PV TECH POWER

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MONO IS THE FUTURE

PV TECH POWER

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Introduction

The problem with new technology is that for every winning new innovation there's a loser cast onto the pile marked 'obsolete'.

For large-scale solar projects, collapsing costs and technology improvements mean many older, underperforming assets don't hold up to scrutiny. Module and inverter swap outs are a growing line of work for O&M providers. Emerging issues, such as potential-induced degradation, are among those exposing the shortcomings of projects built without adequate monitoring capabilities. In this issue, RINA Consulting presents the base case for repowering, retrofits and life-extending technology that can offer investors better value for money than the status quo. We'll also take a look at lessons to draw from those already retrofitting solar technology at all scales (p.18).

It wouldn't be an Intersolar Europe edition of this journal without a look at a solar market closer to home. Liam Stoker takes a deep dive into the resurgent French market as it looks set to provide a major source of demand and give European solar a much-needed shot in the arm (p.23).

With an expected average of US$225 billion a year to be invested in solar out to 2050, TÜV Rheinland presents what could prove to be an investor's best friend. In its technical paper on page 60 it presents a method to push energy yield performance calculations for modules beyond an extrapolation of their standard test conditions, instead incorporating a host of real world factors. This could provide a key tool for that all important module selection.

Fraunhofer CSP looks at the need for new standards on light-induced degradation (LID) (p.76). The advent of new cell technologies, PERC in particular, increase the phenomenon creating a requirement for increased focus on LID mitigation.

We also introduce our new conference, PV ModuleTech, to be held in Malaysia this November (p.88). The event is dedicated to scrutinising the technical performance claims of manufacturers and seeking out best practice in module manufacturing at a time when the design and material options on offer are perhaps more diverse than ever.

In the world of energy storage, Danielle Ola explores the rapid-fire deployment of utility-scale battery storage projects in response to the Aliso Canyon gas leak in California (p.102). Andy Colthorpe, meanwhile, lifts the lid on the nascent O&M market for energy storage (p.98). With an increasing number of large-scale tenders driving deployment, it is never too soon to plan for the lifetime support these assets will require.

In many instances, the addition of storage can offer a fresh revenue stream to a solar project with spare grid capacity. But if obsolete inverters can't support the necessary energy management tools, it might be time to review how the economics of that retrofit stack up now.

We'll be onsite at Intersolar Europe for those of you in attendance as well as at out our own Solar & Storage Finance events. The London conference (19-20 June) will focus on emerging markets while on 4-5 July we'll be headed to Singapore for the Asia edition looking at markets from India to Japan to Australia.

John Parnell
Head of content, Solar Media

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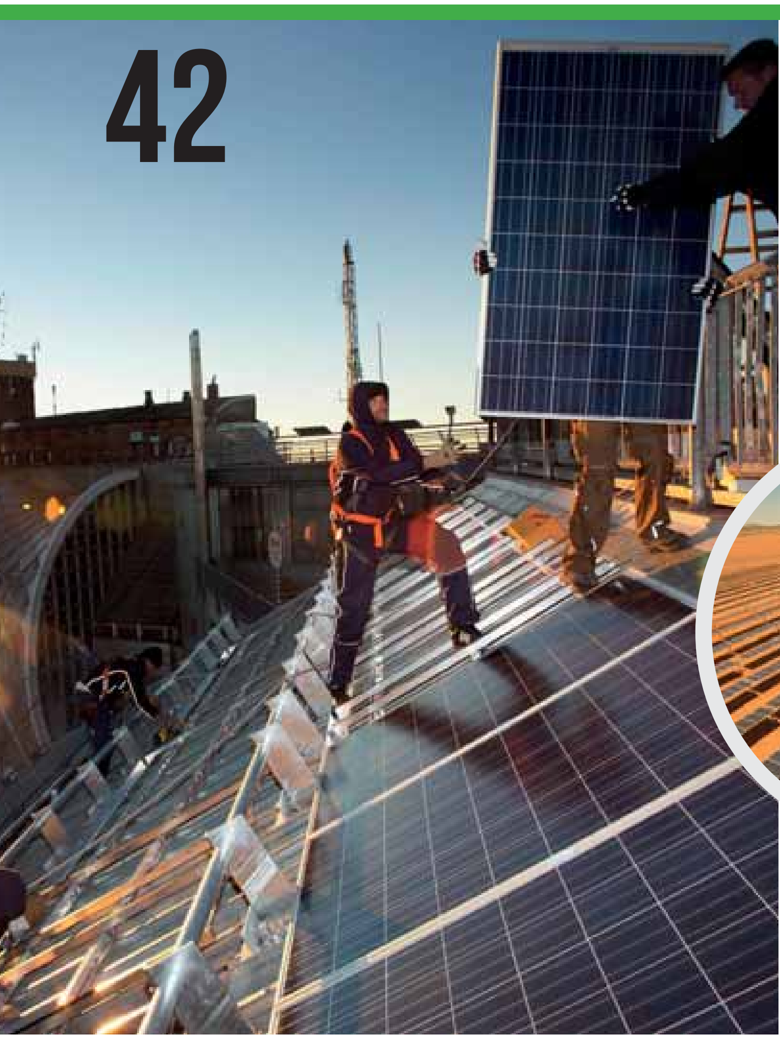

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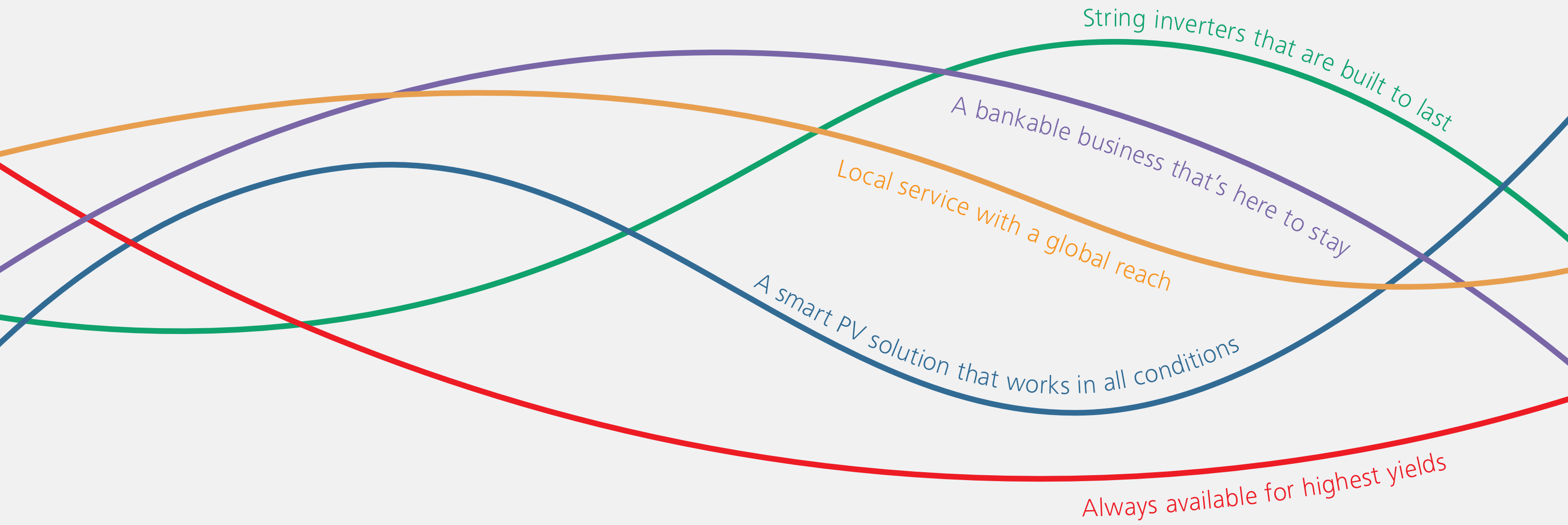
HUAWEI

Intersolar Europe 2017
31 May-2 June | Munich
Huawei Booth: B3.310

Solar intelligence, with strings attached.



Global #1 Inverter Shipment

Our SUN2000 string inverters use intelligent software that lets you monitor your solar system from your phone or tablet,so you're always in control of your yields.
And with no fuses,and no moving parts to replace, our inverters are built to last for 25 years or more.

We're stable, we're bankable, and we're here for the long haul.

Huawei FusionSolar

FusionSolar Smart PV Solution
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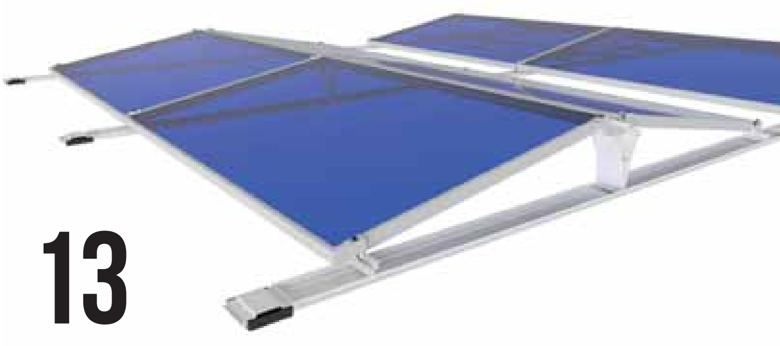
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EUROPE

SolarWorld insolvency will not impact EU trade measures

SolarWorld AG's insolvency will not impact the continuation of the minimum import price (MIP) with the extension of the measures already enshrined in law by the European Commission. The complaint was brought about by EU ProSun, which represents European solar manufacturers, with SolarWorld the major backer of the trade group. This has prompted some to speculate over the future of the measures that are currently set to expire in September 2018 unless a request is made for an investigation into their extension. Milan Nitzschke, vice president of SolarWorld and president of EU ProSun said the other members of the group would continue its work. SolarWorld filed for insolvency in May, with key German-based subsidiaries also filing for insolvency proceedings, while its US arm said it would try to go it alone.


Credit: SolarWorld

Winners

Hanwha Q CELLS and Kalyon Enerji win 1GW solar tender in Turkey

A 50:50 joint venture formed by PV module producer Hanwha Q CELLS and Turkish firm Kalyon Enerji has been awarded a 1GW local content solar project in the Karapınar region in Turkey at a tariff of US$0.0699/kWh. The price will be valid for 15 years and the solar equipment used must be domestically sourced, according to a release from Gunder, an organization that represents the Turkey section of the International Solar Energy Society.

France reveals winners of 150MW rooftop solar tender

In late April Ségolène Royal, France's minister of the Environment, Energy and the Sea announced the winners of the first period of the country's rooftop solar tender. The Request for Offers (RfO) of the tender was launched in September 2016 for solar installations on buildings for a total volume of 1,450MW. 361 winners were announced for the first period of the invitation to tender, winning up more than 150MW between them. The selected project will produce electricity at an average price of €106.7/MWh (US$116.78/MWh), which marks the continuous decline in price of solar equipment. Projects will be paid an additional annual premium of €3/MWh (US$3.28/MWh) to cover the investments. France is also running other tendered solar programmes, including for 3GW of utility-scale PV.

Brexit

UK told to follow EU environmental rules as Brexit negotiations begin

The UK will have to adhere to the European Union's environmental and climate change-related policy if it is to have any future agreement with the trading bloc, according to the first EU response to the triggering of Article 50. Prime Minister Theresa May officially notified EU Commission President Jean-Claude Juncker of the UK's departure from the union in March, starting a two-year negotiation period. A leaked copy of a draft motion for a resolution from the European Parliament stresses that "any future agreement between the European Union and the United Kingdom is conditional on the United Kingdom's continued adherence to the standards provided by the Union's legislation and policies, in among others the fields of environment, climate change…"


Credit: Flickr/European Peoples Party

DATA WATCH

6.7 GW

PV deployed in Europe in 2016, says Solar Power Europe.

Money

Sonnedix acquires 136MW Spanish PV portfolio from Centerbridge Partners

International PV developer and investor Sonnedix has acquired a 136MW solar portfolio from Centerbridge Partners in Spain. The portfolio includes 43 operating and financed projects. The cost of the investment was not disclosed. Sonnedix has also partnered with the management team that worked with Centerbridge to build and operate the projects in order to acquire further solar PV assets in Spain and elsewhere. In March Sonnedix also acquired a 21.6MW solar portfolio comprising five ground-mount projects in Italy from private equity firm First Reserve.

Cubico acquires 105.6MW PV portfolio in Italy

Renewable energy investment company Cubico announced Friday that they have acquired a solar portfolio of 18 projects in Italy. The portfolio, totalling 105.6MW in generation capacity, was acquired from Silver Ridge Power Italia – a joint venture between Riverstone and SunEdison. Located in three regions across Italy (Apulia, Lazio and Sicily), the solar projects range from 1MW to 43MW and all became operational between 2010 and 2013.

Conquest raises US$124 million in first close for renewable energy fund

Multinational asset management and advisory firm Conquest wrapped up initial close for its renewable energy fund in March, with the company securing US$124 million from solicitations and commitments from European investors, including insurance companies, pension funds, banks and global energy corporates. Conquest Renewable Yield Europe possesses a 20-year strategy of deploying equity in OECD renewable power real assets – primarily focusing on Western Europe brownfield solar and wind portfolios.

