation in the modules.

Credit: Tom Kenning

Hybrid cost savings

Not only does the hybrid system share the transmission infrastructure, but the operations are also shared by the same teams, thereby reducing costs even further.

However, operations and maintenance (O&M) teams are different since the solar system requires manual, water-based cleaning twice a month, in this extremely dusty region. Munjal said barren land is naturally dusty, but there are two types of dust that impact solar. Dry dust, as in the arid, desert state of Rajasthan, can be easily wiped off or blown off by the wind, but dust in humid conditions tends to stick the panels, which can cause soiling in the long-term and impact on the modules' performance.

Energy storage lurking

In its draft solar wind hybrid policy, the Ministry of New and Renewable Energy (MNRE) had targeted 10GW by 2022. Following this, the state of Andhra Pradesh released a draft document outlining its plans for 3GW of wind and solar hybrid projects by 2019/20. But while policy action stuttered since these announcements, the next stage after wind and solar hybrids, which introduces a third pillar in the form of energy storage, seems to be progressing.

Andhra Pradesh authorities are already planning to tender a project involving 120MW of solar, 40MW of wind and 20-40MWh of storage this year. Meanwhile, Kerala's Agency for Non-Conventional Energy and Rural Technology (ANERT), is working on an experimental, technology demo to include 3MW of solar, 4MW of wind, and battery storage.

Indian power minister R.K. Singh also recently chaired a meeting with battery-based energy storage manufacturers calling on them to set up manufacturing units in India. His urgency stemmed not only from the government's push on electric vehicles (EVs) and its expected surge in the coming years, but also because Singh said future tenders will cover hybrid solar and wind projects to be coupled with energy storage.

Munjal said he believes that large-scale coupling with energy storage will proliferate in the next two to three years. While price remains a problem, Hero is already using storage to benefit its own plants but at a very small scale - carryng out studies with small batteries.

Raaizada said Hero is looking at future smoothing of the grid using storage and also releasing stored energy at peak times on the grid.

More room for error

Karnataka was among the first states to take on new forecasting rules, following the example of Tamil Nadu, so it requires plant operators to provide more frequent and accurate projections of energy production or face penalties.

Rather than making this forecasting more challenging, the overlapping of wind and solar generation has actually increased the room for error, thus increasing the overall performance of the project's scheduling and forecasting.

Munjal said that forecasting software is also becoming more and more reliable, but while strict rules on forecasting are necessary for the industry, how to penalise for non-compliance is up for debate.

"It has to be a three, four-year programme," he said. "Rome wasn't built in a day – you can't expect us to be perfect at it from day one. So, some of the states are more stringent than they should be; other states understand it but are giving us a little bit of a breather and saying as long as we see a positive correlation, we give you a couple of years to stabilise your systems."

The problem is that developers rely on several sets of data: from NASA, satellite data, and third-party software. Nonetheless, the hybrid project benefits actually negate the threat of unreliable data and inaccurate readings.

India's hybrid future

Looking at how India can drive wind-solar hybrids into the mainstream, Munjal said: "We should start a narrative where we ask the government as the industry to come up with wind-solar hybrid tenders."

Existing solar park projects, where the government has been monitoring progress closely, will be the most suitable locations to add wind, while fresh tenders for new wind and solar together will be easier to bid out and get a price for both sources together from scratch.

Vinay Rustagi, managing director of consultancy firm Bridge to India, told PV Tech: "There are two main benefits of wind-solar hybrids. The first one is, obviously, there is better and more efficient use of the land and transmission infrastructure, so that reduces the capital cost by something like 5-7% and results in overall lower tariff. So I think the Discoms and the power purchaser should actually be keen on hybrid projects like this.

"The hybrid power project also makes the power output a little bit more reliable than a standalone solar or standalone wind project. So that, again, from a Discom's point of view or from a transmission grid stability point of view should be better for the entire system."

The benefits of hybrid renewables have been made clear and, if Munjal is correct, Hero Future Energies' pioneering mark on the industry should see plenty more players following suit, but only with private off-takers until a suitable government policy is released. ■

How embedded micro-forecasting changes the decision making for portfolio maintenance

O&M | The optimal and profitable operation of solar assets is become increasingly challenging as portfolio sizes increase. Stijn Stevens and Michael Matthes explore how device-level energy forecasting is helping prioritise O&M activities across dispersed fleets

Credit Skytron energy

Power generation from solar energy is becoming ever more attractive: in 2018 the global installed photovoltaic capacity is expected to approach 500GW. Favourable financing conditions and falling costs have made PV into an attractive investment. In many regions of the world the production costs (levelised costs of electricity, LCOE) for utility-scale solar are now well below the LCOE of nuclear or coal-fired plants. The barrier of entry into the energy generation market has thereby become much lower today than it was only a few years ago, when the building of a conventional power plant involved huge investment costs and only a few participants dominated the market. Investment companies or family offices with an international focus are taking advantage of the new opportunities and have already assembled sizeable, globally diversified portfolios. These so-called independent power producers (IPP) – power producers without direct access to the grid network – are putting pressure on traditional, often regional or national utilities that, hampered by their portfolio of conventional power plant, can react much less flexibly. Utilities, for their part, are countering by investing in renewable energy for power generation, cutting their investment in conventional power plants or by splitting up. Whether IPP or utility, a global trend has become the steady growing photovoltaic portfolios, with generation capacities of more than 500MW or even 1,000MW, becoming the rule.

Embedded micro-forecasting supports the centralised operation of PV portfolios

This growth in portfolio size is bringing with it an increasing demand for optimal management of the assets as a whole: minimising investment in operations and maintenance (O&M) whilst maximising the earnings/cash flow from energy production at the same time. The achievement of these goals is increasingly being assisted

by data analysis, error identification and solution-oriented decision making using software solutions that are able to analyse the incoming data streams from the SCADA (supervisory control and data acquisition) systems in the individual plants and compare them with the overall portfolio performance. The human operator in the control room – the so-called Network Operations Center (NOC) – is turning into a "pilot" who has to "fly" the portfolio while managing a steadily increasing MWp volume at the same time.

Given the limited availability of resources and sustained pressure on costs, the prioritisation of the necessary activities has become crucial. One aspect that can help in this context is embedded micro-forecasting. By this, we mean the use of energy production forecasts down to device level across a regionally diversified portfolio of photovoltaic plant having heterogeneous device types (in particular inverters). These forecasts are then used to prioritise maintenance so as to minimise expected energy losses. In the event of any malfunctions, service calls are optimised according to a cost/benefit analysis.

	Pyranometer Secondary standard (ISO 9060:1990)	Temperature Sensor
Used to measure	Radiation [W/m²]	Temperature (module & ambient air temperature)
Typical measurement range	100W/m² to 1,500W/m²	-40°C to +80°C
Accuracy	Uncertainty ≤ 3%	Uncertainty ≤ 2°C (module level), Uncertainty ≤ 1°C (ambient air level) Commonly used are[1]: Class A ± 0.15° + 0.002 [t] or Class B ± 0.3° + 0.005 [t]
Maximum sampling-interval[2]	3 seconds	3 seconds
Maximum recording interval[2]	1 minute	1 minute

Digital Weather Station					
	Relative Humidity	Air pressure	Wind speed	Wind direction	Precipitation quantity
Typical measurement range	0% to 100%	400 to 1,100hPa	0 to 70m/s	0° to 360°	-
Accuracy	± 3%	± 0.5hPa	≤ 0.5m/s (wind speed ≤ 0.5m/s) ≤ 10 % (wind speed > 5m/s)	± 5°	± 5% to ± 10%
Maximum sampling-interval[2]	1 minute	not specified	3 s, suggestion: track maximum values to determine gusts	3 s	1 minute
Maximum recording interval[2]	1 minute	1 minute	1 minute	1 minute	1 minute

Notes: 1) According to IEC 60751; 2) IEC 61724-1:2017, Class A – high accuracy

Table 1: Characteristics of widely used sensor types in PV plants

Forecasting at a plant level

Meteorology has been the recipient of a wealth of innovation in recent years. The availability of powerful computer technology and high-resolution satellite data, combined with associated improvements in weather models, now provide for significantly improved forecasting quality. In addition to global models such as the American Global Forecast System (GFS), having a mesh width between individual grid points of around 28km [1] or the German ICON model (Icosahedral, Non-hydrostatic) with a horizontal mesh width of approximately 13km [2], there is a multitude of localised area models offering a substantially finer-grained grid structure.

For example, the COSMO-DE model provides a horizontal resolution down to 2.8km for Germany, Switzerland and Austria [3]. In general, it can be said that the quality of forecast increases with reducing mesh size; however at the same time, the reliable forecasting period decreases owing to the increased complexity. On one hand, global, coarse-meshed models such as GFS can provide a forecast up to 16 days in advance [1], whilst on the other, smaller mesh models such as the COSMO-DE are often limited to about 24 hours [4]. This discrepancy between the forecast period and quality has given rise to new business models: independent providers have been able to combine widely differing models using their own computer technology, sometimes enriching the results with locally measured values or correction factors, so as to be able to offer a refined forecast for a particular location for longer time periods.

The data channels shown in Figure 1 are particularly interesting for PV plants.

The irradiation forecast is based on satellite imagery, through which the irradiation data can be optimised using clear-sky algorithms and statistical models. As a rule of thumb, the lower the cloud cover at any particular site over the year, the more accurate will be the irradiation forecast. At the same time, short-term forecasts of

Forecast-Data Channel	Forecastability	Application
Global Horizontal Irradiation GHI (W/m²)	Challenging	Power forecast
Diffuse Horizontal Irradiance DIF (W/m²)	Challenging	Power forecast: Estimation of Plane of Array irradiation (POA)
Direct Normal Irradiance DNI (W/m²)	Challenging	Power forecast: Estimation of Plane of Array irradiation (POA)
Ambient temperature (°C)	Good	Power forecast: Dissipation of module temperature
Wind speed (m/s)	Good	Power forecast: Dissipation of module temperature; Tracker-based plants
Wind direction (°)	Good	Tracker-based plants

Figure 1. Forecast data for PV applications

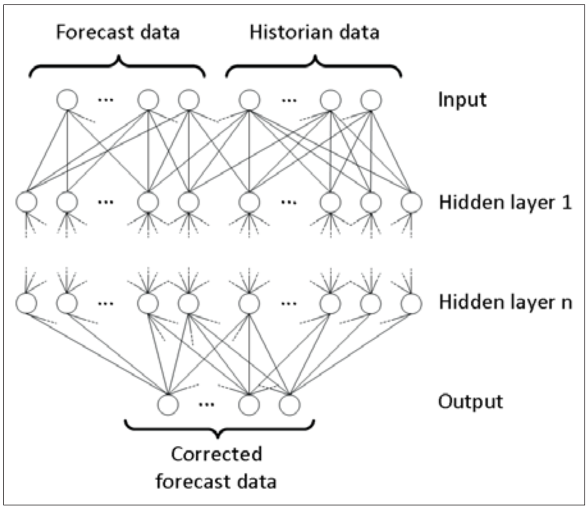


Figure 2: Neural network to tailor the model

the GHI (intra-day forecasts), derived from satellite images of cloud tracks, allow much higher hourly accuracy [5].

The availability of local weather measurement data is fundamental when deriving key performance indicators (KPI) for assessing the performance of a PV system. Without this data, especially irradiation and temperature, the energy production of a PV power plant cannot be assessed. Innovations and cost reduction by the producers of meteorological sensors has led to the situation where today almost every plant with >1MWp rated output is equipped with its own measuring technology. The recommended sensor scope and sampling rates are specified in IEC 61724-1:2017 "Photovoltaic System Performance - Part 1: Monitoring". Pyranometers are widely used for measuring global irradiance and temperature sensors are usually in place for recording the module temperature. Digital weather stations provide measurements of data such as air pressure, ambient temperature, humidity, precipitation, type of precipitation (rain, snow), wind speed and direction. As a result, every large PV system usually has extensive, site-related weather data available across the whole of the system's life.

Forecast providers often offer predictions for energy yield based on an irradiation prediction combined with a simple system model: tilted surfaces, system capacity and an assumption about performance ratio. This is inadequate for maintenance scheduling, especially in areas with volatile weather conditions.

The first key element in obtaining a reliable basis for O&M decisions is to combine these forecasts with data from local weather sensors. This increases the accuracy of the plant forecast and, indirectly, allows the local geographic physiology to be learned over time. The second element is to get the component models to match the reality. Both objectives are obtainable by moving to machine learning of a different kind.

To increase forecasting accuracy a neural network approach is suitable, although not always needed. Picking the correct number of nodes, both for the inputs as well as for the hidden layers, is far from trivial and if not done well can lead to neural network models that are computationally very expensive. Here, it is essential to tailor the model to the plant. If this is setup correctly, the neural network will be able to learn the geographical characteristics of the plant and its evolution over time, based on the constant plant feedback.

The irradiation forecast is then used to predict the plant's energy yield by using a plant model consisting of a series of component/loss models: surfaces, soiling, shading, modules, DC cabling, inverter, AC cabling and a transformer model. The

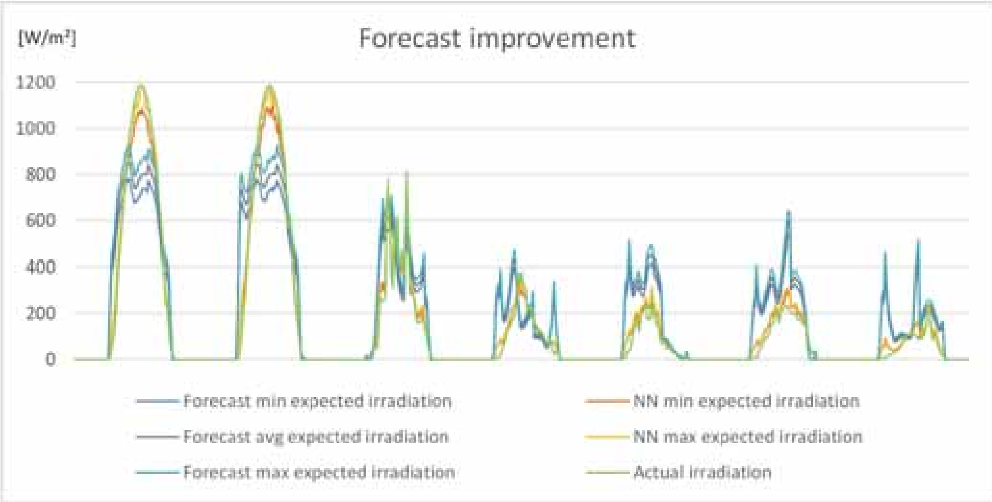


Figure 3. Irradiation forecast improvement through neural network (NN) model

parameters of some of these models are fixed, such as the surface model which incorporates the module orientation and occasionally tracking. Other models require data from datasheets or other parameters that are estimated from the plant's historically measured data. Simple quality factors or machine learning can be applied in both cases, either to determine or to verify and correct these parameters, so that a best fit can be obtained between measured data and models.

As an example, a generic Sandia inverter model [7] can be inversely modelled inversely, so that the parameters of the model (the manufacturer datasheets) become the variables of the equation. By using the actual inverter and measurement data, a best fit for these variables is looked for. Using linearisation and assuming that the parameter variables have a Gaussian distribution, a Kalman filter structure can deliver a best guess for the parameters. The power generation predictions will become more accurate against the fitted data and, in addition, this allows unexpected changes in parameters to be used for predictive maintenance.

Micro-forecasting at a device level

A significantly improved picture about the expected yield can be gained by compiling a forecast at an inverter level. In this, the expected yield in the future is based on the forecast weather data for each individual inverter across the entire portfolio. Individual correction factors for the weather data can be included separately for each inverter in the calculation.

If the monetary worth of the individual kWh output is included to enrich this data, one can quickly put together a prediction of the total revenue for each individual inverter. The illustration in Table 2 shows an example of a financial ranking for three PV systems which use central inverters but have different remuneration schemes. The ranking is based on an energy forecast at device level.

This type of micro-forecast at device level is especially well suited to decision making for large portfolios incorporating many plants, including perhaps with extremely large numbers of inverters. Especially when combined with a Computerised Maintenance Management System (CMMS), the information provided, including estimates of the financial impact of faults across several inverters, can be used to prioritise repair work. Sensible decisions can then be made about when to send technicians to which sites, so that the repair can work be optimised from a cost-benefit perspective. If internal resources are overstretched, it can make a clear case for calling in external technicians – or not. In this way, micro-forecasting allows transparent decision making: whether such a strategy would pay off economically or whether repairs should be delayed because the expected yield would not justify the higher cost. For plants that use string inverters, where an outage of an individual inverter might not have a huge financial impact, it allows the development of a sensible agglomeration strategy.

In the other direction, long-term planned maintenance intervals for inverters can also be included in the forecast. Here, the maintenance planning in a CMMS would be directly linked with the production of the yield forecast for the power plant. If maintenance is planned, the generation capacity available is suitably reduced and the yield forecast at a power plant level adjusted to match. In this way a refined overall plant forecast can be assembled, which includes factors that are independent of the weather.

Conclusion

Forecasting will continue to gain in importance in the future. Large, centralised power generation plants burning fossil fuels will increasingly be replaced by decentralised plants based on renewable energies. This will place high demands on availability planning if a stable and reliable grid is to be guaranteed into the future. It will also increase the attraction of battery storage systems or other innovative conversion technologies such as power to gas, which allow surplus power to be converted and stored during periods of high yield and retrieved during periods of low yield. Managing this increased complexity in the electricity market will require reliable estimation of energy production, which, in turn, will require high accuracy production forecasts.

The incorporation of plant-related weather forecasts is therefore a significant

			Energy Yield							
PV-Plant	Inverter	Inverter DC-Power	Current day	Forecast current day	Forecast +1 Day	Forecast +2 Days	Forecast +3 Days	∑ Forecast 3 Days	$/kWh	∑ Forecast 3 Days / $
Plant 2	Central Typ B / No.2	2.850 kWp	6.200 kWh	9.600 kWh	9.380 kWh	10.750 kWh	4.980 kWh	25.110 kWh	0,06	$1.507
Plant 3	Central Typ C / No. 7	860 kWp	1.600 kWh	2.850 kWh	3.810 kWh	2.150 kWh	4.530 kWh	10.490 kWh	0,14	$1.469
Plant 3	Central Typ C / No. 1	840 kWp	1.560 kWh	2.810 kWh	3.760 kWh	2.130 kWh	4.595 kWh	10.485 kWh	0,14	$1.468
Plant 3	Central Typ C / No. 8	855 kWp	1.595 kWh	2.845 kWh	3.790 kWh	2.140 kWh	4.520 kWh	10.450 kWh	0,14	$1.463
Plant 3	Central Typ C / No. 9	860 kWp	1.580 kWh	2.830 kWh	3.800 kWh	2.150 kWh	4.500 kWh	10.450 kWh	0,14	$1.463
Plant 3	Central Typ C / No. 5	840 kWp	1.550 kWh	2.800 kWh	3.770 kWh	2.130 kWh	4.510 kWh	10.410 kWh	0,14	$1.457
Plant 3	Central Typ C / No. 2	840 kWp	1.540 kWh	2.790 kWh	3.760 kWh	2.120 kWh	4.500 kWh	10.380 kWh	0,14	$1.453
Plant 3	Central Typ C / No. 6	835 kWp	1.540 kWh	2.790 kWh	3.760 kWh	2.120 kWh	4.500 kWh	10.380 kWh	0,14	$1.453
Plant 3	Central Typ C / No. 3	840 kWp	1.550 kWh	2.800 kWh	3.770 kWh	2.100 kWh	4.500 kWh	10.370 kWh	0,14	$1.452
Plant 3	Central Typ C / No. 4	840 kWp	1.560 kWh	2.810 kWh	3.730 kWh	2.100 kWh	4.490 kWh	10.320 kWh	0,14	$1.445
Plant 3	Central Typ C / No. 10	860 kWp	1.570 kWh	2.820 kWh	3.730 kWh	2.130 kWh	4.460 kWh	10.320 kWh	0,14	$1.445
Plant 2	Central Typ B / No.1	2.750 kWp	6.090 kWh	9.490 kWh	9.110 kWh	9.860 kWh	4.910 kWh	23.880 kWh	0,06	$1.433
Plant 2	Central Typ B / No.5	2.650 kWp	5.460 kWh	8.860 kWh	8.700 kWh	10.290 kWh	4.560 kWh	23.550 kWh	0,06	$1.413
Plant 2	Central Typ B / No.3	2.850 kWp	5.450 kWh	8.850 kWh	8.500 kWh	9.480 kWh	4.400 kWh	22.380 kWh	0,06	$1.343
Plant 2	Central Typ B / No.4	2.630 kWp	5.540 kWh	8.940 kWh	8.650 kWh	9.070 kWh	4.550 kWh	22.270 kWh	0,06	$1.336
Plant 1	Central Typ A / No.4	1.060 kWp	2.355 kWh	6.855 kWh	2.620 kWh	2.900 kWh	6.280 kWh	11.800 kWh	0,10	$1.180
Plant 1	Central Typ A / No.1	1.060 kWp	2.300 kWh	6.800 kWh	2.600 kWh	2.920 kWh	6.225 kWh	11.745 kWh	0,10	$1.175
Plant 1	Central Typ A / No.3	1.060 kWp	2.270 kWh	6.770 kWh	2.610 kWh	2.920 kWh	6.195 kWh	11.725 kWh	0,10	$1.173
Plant 1	Central Typ A / No.2	1.060 kWp	2.250 kWh	6.750 kWh	2.620 kWh	2.900 kWh	6.175 kWh	11.695 kWh	0,10	$1.170

Table 2. Example of an energy yield prediction at inverter level

way of improving the plant-by-plant yield forecasts of an operational fleet. As a further step, forecasts can be compared with historic data under similar weather conditions, making use of pattern recognition algorithms. Such innovations have the potential to reduce the uncertainty and increase the quality of the local irradiance forecast by several factors, thereby optimising the yield forecasts for individual plants. In this process, the differing quality of the recorded data, which is subject to factors such as contamination, shading and the state of sensor calibration, will have to be taken into account in order to minimise negative influences. This can only succeed if the data is viewed holistically and data from the SCADA system can be amalgamated with information from the CMMS.