AMERICAS

Latin America

Enel's 745MW solar plant in Mexico

Italian power giant Enel is set to continue its domination of Latin America by developing a record 754MW project, having already bagged the largest solar plants completed or under construction in both Chile and Brazil. The project will be the largest in the entire Americas and will be known as the Villanueva Project near Viesca, Coahuila State, in north central Mexico, aiming to power the equivalent of 1.3 million households with the production of around 1,700GWh per year.

NDB loans US$300 million to Brazil's development bank for renewables

The New Development Bank signed a US$300 million loan agreement with the Brazilian Development Bank (BNDES) to support investment in energy from wind, solar, small hydropower plants, biomass, biogas and agricultural residues. The loan is forecast to help enable the addition of around 600MW to Brazil's generation capacity.

BNDES will also use the funds to promote its existing lines of financing for renewables.

Market watch

Tesla starts taking solar roof tile orders

Tesla began taking orders for its solar roof tile products as of 10 May. CEO Elon Musk revealed that the company would take orders for any territory and confirmed overseas delivery would begin next year. US deliveries will start before the end of 2017. The initial orders will be for the black smooth and textured tiles with the Tuscan and French slate models following six months after. According to Tesla's most recent quarterly results, manufacturing of the tiles will begin in Q2 2017. Tesla also reported Q1 2017 solar installations of 150MW, down from 201MW in the previous quarter, a 25% decrease, due to selection criteria biased towards customer owned PV systems rather than leased.

Credit: Tesla

SEC investigating SolarCity and Sunrun over customer cancellation disclosure

The Securities and Exchange Commission (SEC) launched an investigation into whether SolarCity and Sunrun are adequately disclosing how many customers have cancelled solar contracts. In response, the SEC subpoenaed Sunrun to interview employees about their respective disclosures on cancellations. Some homeowners have indicated reasons for cancelled contracts pertain to aggressive sales tactics; leaving some feeling they have been muscled into an unwanted contract. Sunrun shares fell nearly 10% in trading after news of the investigation broke.

Market casualties

Suniva

US-based high-efficiency module manufacturer Suniva, majority owned by Chinese diversified renewables firm Shunfeng International Clean Energy (SFCE), carried out a number of unspecified job cuts across its operations in Georgia and Michigan before finally filing for Chapter 11 bankruptcy in April. The company blamed overcapacity due to mass influx of cheap Asian solar panels that Suniva claimed were undercutting domestic production. Afterwards the company filed an anticipated petition requesting a minimum import price (MIP) of 78 cents on all non-domestic solar modules, which China's ministry of commerce labelled as an "abuse of trade remedies."

Sungevity

After filing for Chapter 11 bankruptcy protection in March, Sungevity was approved for sale to Minnesota private equity firm Northern Pacific Group for US$50 million, following a failed US$350 million acquisition by Easterly Capital. Sungevity has US$188.9 million in debts and US$800 million in assets. The sale order hands over Sungevity in exchange for its combined debt claims.

Beamreach Solar

After going bankrupt in January, Beamreach Solar's pilot production line in Milpitas, California was put up for sale by Silicon Valley Disposition Inc. SVD and Onyx immediately offered the facility as a Turnkey / In-place sale, rather than through an auction. The 72,000 square foot facility is equipped with a turnkey line, said to have cost over US$22 million in the 2014/15 period.

Mexico

GTM: 2018 will be 'take-off year' for solar in Mexico

Analysts and developers alike have been saying that Mexico will be the next biggest solar market for years now. But according to GTM Research's Manan Parikh, the time is finally approaching for solar to 'take-off' in Mexico, with 2GW of new solar forecast for 2018 alone. Even though Mexico has been poised to be solar's Next Big Thing for several consecutive years, it is still a relatively small market with a little over 400MW of installed capacity. The growth is primarily being driven by the fruits of successful independent power auctions in March and September 2016, with a third scheduled for November.

Credit: Flickr/Martin D

Clean energy mandates in the last three months

State	Town	Clean energy percentage (%)	Deadline
Georgia	Atlanta	100	2035
Maine	Portland	100	2040
Illinois	Chicago	100 (all public buildings)	2025
Florida	St. Petersburg	100	N/A
Oregon	Portland	100	2050

SOLARWORLD TIMELINE TO INSOLVENCY

26 APRIL
SolarWorld refrains from supporting Suniva's request to impose a minimum import price (MIP) of US$0.78/W

3 MAY
SolarWorld reduces losses on higher total product shipments in Q1 as global solar panel prices decline

10 MAY
SolarWorld AG officially announces that it has been forced into bankruptcy proceedings

12 MAY
The company confirms that its key German-based subsidiaries have also filed for insolvency proceedings

13 MAY
US subsidiary SolarWorld Americas Inc. attempts to go it alone and continue operating its Hillsboro and Oregon plants as normal

26 27 28 29 30 01 02 03 04 05 06 07 08 09 10 11 12 13

APRIL MAY

MIDDLE EAST & AFRICA

Egypt

Big step forward for Egyptian solar as Scatec signs 400MW PPAs

Egypt's solar market took a big step forward with the signing of 400MW of PPAs by Scatec Solar and its partners. Scatec and a number of other investors began work on a compromise deal with the Cairo government that was secured in September. An offshore seat of arbitration was exchanged for a reduction in the agreed FiT. Projects between 500kW and 20MW were reduced from US$0.136/kWh to US$0.0788/kWh and those from 20MW-50MW from US$0.1434/kWh to US$0.084/kWh. Scatec signed contracts for six projects that it will build, own and operate.

Scatec's Druenberg solar farm in South Africa. The company has big plans for Egypt after its success at the opposite end of the continent.

Egypt

EBRD mulling support for 750MW of Egyptian solar

Utility-scale solar projects totalling 750MW could receive support from the European Bank for Reconstruction and Development (EBRD). Documents published in early May list 16 projects up for consideration with developers including EDF, ACWA and Scatec Solar. The total value of the EBRD's potential debt contribution is US$458.1 million. Scatec would be the largest individual recipient with six 50MW projects in line for US$243 million of support.

64MW solar project secured under round one of Egypt Feed-in Tariff

Infinity Solar and Germany's ib vogt and Solizer have reached financial close on a 64.1MW solar PV plant under round one of Egypt's FiT. Once operational, the plant is expected to produce more than 110,000MWh annually; providing enough clean electricity to power around 69,000 homes. Electricity will be sold via a 25-year PPA to the EETC. Ib vogt will assume construction, EPC and O&M responsibilities for the project, which will create more than 400 jobs in the region during this phase. Construction is already underway and the plant is expected to be operational by early Q4 2017.

Alfanar Energy signs PPA for 50MW solar plant in Egypt

Saudi Arabia's Alfanar Energy signed a PPA with the Egyptian Electricity Transmission Company (EETC) for the development of a US$100 million 50MW solar plant in Egypt. The PPA was signed as soon as the 50MW project, under the country's FiT, reached financial closure. The plant will be located at the proposed 1.8GW Benban solar complex in the Aswan province and is being financed by the EBRD and the Islamic Development Bank (IDB), and is one of Egypt's first utility-scale solar plants.

FACT:

After South Africa's Eskom missed its 11 April 2017 deadline imposed by the energy minister to sign the 37 outstanding PPAs under the REIPPP, the National Energy Regulator of South Africa (NERSA) launched an investigation to determine whether Eskom is in contravention of its utility licence.

Middle East

Project profile: Iran's 10MW Ghadir plant

- The country's largest PV plant
- Investment: IRR600 billion (US$18.5 million)
- Location: Isfahan province
- Developer: Ghadir
- Construction timeline: 7 months
- No. of PV panels: 39,000
- Agreement: 20-year PPA with SATBA

JinkoSolar in deal to build 1.2GWp solar plant in Abu Dhabi

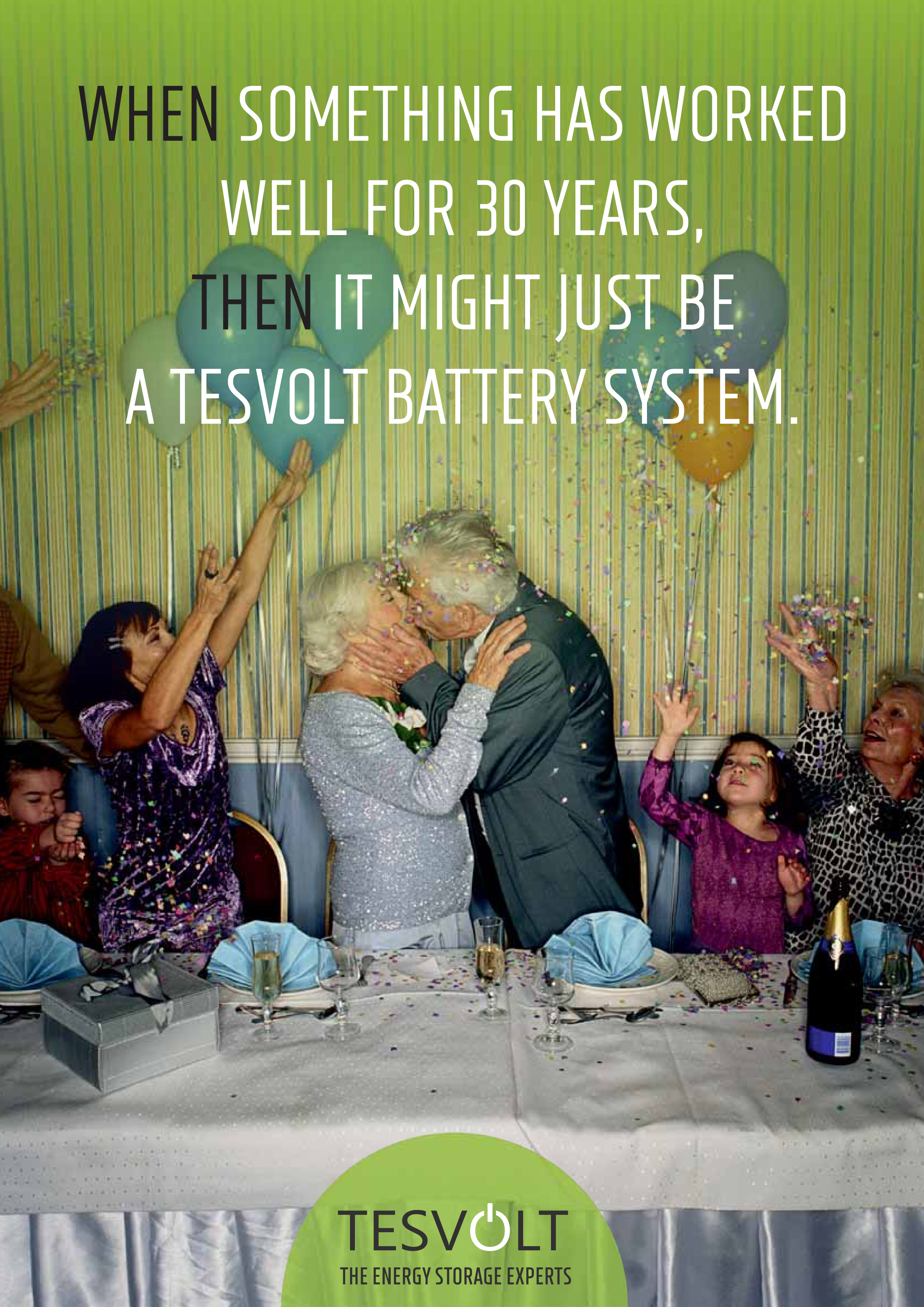
JinkoSolar has established a consortium with Marubeni Corporation and the Abu Dhabi Water and Electricity Company to build a 1,177MWp (DC) PV power plant in Abu Dhabi. A special purpose company jointly owned by the consortium will construct, operate and maintain the PV plant for the duration of a signed 25-year PPA. The project was said to be located in Sweihan. JinkoSolar and Marubeni originally submitted a bid for the 1,177MWp solar PV capacity, with a base tariff of just US$0.0242/kWh. Financial agreements for the project should close in April 2017, with commercial operation expected to begin in 2019.

New 200MW phase of Mohammed bin Rashid Al Maktoum Solar Park begins operations

The 200MW second phase of the Mohammed bin Rashid Al Maktoum Solar Park was inaugurated in March. This phase of the solar park stands as the largest solar-energy project in the region, based on the IPP model. The phase was completed by a partnership between the Dubai Electricity and Water Authority (DEWA) and a consortium led by ACWA Power – the main developer of the project – and Spain's TSK, the main contractor for the park. The 200MW second phase can produce enough power to provide clean energy for 50,000 residents in Dubai.