For operators of large portfolios, the integrative use of SCADA and CMMS will not only improve the yield forecast at plant level, but also offer a great opportunity to optimize cross-portfolio maintenance work from a cost/benefit perspective, for example at inverter level. The developments in this area are still young; the potential is very promising.

Authors

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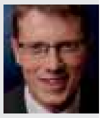
Michael Matthes is responsible for product management at skytron energy and has more than 10 years' experience in renewable energies. He previously worked for the CIGS thin-film module manufacturers Solibro GmbH and Soltecture GmbH and holds an engineering degree in geo-informatics and industrial engineering.



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On-site PID testing

Power degradation | Potential-induced degradation (PID) is still one of the main reasons for unpredictable power losses in PV power plants. Volker Naumann, Nadine Schüler and Christian Hagendorf of Fraunhofer CSP and Freiberg Instruments present an approach for quick on-site PID testing of mounted PV modules, allowing PID diagnosis and prognosis of PID-related yield losses

In the last few years many European plants with c-Si solar modules which have been in operation for a couple of years have become suspicious that they may be affected by PID [1]. The most frequent type of PID in c-Si modules is the shunting type [2], also called *PID-s*. When it is suspected that PID is responsible for some observed power loss, electro-optical inspection by infrared thermography (IR) or electroluminescence (EL) is usually performed, in order to detect or exclude the occurrence of distinct PID signatures (e.g. checkerboard pattern) along complete module strings. Alternatively, the measurement and comparison of the string voltage level at the maximum power point under weak irradiation is used as an indicator for PID-s.

All these methods are indirect and therefore leave room for interpretation; in other words, the findings cannot always be clearly and unequivocally attributed to PID. Furthermore, these methods are not able to predict the susceptibility of modules to PID when as yet no measurable power loss has occurred. For this reason, modules are dismounted to seek further proof of PID sensitivity at testing institutes. Laboratory PID tests are usually carried out in large-scale climate chambers in accordance with the technical specification in the IEC TS 62804-1 standard [3]. This procedure is very time-consuming and incurs a high cost in relation to dismounting, shipping and testing. It is therefore much more attractive to perform PID tests on-site, following the set-up and procedures used in the laboratory, without any need for dismounting. Moreover, up until now it has not been possible to satisfactorily predict the rate of recovery, which is often the intended parameter to be boosted by retrofitting specific recovery devices.

Design of the on-site PID test

The on-site (outdoor) PID test procedure is simple in design for easy handling; it is quick and reliable, but also not too far removed from the existing test standards that are commonly used in the laboratory. The only existing PID test standard – the IEC 62804-1 technical specification – is used as a starting point. Since the severity of the outdoor PID test method should not depend on the surface conductance of the module glass (influenced by dust, dirt, humidity), the stress method (b), namely "contacting the surfaces with a conductive electrode", of IEC TS 62804-1 is adopted for outdoor testing. This consists of a conductive foil on the front surface of the module and an applied voltage corresponding to the module rated system voltage between the grounded conductive foil and the cells. Typically, this test takes 168 hours at 25°C, but it is also permissible to apply higher temperatures to accelerate the PID process. Thus, the two crucial parameters of an accelerated PID test are: 1) a high voltage between the glass surface and the cells to incite leakage currents; and 2) an elevated temperature to accelerate the degradation.

"The on-site PID test procedure is simple, quick and reliable"

Characteristic	IEC TS 62804-1, stress method (b) [3]	PID outdoor test	Remarks
Application of high voltage	Module rated DC system voltage between a conductive foil on the total area of light-facing surfaces and framing, connected with the ground terminal of a DC voltage supply, and cells (module connectors).	Module rated DC system voltage between a metal sheet on the light-facing module surfaces, connected with the ground terminal of a DC voltage supply, and cells (module connectors).	Neither accounts for module-level designs intended to mitigate degradation by reducing leakage current pathways to ground; the PID sensitivity of module-level designs without a metal frame might be overestimated.
Temperature	Module temperature of 25± 1°C, or alternatively 50°C or 60°C if greater acceleration is desired.	Module temperature of 85°C in the module area that is covered with the metal sheet.	
Humidity	Dry (RH < 60%).	Dry and clean module surface; RH is low as a result of external heating and heat insulation.	For the PID outdoor test, the humidity level can be neglected because of intentional grounding of the module surface.
Irradiation	Dark condition due to metal foil on the total area.	Dark condition due to heat insulation.	
Duration	Dwell duration: 168h.	Test duration: 4h.	
Assessment of power degradation	Maximum power determination as specified in section 10.2 of IEC 61215:2005 – before the voltage stress test, and between 2 and 6 hours after the test.	Continuous recording and display of in-situ measured forward current in the dark at $1/3V_{oc}$, and of dark *I–V* curves every 5 min.	Forward current is used as an indicator; an electrical model is used for estimating the power loss.

Table 1. Comparison of the proposed PID outdoor test with stress method (b) in IEC TS 62804-1

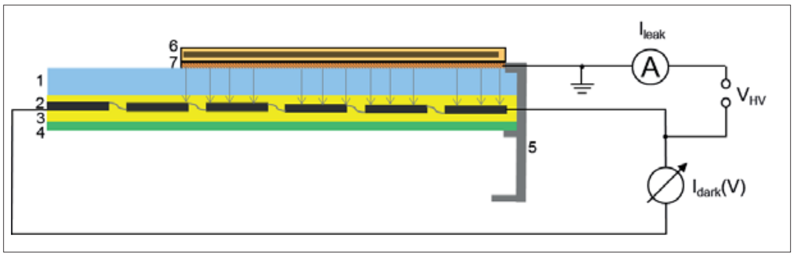

Figure 1. Wiring scheme for the PID test (1: module cover glass, 2: cells, 3: encapsulation polymer, 4: backsheet, 5: module frame, 6: heating pad, 7: metal sheet for grounding)

Figure 2. (a) Grounding metal sheet (silver) and heating pad (orange) attached to a freestanding module on a test field; (b) the same set-up, covered by the heat-insulating blanket (black), deployed in a large-scale PV power plant

For the outdoor application, the grounding on the front surface and the increase of the module temperature are realised by means of a thin metal sheet and a heating pad. In a laboratory PID test, using the stress method (b), both the temperature and the high voltage level are laterally homogeneously distributed over the module area. For an outdoor PID test, this cannot be accomplished with a reasonable amount of effort and power consumption because of the heat losses at the edges and the rear of the module. For this reason, a heating pad and a metal sheet for grounding that cover only approximately half of the area of a standard 60-cell module are used; these can then be applied to several different module sizes. In consequence, only a fraction of the cells in a module is subject to PID stress, but since the in-situ measurement of the electrical module parameters is very sensitive to PID, the result can be extrapolated to the total module area.

It has been determined from relevant studies that the most sensitive electrical parameter is the forward current (the current flowing through serially connected cells with a forward bias) under dark conditions. A voltage equal to one-third of the open-circuit voltage is chosen as a good trade-off between achieving high sensitivity to PID and not demanding the measurement device to handle overly high forward currents. (For reference, the increase in the forward current due to PID is visualised in the *I–V* curves in Fig. 3, presented in a later section.) Table 1 presents a summary of the design of the outdoor test, along with a comparison with the established stress method (b) of IEC TS 62804-1.

Description of the test set-up

A prototype test set-up, based on the general design above, was constructed. The wiring scheme is illustrated in Fig. 1, which shows the equipment for heating, application of high voltage and measurement of the forward current.

With the current test set-up, 24 Si cells of a 60-cell module were subjected to high PID stress by grounding the front glass surface and simultaneously heating the module area, while a high negative voltage was applied to the cells. The set-up and measurement principle were tested outdoors on two different 60-cell modules: one freestanding module installed on a test field and one module deployed in a large-scale PV power plant. Fig. 2 shows the prototype of this outdoor PID test set-up, attached to the Si solar modules for the first tests.

The module used for the outdoor test on the test field was specially manufactured at Fraunhofer CSP and equipped with eight thermocouples; this arrangement makes it possible to determine the temporal and spatial distribution of the module temperature. It was discovered that the design and application of heat-insulating materials are crucial for the PID outdoor test, since a relatively high temperature of 85°C needs to be reached within a short time and homogeneously maintained over the tested module area. Therefore, in addition to the insulating blanket (Fig. 2(b)) on the front side of the tested module, the rear side is lined with heat-insulating foam pads.

Initial results on the feasibility of on-site PID tests

Laboratory testing

PID tests were initially performed using the prototype test set-up in the laboratory on nine 60-cell multicrystalline Si modules from different manufacturers with different PID sensitivities. These tests showed that the test set-up was able to clearly demonstrate the PID sensitivity of solar modules by means of an in-situ measurement of the forward current. Fig. 3 shows the behaviour of the dark *I–V* curves after increasing PID test durations for one of the modules at a temperature of 85°C and a voltage of –1,000V applied to the cells. It can be concluded that a test duration of less than one hour is sufficient for differentiating between PID-resistant and PID-susceptible modules. With the forward voltage of $1/3V_{oc}$, a very high sensitivity of the current with respect to PID is achieved; this corresponds to 12V for this particular module (the arrow in Fig. 3).

In the PID test run with all nine modules, the current is measured under dark conditions at a forward bias of 12V, with a narrow time interval of one minute between two measurement

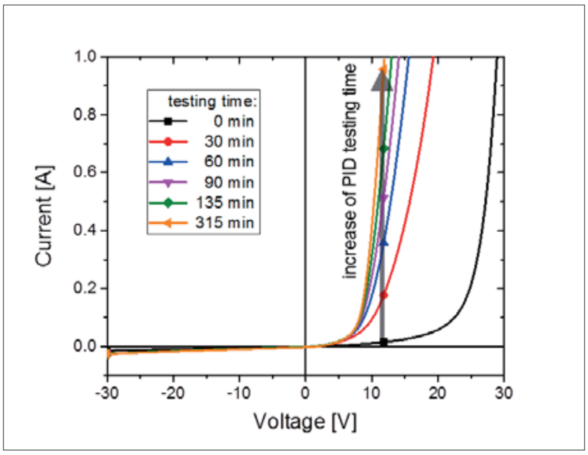

Figure 3. Dark *I–V* curves, acquired in situ, of a 60-cell module (V_{oc} = 36V) when 24 cells were subjected to a PID stress of –1,000V at 85°C, showing the evolution of PID with time

"The test set-up was able to clearly demonstrate the PID sensitivity of solar modules by means of an in-situ measurement of the forward current"

points. This results in the generation of the curves for the forward current as a function of time over the entire test duration.

Fig. 4(a) shows the curves for four representative samples that were measured in the laboratory in identical conditions (ambient temperature 22°C, module temperature 85°C, voltage at the cells –1,000V with respect to the grounded frame and glass surface). The modules exhibit clearly different behaviours; while module C does not show an increase in forward current at all, the other three do exhibit an increase.