Utility-scale solar in Nigeria

Date	Developer/Investor	Project PV capacity (MW)	Location	Agreement type
March 2017	GreenWish Partners	50	Jigawa State	NBET PPA
March 2017	GreenWish Partners	50	Kaduna State	NBET PPA
March 2017	GreenWish Partners	100	Enugu State	NBET PPA
April 2017	Dangote Industries	100	Kano State	N/A
April 2017	CT Cosmos Nigeria	70	TBC	NBET PCOA
April 2017	Afrinegia Nigeria	50	TBC	NBET PCOA


WHEN SOMETHING HAS WORKED
WELL FOR 30 YEARS,
THEN IT MIGHT JUST BE
A TESVOLT BATTERY SYSTEM.
TESVOLT
THE ENERGY STORAGE EXPERTS

ASIA-PACIFIC

Japan could strip FiT for a quarter of approved clean energy pipeline

Japan may remove feed-in tariff (FiT) support for a significant number of clean energy projects certified before July last year, because they missed a deadline to secure grid access. Out of the 3.15 million clean energy projects with a combined total of 106.5GW capacity that had secured approval for the subsidy by the end of June 2016, an estimated 456,000 projects with a combined capacity of 27.7GW missed a 1 April deadline and could soon lose access to this support mechanism. This means roughly 26% of certified capacity and 14.5% of individual projects could be affected. However, projects that received certification after 1 July 2016 still have nine months to secure grid access.

Credit: Flickr/caribb

Policy

Vietnam introduces utility-scale solar FiT and rooftop net metering

Vietnam has confirmed a long-awaited FiT scheme for utility-scale solar projects along with a net metering scheme for rooftop PV systems. The FiT would be valid from 1 June 2017 to 30 June 2019, although the Ministry of Industry and Trade (MoIT) is also conducting a study on how to support solar projects after this date. The FiT for utility-scale solar PV would be VND2.086/kWh (US$0.0935), exclusive of Value Added Tax, only applicable to projects where cell efficiency is more than 16% or module efficiency more than 15%. Monopoly utility Vietnam Electricity Corporation (EVN) will buy all the power from the solar projects.

Malaysia to auction 460MW of large-scale solar PV

The Energy Commission of Malaysia (EC) has issued a Request for Proposal (RfP) document hoping to auction up to 460MW of large-scale solar capacity. Under EC's second competitive bidding programme, it hopes to awards projects of 1-30MW capacity to make up a total of 360MW in Peninsular Malaysia and 100MW in Sabah and Labuan in the East. All solar plants will be connected to the grid, with power purchase agreements to be signed with utilities. Deadline for submissions is 1 August 2017. Malaysia installed 32MW of solar under FiTs in 2016.

Credit: SEDA

DATA WATCH

5.5 GW

The amount of solar capacity India added in the 2016/17 financial year according to official figures.

Money

European Investment Bank providing €200 million for Indian large-scale solar

The European Investment Bank (EIB) is to supply State Bank of India with a €200 million (US$214 million) 20-year loan to support utility-scale solar PV projects in India. The loan backs up a total €650 million of investments in five projects. At present four projects with a total 530MW capacity have been identified for what is EIB's largest ever support for solar in Asia. The investments will be part of India's National Solar Mission, its flagship scheme aiming to deploy 100GW of solar by 2022. EIB has also opened its first permanent office in India in New Delhi.

Yet another India solar tariff record of 2.44 rupees in Rajasthan

After Indian solar tariffs breached a jaw dropping US$0.04/kWh in early May in a Rajasthan auction, prices dropped to yet another record in the same location. This time, the Solar Energy Corporation of India tender was for a 500MW section of the Bhadla Solar Park, the infrastructure of which is being constructed by IL&FS, an infrastructure and finance company. Indian firm Acme won 200MW with a bid of INR2.44/kWh (US$0.038), while SBG Cleantech, a joint venture between Softbank, Foxconn and Bharti Enterprises won 300MW at a tariff of INR2.45/kWh.

GSSG Solar to acquire 350MW portfolio of solar in Japan

Solar investment firm GSSG Solar will provide over US$120 million in additional commitments to the firm's investments in Japanese solar projects. As a result of this increased capacity, GSSG will invest in the acquisition and financing of an incremental US$1 billion of Japanese mega-solar plants over a three-year investment period.

Storage

Giant 4,000MWh Li-ion battery storage facility proposed for 800MW PV farm in Queensland

Developer SolarQ is planning to build a 350MW(AC) solar plant combined with a ground-breaking 4,000MWh lithium-ion battery storage in Queensland, Australia. There are plans to ramp up the PV project to 800MW(AC) within four years. The project is still at concept stage and could cost more than AU$2 billion (US$1.5 billion). Meanwhile, Brisbane-based renewable energy investor Lyon Group will soon start building a AU$1 billion (US$767 million) solar-plus-storage farm in South Australia – the world's largest – featuring 330MW of solar PV and a 100MW/400MWh Li-ion battery system.

South Korea

KACO New Energy and DNE Solar to provide 300MW inverters for South Korea

South Korean PV specialist DNE Solar has signed a framework agreement with German inverter manufacturer KACO New Energy for the delivery of 300MW of string inverters. The two companies are boosting their long-term partnership with a bulk order of blueplanet 20.0 TL3 INT and 50.0 TL3 inverters as well as the Powador 60.0 TL3 ground-mount unit, which are generally used in commercial rooftop systems and solar parks.

Product reviews

Inverter | Ginlong's new string inverters improve energy transfer smartly and safely

Product Outline: Ginlong Corporation has launched new high performing, safe and smart PV inverters, the Solis 4G and Solis HV series, both for single- and three-phase applications.

Problem: With large-scale development of distributed generation increasing, ensuring efficient operation, smooth energy transfer, reliability and smart control has been at the forefront of the latest PV inverter model designs.

Solution: The Solis-4G single-phase series with high switch frequency technology

makes the inverter smaller and smarter. Single-board design reduces the risks caused by the connectors between the PCB board, and the ultra-wide input voltage range reduces temperature increases, improving the lifetime reliability of the inverter. The latest generation components from international suppliers increase performance and efficiency throughout. The Solis-HV high voltage three-phase series adopts a four-MPPT algorithm to ensure high energy transfer efficiency. Anti-resonance technology enables the connection of 6M+ inverters in parallel. With advanced commercial site monitoring solutions, improved design and intelligent internal air circulation the maximum efficiency is over 99% and the THD is lower than 3%, according to the company.

Applications: Full range from domestic 1kW installations through to 50MW++ utility plants.

Platform: Models comply with AS4777.2:2015, with multiple fault protections levels. Both the Solis-4G and Solis-HV series have RS485, WiFi/GPRS and Ethernet interface available.

Availability: Available since April 2017.

Inverter | Growatt offers scalable off-grid inverters compatible with lead-acid and lithium-ion battery technology

Product Outline: Growatt has combined a unique technology and design concept into the Growatt SPF3000/5000 series to provide power independently and cost-effectively in off-grid and self-consumption applications.

Problem: The main use of off-grid solar PV systems is in places where the grid may not be available or is unstable, such as rural regions of Africa. Off-grid solar systems are also very useful in applications like street lights and street signage where the grid might be in proximity but it is more convenient and cost-effective to have a standalone or off-grid system. On isolated islands, the off-grid storage system is an obvious solution for residential and light commercial applications that replace diesel generators.

Solution: SPF3000/5000 off-grid inverters have two built-in MPPTs for higher yields and are compatible with lead-acid and lithium-ion battery technology. Source priority to charge batteries and power loads are also programmable. SPF3000/5000 inverters are scalable and can be wired in parallel up to six units, enabling flexibility for a wide variety of applications and suitable for single-phase and three-phase systems. Charging power can be increased by adding an expansion charge controller unit.

Applications: A wide variety of off-grid applications and compatible with lead-acid and lithium-ion battery technology. The SPF3000/5000 off-grid inverters can also be used as back-up power in industrial applications.

Platform: The inverters are of a compact size and low weight (12.5kg). Dual MPPT and the ability to add an MPPT charge controller can double PV input power for larger energy storage requirements.

Availability: Available since March 2017.

Module | Hanwha Q CELLS launches first p-type monocrystalline PERC modules in Europe

Product Outline: Hanwha Q CELLS has launched its first PV modules using p-type monocrystalline PERC cell technology. The Q.PEAK module series is now available for European customers in two variations: Q.PEAK-G4.1 with black frame and white back sheet and as the all black Q.PEAK BLK-G4.1. The Q.PEAK-G4.1 comes in power classes ranging from 295Wp to 305Wp and efficiencies of up to 18.6 %.

Problem: High-efficiency PV modules are increasingly being used for residential rooftop PV systems as incentives have declined under feed-in tariff systems in Europe for several years. With a growing focus on 'self-consumption' PV modules providing high efficiency and long life at

attractive prices are required. Aesthetics are also increasingly becoming a important factor in the residential market.

Solution: The Q.PEAK series combines high power classes, leading to low levelised cost of electricity (LCOE), primarily for residential markets. Moreover, a special technology protects Q.PEAK modules against the power loss through light-induced degradation (LID). LID is a common effect leading to power losses in the early operation lifetime of conventional monocrystalline solar modules.

Applications: Primarily the residential rooftop market.

Platform: Q.PEAK modules feature excellent stability and are tested for wind loads up to 4,000Pa and snow loads up to 5,400Pa. At the same time the frame design has been optimised with a frame height of 32mm, leading to 10% reduction on logistics and storage cost compared to the previous G3 generation. The modules weigh only 18.8kg, making them easier to handle during installation.

Availability: Available in European market since April 2017.

Product reviews

Module | HT-SAAE launches second-generation n-type PERT bifacial module

Product Outline: Shanghai Aerospace Automobile Electromechanical Co., (HT-SAAE) has introduced its Milky Way n-type bifacial dual-glass five-busbar PV modules. The new bifacial module brings a 10W increase in power output compared with the first generation of Milky Way PV modules with four-busbars.

Problem: Compared with p-type cell technology, n-type cell technology has more potential in improving cell efficiency and reducing material costs. Bifacial modules can provide high output power and reduce the levelised cost of electricity.

Solution: The Milky Way n-type bifacial dual-glass five-busbar PV modules adopt the second generation of n-PERT cells developed by HT-SAAE. With the latest five-busbar cell and high-quality surface passiva-tion technology, the average efficiency of a cell can reach up to 21.2%. By optimising back side diffusion, the back side cell efficiency is over 88% of the front side. The new generation of bifacial modules uses the latest high reliability encapsulation material and redesigns optics and electricity matching based on the performance of the new generation of n-PERT cell. The output power can reach up to 305W and the total power output can go up to 340W and above.

Applications: The n-type bifacial dual-glass PV module can be deployed with ground-mounted projects, commercial rooftop, agricultural greenhouses and water surface projects.

Platform: The Milky Way n-type bifacial dual-glass PV module series is claimed to be the first n-type bifacial dual-glass PV module series which has achieved volume production.

Availability: Available since February 2017.

Monitoring | Kipp & Zonen offers easy measurement of utility-scale solar panel soiling

Product Outline: Kipp & Zonen is launching a new technology and product to monitor PV panel soiling at Intersolar Europe 2017. Based on Kipp & Zonen's unique optical technology, 'DustIQ' measures the soiling ratio (SR) and can be easily added to new or existing solar arrays and integrated into plant management systems.

Problem: The performance ratio of PV panels is primarily determined by four main parameters: the incoming solar irradi-ance, the cell (back panel) temperature, the soiling ratio and the power produced. Soiling of the panel glass is one of the major problems in the rapidly expanding solar energy market, with the attendant loss of efficiency and reduction in performance ratios.

Solution: DustIQ measures the SR, which can be translated to generating power loss in real time. This enables the plant operation and maintenance staff to know when a critical level of soiling is reached and cleaning is necessary. Dust IQ needs no maintenance and is cleaned in the same way, and at the same time, as the panels around it. Large solar parks have different soiling rates across the site, which is why IEC 61724-1 requires multiple measurement points. The significantly lower purchase, installation and maintenance costs of DustIQ compared to traditional systems make this much more economic, so that cleaning can be scheduled when and where it is needed.

Applications: Soiling ratio measurements for large commercial and utility-scale PV power plants.

Platform: DustIQ communicates digitally via 'Modbus' and has an input for an optional back panel temperature sensor. It can be networked with Kipp & Zonen smart pyranometers for irradiance measurements and be integrated into a plant SCADA system.

Availability: From May 2017.

Module | LONGi Solar Hi-MO2 bifacial mono-PERC module reaches 360-365W in 72-cell configuration

Product Outline: Monocrystalline solar cell and module manufacturer LONGi Solar has introduced its first high-performance mono-PERC bifacial module series that comes in both 60-cell and 72-cell configurations.

Problem: Conventional mono-facial Al-BSF solar cells are reaching efficiency limita-tions, while mono-PERC cells provide both higher efficiencies and can be cost effec-tively converted to bifacial for dual-glass PV modules, providing between a 10% and 30% efficiency gain by harnessing diffused light on the rear side of the cell, resulting higher kWh of electricity generation and lower levelised cost of electricity.

Solution: The Hi-MO2 module has front side cell equivalent to conventional PERC technology with cell efficiency exceeding 21%. The back side adopts a glass package, achieving bifacial light reception and power generation. Backside efficiency is no less than 75% that of the front side. The backside can increase energy yield up to 25% (varying with the design and background condition of the PV system), and can bring higher returns.