The leakage current that is measured in the high-voltage circuit of the test device represents the conductivity of the module encapsulation materials under the influence of high-voltage stress. This current is recorded in the same time interval as the forward current and provides additional information about the stress that the cells within the module have been exposed to. The leakage current curves are shown in Fig. 4(b). Note that modules A2 and B, for example, appear to exhibit approximately the same PID sensitivity, given the shape of the curves of the forward current over time (Fig. 4(a)). The leakage current of module B, however, is more than double that of module A2; this strongly indicates that the cells in module A2 have in fact a higher PID sensitivity than the cells in module B, which features a higher conductivity of the encapsulation materials, leading to a higher voltage stress level for these cells. This can be explained by the so-called *voltage divider model* [4].

The measured forward currents after the completion of the tests demonstrated the same ranking of PID sensitivity as that corresponding to the power measurements and EL images used as a reference for assessing the PID sensitivity. The EL images that were acquired for modules A2 and C are shown in Fig. 4(c) and 4(d). In the case of the PID-sensitive module A2, it is clearly visible that only the cells that are located below the grounded metal sheet and below the heating pad (see Fig. 2) suffer PID. The basic functionality of the PID outdoor test is thus validated.

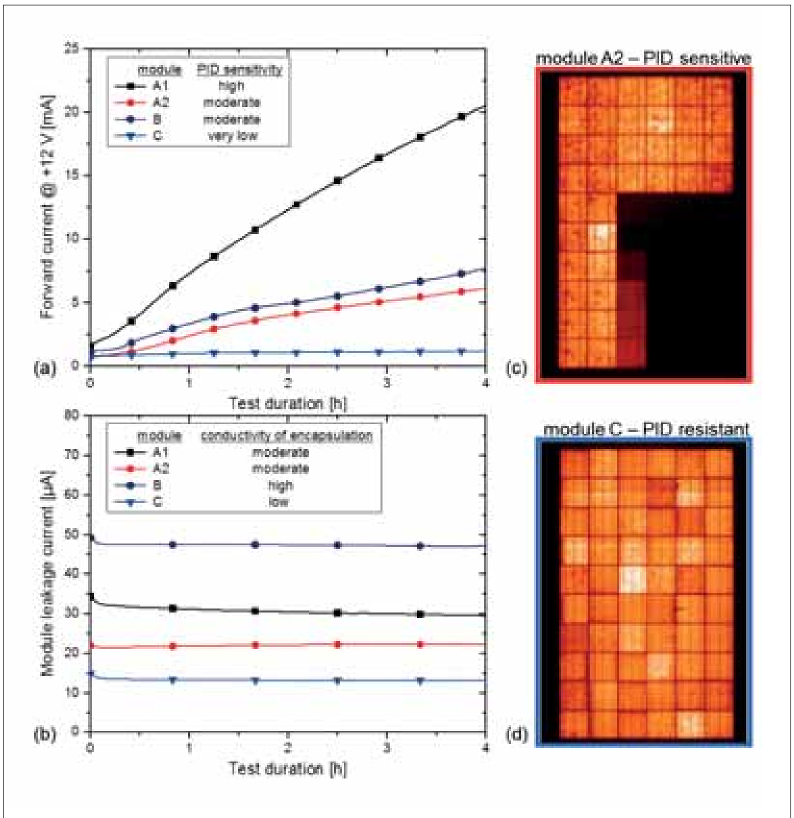

Figure 4. (a) Forward current and (b) measured leakage current for four different modules subjected to the outdoor PID test procedure; EL images acquired after the PID test for (c) the PID-susceptible module A2, and for (d) the PID-resistant module C

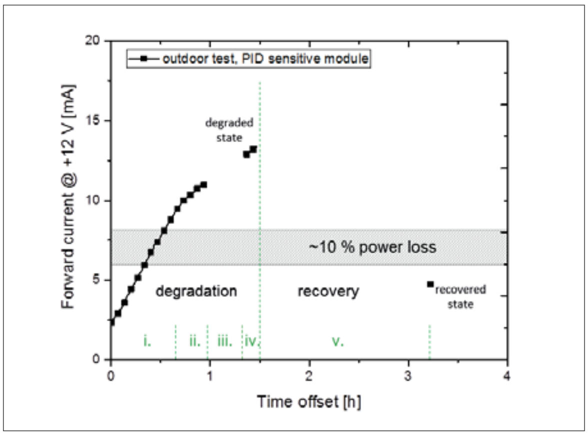

Figure 5. Forward current and measured leakage current of a module undergoing the PID test procedure in real outdoor conditions at a PV power plant

Outdoor testing

The test set-up was used to demonstrate the measurement principle under real outdoor conditions in an operating PV power plant (see Fig. 2(b)). The test was conducted on a partly cloudy day, with strong winds (gusts up to 30km/h) and rain showers, at ambient temperatures of 16–19°C. The test temperature at the module surface was 85°C and the high voltage (–1,000V during the degradation phase, and +1,000V during the recovery phase) was applied to the cells with respect to the glass surface grounded by the metal sheet and grounded module frame.

The graph of the recorded forward current as a function of test time is shown in Fig. 5. It can be seen that the initial increase of the forward current is even steeper during the first 40 minutes, indicating a very high PID susceptibility of the module installed in the PV power plant. The estimated threshold of a 10% power loss due to PID is already exceeded after approximately 30 minutes of PID stress time.

It should be noted that the outdoor test measurement shown in Fig. 5 was divided into five phases (marked in green) for the sake of studying the dependencies of the PID severity (and the leakage current) on module temperature and polarity of the high voltage. The five phases of the outdoor test that can be distinguished are:

i. PID testing at a constant temperature of 85°C.
ii. PID testing during the cool-down.
iii. Heating up to 85°C.
iv. PID testing at 85–90°C.
v. Recovery and short measurement of forward current after recovery.

By means of the applied reversed polarity (cells at +1,000V with respect to the grounded module glass) at the end of the outdoor test, it was demonstrated that the module could be recovered to almost its initial state within a short period after a PID test.

Future developments

Within the framework of the research project 'PID-Recovery', the on-site PID test device will be adopted for routine measurements; the PIDcheck test device (Fig. 6) will be used to perform PID tests in four different solar parks in Germany. A special emphasis will be placed on an investigation of the recovery process. The behaviour of the estimated module power loss, which can be calculated from the dark *I–V* curves acquired during PID and recovery tests, will be used for extrapolating the future electricity yield, both without and with a retrofit of the recovery methods. With this set-up, the cost effectiveness of PID countermeasures, such as changing the modules or retrofitting recovery devices, will be assessed.

Figure 6. Control unit of the on-site PID test device 'PIDcheck' from Freiberg Instruments, due for market introduction in summer 2018

Acknowledgements

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STORAGE & SMART POWER

Energy Storage NEWS

Introduction

Welcome once again to 'Storage & Smart Power', brought to you by Solar Media's Energy-Storage.News. We're just about halfway through 2018 and already we've seen more energy storage deployed in the US while more and more energy storage policy breakthroughs seem imminent, more virtual power plants to boost the residential sector, lots of big projects in Korea and Australia and lots of C&I storage in Canada.

The likes of Thailand, Lebanon and Armenia are about to get their first real taste of advanced energy storage and in recent memory the Czech Republic and the Philippines have done exactly that.

There's been a lot to write about on the site this year already, and these long-form features give us the chance to explore in a little more depth some of those industry-changing, world-changing moments.

Solar Media writer David Pratt discusses Smart Islands and how the economic and environmental case for deploying renewables for remote areas both enables immediate improvements to human lives and teaches valuable lessons about clean energy as base load. There are plenty of examples to choose from and David's exhaustive research has yielded insights into existing projects and the opportunities and challenges that still exist. And some great project pictures too.

Bringing the 'smart power' conversation on even further is 'Like using a hammer to put on your shoes…', in which Gianluca Mauro of AI Academy recommends strongly that executives and senior professionals become friends with the digitalisation of energy and commerce. As part of the European InnoEnergy collaboration for sustainable energy innovation, Mauro and AI Academy are training those in senior positions to realise the potential of advances in data analytics, machine learning and more.

We're also looking at long-duration energy storage. Having blogged on the subject of commercialising flow energy storage in the past few months, I've been speaking with four manufacturers of systems, each with different approaches and technologies. VRB Energy/Pu Neng, RedT, Primus Power and ESS Inc all spoke candidly about their ambitions in becoming the weapon of choice for renewable energy paired with long-duration storage.

We hope you are informed by and enjoy reading this edition of 'Storage & Smart Power'. It's certainly been informative and enjoyable to create!

Andy Colthorpe
Solar Media

Mahindra lowest bidder again in India's Andaman solar-storage retender

Major Indian solar EPC firm Mahindra Susten put in the lowest bid for a solar and energy storage auction in the Andaman and Nicobar Islands for the second time, having seen its victory in the original auction torn away by authorities as they reportedly explored other sources of power generation. In April's second staging the company quoted a price of ~INR1.33 billion (US$20.29 million) for the 20MW of solar PV and 8MWh of energy storage up for grabs from state-run mining and power firm NLC India. However, there is a clause in the bid, which says that bidders with more than 50% local content will be given a chance to match the L1 price.

Ireland's system operator sets out conditions for 300MW grid services tenders

Storage developers eyeing opportunities in Ireland's DS3 programme to procure grid services will be able to bid for six-year contracts providing frequency response and reserve in September when transmission system operator EirGrid will launch a new procurement process. But a number of stipulations have been put in place to cap the volume of applications that could be put forward to limit any expenditure risks identified by the TSO.

Hyundai group awards itself 65MW / 130MWh South Korea solar-plus-storage contracts

Various companies in the Hyundai engineering and industrial construction group will work together on a 65MW solar PV plant with 130MWh of co-located battery energy storage in Seosan, South Korea. Hyundai Engineering and Construction (Hyundai E&C) awarded KRW100 billion (US$94 million) of contracts to two of its affiliates, Hyundai Heavy Industries Green Energy and Hyundai Electric & Energy Systems, both part of Hyundai Heavy Industries. The projects are in South Chungcheong in the north-west of South Korea.

National Grid guidance on co-locating storage with generation welcomed by UK trade group

Guidance issued by Britain's transmission grid operator on how to co-locate energy storage with generation facilities was welcomed by an analyst at industry group the Renewable Energy Association. National Grid published a short document near the end March on existing processes and arrangements for generation – both renewable and non-renewable – to co-locate with energy storage onsite. Frank Gordon, a policy manager with the UK trade association, told Energy-Storage.News that the REA believes "energy storage located on-site at renewables projects is a key market for future energy storage deployment".

New Jersey could get 2GW of storage to help reach 50% renewables target

New Jersey is the latest US state to set itself targets for the deployment of energy storage, with newly passed legislation calling for 600MW of the technology within three years. A bill, S2314/A3723, passed in Mid-April as one of three sustainability and low carbon measures for the state going forward, calls on the New Jersey Public Utilities Board to analyse the costs and potential benefits of energy storage as well as making revisions for community solar, energy efficiency, peak demand reduction and solar renewable energy certificate programmes.