Applications: The Hi-MO2 module can be used in large-scale utility power plants, commercial rooftops, fishery-PV integrated floating power plants and other distributed PV projects.

Platform: The Hi-MO2 developed on the basis of Hi-MO1's low LID technol-ogy and bifacial PERC technology can achieve first-year degradation of less than 2%, and average annual degrada-tion less than 0.45%, both superior to conventional modules, according to the company. The 72-cell module in the Hi-MO2 series has a power of 360-365W, while the power of the 60-cell module reaches 300-305W.

Availability: Available since April 2017.

Product reviews

O&M | QOS Energy's O&M cloud-based analytics platform integrates any type of data

Product Outline: SOLV, a division of Swinerton Renewable Energy that provides operation & maintenance services for solar PV plants, has begun deployment of QOS Energy's 'Qantum' software to monitor and support the operations and maintenance of more than 1GW of PV plants in the US. Qantum is an innovative cloud-based analytics platform that allows SOLV to harness the power of the data generated by the multiple PV installations they manage on behalf of leading renewable energy project owners.

Problem: To deliver best-in-class O&M services for solar PV plants of any size, the ability is needed to integrate any type of data and visualise, understand, streamline and maximise global operational performance using a simple web browser.

Solution: Qantum is a hardware-agnostic energy management SaaS platform that gathers data from any wind or solar plant monitoring system, such as databases, SCADA or data acquisition systems. Qantum collects and transforms the data into comprehensive, next-stage analytics, enabling SOLV to identify performance issues quickly and accurately, according to the company.

Applications: O&M services for solar PV plants of any size.

Platform: The cloud-based suite features a complete set of customizable charts, operating dashboards KPIs and alerts helping to gain a deeper understanding of the asset's performance at a glance and to identify root causes of underperformance. Additional KPIs and technical indicators have also been created specifically for the trackers installed onsite. The platform offers a fully integrated maintenance management system to help reduce downtime by streamlining maintenance workflows for large and complex renewable energy portfolios.

Availability: Available since March 2017.

Module | REC launches its first all-black multicrystalline TwinPeak 2 module

Product Outline: REC Group has introduced an all-black variant of its 'TwinPeak 2' Series PV module for US and European residential markets using its half-cut cell and PERC technology, and uniformly black-coloured multicrystalline cells.

Problem: Mature residential PV markets such as the US and Europe often require improved module aesthetics for less intrusive rooftop installations. All-black module designs including dark uniform solar cells can provide the required aesthetic look.

Solution: The REC TwinPeak 2 BLK2 Series modules use a proprietary cell technology in the production of black multicrystalline cells. When assembled together with a black frame and black backsheet, the result is the first full-black panel from REC. With a nominal power rating of up to 285Wp, the REC TwinPeak 2 BLK2 is the second product in the REC TwinPeak 2 family and packs in several evolving REC TwinPeak technologies such as cells made from larger wafers for increased current production as well half-cut cell technology to further reduce internal resistance. The modules also include five-busbar technology for reduced cell resistance. A split junction box spread across the middle of the panel allows for improved performance in shaded conditions.

Applications: Residential rooftop markets of Europe and the US.

Platform: This '60-cell' full-black panel from REC is certified according to IEC 61215 and IEC 61730, as well as UL 1703 and has a maximum system rating of 1000V and is 100% free from potential induced degradation (PID).

Availability: Available since March 2017 in the US and Europe.

Racking | Renusol has added innovative screw connection and lightweight structure to east/west mounting system

Product Outline: Renusol has introduced its optimised FS10-EW system for mounting photovoltaic systems on flat roofs without penetration. Thanks to the innovative screw connection and the lightweight but high-tensile design, modules with a 10° inclination with an east/west orientation can be easily installed on any flat roof.

Problem: Conventional systems with long rails may shift over time because they expand more when the temperature fluctuates and then slither down the slanted roof like a caterpillar.

Solution: The connectors of the new FS10-EW are able to absorb and offset any temperature expansion. In the new system, the screw joint between the rails and connectors does not need any nuts. The system requires just five main components and the standard Renusol module clamps, which makes mounting and storage simple. The maximum rail length is 2.3 m. Fewer components and shorter rails provide advantages for wholesalers, for installers, who can mount the rails quickly and easily, for transporting components to the site and also for installation operators, as the intelligent design rules out installation errors or re-adjustment.

Applications: East/west PV systems on flat roofs.

Platform: The lightweight construction boasting a system area load of 1.2kg/m2 without a module and ballasting, and the design optimised in the wind tunnel enables solar installations to be mounted on roofs with particularly low load-bearing capacities, where penetrating the roof membrane is undesirable.

Availability: Available since April 2017.

Inverter | Sungrow's 1,500VDC SG125HV string inverter enables 5MW PV power block designs

Product Outline: Sungrow's SG125HV 1,500VDC string inverter is designed to significantly reduce installation and balance-of-system costs for utility-scale PV systems. At a higher rated voltage, the SG125HV is claimed to further reduce installation and balance-of-system costs.

Problem: 1,500V solar systems are expected to dramatically reduce system costs and improve power generation efficiency. The solar industry has long demanded a 1,500V string inverter to reduce levelised cost of electricity for commercial and utility-scale PV power plants.

Solution: The SG125HV comes with

Sungrow's patented five-level topology design, which enables the inverter to lift the maximum efficiency up to over 98.8% (Euro maximum efficiency 98.5% and CEC efficiency 98.5%) with a 5MW PV power block design reducing AC transformer and labour costs, while eliminating the need for AC combiner boxes. DC side cabling costs can also be reduced significantly. The company claims ~US$1.1/Wp system cost saved (inverter cost not included) on a 100MW power plant, providing lifetime savings of over US$1.1 million.

Applications: Utility-scale PV power plants in 2-5MW block designs.

Platform: The SG125HV weighs only 68kg and therefore does not require heavy machinery for loading, unloading and installation. Due to its compact design and natural air cooling (NEMA 4X (IP65) fan cooling, with no derating up to 50 degree C, it can be installed in flexible angles and therefore adaptable to different conditions.

Availability: Released globally in early 2017.

Module | Trina Solar launches 60-cell mono-PERC 'DUOMAX Twin' bifacial 300W module

Product Outline: Trina Solar has launched its high-efficiency p-type mono-PERC bifacial 'DUOMAX Twin' module. The modules has a 0~+5W positive power tolerance and have a 285-300W power range with 18% maximum conversion efficiency.

Problem: With conventional solar cells reaching efficiency limitations, PERC technology provides both higher efficiencies as well as the ability to be converted to bifacial for dual-glass PV modules. This provides efficiency gains by harvesting harnessing light on the rear side of the cell.

Solution: DUOMAX Twin generates power from both the front and back sides of

the solar module and performs well even under weak light conditions, according to Trina. The front side receives direct sunlight while the back side receives reflected and scattered light. Compared with traditional single-sided modules, the DUOMAX Twin can deliver as much as 25% additional energy yield. The bifacial enables increased energy density and higher output, while maintaining development costs at a comparable level as for standard modules.

Applications: These include ground-mounted utility-scale, commercial/industrial roofs, car ports, BIPV and floating solar applications.

Platform: The DUOMAX Twin uses p-type monocrystalline PERC (156.75 × 156.75 mm) cells in a 60 cell spaced format to improve dispersed light capture on the rear side of the cell. A unique J-box design and installation method is used to avoid shading on the back side of the module.

Availability: Available since April 2017.

Inverter | Huawei offers its first residential smart solar solution

Product Outline: Huawei Technologies is launching its first smart inverter solution to the global residential PV market. The 'FusionHome Smart Energy Solution' offers a number of key capabilities for future residential home needs such as power optimisation, energy storage and smart home integration.

Problem: With residential PV incentive policies such as net metering and feed-in tariffs under constant reductions and changes, 'self consumption' strategies need to evolve to provide PV system performance optimisation, intelligent energy storage and be smart-home-compatible. Distributors and installers have to make procurement of multiple inverter and module brands, leading to

complex inventory management.

Solution: The FusionHome Smart Energy Solution incorporates an inverter with leading performance (European weighted efficiency 98%) that also accommodates the use of PV optimisers on selected modules that may have shading or different roof orientation enabling greater ROI. The inverter comes with a simple plug-and-play battery interface as standard, eliminating the need for inverter retrofitting when the PV system is upgraded with energy storage. The system comes with the capability to provide a fully digitalised and connected smart home service with a smart PV cloud-based home energy management centre.

Applications: Residential systems.

Platform: The FusionHome Smart Energy Solution inverter uses advanced five-level topology with less copper and more silicon semiconductors, reducing inductor and cooling sink size significantly. An optional optimiser increases yields by up to 30%, according to the company.

Availability: From mid-2017.

Second life: The case for performance optimisation, repowering and lifetime extension

O&M | As the world's global installed solar capacity ages, technology costs drop and sophistication grows, the benefits of a health check and potential plant upgrades also increase. As part of our repowering review, Mariano Melero, principal consultant, RINA Consulting discusses the benefits of looking after aging assets

Make no mistake, utility-scale solar PV is still a young industry. Despite great strides in recent years towards the objectives of global deployment and becoming a truly investment-grade asset class, by comparison to other technologies – even wind and other renewables – its operational track record is limited.

While the lifetime of a typical solar project is expected to be at least 25 years, only a small proportion of the global installed asset base has exceeded 10 years of operations, of which the majority is concentrated in the more established markets of Germany, the USA and Spain. Indeed, even the oldest megawatt-scale PV project still in operation, in Toledo, Spain, has not yet reached the 25-year milestone, having been running since 1996.

The result is that there are still a lot of unknowns when it comes to assessing the true longevity of solar PV technology, and its reliability beyond the 10-year mark. Forecasts of when and where operational issues may arise are based on assumptions from other industries, accelerated aging testing, or extrapolations of just 5-10 years of data from PV projects, and must also take into account the additional variable of changing technology, which adds further uncertainty to the process.

Given this state of affairs – where assets are still new, mostly performing well, and with an expected lifetime that has not been fully ascertained – it may seem counterintuitive for asset owners to start thinking about options for repowering and lifetime extension.

In fact, the concept of 'repowering', as it has been applied in the wind energy sector, doesn't yet offer the same commercial opportunities for solar asset owners and investors. In wind, the drive towards maximising output has led to a three-fold increase in turbine capacity over the last 15 years. This means that, in theory at least, swapping out older turbines for new models can be a smart investment, providing a significant boost to the production and revenues of a wind farm, without increasing the footprint of the site. In the case of PV, while swapping modules might be more straightforward in practice than installing new turbines, efficiency hasn't improved significantly, especially with regards to space requirements, meaning that this model of repowering isn't a clear, economically viable, option at present.

Credit: Wikimedia/NREL

However, there are other factors that may drive the adoption of lifetime extension and performance optimisation strategies as solar PV projects enter the long-term operational phases.

As the sector as a whole matures, the growing market for secondary acquisitions is creating a heightened focus on plant performance during the early years of operation. For secondary investors and

Improved monitoring is one of the quickest ways of detecting and remedying poorly performing PV assets

their technical advisors looking at operational assets, seeing a detailed operational history, including historic performance, is critical – alongside factors such as operator performance, and contractual and legal risk. This is incentivising project owners to make sure that their assets are performing in line with expectations from day one.

Beyond these early phases, there is still room for improvement in the way performance is managed in the long-term. It's fairly evident that cost reduction is still the main driver for the PV market, above quality or reliability. Extending the lifetime of assets is an obvious way of increasing revenues, however the PV industry still needs to increase its efforts to ensure long-term reliability before this is generally feasible.

As a result of the drive to reduce costs, the standard of equipment monitoring and O&M in the PV sector is below market standards in other industries for similar equipment. Achieving a better balance between the upfront cost of measures to enhance

reliability and performance and their long-term impact on revenues will be a crucial consideration as assets do start to age.

Older PV plants are likely to face a number of common technology issues, ranging from module degradation to spare parts availability for key components such as modules, inverters and trackers. The ever-present threat of manufacturer insolvency and its impact on replacement supplies means that thorough maintenance is increasingly important.

Additionally, as solar PV installations begin to proliferate in new territories, changing environmental conditions may place extra strain on components and affect degradation rates. Conditions in the Middle East and Asia, for example, may be vastly different from North America and Europe, raising questions as to how PV systems might respond in the long term to extremes of temperature and weather.

What's more, we may start to see manufacturing or installation errors that weren't immediately apparent during the development phases become exacerbated with time, leading to equipment failures, malfunctions or anomalies in performance.

So, faced with these potential problems, what options are currently available to project operators to optimise performance and extend the lifetime of their assets? And what is the economic case for undertaking them?

Inverter swap outs

Replacing inverters or inverter components would typically be undertaken during the 25-year lifetime of a PV system. Inverter lifetimes are estimated to be between 10-15 years, and so this is always a consideration for long-term asset owners.