Credit: SDG&E

California utilities including SDG&E were among leaders for MWs of storage deployed, as expected.

Hawaii, California lead the way in SEPA's utility energy storage rankings

The US Smart Electric Power Alliance (SEPA), has just published a set of four Top 10 lists, ranking utilities in the country by annual megawatts of utility solar deployed as well as a separate table for annual Watts per customer. SEPA repeated the format for energy storage, looking at Watts per customer, which KIUC (Kaua'i Island Utility Cooperation) in Hawaii topped. In terms of total megawatts deployed, Southern California Edison and SDG&E, both California investor-owned utilities, topped utility storage rankings.

Lebanese solar-plus-storage tender could enable private supply of renewables

The Government of Lebanon is seeking to enter power purchase agreements (PPAs) for renewable energy supply and has called on "private investors and companies interested" to submit expressions of interest (EOI) to deliver multi-megawatt solar PV projects with co-located energy storage. PPAs will be bought by Electricité du Liban (EDL), Lebanon's main electricity supplier, on behalf of the Lebanese Republic Ministry of Energy and Water (MEW). It was made clear the government wants to buy up the electricity supply, not to own the assets themselves.

IHS Markit: 40% of energy storage pipeline is co-located with solar PV

As much as 40% of grid-connected battery storage projects that have been announced worldwide propose co-location with solar PV, from a pipeline of more than 10GW, according to analysts at IHS Markit. The research firm has just published its analysis of the global battery storage market in 2017, extending into the first quarter of this year. It found that the "global utility-side-of-the-meter pipeline" increased by 2.9GW in Q1 2018 alone, from 7.5GW at the end of 2017 to 10.4GW today. It's important to note that the pipeline is collated from announced, not completed, projects.

Kokam's high power batteries increase gas turbine efficiency at Australian mine

Kokam has deployed high power battery storage at an off-grid site in Australia, which the company claims increases efficiency of onsite gas turbines at lower cost than rival grid-scale lithium projects. The South Korea headquartered maker of industrial battery systems announced in May that a project for Australian utility Alinta Energy, which pairs Kokam's Ultra High Power lithium-ion nickel manganese cobalt (UHP NMC) batteries with an existing 178MW open cycle gas turbine power station, has been completed.

North America's largest solar and storage event takes place this September

Solar Power International (SPI) and Energy Storage International (ESI) bring over 20,000 energy professionals and 700 exhibitors from more than 110 countries. The event features new markets that help connect all things solar – from storage, IoT and beyond. If you want to see the future of North America's energy market, this is the event to attend.

SPI and ESI are powered by leading industry groups, Solar Energy Industries Association (SEIA) and Smart Electric Power Alliance (SEPA), and will take place on September 24-27, 2018 in Anaheim, CA.

INNOVATION AT ITS CORE: WHAT TO EXPECT AT SPI AND ESI

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- **HYDROGEN + FUEL CELLS NORTH AMERICA,** *Co-located with Solar Power International*
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  The 2018 Smart Energy Microgrid Marketplace will feature a fully-functioning microgrid, energy management systems, automation products, electric vehicle charging stations, energy storage providers, and solar panel manufacturers.

- **The Technical Symposium,** *Presented by Solar Power International*
  The Technical Symposium offers professionals from the academic, R&D, technical and scientific disciplines in photovoltaics, energy storage and 'smart' energy to learn about the technology from an academic and scientific viewpoint.

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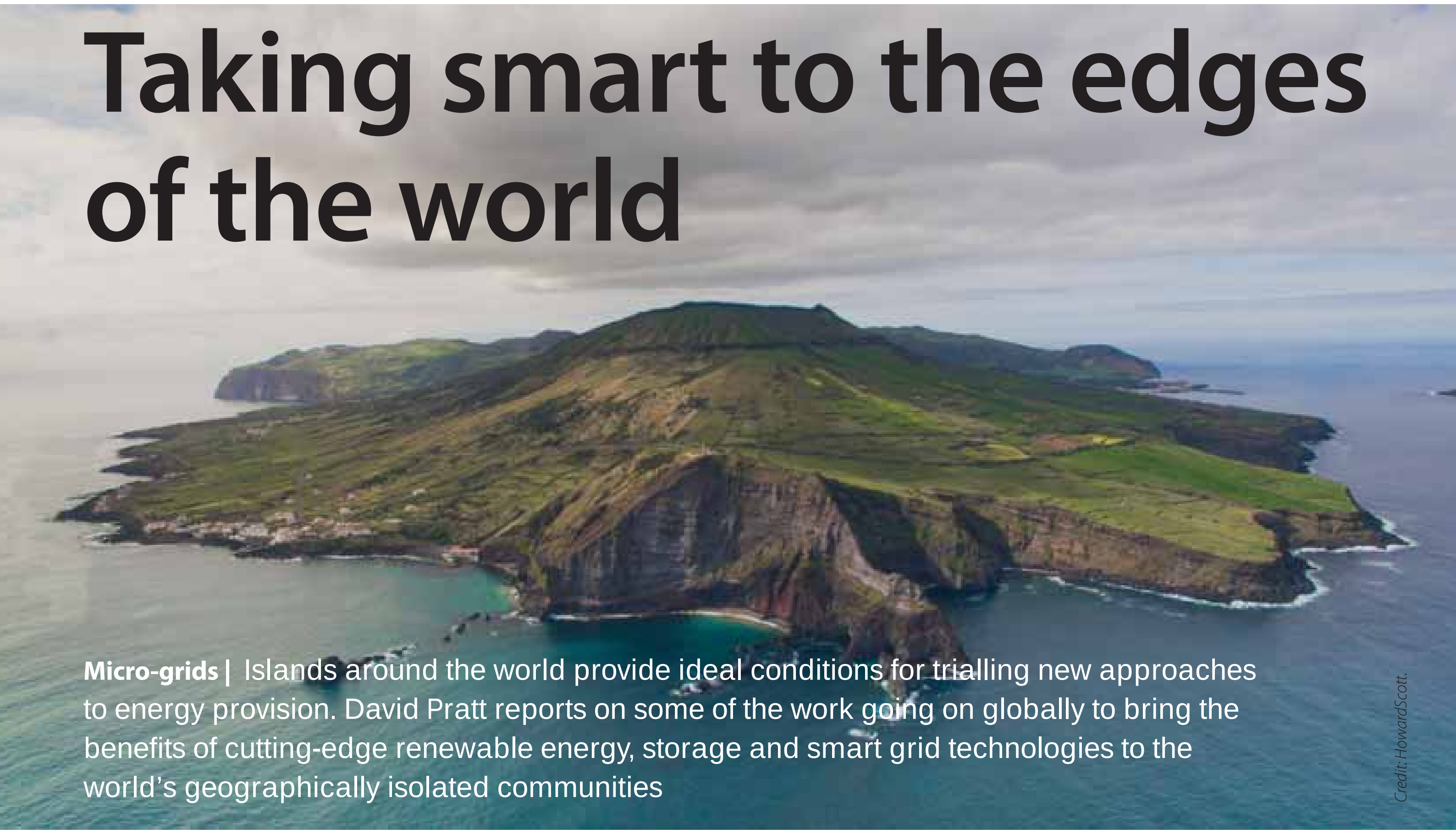
Taking smart to the edges of the world

Micro-grids | Islands around the world provide ideal conditions for trialling new approaches to energy provision. David Pratt reports on some of the work going on globally to bring the benefits of cutting-edge renewable energy, storage and smart grid technologies to the world's geographically isolated communities



Credit: HowardScott.

It's been a whirlwind few years for energy storage technologies, with the proliferation of renewable energy around the world and continually falling costs leading to new and innovative business models coming to the fore.

But where front-of-meter, grid-scale batteries have emerged in the last few years, in particular on mainland locations, as well as growing numbers of domestic installations and behind-the-meter applications, one area of deployment has had the perfect conditions for the technology for much longer.

Islands have suffered under conditions imposed by traditional generation and grid technologies for decades. Where coal- and gas-fired power stations offered cheap forms of energy on the mainland, such technologies have come at great cost to island inhabitants.

These locations have been subject to higher energy prices owing to the cost of importing fuels to them, all while suffering from the more acute environmental impacts of burning fossil fuels.

Emanuele Taibi, of the International Renewable Energy Agency's (IRENA) power sector transformation strategies team, says: "The impact of pollution from fuel transport, storage and combustion is especially evident in a small place. In a densely populated small island the diesel power plant has a significant environmental impact for the delicate ecosystem."

Combined with weak grid systems, islands have been calling out for an alternative much longer than those on mainland geographies.

At the same time, they have also been far more suited to the benefits of renewables, energy storage and smart systems than larger grids. A study published by IRENA in 2015 of Fiji, the Marshall Islands and Vanuatu found that using the likes of solar, wind, geothermal, marine, biomass and biofuel could lower power generation costs, while improving access to energy and energy independence.

The environmental case

As part of their efforts to overcome the polluting presence of traditional generation, many island territories are looking to adopt 100% renewables in the coming years.

John Jung, president and CEO at Greensmith, explained: "People are implementing and transitioning grids from base load generation into intermittent resources very quickly, where you almost want solar and wind to become the new base load.

"As islands or other localised grids get anywhere in excess of 70%, up to 90% renewables, I think you need to start thinking about large quantities of batteries and inverters as well."

Islands stand to benefit significantly from new decentralised energy technologies

Such ambitious targets can be found on the French island territories, where very ambitious targets would see these islands reach 50% renewables in 2020 and absolute energy independence in 2030.

The economic case

These targets have been helped, and in some ways brought about, by the fact that costs have come down so sharply for renewable and associated technologies – a stark contrast to the high costs of diesel gensets on island locations.

Taibi continues: "It's just cheaper. How much cheaper depends on how you design the project but a well-designed project is typically modular, so you start going the

Twelve solar-plus-storage projects on Martinique were awarded contracts in French island tenders in 2015 and 2016

Credit: Flickr/_dChris.

Territory	Number of projects	Allocated power (MW)
Corsica	20	8.4
Guadeloupe	16	15.6
Guyana	4	11.1
La Réunion	17	22.3
Martinique	4	2.5
Mayotte	6	3.4
TOTAL	67	63.3

Table 1. French Island tender winners 2016/17.

first mile as a least cost system today. Then tomorrow renewable technologies will keep getting cheaper, the price of oil will probably keep going up so you expand the amount of renewables in the system.

"You can also definitely do a one-off project, which may be more costly initially but it gets you off the diesel fuel supply chain completely and that makes a lot of sense from an economic perspective."

This can be seen clearly on the French islands, where a tender for solar-plus-storage projects on territories including Corsica, Guadeloupe and Martinique saw winning bids announced in August 2017 often 40% lower than the victors of previous reverse auctions.

The 67 projects that include PV panels and batteries totalling 63.3MW attained a guaranteed purchase price for their generated power of €113.6 (US$133.97) per MWh (Table 1).

By comparison, a 52MW tender in June 2016 awarded feed-in tariffs (FiTs) at a weighted electricity price of €204/MWh (US$229.77/MWh), while France's ministry of ecology, sustainable development and energy has previously stated power prices on the islands stood at around or over €200 per MWh.

Corentin Baschet, analyst for Paris-based technical consultancy Clean Horizon, says: "The motivation is that in the French islands, as in a lot of other islands, electricity production costs are very high because it relies on fuel, like imported diesel which is then burnt in a very low efficient engine or even worse, that engine is a gas turbine that burns oil.

"So we're talking about 20% efficiency, and it's a small engine so it can be even more inefficient. That results in the cost of electricity being probably three times as high as in continental France. What is shown by the reduction in PPA prices for PV-plus-storage is that it is less expensive than conventional generation on the islands."

Such progress shows the course that renewables and batteries are likely to follow. In the French islands, 50MWh of energy storage had already been deployed by September 2017. However, 140MWh has been contracted to 2020 and according to Baschet, this could edge closer to 200MWh by the end of the decade – four times that of current deployment.

Will fossil fuels endure?

So while islands are increasingly able to latch on to the environmental and economic benefits of renewables thanks to advances in energy storage and connected systems, going 100% renewable still offers its challenges, and they remain centred on cost.

Philip Hiersemenzel of Younicos, which has been working on the Azorian island of Graciosa since 2012, claims increased renewables penetration, and the resulting need for batteries, may never reach a fully economic case.

"You still need back-up generation simply for economic reasons. Wind and solar are cheap, storage has become cheap too but we've run simulations here and depending on the load and geographic conditions, the economically optimum result is usually between 60-80% renewables share," he says. "The farther you go to 100%, the more expensive it becomes.

"What makes sense is to have some sort of back-up thermal capacity and then to integrate that into the grid. Since the thermal capacity no longer has to play the role of stabilising the grid, it can do what it likes best, which is to run at its most fuel-efficient point."

Taibi adds: "The diesel itself doesn't have to stay there but some form of thermal generation such as biodiesel could really help in reducing the size of the battery.

"It's much more efficient to keep some sort of dispatchable generation and given it's so little, a little bit of biodiesel stored somewhere for those cloudy days of the year in a row makes a lot of sense because it minimises system costs."

The exception to this can be found in high levels of pumped hydro storage, such as in Iceland which is thought to be the only country in the world to obtain 100% of its electricity and heat from renewable sources – namely hydro and geothermal.

However, in smaller cases there remains a critical need for batteries such as on Kodiak Island, Alaska. The Kodiak Electric Association (KEA) set a goal in 2007 to produce 95% of Kodiak Island's energy from renewable sources by the year 2020 – a goal it reached in 2012.

Younicos integrated a 3MW lithium-ion battery last year to replace a lead-acid solution it had previously installed to work alongside the island's 9MW wind park and two 11.5MW hydroelectric turbines.

According to Hiersemenzel, the hydro can meet many of the island's needs aside from dealing with the fluctuations brought on by the wind generation. However, where traditionally a thermal generator would be called on, the battery solution offers the missing piece of the puzzle.

"The hydro isn't thermal but it's still a rotating mass with all the advantages and disadvantages that brings. You then have the variability of a wind farm so this is really again where the battery and its grid forming ability is of critical importance.

"It stabilises the grid in the short [term] which allows the hydro then to react. That also allows you to become an almost 100% renewable energy system if you have a huge pumped hydro," he explains.

Credit: Younicos

Kodiak Island, Alaska, has a critical need for batteries

The missing piece

Therefore much like on mainlands across the world, the energy storage element is key to integrating renewables on island locations, to dealing with inherent fluctuations within the generation profiles of these technologies and shifting generation to times of need.

"There's always storage in an isolated power system where your main resources are variable and if your footprint is very small. The debate of storage versus transmission ongoing in continental systems is not necessary in an island as very often there is no option for interconnection to the mainland so you do need some sort of storage to get close to 100% renewables," Taibi explains.

As this continues, with more and more players entering the smart islands market, Baschet suggests that this could see the nature of the storage deployed change to meet the impacts of ever increasing levels of renewables.

"The first problem you see on the grid is intermittency, so the first business case for storage on islands is frequency regulation and that, usually speaking, is short duration storage.

"As you move forward, with the intermittency of renewables, there is a need for a bit longer duration storage and that's what you can see in Hawaii for instance, which started with frequency regulation batteries and that now has a PPA for a four-hour storage system to really shift PV energy from the day to the night.

"That's the logical trend; to start with a bit of short-term duration storage and as you increase the share of PV or wind, to put in a bit longer duration storage."

However while energy storage no doubt plays a significant, almost grid-forming role in smart island projects, there is debate over whether or not it is in fact the grid-maker.

The grid-maker

With all these technologies seeking to work in unison, a battery is just one more resource bringing them all together. But a new market is emerging for another resource, namely the software platform that brings them all together.

Greensmith's Energy Management System (GEMS) on Graciosa is able to integrate any generation source with batteries and bi-directional inverters to optimise the different sources against load predictions and weather forecasts for wind and solar output. It also provides a supervisory control layer providing controls across the grid system.

"An island grid is an ideal application because they have less conventional legacy tools to solve grid congestion issues, which is why not only energy storage but something like a GEMS platform that can basically optimise an entire island grid is what we're really excited about delivering on Graciosa," Jung explains.

These systems can also add an element of synchronicity to renewable generators that can overcome a key criticism often levelled at them, namely that they fail to offer continuous generation deemed as an essential part of mainstream energy production.

Jung continues: "The virtual synchronous generator mode is essentially what you need to form a proper grid. It's actually a lot more important than if you have a spinning mass or not, and simply by the nature of the intermittency of these resources, they have an almost take it or leave it kind of generator quality to them that requires additional help in voltage frequency from the grid.

"Whenever you have inverter-based power being generated, you need additional things to compensate for it especially around voltage and frequency.

"One of the key challenges is establishing the right controls and set points to ensure that when multiple assets are forming the grid together they aren't working against one another but toward a common goal. Unless you have the right software delivering the right business model, it's not going to deliver a lot of value."

Case studies: Graciosa

- Integrating more than 1MW solar, 4.5MW wind, 3.2MWh battery with around 6MW of thermal generation.
- Aims to use renewables-plus-storage system to stabilise the grid network and greatly reduce the need for thermal power generation and costly fuel imports to the island, reaching 65% renewables by the time the project is fully up and running.
- Status – technologies deployed, final testing underway before being commissioned within weeks (at time of writing)

Dubbed "ground-breaking for the entire industry" by Younicos' Philip Hiersemenzel, this project was one of the first smart islands announced back in 2012. Having undergone a series of setbacks since, not least as a result of the financial and Euro crisis, Graciosa is now ready to test the theories that have gone into it.

"Graciosa stands apart because it's of a certain size [over 60 square kilometres, around 4,500 inhabitants]. When you have smaller islands that have gone more or less towards 100% renewables, it's a different story because it's all solar which in a way is somewhat easier and they have a lot less fluctuations.

"Graciosa has villages, a little industry, a dairy farm so you have load jumps which does set it apart," Hiersemenzel said.

It had been intended that Graciosa would reach 100% renewables however Younicos found that a diesel engine was still needed to cover the periods of bad weather not served by wind and solar.

There would also be the result of excess renewables in comparison to the amount of energy storage that could be economically envisaged. Despite this, John Jung of software platform provider Greensmith maintains the importance of the project.

"Graciosa may represent the most advanced micro-grid anywhere in the world [and] reflect the spectrum of complexity on any grid," he says.

"Issues like harmonics and dynamic instability can cripple high renewable energy penetration, particularly on an island like Graciosa where most of the electricity generating will probably come from wind and solar.

"So this is why we pay close attention to these issues and challenges and needs, but we ensure that our knowhow and our integration and design but also our GEMS can actually mitigate these risks in real time, and I mean milliseconds."

The Graciosa project integrates solar, wind, energy storage and thermal generation under a management software platform

Case studies: Isles of Scilly

Key facts

- Doubling renewable capacity to 449kW through the addition of rooftop solar and two commercial-scale solar arrays, at least 1MW of storage added across households and V2G charging a large storage solution.
- Its goal is to provide 40% of electricity demand using renewables, to cut electricity bills by 40% and for 40% of vehicles on the islands to be electric or low-carbon – all by 2025.
- Status – software development underway alongside consumer engagement.

Hitachi gave *PV-Tech Power* an update on breaking new ground:

PV Tech Power: What are the specific benefits to island inhabitants of transitioning to a smart energy system?
Hitachi: The expected outcome of the Smart Energy Islands project is to enable the more efficient use of locally produced energy with home batteries, electric vehicle management and smart heating technologies matching supply with demand.

The Smart Energy Islands project will be installing solar PV arrays this summer on the islands. When these are connected to the internet, communications and data will combine to allow a much more intelligent use of energy resources. The benefits will be shared through a community venture, which will offer an energy tariff to islanders and reliance on mainland power and local energy costs will be reduced.

What is the importance of a high-level software platform using IoT, machine learning or AI in bringing these together?
At the heart of the Smart Energy Islands project is a simple idea – that an Internet of Things (IoT) platform for the Isles of Scilly, which will respond digitally to balance electricity demand and supply, will enable the more efficient use of locally-produced energy.

The Internet of Things platform will monitor electricity loads in houses and businesses, as well as electric vehicles, home batteries, smart heating technologies and other infrastructure, to optimise local energy use. Without a solution like this, the Smart Islands' ambitions could not be met.

What are the lessons Hitachi hopes to get out of the project and how are they likely to be applied?
The Smart Islands Programme aims to improve buildings and public infrastructure on the islands with additional energy generation and a community venture to channel the benefits of local energy generation to consumers. The community venture will facilitate the wider rollout of renewables, energy efficiency and smart energy technologies on the islands.

The Isles of Scilly, the focus of Hitachi's Smart Energy Islands project

It's therefore no surprise that for Jung, Greensmith's fifth-generation platform offers more value to a smart island project than the sum of its parts, suggesting that such a system would still be able to deliver value to a project even without battery storage.

Others are seemingly taking on this view, with domestic battery manufacturer Moixa developing the integration software for the Hitachi-led Smart Energy Islands project on the Isles of Scilly, off the coast of the UK.

This project is looking to double Scilly's renewables capacity through both rooftop and ground-mount solar, add 1MW of energy storage and integrate a higher percentage of electric vehicles to the isles.

Working with Hitachi and its Internet of Things platform to use these technologies to balance supply and demand of electricity, Moixa's project lead for the venture, Johnathan Linfoot, explains that the key is to ensure as many varying technologies as possible can be controlled under one system.

"Our aim is for the platform to be able to manage, agnostic of device. Our technology really focuses on managing a heterogeneous set of assets and doing that intelligently," he says.

"If you look at the ways to tackle the energy issues around Scilly, we think it's best to look at a distributed smart system because you can ultimately tailor that to exactly what the problem is rather than applying some sort of large network-scale asset to solve the problem."

Testing out the future

This ethos is one that will be familiar to anyone involved in planning the energy system of the future, with smart islands offering a glimpse at what the world could look like one day on a macro-scale.