As a rule, inverter efficiencies cannot be improved significantly and performance improvements will be limited to specific projects that may have atypical string configurations or suffer from shading issues. However, due to the potential size of this market, it's expected that brand new equivalent inverters will become available for the purpose of regular replacements at projects where inverters have reached the end of their lifetimes, or experienced faults.

Potential-induced degradation mitigation

Potential-induced degradation (PID), typically caused by ions migrating from the glass surface of the module to the active material, shunting the p-n junction of the cell (PID-shunting degradation mechanism), has been known to reduce output by more than 40% over a short timeframe.

Top four tips for repowering

Mariano Melero, principal consultant, RINA Consulting

As a technical advisor to PV owners, operators and investors, my main pieces of advice for those looking at optimisation and lifetime extension would be:

- Where possible, explore the use of co-located energy storage systems (ESS) with your existing PV assets. This will help maximise production and unlock additional revenue streams from ancillary services to the grid.
- Improve your control of energy exports at the point of connection. Use an appropriate power plant controller that is able to adapt to new power requirements from the grid operator.
- Identify and monitor the specific energy losses taking place at your site. Targeting your efforts towards addressing specific problems – for example soiling losses – is likely to be more beneficial and cost-effective in the long-term than only monitoring overall performance.
- Finally, maintain the highest standard of O&M and monitoring that is economically viable at your site. Preventing production shortfalls by identifying and mitigating performance issues as soon as they arise will keep your asset running and your stakeholders happy.

PID is reversible to a certain degree, and curing methods are increasingly being developed and used to restore the performance of modules. These include referencing the negative pole to ground (for p-type cells), which completely removes the negative potential stress on the module, reversing the string polarity periodically, or applying a positive system voltage bias on modules at night to accelerate recovery.

However, some of these PID curing methods have been shown to impact the rate of module degradation in the long term, and can invalidate module performance warranties, so the economic benefit must be carefully evaluated on a site-by-site basis before a decision is made.

There are several other methods of mitigating PID degradation – ranging from changes to the electrical configuration of the plant, to replacement of affected modules, or recovering part of the original capacity in a laboratory with heat and time – each with different levels of power recovery. Grounding of one of the DC poles is a common solution – but the future impact on module degradation associated with other methods is still under investigation.

Module degradation testing

Accelerated degradation testing, carried out by an IEC 17025-accredited laboratory, or equivalent, is an effective means of assessing how the performance of modules is changing over time.

Putting a testing programme in place, including aging tests, during the operation of the plant enables the operator to call in the performance warranty as soon as an anomalous degradation trend is detected. This can be a particular advantage in the secondary market.

Optimisers

Power optimisers are DC/DC converters, which can replace the standard junction box in each PV module. Optimisers track the maximum power point of each module individually to increase the overall power output. They can also monitor and transmit performance data to a central system.

While the upfront costs of installing optimisers across a plant must be considered, doing so can provide greater control over maintenance, enabling preventative action, and boost performance in the long-term. The use of optimisers allows full modularity when it comes to replacement of modules, with clear potential benefits for lifetime extension.

Advanced monitoring

Improving monitoring quality, with advanced systems such as the above, is the most effective means of helping asset operators and maintenance providers to identify and address issues or anomalous performance trends as soon as possible. Advanced monitoring may also assist independent performance evaluation as part of refinancing operations.

Common monitoring solutions include the use of web interfaces and standard protocols, monitoring of IED (Intelligence Electronic Devices, including meters, protections, etc.), improved data buffering capabilities in case of communication failures and other control features.

However, achieving a balance between the level of monitoring and its cost is always complex. A monitoring solution that works for one plant may not be economically viable in the long term at another.

Overall, the common theme is that there is no single solution for performance optimisation and lifetime extension. While each of the above options can deliver long-term benefits if deployed correctly, the economic case for each option must be evaluated via a detailed, project-specific analysis.

Authors

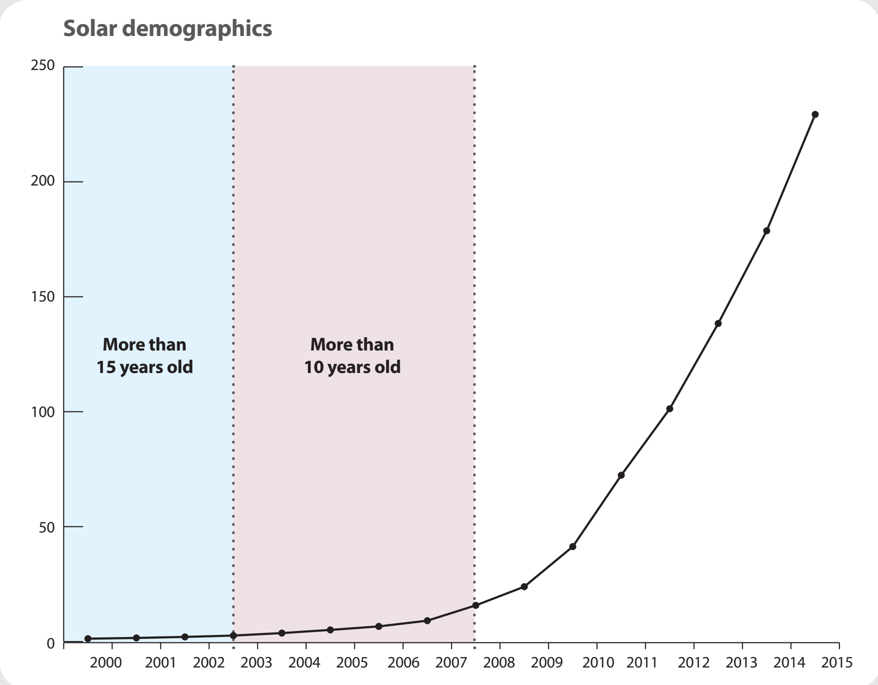
Mariano Melero is principal consultant at RINA Consulting. He specialises in providing technical advice on PV projects.

Repowering lessons

The market for repowering can only grow as projects age. Already, many lessons from older plants and even the experiences of rooftop installers can help prepare the industry for what is ahead. John Parnell looks at how investors, developers and manufacturers alike can play their role in mitigating the risk of problems and dealing with those already out in the field

Respect your elders

While annual installs of grid-connected solar PV have run into the double-figure gigawatts every year since 2009, the most fruitful opportunities for repowering may lie with older assets. These are currently in short supply and our knowledge and experience with older plants is somewhat limited. Less than 10GW of solar is currently more than 10 years old. By the end of the decade the figure will be more than 40GW.



Credit: SolarPower Europe/Global Market Outlook 2016-2020

Inverters out

When recently visiting the control centre of a major PV monitoring base with almost 1GW of European solar assets under control, there was a clear winner of the 'greatest source of headaches' award. One screen in the dizzying array of visuals was flagging issues in real time and almost every fault worth its own entry was from an inverter.

Replacing inverters is not exclusively about occasional and isolated faults. Many are reaching their natural end of life, some are no longer covered by warranty as manufacturers have folded. In other cases a firm may have left the solar industry leaving owners with token support.

Inverter manufacturer SolarMax has found success with repowering systems, initially in the residential market but the expectation is for large-scale plants to gain a similar focus.

Credit: Siemens

Siemens is one of many companies to exit the solar inverter business.

"SolarMax has been able to successfully implement several repowering projects. Since many systems are currently getting old, it is necessary to exchange many outdated inverters piece by piece," says Pierre Kraus, managing director, SolarMax Sales and Service.

"Many plant operators want to make their systems fit for the future in view of the many technological advances of recent years and thus secure their earnings. Therefore, this market ▶▶

Inverters out cont...

▶▶ is interesting for us because it offers an exciting potential to find customers," adds Kraus.

In July 2016, Fronius announced it was establishing a base in Greece.

"Until 2012, Greece was a major photovoltaics market," said Hannes Wendeler, area sales manager at the time of the announcement. "Some of these PV systems are now coming out of warranty, and many of the inverter manufacturers from those days are no longer in business or do not offer any technical support services. This is a huge opportunity for the repowering service from Fronius."

Another critical new development that could stimulate inverter swap-outs is the rise in demand for energy storage. A modern inverter and energy management system offers access to new revenue streams that could more than tip the economic scales in favour of what might seem like a daunting hardware investment and logistical nightmare. With tenders in the UK and US for utility-scale storage projects already complete and more in the pipeline, storage offers a stable source of revenue to utilise any spare grid capacity at an existing site. But those vintage inverters could very well hold you back.

Lessons from the rooftops

Ryan McShea, managing director of UK installer Empower Energy.

Rooftop solar is a little ahead of the curve when it comes to retrofits and repowering. While much of the engineering and technology won't translate, some of it does.

Ryan McShea is the managing director of UK installer Empower Energy. The company has already carried out a number of refits for residential customers as well as on larger rooftop portfolios.

Its own analysis has found variations in the performance of modules in the same system of as much as 5% inside one year of operation.

"That's purely from module mismatch," he explains. "We all age differently, it's the same for modules, and as time goes on that difference could expand further."

Empower insists that a vital tool in its repowering arsenal is microinverters and optimisers.

"A few years ago we had a client with 0.5MW across eight roofs. They were having problems with warranties from their inverter manufacturer. We installed SolarEdge inverters and optimisers. Since then they have done another 1MW and now SolarEdge is all they will fit. We practise what we preach and we have two 250kW of our own and they both use SolarEdge too."

McShea insists the benefits of this approach carry across to larger plants.

"It's scalable. A lot of utility-scale plants have fairly primitive monitoring. If I owned a 20MW solar farm I'd want to know what it was doing right down to the nuts and bolts," adds McShea.

He suggests that large-scale projects could have further challenges ahead as the investor is often less likely to be attached to the plant throughout its full lifespan.

"Unfortunately, a lot of people have invested in a race to the bottom. A lot of the value has been lost and quite frankly, the important thing is that with utility-scale, investors will flip projects every three years so as far as they are concerned its someone else's problem anyway. They'll have the same asset value whether or not they have initially installed panels that will create problems further down the line."

"I always sell quality but because I have panel-level monitoring, in the event that there is a problem, it will highlight that to me straight away. We have 350 sites and I can see all of them," says McShea.

"If your O&M supplier can only see at the inverter level then all the investor has is the data on the meter for the whole site. It leaves the scope for so many problems to slip under the net. But it will be the second or third investors down the line that end up footing the bill for it."

Diffusing the PID timebomb

PID is in some ways the great unknown. Its development has been modelled but there is now real world evidence that in some markets, its onset is faster than expected.

Belgian developer Edison Energy spun out a PID-focused solution provider Pidbull. Its managing director Davy Verheyden explains what they have learned from their experiences so far.

"With PID there is the timing effect, it takes a few years before you see the first impacts and there are also the environmental conditions, the humidity and temperature. A lot of solar was installed in western European countries in 2008-2010 so they are now six or seven years old. But we are getting a lot of inquiries about projects in places like the Philippines and India where there is both high humidity and temperature. So there you see the effects very clearly. In our opinion it is also the reason that, for example in Greece, there is more PID."

The trend for higher voltage architecture is also creating headaches according to Verheyden.

"As voltages increase, we are now seeing 1,500V used more often, which is a disaster for PID! Instead of taking three to four years to present it takes two years," he claims.

The second reason why PID could yet present headaches for existing assets is the lack of sufficient monitoring on many older projects, both in terms of the scrutiny of data and the availability of that data in the first place.

"In the beginning of PID you get losses on the worst-affected panels of around 20% but in total across the power plant only 2-3%. That is very difficult to detect. Not least because you can have more than 2-3% variation in radiation each year and a lot of financial institutions just look at the final numbers. But what we are seeing in countries like Greece and Italy is a lack of monitoring, some plants don't even have decent monitoring to do the detection in the first place. We are sure there is a lot of PID in the market, it's just undetected.

Verheyden estimates that only 20% of Greek plants have sufficient monitoring compared with around 60% of those in France and Pidbull's native Belgium. He says addressing PID on older plants offer a direct and

Credit: JA Solar

JA Solar modules undergoing a 500 hour PID test.

indirect benefit.

"There are two aspects: first of all of course, the higher yield leads directly to a positive cashflow effect. Secondly, risk mitigation – if you wait too long it can be too late for some panels."

Ensuring a site with 'PID-free' modules delivers just that requires a deal of due diligence that Verheyden says must occur at the point of origin.

"If you want to be 100% confident in a PID-free panel, you should do a PID stress-test first, and ask the manufacturer of the exact bill of materials used for all delivered panels. Ideally, check on site during the manufacturing process that the exact materials are used [in production] as for the panel in the PID-free test." ■

La Renaissance Solaire

France | With Europe in search of another PV poster child, an Emmanuel Macron-led France looks all but set to truly embrace the solar revolution. But will it learn from the mistakes of other boom markets that have preceded it? Liam Stoker reports

Credit Neoen

France is now Europe's most active solar market and home to its large PV power plant, Cestas

European solar has a habit of being driven largely by individual markets that hit a hot streak. Germany, Spain and, most recently, the UK have all had their years in the sun, so to speak, and now all the signs are it's the turn of France. Ambitious climate targets, political will to meet those targets and ideal generating conditions – particularly in the country's south – make France an ideal destination for a legion of financiers, developers and engineers in search of new opportunities.