It's no secret then that many of these projects are being carried out with that in mind, with Hitchi's involvement in Scilly predicated on its future plans for smart city applications.

Taibi says: "They are indeed living laboratories for testing technologies that are not possible to test in a large continental system in the way that you can do it in an island.

"There's a lot of need for system integration not only in the island systems, however you can test it better there in a system where you leave the hardware to operate in the real world, often in harsh environmental conditions."

How this can be applied in the future is not yet clear, but with cities around the world implementing their own renewable energy, storage and carbon targets, it's not out of the question that these metropolises could use the technologies being applied on islands to become islands themselves.

"Cities are at the moment one of the hot topics for the energy transition. [If] you want to start having the possibility of operating the city as an islanded power system, with the distribution system disconnecting from the transmission and running stand-alone, for instance in the event of extreme weather events, I see a convergence between islands, energy access in off grid systems and cities," Taibi concludes.

For Jung, the question remains – why stop there?

"The US is an island too and I think we'll see a time when control platforms are going to increasingly integrate the different control systems that grid operators are really not only contending with but are challenged by right now, because they're not getting maximised orchestration of these resources.

"There's also a desire and need for grid operators in many parts of the world to select one common platform so they can almost plug and play these different assets on the grid, including network assets. I feel like that's what we're getting to and is what we continue to invest in."

2018 Energy Taiwan and Circular Economy Taiwan connect Taiwan's green industries to create a new era of application with double "zeros"

To be held at Nangang Exhibition Center, Hall 1 from September 19 to 21, 2018, Energy Taiwan and Circular Economy Taiwan will showcase the most popular current new industries, centred around green energy and eco-technology, under the theme of "zero energy consumption" and "zero waste". The two shows are estimated to attract 17,000 buyers from domestic and international markets.

With the success of the 2017 PV Taiwan Show, which enjoyed substantial growth both in scale and the number of visiting buyers, Taiwan External Trade Development Council (TAITRA) and SEMI will scale up "Energy Taiwan" this year to showcase the highlights of the renewable energy industry, such as photovoltaics and wind energy. It will join up with TAITRA's first-time-held Circular Economy Taiwan (CE Taiwan), focusing on topics such as green design and production and waste management. From "energy creation, energy storage and energy saving" and "resource circulation", this year we are moving towards a new era of applications with the double "zeros" of "zero energy consumption" and "zero waste", aiming to create Taiwan's most professional and complete exhibition platform for green energy and the circular economy.

With the support of governmental policies such as the "Two-year solar power promotion plan", "Four-year Wind Power Promotion Plan", and " Forward-looking Infrastructure Development Program", the industry expects to have more than 24 billion NT Dollars of special budget from the government for the construction of green energy facilities. Industries are mostly optimistic about the development of the domestic market for green energy and resource circulation that are expected to become the next stellar industries in Taiwan. Thus, to reflect government policies and the needs of industry, PV Taiwan and the Taiwan International Green Industry Show (TiGiS) will transform and scale up to "Energy Taiwan" and "CE Taiwan". From manufacturing to application, commercial to home-based sustainable products and equipment, these shows will fully present the entire green supply chain of renewable energy and resource circulation.

In addition to these rich and exciting exhibitions, industry summit forums will be held during the show on topics such as solar energy, wind energy, hydro-energy

and circular cities, along with the second "East Asia International Forum for Technologies to Purify Indoor Air", product launches and more than 50 other exciting events. Industry experts and major companies will be invited to share their experiences in their specific industries, accompanied by presentations of the latest technologies and forecasting of future trends for development of those industries.

Both "Energy Taiwan" and "CE Taiwan" will be held from September 19 to 21, 2018, at Nangang Exhibition Center, with up to 600 show booths expected, together with 17,000 buyers from domestic and international markets.

Websites:

Energy Taiwan: www.energytaiwan.com.tw

CE Taiwan: www.cetaiwan.com.tw

Long time coming

Battery technology | First developed by NASA, flow batteries are a potential answer to storing solar – and wind – for eight to 10 hours, far beyond what is commonly achieved today with lithium-ion. In the first of a two-part special report, Andy Colthorpe learns what the flow battery industry faces in the fight for commercialisation

Credit: Primus Power

Primus Power's zinc bromine EnergyPod solution. Flow batteries are emerging as a long-duration alternative to lithium-ion technology

Solar is easy to explain. Sunlight hits panels, electricity hits grid. Then come the inevitable questions about using power when the sun doesn't hit the panels, about batteries and the well-rehearsed explanation comes that yes, while it would be great to use solar power 24/7, we're just not there yet with the cost of technologies as they are, for the most part.

So the more complex explanation follows that lithium batteries are being deployed at large-scale to store energy for short periods of time, to deliver frequency regulation, or to remove specific hours of a peak demand period.

A market need for long-duration storage remains elusive outside of specific circumstances such as remote grids where batteries and PV are replacing expensive diesel. Providers of flow batteries would beg to differ.

While acknowledging that lithium's head start from a mass production perspective and other factors contribute to a higher capex overall for flow, flow energy storage providers are quick to point out the long lifetimes of their machines, the low cost of their raw materials, the comparative lack of fire hazard and associated balance-of-system costs and sheer ability to store huge amounts of energy, rather than power, mean flow could be the cost-effective long-duration choice of the renewables industry.

"People used to ask us what we needed the fifth hour for and now they ask if we can go to 10 hours," Jorg Heinemann, chief commercial officer at Primus Power says.

Heinemann joined zinc bromine stationary energy storage maker Primus Power after eight years developing utility-scale PV with SunPower, believing long-duration storage to be the natural next step for renewable energy. Customers that have large amounts of solar PV are now approaching Primus with the intent to use solar-plus-storage as peaker replacements and to use behind-the-meter battery assets to offset transmission and distribution (T&D) investment costs.

"That's beyond four hours [of storage], that means putting in a request for five, six or even eight hours, to take renewable power and add it to the storage and you've eliminated the need for a peaker. That last wave of use cases, T&D deferral, gas peaker replacement, heavy duty renewable extension, those are new, at least new to us. People have talked about them in theory, we're now getting those active requests."

In California, where Primus is headquartered, lithium batteries have now been deployed to provide capacity in the wake of natural gas plant retirements and questions over security of supply following the Aliso Canyon gas leak, marking a milestone for batteries to be used on the grid for more than short-term balancing services. The state's main investor-owned utilities now also have to include consideration of four-hour duration energy storage in their Resource Adequacy Plans. Other parts of the world are moving there faster, with various dispatchable solar projects announced in recent months.

Flow energy storage, which can use a variety of chemistries including vanadium, zinc bromine and in one instance, iron for the electrolyte, puts a central battery stack between electrolyte in tanks. As Navigant Research analyst Ian McClenny points out, the levelised cost of energy decreases as discharge duration increases. In other words: scale up the tank size, scale up the project's energy need (as opposed to power), bring down the cost.

"The cost over the lifetime of the storage asset is heavily dependent on what type of applications the device will be serving," McClenny adds, and although the capex required for flow might be higher than lithium, flow battery makers would argue that that initial cost is outweighed in the long run by the other benefits of ruggedness and long lifetime that they claim.

Navigant also sees flow energy storage as a four-hour+ duration storage device and the firm has identified flow batteries as one of the clean and distributed energy technologies expected to grow fastest in the next 10 years in terms of market share. McClenny says at present the majority of advanced energy storage being deployed around the world is still providing services that require less than four hours' duration.

"Consequently, Li-ion batteries can provide the same services that flow can at a lower capex," within the context of most current global markets, McClenny says.

More duration, more dispatchable power

However, as Primus Power's Jorg Heinemann argues, the planet is "heading toward close to free power during daylight hours" and the "base case that will eventually run the planet is to take renewable electricity, store it with long duration storage and dispatch it in the evening, night-time and early morning hours when the sun is not shining".

Prices are falling and many utility-scale PV plants that are 10 years old today will be producing power almost for free in another 20 years, Heinemann cites as an indicator.

"Now the typical solar developer or independent power producer is recognising energy storage as a very doable and economic thing, and a good value proposition."

Jim Stover, business development VP at Pu Neng, soon to be rebranded VRB Energy in markets outside China, points out that that country's renewable energy sector is about to put wheels in motion that could make flow unstoppable. Pu Neng, now US- and Canada-headquartered VRB's subsidiary, is among the vanadium flow battery makers to be in the running for projects in China that will provide multiple hundreds of megawatt-hours of storage to local grids. China's government set out its official stance on energy storage for the first time ever in October 2017 when it issued "Guiding Opinions on Promoting Energy Storage Technology and Industry Development", the policy which informed the mammoth decision.

Already awarded is a contract for Rongke Power, which has a well-known subsidiary in the US, UniEnergy Technologies (UET), to install a 200MW/800MWh flow battery system in Dalian Province, with the company itself having emerged from the Dalian Institute of Chemical Physics originally.

The China National Energy Administration approved that project and is considering developers for a further 100MW / 500MWh system - for which Pu Neng is installing a 3MW / 12MWh demonstration project - and two further, reportedly 1GWh projects paired with wind energy and a nuclear plant. This would massively skew megawatt-hour deployment figures worldwide in flow's favour, although the projects themselves are unlikely to be connected for at least another 10 years.

"The Chinese government I think in particular is happy to incentivise or call out vanadium like this. They want to push a number of technologies, but there is an awful lot of vanadium resources in China, both from mine sites and from steel slag recovery," Jim Stover says.

"They're trying to seize that as a good and natural fit, they don't have a lot of lithium. They have a lot of lithium manufacturers but not a lot of lithium itself, or cobalt, or nickel even. That's one of the dynamics in China."

Big batteries, long durations, and (mostly) huge amounts of renewables enabled; the signs seem positive. Nonetheless, we have seen the likes of VIZN and Imergy hit the scene with numerous deployments and promising low cost storage, only to succumb to bankruptcy and layoffs. As Navigant's Ian McClenny says, despite flow being his team's forecasted "fastest growing electrochemical energy storage device over the next 10 years", there are still "short term hurdles".

Education and cost-competitiveness

It's partly on flow manufacturers to educate would-be customers on the benefits of their technologies, McClenny says. Indeed, while one perceived hurdle is cost, Primus Power claims a lower price point than lithium-ion for long duration when both capex and opex are included.

"Lithium is fundamentally a power battery. For a four-hour energy duration, we'd have to oversize that battery, augment it over time, plan for a refresh at the latest by year 11, and all the while we have to be extraordinarily careful we use the battery within its defined limits, so never let it discharge too far, charge too much, cycle strictly once a day or whatever the specification is," Primus' Jorg Heinemann says.

"Then we say, 'do you want to cycle twice a day instead of once a day, what if you want to go 30 years instead of 10 years'? They soon realise 'this is crazy, I need a flow battery'. That problem only gets worse I guess if you're lithium and better for us as the durations get longer."

Craig Evans, CEO of ESS Inc, which has patented and makes the only 'all-iron' flow battery using saltwater electrolytes, goes further, arguing that the lack of need for expensive HVAC and fire suppression is another overlooked aspect of lithium grid-storage costs.