But, much like Europe's boom countries that have preceded it, France isn't without its share of obstacles. Solar has had a rough ride previously with an up-and-down feed-in tariff, while grid constraints make negotiating a connection contract a tough job for even the most seasoned of developers. Coupled with a presidential election that proved to be more divisive than expected, and you'd be forgiven for erring on the side of caution.

France has a history with solar PV that stretches back beyond a decade but started deploying the technology in earnest in 2008. By the end of that year it had 104MW of capacity, a figure which had more than doubled by the succeeding year. The introduction of the country's first feed-in tariff in 2010 however caused a mini solar boom that piqued the interest of solar professionals across Europe, and by the end of 2011 almost 3GW had been deployed.

Marceau Leroux, business developer at German developer Enerparc and the firm's country lead for France, says the early years of France's solar market were "hectic", even before 2012's introduction of a tender process was put into place. "It then became very competitive to develop projects…and many companies were still in the market so it was difficult to get your piece of the cake," he adds.

That intense period of competition period proved to be somewhat short-lived. Cuts to the government's feed-in tariff scheme – warranted due to its having failed to adjust to falling component prices – cooled the market on previous years.

However those times appear to be over, and according to Paul-François Croisille, chief operating officer at IPP and solar developer Neoen, many companies are rushing back into the fold due in no small part to the visibility and predictability of its newly prepared tender regime.

In April 2017, France placed its aggregate solar capacity at around 7.1GW. The country has targeted an overall capacity of between 18 and 20GW by the end of 2023, meaning that deployment will have to ramp up to a pace unseen in the country previously, and one more akin to the UK and Germany in recent years.

Tom Heggarty, senior solar analyst at GTM Research, said: "France looks set to be the largest market in Europe over the next three to five years – demand will be driven by competitive reverse auctions for feed-in premiums, so not FiT-free as such, but a more market-based approach than we've seen in most European markets in the past. There are confirmed tenders for around 3.5GW of new capacity to be held between now and the end of 2019, for both ground-mounted and larger roof-mounted installations. We're anticipating around 1.7GW of demand in France this year, up from less than 600MW last year. "

To this end, a 3GW tender programme has been established which will take France out to 2019, with auctions of around 500MW held every six months for utility-scale solar. A separate award for self-consumption solar has also been arranged, while support for innovative projects such as solar roads is also on offer.

Developers submit for support based on the price they expect they can produce power at and other factors are taken into consideration, most notably the carbon emitted in the manufacture of the solar cells used. It's an interesting and all but unique design feature which allowed First Solar and its frameless modules – free from the extra carbon in the aluminium casings alternative modules possessed – to steal a march on competitor modules within France's earlier tenders. Speaking at Solar Power Europe's Solar Summit in March, First Solar's Stefan Degener said the firm had continued to enjoy a significant market share, being the module supplier of choice for between 30 and 40% of projects in the last tender. Another quirk is the necessity for the project application to originate from a France-based company, something which developers achieve by establishing special purpose vehicles for these assets.

Such requirements have been enough to cause many developers a headache; however Croisille says the more recent programme is much improved on previous iterations. "When you read the rules of engagement of those tenders you need to understand what are the real objectives and play by those rules, and those rules might not make immediate business sense compared to what we see in other markets. But it must be said they have come a very, very long way since the first tender to simplify and to make sure the economic aspect has become the largest component of the grading of the projects. It's going the right way," he says.

These schemes have been further enhanced by France receiving European state aid approval – just days before the country's election – for a FiT scheme to support 2.1GW of small-scale rooftop solar. FiT payments will be linked to both the size of the system and the business model lying behind its design; either self-consumption or for export. At a cost of €190 million the FiT – and additional tariffs announced earlier this year – build on regulation in France passed in 2016 mandating all new public buildings to include either rooftop solar or a so-called 'green roof' in its plans.

Security and stability

France kicked off its new utility-scale programme in March this year when energy minister Ségolène Royal awarded contracts to 79 projects. The country's maiden award generated an average strike price of around €62.50/MWh, a price which Leroux says reflected continuing downward trends in panel prices. In contrast, the first (and possibly last) projects to receive competitive funding in the UK under its Contracts for Difference mechanism were completed in 2016 at a strike price of £85.02, equivalent to around €100.

> "We need to make sure that something that looks interesting under today's constraints will remain interesting in two or three years' time"

A notable contributing factor towards that average price will however also be the location of projects. A healthy majority – 54 – of the 79 projects to receive support are located in the three regions that make up France's southern base – Nouvelle Aquitaine, Alpes Cote d'Azur and Occitanie – where solar irradiance is considerably higher.

Leroux argues that the design of the new tender scheme also happens to offer developers far more security than its predecessor as they know what to expect and, crucially, when to expect it. "Before, we had no perspective about the frequency of the national tenders. We just heard it might be every year, but we didn't have any dates of submissions and the volume," he says.

But winning a tender is no mean feat. The first 500MW tranche was oversubscribed more than five times, attracting roughly 2.7GW of bids. Croisille says this has heaped pressure on developers to control costs as much as possible, both in relation to site selection and technical aspects. "There is no escape from needing to be good at what you do to come out on top. It's the normal way of doing business," he says.

There is also the suspicion that utilities and other large companies are better placed to win tenders in a process with such a heavy importance placed on price. Leroux says that while utilities are not necessarily favoured – as best evidenced by the fact they didn't win a single megawatt in the most recent round – the price focus does tell. "It's a system that is extremely focused on the price, so obviously there are economies of scale that make larger players much more competitive than others," he adds.

Eligibility criteria for subsequent tender rounds – submissions for the second round are to close around 1 June 2017 – are being tightened and Croisille expects that this will reduce the oversubscription from a ratio of 5:1 to 3:1, but that will not stop the underlying assumption that France could be deploying a considerable amount more solar than it is now, and at a compelling cost. Croisille says the industry is remaining patient for now. "There is obviously more room to grow and to produce more than 1GW in a year, but I think the balance is there. We would love to do more, but we – the rest of the industry – appreciate the fact that we now have some visibility on how we can invest in development."

But what – aside from an understood need to steady the flow of solar into an easily manageable trickle – is standing in the way? For most projects it would appear to be factors solar is all too familiar with.

Bureaucrats and politics

Prolific solar developers the world over – but especially those in Europe – will have come to dread the mere mention of the words 'grid constraints', and it's one factor France has not managed to avoid. France's grid is particularly, and predictably, congested in the south of

Credit Wattway

The French government has offered support for innovative projects such as solar roads

Credit Frederic de la Mure

Emmanuel Macron's victory in the presidential election augers well for PV in France

the country, with the south west region surrounding Bordeaux hardest hit. These localised grid constraints are compounded by regulatory and environmental red tape that so often shrouds promising projects in France's south eastern region.

Croisille says projects in these areas, which are for obvious reasons the most highly sought after, can take as long as three or four years to be green lit by the relevant authorities. And it's these reasons which place even greater importance on compelling economics. "It's quite long to develop a project in France because the authorisation process is quite meticulous and detailed, and we need to make sure that something that looks interesting under today's constraints will remain interesting in two or three years' time," Croisille adds.

Developers also bemoan the political desire, in true French, socialist fashion, to share the wealth. Projects submitting in the tender process are limited at around the 17MW mark and this makes it difficult for developers to both realise true economies of scale and gain any momentum.

France's market has been a highly nuanced one that developers have found difficult to get their heads around. It's perhaps why so many breathed such a heavy sigh of relief just after 7pm CET on Sunday 7 May 2017, when exit polls allayed their worst fears.

Macron economics

While Emmanuel Macron has not perhaps enjoyed the popularity other candidates have in the past, his victory in May's French election was undoubtedly viewed favourably given the contentious politics of his opponent, Marine Le Pen. Macron has appeared wholly supportive of PV. In a video released not long after US president Donald Trump's proposals to row back on Environmental Protection Agency funding in February 2017, Macron appealed to American researchers, engineers and entrepreneurs working in climate change and renewable energy, offering them the chance to continue their work across the Atlantic.

> "We may be at the onset of a French solar renaissance"

Politically charged, point-scoring rhetoric aside, Macron has backed up his sentiment with tangible pledges. Implementing the Paris Agreement is to be a priority under his government and he has promised to double solar and wind generation capacity in France by 2022, using state funds to mobilise private investment. Red tape will be removed to shorten the timeframes for deploying renewables. France's congested grids will also be strengthened with research and development ploughed into both battery storage and smart grid technologies.

It stands to reason, then, that France's ambitions for solar will not be negatively impacted by political developments, unlike other markets and most notably in Europe's former boom market, the UK. Under that country's now defunct Renewables Obligation more than 5GW of utility-scale PV was deployed in just three years, with as much as a further gigawatt expected to have been deployed in Q1 2017. This scheme was scrapped all but overnight following the surprise majority victory of David Cameron's Conservatives in May 2015 and when the highly successful feed-in tariff regime was kneecapped six months later, UK solar all but ground to a halt. Under Macron there are no such rollbacks on the French horizon.

Speaking between the two election rounds Leroux regarded the vote as a "potential risk" for the industry, but saw no reason for immediate alarm. "As a minister of the economy [Emmanuel Macron] signed most of the decrees that were taken regarding renewables, so I don't see him going back on his word," he said.

Solar Power Europe, the trade association representing European solar's interests, regarded Macron's victory as one the whole of Europe could enjoy. "Macron is good news for French and European solar. [Macron's solar plans] would ensure France as one of the top markets for solar, and position France as a renewable energy leader in Europe," an SPE spokesperson said

"Macron has also confirmed that he will pursue the renewable energy objectives set in the 2015 energy transition law. This will increase investor confidence and ensure predictability for the French solar sector. We may be at the onset of a French solar renaissance."

European developers feel like they may also have dodged a bullet. One developer spoken to for this feature who did not wish to be named feared that a victory for Le Pen and her nationalist politics would have left international companies at risk of being excluded from future tenders in order to preserve domestic interests.

For now, the French market feels like it is riding the crest of a wave, picking up where other markets have left off. It has significant solar potential, ambitious targets to fulfil and, crucially, the political will to do so. Developers will however need to enter France in full knowledge of its quirks and accept that it's certainly not going to be flipped for a quick buck – with project lead times lasting longer than many other European countries' policies, France is more slow burner than quick earner. Which is perhaps why so many developers are so clearly excited about what French solar represents: a stable and secure market providing just the right levels of support to guide the technology towards grid parity. ■


Credit OCI Solar

Mexico: 'The place to be'

Market update | Mexico as yet has only a small installed base of solar PV. But with widely lauded market reforms beginning to take effect, and a succession of highly competitive tenders under its belt, this is a market whose time is about to come. Danielle Ola reports

Mexico's solar market is deceiving. With just under 400MW of PV currently installed, it's not much compared to other international markets. Relatively on the smaller side, solar energy currently accounts for just 19% of Mexico's renewable energy capacity.

However, the country is at a crossroads as the amount of growth that is expected in the sector within the next couple of years is extremely high.

"In my opinion this is going to be the most enjoyable country from an energy point of view all around the world," says Paolo Romanacci, head of renewable energies for Central America for Italian developer Enel, which is currently building what is set to be the largest PV project in the Americas. "Mexico is going to be the place to be in the next three to seven years."

A recent energy reform opened up the country's electric power sector to private players, allowing installers and investors to tap into Mexico's expansive renewable energy potential. The Energy Secretariat (SENER) and the National Energy Control Centre (CENACE) expect the reforms, approved in 2014, to bring up to US$9 billion in investment to the sector by 2019.

Mexico's strong outlook is underlined by the successful power auctions the country held in March and September last year, which drew in some of the biggest international renewables energy players such as Enel Green Power and Engie. The first auction brought in 1,860MW of renewable energy capacity – with solar constituting 74% of that. The first auction also saw some of the lowest PPA prices globally, at an average contract price at just US$50.7/MWh.

"With the creation of the auction structure, it's really made it very enticing for developers and large consumers of electricity to look at cleaner options, and adopt technologies like wind and solar," says Manan Parikh, Latin America expert and senior solar analyst at GTM Research. "I think the real driving force behind a lot of that policy is the targets."

With the foundations now laid, Mexico's solar market is expected to witness rapid growth from 2018

Mexico is working for renewables to account for 25% of power generated by 2018, 30% by 2021, 35% by 2024, and 60% by 2050. It is this incentive alongside the auctions that sets Mexico on the path to leading Latin America in solar power generation a lot sooner than you might think.

Second long-term power auction

The second auction saw a total investment of US$4 billion and 2,871MW of new capacity coming in at an even lower US$33.47/MWh. Solar energy dominated once again, securing 54% of the supply and 53% of the contracts awarded.

A total of 23 winners were selected by CENACE, winning both long-term energy contracts and clean energy certificates (CELs). Among the qualified bidders were Iberdrola, Enel

Green Power, IEnova, Engie, Fotowatio, Canadian Solar, Recurrent Energy and Gestamp, along with local developers and independent power producers (IPPs).The tariff rate revealed a "highly competitive price", according to Mexico's energy ministry. Joaquin Coldwell, secretary of energy, confirmed this price was down 30% from the March auction.

Preliminary results revealed an economic surplus of 32.91%, which represents the savings achieved between the maximum prices that national utility Comisión Federal de la Electricidad (CFE), who purchased the energy in PPAs, offered to buy, and the price that bidders have offered to sell.

Over the next three years, the winners will build 36 new power plants cumulatively, including solar projects across 15 Mexican states. Projects are focused in the state of Yucatan – with one third of all capacity awarded allocated here, despite having the highest nodal prices. According to GTM Research, the most competitive prices were achieved in the northern state of San Luis Potosí, at US$26.99/MWh, and the highest in Chihuahua, at above US$49/MWh.

Realisation of the projects awarded in the auction is expected to spur exponential growth in the country's installed capacity.

"Next year we're forecasting a little over 2GW in 2018 alone – and that is pretty significant because 2GW in a whole year is quite a bit," says Parikh. "If you look at the cumulative forecast that I have for 2017-2022, that's about 18GW of combined solar in Mexico. 2018 is kind of the take-off year, and then the market will continue growing in subsequent years after that."

Project progression

Construction is already well underway by developers that won projects in the last round. Analysts are reporting a lot of movement, especially for the plants with a 2018 commercial operation date, with the vast majority of those projects expected to be completed on time.

"There have been situations in certain markets where projects are won but it turns out that those projects are just sitting there. But the Mexico pipeline is really advancing quite a bit and at least 85% of those projects will certainly complete," confirms Parikh.

Many market veterans are already setting up shop by putting projects in the ground already.

Italian power giant Enel Green Power is one such contender. Already operating 500MW worth of clean power plants in Mexico, it secured a contract to build a 93MW wind farm in Tamaulipas that is set to be operational by 2019, when it will generate around 400GWh of electricity annually.

Likewise, France's Engie was drawn to the market following its comprehensive reforms.

"We've been in operation in Mexico for 16 years or so, but in terms of renewables we've been focusing on other parts of Latin America," says Fernando Tovar, head of Engie Mexico. "The reform here in Mexico changed things for us significantly; the Mexican government has instituted the changes to create more possibilities for renewables projects to be offered. The reform was when we really started putting our focus on Mexico."

> "2018 is kind of the take-off year, and then the market will continue growing in subsequent years after that"

Engie netted contracts for 15 years for 209MW of wind and solar projects last March. The company has announced plans for a 157MW Trompezón solar farm that will be built in the central state of Aguascalientes. Construction is scheduled to begin in early 2018 with commissioning the following year.

Engie says its internal team is designing the project, and is currently selecting the right technology, which includes single-axis trackers to increase the yield. Altogether the company invested between US$250-300 million in its renewable energy projects from the previous round, reflecting its staunch belief in the market.

Spanish renewable energy firm Acciona Energia won a contract in a 50-50 joint venture with Tuto Energy. The duo plan to build an 180MW solar PV plant in Sonora state, known as the Puerto Libertad. Construction is expected to start in late 2017 with completion in early 2019. Acciona said that the average bidding price represents 44.2% below the maximum price set by the CFE.

The company intends to capitalise on that project with further developments.

"We want to join that 180MW of PV with a private project in the same area so that the plant will have a total of 270MW," says Miguel Angel Alonso, director for Acciona Energy in Mexico. "Our intention is to make it even bigger for a total of 330MW. We are looking at future developments because these things are modular."

Fellow Spanish firm IEnova won 141MW of solar projects in the auction: the 100MW Tepezala II single-axis PV farm and the 41MW Rumorosa PV farm. The projects are to be built in Aguascalientes and Baja California, respectively. The 100MW project is reportedly being developed in conjunction with Chinese module manufacturer Trina Solar. Construction of both projects is scheduled for 2018 with operation likely in the first half of 2019.

Third long-term power auction

The energy ministry announced that the third power auction will be held in November 2017, with bid guidelines published 8 May, as this publication went to press. Developers must submit technical bids between 12-20 September.

There have been a large number of bidders in both rounds, indicating a lot of interest in the Mexican market, spurred on by the successes and bankability displayed so far.

That being said, the key players are poised to do it all again, bigger and better in the upcoming round.

"Right now we are working on putting some portfolios together for both solar and wind projects," says Tovar. "We are obviously trying to find projects that are in nodes where there is less congestion, and we are also trying to get projects that are sizeable and hoping to present several hundred megawatts in total."

"For the third auction, we are developing another 130MW of PV, so will probably be close to 500MW by the end of next year," adds Acciona's Alonso.

Whilst this auction is expected to mirror its predecessors, this time will be different as CFE will no longer be the sole off-taker, bringing opportunities for private and industrial off-takers alike to make offers for power, increasing

competition. CFE will still have a bit of an advantage in its ability to enter the auction round for a couple of weeks before the other independent players.

"[CFE not being sole off-taker] is going to be a factor that changes the auction a little bit, but I think it means more opportunities for us to be able to place power in the market," says Tovar. "It complicates things a little bit, but hopefully it's another opportunity."

Market volatility

Whilst increased competition might be good from a wider economic perspective, the market has been exposed to some volatility, with a hit to the peso following Donald Trump's election as US president raising question marks over currency depreciation and the associated risks.

A lot of the projects were awarded through peso-dominated PPAs, with developers holding on to the advantages of local currency whilst hedging their bets that the peso would improve.

Pricing

Evidently Mexico's solar market has hit a sweet spot after record-low prices for solar projects have allowed for a smooth transition into construction phase for many developers. Power auctions have become more commonplace in Latin America over recent years, leading prices to continue to plummet.

The Mexican auctions supported both the largest capacity projects and the lowest prices in the region.

The average price for solar in the second round was around US$32/MWh and GTM's Parikh says that next round's prices are not expected to go too much lower, thanks to an internal backstop in place to prevent prices going too low and affecting project viability. Therefore, sub-US$30/MWh prices are not expected.

"Somewhere in the mid-US$30s-US$40/MWh is a realistic guess," he says. "I think closer to US$35-36/MWh is probably the best bet."

Electricity prices have fluctuated historically in Mexico. Retail rates have been increasing over the last year or so. Certain tariff classes within the residential, commercial and industrial segments have consistently been on the rise, which in turn means more opportunities for distributed generation.

"Solar's pricing is so competitive that even without subsidies there's really no shortage of opportunities to secure contracts either through an auction or as an IPP," says Parikh. "Not only have the prices been competitive, but so have the cost of the CELs – which ultimately determine what the real returns on some of these projects are."

Harnessing potential

It is evident that all the conditions are right for Mexico to be solar's next big thing: falling equipment prices, competitive bidding prices, plenty of investor interest and excellent interconnectivity.

However, analysts have been predicting the Mexican market to be the new big market for years now, with hurdles still clearly in the way of the country harnessing its full potential.

"I think a lot of that in the past was due to an uncertainty as far as where the policy was headed and where the market really was going, and that's because people just didn't even know," says Parikh.

But as the various stages of the energy transition are being rolled out, stakeholders are finally seeing a lot of developments take place this year. 2018 is tipped as the take-off point for the market due to a lot of projects having CODs in that year, with 2017 bearing the brunt of growing pains and a mass of construction.

Beyond that, financing is always a sticky point for Latin America and developing markets in general. There is a lot of currency risk associated with these projects and investors definitely get a little hesitant to lend in a place where they don't know if it's been done before.

"We've come a long way just from a year ago. There may be some uncertainty as to whether energy targets can be met, whether projects can complete on time...but those aren't necessarily bad things, they are things we were expecting in the market. If they happen, they are not a surprise," says Parikh.

"Mexico needs to ensure that whatever of these uncertainties does take place, there's at least enough of a buffer to ensure they aren't setting themselves up for failure, and that's the key." ■

The Americas' largest solar project

Capacity won in the first auction is already taking shape for Enel Green Power México (EGPM), a local subsidiary of Italy's Enel, with the mammoth 754MW Villanueva project near Viesca, Coahuila State, in north central Mexico, underway. Upon completion, it will be the single largest PV plant in both North and South America – generating around 1,700GWh per year and aiming to power the equivalent of 1.3 million households.

The firm was awarded 15-year supply contracts and 20-year CELs for 992MW of solar – 754MW for the Villanueva project and the remaining for the 238MW Don José PV project.

Construction on Villanueva has already begun, and Enel expects to bring the project, which is highly compartmentalised, online in the second half of 2018. Citing a sound and stable market feeling, Romanacci is confident that Mexico was the perfect location for such a project.

"We come out from a system reform that is practically privatising the sector and is boosting renewables," he says. "I don't see any other country in the world [except some Asian countries] that is of the same size with the same resources, with a clear regulation, with a stable economy and with fair conditions to construct and operate a plant like Mexico."

Credit Enel

The site for the giant 754MW Villanueva solar project, set to be the largest in the Americas

Solar torrent in post-Abbott Australia

Credit ARENA

Utility-scale PV | Since the fall of former prime minister Tony Abbott two years ago, the prospects for large-scale solar in Australia have enjoyed a dramatic turnaround. Tom Kenning reports on the changing fortunes of the industry and how storage looks set to become a key partner technology for utility solar

Investor confidence has rebounded in Australia's utility-scale renewables with more than 20 projects under or about to start construction this year. Despite months of stagnation, big solar has finally broken out and looks set to be an unstoppable force at least until 2020, after which the parameters of the country's renewable energy target (RET) mandate are still uncertain. Kick-started by a major funding programme from the Australian Renewable Energy Agency (ARENA), foreign players are closing in for a piece of the action and large-scale project plans are flying in, often with ground-breaking innovations around energy storage and hybrid technologies (see boxout). While the country has been embroiled in a fierce national debate about energy security and whether renewables are to blame for blackouts – even Tesla chief Elon Musk got involved with a giant energy storage proposal – the solar sector Down Under has swept away the dust of politically driven inertia and looks forward to a golden period of opportunity.

Just in 2017, there were 1,569MW of large-scale (>5MW) solar projects under construction or with financial commitment ready to commence building, according to analysis in February by Australia's Clean Energy Council (CEC). To put that into perspective, at the end of 2016, only 12 large-scale plants were operational in the entire country with a cumulative capacity of just 318MW.

The 52MW Broken Hill project in New South Wales looks set to be joined by a new generation of large-scale PV projects in Australia

Market fundamentals

The political changes that form the background of this solar surge have been well documented. In brief, months of uncertainty around the RET came to an end in 2015, while the former prime minister Tony Abbott, a controversial

Technology	State	Developer	Project (MW)	Investment (AU$ million)
Solar	Queensland	Sun Metals	100	155
Solar	Queensland	ESCO pacific	135	225
Wind/Solar	Queensland	Windlab	40	120
Solar	Queensland	Genex	50	126
Solar	Queensland	FRV	100	190
Solar	Queensland	FRV	100	400
Solar	South Australia	Snowy Hydro	100	200
Solar	New South Wales	Neoen	110	230
Solar	Western Australia	APA	20	50
Wind/Solar	South Australia	EDL	4	37
Solar	Queensland	Sunshine Coast	15	50
Solar	New South Wales	Goldwind	10	26
Solar	Queensland	Conergy	10.8	42.5

Source: Clean Energy Council

Table 1. Australian large-scale solar projects under or about to start construction this year as of February 2017

enemy of renewables, left office last year, bringing instant confidence back to investors. This was against a backdrop of global PV module oversupply, cost reductions in key components, lowered risks and speedier installations – all factors that have driven downstream PV progress across the globe and not just down under.

"The RET decision meant that electricity retailers, who have the largest share of liability under the RET scheme, were also able to forecast their future liabilities under RET more confidently," says Geoff Burns, project director at Canberra-headquartered renewables developer Windlab Systems, which started focusing on large-scale PV in 2015. "This meant medium to long-term power purchase agreements (PPAs) were back on the table for project proponents."

Alongside this there has been more acceptance of solar at individual and community levels, says Burns.

While the RET debacle slowed down investment "terribly", according to Darren Gladman, director of smart energy at CEC, the target is harder to meet in the short-term as a result. This means that the price of large-scale generation certificates (LGCs) – which RET-liable entities can purchase to fulfil their obligations – has become higher than people expected them to be at this stage a few years ago.

In conjunction, the prices of wholesale electricity have also risen recently, partly following the recent closure of one of the largest coal-fired power stations, Hazelwood. This was another factor setting the stage for large-scale solar to prosper.

"The fundamentals are looking pretty good," says Gladman.

The effects of LGC price increases can be seen in Australia's energy retailers flocking back to the PPA market, adds Gloria Chan, director of corporate and project finance at the Clean Energy Finance Corporation (CEFC), which provides low-cost debt financing for Australian clean energy projects. The big retailers such as EnergyAustralia and Origin started signing solar PPAs again and that momentum has also led to movements from second-tier retailers as well. Chan also notes a surge of interest in corporate PPAs at present, a space that will be up and coming in the next six to 12 months.