At one micro-grid project in San Diego, "the safety report on our chemistry was three sentences long on how the fire marshal should handle our battery in case of an event", Evans says, while apparently another California project at a vineyard was ruled safe in the event of leakage since the contents of the battery were "essentially fertiliser".

"A lot of PPAs, particularly with solar, those are going to be typically about 20 years. [If] you're going to do all that installation, you're going to want the battery to last as long as the solar, so you don't

Credit: VRB/Pu Neng

Pu Neng's North American parent company is rebranding as VRB Energy ('Vanadium Redox Battery')

incur multiple costs over the lifetime of the project. So you want a battery that can cycle tens of thousands of times. 20,000 cycles on the battery is not going to be an issue and we can do that with zero capacity fade."

Navigant's Ian McClenny claims costs need to come down and suggests there could be better material for electrolytes than vanadium and zinc bromine, which are among the more common electrolyte solutions found in the batteries.

Craig Evans says the iron flow battery, just announced in May to be deployed in Brazil in a trial for investor Pacto GD, is a low-cost, environmentally-friendly chemistry (like vanadium and zinc bromine much of it can be recycled, but unlike vanadium it is not classifiable as hazardous for transportation purposes). It was first kicked around as an idea by others in the 1970s but dropped until ESS Inc more recently took a look and "realised what iron could do".

With five issued patents and 23 more pending, covering everything from the chemistry to the power module and electrolyte maintenance, Evans says it is not so much that others do not want to follow ESS' into iron flow, "but that they can't."

LCOE: a lifetime decision

Lithium-ion project developers have large balance sheets to put their projects on in many cases and the Li-ion battery industry as a whole exploits the scale-up of EVs and portable consumer electronics to drive down cost, Evans admits, but it's over the all-important lifetime LCOE that flow can win the long-duration race.

"[Lithium battery storage companies] have warranty issues, augmenting the pack over time. Deploying it in hot environments, they won't be able to meet the efficiency requirements because they've got huge HVAC loads. Our battery operates at 50°C.

"That's what's got their foot in the door, history, the electronics and EV markets. Where these flow batteries really come into the market and long duration really gains is with low cost renewables. I think you'll see more and more flow batteries out there. Deployments will get you more deployments."

VRB/Pu Neng's Jim Stover says that at the recent Energy Storage Association annual conference, questions about the cost per kilowatt-hour of lithium batteries were accompanied by lengthy explanations that certain percentages of the battery were not usable, due to cycling concerns.

"If the warranty [on a lithium battery] says you can go between 20% and 80% state of charge, you're not using 40% of your battery. Well, okay, isn't that 40% more expensive – to buy 40% you're not using? That's even before we get to the issue of degradation and lifetime of lithium cells."

Storage is driven by PV

Of course, there has to be an economic imperative to using these systems. Scott McGregor at RedT, a UK company making vanadium-based energy storage units and modelling business cases around them, takes up the baton, arguing that cheap renewable energy is what has "cracked open the energy storage market", the choice of storage technology being "irrelevant", so long as it works.

As such, McGregor says, getting customers more and more PV capacity is the primary interest and it's important to RedT to do what it can to rapidly commoditise its own technology. The CEO has banned staff from talking about their devices as batteries, instead calling them 'flow machines' and encouraging potential customers to consider their purchase as an infrastructure asset.

"We don't agree with the latest flashiest technology," McGregor says of the company's tech.

"We keep it dumb, simple and cheap. It's got to work as energy infrastructure for the next 20 years, so the differentiator is keeping it simple and not doing a sexy new technology because energy storage has to be proven first and in my view it's a very bad idea to take a technology risk in this industry."

RedT models the business case around a customer's wants and energy usage profile, before even determining if vanadium energy storage is the right fit. Once a business case is built – which along with the technology development is about "half of what we do", according to McGregor – the large C&I or utility customer can purchase an energy solution that includes PV and storage and can be invested in as infrastructure.

McGregor says there may also be unforeseen risks in business models based around short durations of energy storage that lithium might struggle to overcome in time. Peak demand reduction schemes are working out for now in the US C&I market, for example, but rely on basing a business case around what the RedT boss describes as a "policy-targeting gamble".

"If everyone's putting in one hour batteries to take out a one hour peak charge, guess what? That peak charge will then become six hours because you have an oversupply issue when everyone's doing the same thing.

"Whereas we maximise a customer's own PV generation – we call that 'cash' because solar's the cheapest form of energy generation. Then, let's take out as much of the peak as we can, that whole six hours of potential peak charges, not what exists [as policy] now because that will change and 80% of the customer's returns are [from] true distributed energy infrastructure, that cannot change, that is very flexible. Whatever happens in the market, the customer's got a safe investment for the next 20 years."

Credit: RedT

Stacks to go into RedT's finished vanadium 'flow machines'

In the next issue

- Market segments the flow industry is targeting
- Bankability
- Proving the technology works
- Manufacturing strategies

UPCOMING SOLAR & STORAGE EVENTS

2018 DATES FOR YOUR DIARY

Solar & Storage Finance and Investment Asia
2-3 July | Singapore
financeasia.solarenergyevents.com

EV Infrastructure Summit
3-4 July | London, UK
ev.solarenergyevents.com

Solar and Storage Australia
4-5 September | Sydney, Australia
australia.solarenergyevents.com

Solar & Storage Finance and Investment Canada
18 September | Toronto, Canada
financecanada.solarenergyevents.com

Future Power Networks: UK
25-26 September | London, UK
networks.solarenergyevents.com

Solar & Storage Live
16-18 October | NEC Birmingham, UK
uk.solarenergyevents.com

Solar Power Portal Awards
17 October | NEC Birmingham, UK
awards.solarpowerportal.co.uk

PV ModuleTech
23-24 October | Penang, Malaysia
moduletech.solarenergyevents.com

Solar & Storage Finance and Investment USA
29-30 October | New York, USA
marketing@solarenergyevents.com

Solar Energy Southeast Asia
26-27 November | Thailand
seasia.solarenergyevents.com

Solar Finance and Investment Middle East & Africa
4-5 December | Marrakech
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Like using a hammer to put on your shoes: energy leaders must learn how to use technology

Future of energy | The Internet of Energy is set to provide flexible, sustainable and affordable power for all. But we must not get complacent. Gianluca Mauro, Co-founder and CEO at AI Academy, argues that for this future to be realised, energy leaders need to develop a digital mindset

Credit: Getty/metamorworks

There is a lot of talk about the future of energy. We hear that we will soon be living in a paradise, where flexible power systems maximise efficiency to provide us all with clean, sustainable energy at a price we can afford.

It sounds fantastic, but let us not get too complacent. We are not in the future yet, after all. And we might never arrive unless those in senior positions within the industry truly understand the complex technologies that come together to form what I like to call the Internet of Energy.

What is the Internet of Energy?

What is the internet, at its most basic? It is a network, on which people and machines exchange information.

The energy industry is following suit. The aim is to move away from a system in which the big utilities pump power downhill towards a group of passive consumers. Instead, the sector is working to build a network in the truest sense, where people produce, consume and exchange energy, peer-to-peer.

The significance of this move cannot be overstated. It could completely change people's relationships with power – shifting the balance in favour of the consumer and a new generation of innovators. And it could boost the economy, paving the way for innovative new businesses to disrupt the established order in the same way Airbnb has shaken up the hotel industry.

Enabling this shift are three key technologies: blockchain, big data and artificial intelligence. And, while we are talking about the energy landscape of tomorrow, these technologies are available today. There is nothing standing in our way. Except, perhaps, our mindset.

Developing a digital mindset

There is a lot of talk about a shortage of technological talent in the energy sector. But I do not think that that is the case. We have an abundance of hugely talented engineers, innovating to solve just about any problem you can imagine.

But there is no benefit in having all of these amazing workers and solutions at your disposal if the leadership is unsure of how to use them. Just as it would be no good having a hammer if you were not sure whether to use it to put up some shelves or to put on your shoes.

This is the big problem that the industry faces at the moment. Indeed, it is the only barrier left in the way of the wonderful energy future we can see before us: C-suite executives and senior operational people such as senior engineers and business development managers must develop a digital mindset. At the moment, they know that these technologies exist, and they know that they have tremendous value – but too many do not know how to use them.

And this represents a real problem. Because these technologies are so fundamental that they necessitate a change in the dynamics of the companies using them. Take AI, for example. It is no good writing an amazing machine learning algorithm or building a state-of-the-art neural network if it is not then applied to solving the business's problems.

If placed at the centre of the business, with a vision for its application to the firm's challenges, AI can analyse all of the data that the company has about customers' energy needs and the power available on the network. It can decide the most efficient series of transactions to ensure that everyone gets the power they need, cheaply and with limited waste. And it can do this all in real-time.

That's just one of the many, many ways in which AI can add real and tangible value. But this can only happen if companies become technology companies, rather than legacy companies in possession of technology that they do not understand.

Fundamentally, this is why Amazon is so successful. Built with technology at its heart, it is an internet business, not a shop. And while it is possible for companies to pivot to technology, it is not easy. This explains why there are loads of failing ecommerce ventures: a shop with a website cannot truly compete with a scalable digital-first retailer.

And technology firms like Amazon represent a threat even to those with whom they are not competing. While the energy sector is currently awash with promising tech talent, they need to be given the opportunities to build the solutions they know they are capable of, they will move to Apple, Google or another company that is structured to give them that chance. For energy leaders, adaptation is a matter of life and death.

Learning to survive

The solution is, of course, education. But I do not mean deep, technical courses. Europe's universities already do an exceptional job of providing us with a skilled workforce that knows the technology inside and out. That is how we ended up with all of these talented engineers in the first place.

Rather, we need courses geared towards helping those in senior positions to understand the underlying dynamics behind these technologies. They do not need to be able to use the tools, but they do need to know what they are used for and how to build a business to support their use.

This is the thinking behind a new course on the Internet of Energy, which I have been developing in conjunction with InnoEnergy. Taking the form of a summer bootcamp, we aim to quickly get energy leaders up-to-speed so that they understand the basic principles underpinning the technologies shaping the future of their sector – and can steer their respective ships in the right direction.

Because you can put your shoes on with your hands. But when you have a hammer, you can build something beautiful. ■

InnoEnergy is the innovation engine for sustainable energy across Europe. Its Internet of Energy Bootcamp runs from 3-7 September and can be attended online or in person

Meet InnoEnergy

InnoEnergy runs a series of programmes to promote sustainable energy in Europe. Its support ranges from on-the-job training to start-up incubation, higher education and entrepreneur coaching. Its shareholders include businesses Total, ABB, Schneider Electric and EDF plus universities and research institutes including France's CEA and the Karlsruhe Institute of Technology. It has supported solar startups across a range of areas including BIPV, thin-film technology and kerfless wafer development.

Author

Gianluca Mauro is founder of AI Academy, a consultancy covering the strategic, organisational, and technical aspects of AI's implementation. He has moved from energy engineering to data science via entrepreneurship and lived in Silicon Valley as a Fulbright BEST scholar. AI Academy is running the Internet of Energy Bootcamp with InnoEnergy, the European incubator for innovation in energy.

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