Beyond grant funding

As a result of PV costs falling dramatically ARENA was able to award AU$92 million grant funding for 482MW of large-scale solar last year in its flagship funding round; more than double the 200MW it had expected. This was complemented by significant debt funding from CEFC.

"Even though that hasn't delivered a completed project yet, it was really quite instrumental in first attracting investment into that sector, but then also in reducing costs," says Gladman. "EPC costs have really come down. It's become a much more competitive space. As we build experience and the supply chain builds in Australia the costs have been coming down progressively."

Franck Woittiez, country manager of French developer Neoen's business in Australia, which has significant projects under construction and in the pipeline, says that until recently projects were unviable without ARENA funding, but now with decreasing costs of technology and higher cost LGCs, projects can go ahead without grants for the first time.

This had to be driven initially by ARENA's large-scale solar funding round, but the amount of grant funding in the capital structure as a percentage of project costs is only 5-10%, which is relatively small, and solar has started to be able to close that gap, adds Chan. Where there is insufficient debt finance, CEFC still has a large role to play, but its facilitation has also helped several projects come to fruition in a highly accelerated period.

"We are at the stage now where we are seeing a lot of projects that don't require any grant funding from ARENA and commercial banks are financing it by themselves where there's a commercial off-taker," she adds. "EPC contractors have sharpened their pencils and become competitive. There's a few EPC contractors coming up now and fighting for those projects, which is great."

Warwick Johnston, managing director at consultancy SunWiz says that people are now happy to take merchant risk for the first time and this has been partly driven by foreign companies, with experience abroad, entering Australia and demonstrating that the conditions for solar are more than adequate.

"That's using some investment outside of Australia," adds Johnston. "In contrast the Australian major banks don't have a lot of experience with solar and are still pretty cautious. Up till now that's been a dampener, because they've waited for a PPA that's been signed by a major electricity retailer. The difference is that there are now solar projects willing to go merchant and that's going to unlock a large number of projects."

In this case, "going merchant" means taking the wholesale spot market price rather than using a PPA as the route to market.

Finance fortunes change overnight

CEC's main annual conference last July in Sydney made it perfectly clear just how dramatic the change in atmosphere around investing in Australian renewables has been.

"Under Tony Abbott it felt a lot like the industry talking to itself, whereas once there was the change of prime minister, even though there wasn't a significant change in policy, you could really see a shift of confidence and in the attitude of investors," says Gladman. "Going to Malcolm Turnbull we had a lot more international investors and representatives from banks coming to the conference than we ever had before."

The Australian trade commission also noted a significant return of international investor interest, marked almost to the day that the role of prime minister changed hands. "Under the former PM you always felt like the next attack was days away and never knew where from," adds Gladman.

Dangers ahead

All of which is not to say that the industry is now trouble free. Despite the growing competitiveness of EPC costs mentioned earlier, Johnston forecasts a major bottleneck forming in terms of sourcing experienced constructors. At present there are only few local companies with experience, but the anticipated volumes of solar deployment activity are very high.

Mega projects and innovations

The 56MW Moree project, completed in March 2017 in New South Wales by developer FRV, was the first in Australia to use a single-axis tracking system. Technical innovation looks set to be a prominent theme in the next generation of large-scale PV projects in Australia, with a flurry of hybrid solar, wind and energy storage proposals on the table:

Kidston

Renewables and storage firm Genex Power has started building the 50MW first phase of the Kidston Solar project in Northern Queensland, with plans for a 270MW second phase. Once complete, this will be the largest commissioned solar project in Australia. The firm is also developing an accompanying 250MW Kidston pumped storage hydro project, which it found could be connected to the solar plant in a recent study. This would give the projects 24/7 power generation capabilities.

Lower Wonga

Queensland-based developer SolarQ is planning to build a 350MW(AC) solar plant combined with a ground-breaking 4,000MWh of lithium-ion battery storage in the Gympie Region of Queensland. Scott Armstrong, SolarQ managing director, says there are plans to ramp up the Lower Wonga PV project to 800MW(AC) within four years. While the hybrid project is at concept stage, the company put in a council development application and has allocated a lay-down area that can carry up to 4,000MWh of batteries. To complete what would be the most ambitious storage project to date worldwide, the firm expects to capitalise on economies of scale.

Kennedy

Windlab is developing Australia's first large-scale hybrid wind, solar and battery storage project, known as Kennedy Energy Park, in central north Queensland.

"Kennedy Energy park will be able to demonstrate a near base-load generation profile and a potential pathway to overcoming the issues of reliability and intermittency as we move to higher penetration of renewable energy," says Geoff Burns of Windlab.

"There will be some deployment of co-located wind and solar to 2020, expected to be mainly the installation of solar PV at existing wind farm sites. However, the main concentration of wind farms is in the southern states, where the level of solar irradiance is significantly less than that of northern Australia."

The 56MW Moree solar farm was completed in March 2017, the first utility PV plant in Australia to use single-axis tracking

Credit FRV

Two further significant threats to the market relate to the RET.

"The current design of the RET sets an increasing target for renewable energy up until 2020 and beyond that it is fixed," says Burns. "In this regard, as supply of renewable energy increases to meet the demand for large generation certificates (LGCs) under the RET, there is a chance that the market price for future LGCs could approach zero. With this in mind the electricity retailers would be reluctant to enter into anything other than short-term PPAs, which will not support investment in new renewable energy projects."

What happens after the RET, a subject of intense debate at political level, is also key. Without bipartisan political support, regulatory uncertainty could rear its ugly head again, leading some states to go their own way and making investors nervous once more.

Gladman is particularly concerned about the need for clarity post 2020. Some energy bodies cite the Emissions Reduction Fund (ERF) as a key enabler, but Gladman disagrees: "The ERF

A carbon price in conjunction with an extended RET is one of the favoured solutions for keeping Australia's large-scale renewables business going

purchases abatement, but frankly it doesn't operate in the electricity sector anyway. It's not a policy that would be of any support to our industry."

The CEC's preferred policy would be for Australia to adopt a price on carbon in combination with an extension of the RET or some variation of it, with the two policies complementing each other, CEC believes

"There is a lot of confidence in the industry now and people can see a lot of opportunities to build between now and 2020, but once we reach 2020, if there's not some sort of policy in place then there's no direction for investors," says Gladman. "It's unclear whether prices are going to come down sufficiently for people just to invest in renewable energy without any policy support or without any price on carbon."

There are hopes that the emergence of energy storage capabilities will push solar along and Chan says that CEFC is already looking at financing storage. Blackouts in South Australia in 2016 and early 2017 caused a vicious national debate with some seizing the opportunity to blame renewables – particularly wind – for destabilising the grid. Despite the bad press, it was made clear that high gas prices and interconnector issues were part of the problem and it also led Elon Musk to boast that Tesla could solve the state's power crisis in 100 days. Since then both South Australia and Victoria have announced major energy storage tenders. The impetus is clearly there and due to its geography, Australia can tap into both pumped hydro and battery-based projects. Chan also believes that transmission upgrades between states would be a significant driver of investment in the renewables sector.

Ultimately, new market developers are probably fairly confident that the RET will stay almost as it is up till 2030, says Gladman, but that's only 13 years away. "That's not that long to recoup your investment so everyone's piling in because they can see there are opportunities now, but in three to four years it's a bit of an open question."

Nevertheless, the picture has transformed out of all recognition since the demise of Tony Abbott and it seems the time has come for large-scale solar in Australia to thrive. ■

The state of play

Industry commentators had strangely conflicting views about which Australian states hold the most promise for large-scale solar, which could be disorientating for budding market entrants. However, this is perhaps a validation of the claims of Franck Woittiez, managing director of French developer Neoen's business in Australia: that in reality there are opportunities in every state in Australia. This is despite variations in irradiance: North Queensland, for example, has slightly more irradiance but also suffers from more cyclonic conditions, so the benefits are evened out.

"In terms of policies, it's hard to say where to go now and it's changing depending on the political mood," adds Woittiez. "But I would tend to say Victoria is the place to go. There is a clear political will to develop 5.4GW of wind and solar by 2025."

Woittiez thinks Queensland is very attractive but the future policy is yet to be announced.

However, Windlab's Geoff Burns says the Queensland government's offering of long-term off-take contracts for up to 150MW of new large-scale solar projects was instrumental in kick-starting development in the state so that there are now more than 2.5GW of PV projects with development approval in this state alone out of roughly 3GW approved nationally.

South Australia is very supportive of renewables and has launched an ambitious programme for the development of storage, adds Woitiez.

Meanwhile, New South Wales is starting to show more willingness to contract long-term renewable electricity. CEFC's Gloria Chan says that New South Wales and Victoria are also attractive because they are the big load centres where most of the population is concentrated. However, the opportunity for wind energy is slightly stronger than PV in Victoria due to its southern location. Both states are also working hard on reaching their renewable energy targets.

SunWiz's Warwick Johnston also claims that the solar opportunities are slightly smaller in Victoria and Tasmania. He cites Queensland and South Australia as having the obvious opportunities, since they both have high solar irradiation resources and high electricity prices driven by large proportions of gas in their generation mix.

Even Western Australia which has a changing political regulatory environment holds some promise, according to the various commentators.

"There's not a magic state," concludes Woittiez. "I think what an experienced developer will do is hedge their risk by developing projects across all four to six states in the main in the electricity market."

BOFT AD

Emerging market briefing

Tom Kenning looks at the latest trends from some of the world's most promising emerging PV markets. This issue features Turkey, Algeria, Saudi Arabia and Malaysia

Malaysia's plays big with 460MW auction

Malaysia has made a play to revamp its large-scale solar sector by going large on a new tender. The Energy Commission of Malaysia (EC) issued a request for proposal (RfP) document hoping to auction up to 460MW(AC) of large-scale solar capacity in February this year.

Under the commission's second competitive bidding programme, it hopes to award projects of 1-30MW capacity to make up a total of 360MW in Peninsular Malaysia and 100MW in Sabah and Labuan in the east.

All solar plants will be connected to the grid, with power purchase agreements to be signed with the main utilities Tenaga Nasional Berhad (TNB) or Sabah Electricity Sdn. Bhd. (SESB).

The auction is still some way away with a deadline for submissions set for 1 August 2017.

Malaysia installed 31.78MW of solar PV under its feed-in tariff (FiT) scheme last year. This brought its cumulative installed solar capacity under the FiT regime to 294.85MW. Also under FiTs, the nation's cumulative renewable energy capacity has reached 458MW as of March 2017. Solar annual installations have declined each year from its 106.5MW peak in 2013.

In related news, major utility TNB signed 21-year power purchase agreements (PPAs) for two large-scale solar projects with UITM Solar Power and Sepang Solar. One 50MW project will be located at Gambang Pahang and the other 50MW plant will be at Sepang Selangor.

The Malaysian Investment Development Authority (MIDA) had also approved MYR2.42 billion of solar investments in the 12 months to the end of December. Roughly MYR1.77 billion was invested in seven PV manufacturing facilities last year, according to the Malaysian Investment Development Authority (MIDA), along with MYR650 million investments in 83 other renewable energy projects.

Malaysia's plays big with 460MW auction

Malaysia's Energy Commission has issued a request for proposals for up to 460MW of large-scale PV

Malaysia of course continues to be a major destination for PV manufacturers, but the new tender shows clear resolve to progress the downstream segment.

Turkey brings mega-scale to bustling market

Turkey's 'unlicensed' solar plants of below 1MW capacity have been installed at breakneck speed, but this year the country has put its ambitions into mega-scale having just completed a 1GW solar tender – the first of many.

Hakan Gazioglu, manager at Turkish PV manufacturer Gazioglu Solar Enerji and member of Turkish solar association Günder, who has been producing modules in the country for the last five years, says that most solar plants are located in the southern part of Turkey, but even the northern areas have 15-20% more irradiance than northern Europe.

Turkey's energy minister has expressed ambitions to make Turkey more self-sufficient in terms of energy, and solar is a key part of this, with 5GW of PV earmarked for a 2023 target of 30% renewables in Turkey's energy mix. As of February, Turkey was just short of a gigawatt, with 800-850MW installed.

However, these big ambitions come with a strong dose of protectionism. Gazioglu says local content rules have become very important, as the country already has 25 module manufacturers with around 1.5GW of annual production. It also has plentiful aluminium and steel producers and more than 100 EPC firms able to construct solar plants. It even has some of the raw materials needed for module production.

The main energy consumption centres are in the north, towards Istanbul, and this makes 1,000 kilometres of transmission from big plants in the south almost unfeasible, so the government is also pushing for distributed generation.

The unlicensed segment – projects that are less than 1MW in capacity – accounts for 90-95% of currently installed systems. They benefit from not having to pay for a licence fee, which can be very steep, yet they also get a feed-in tariff (FiT) of US$0.133/kWh. For this FiT, the purchase guarantee is for 10 years at the moment and eligible systems get connection priorities.

As of June 2016 there were 443MW of unlicensed projects, which rose to 848MW by February 2017, and this is expected to more than double to 2GW by the end of 2017.

The pipeline of the larger 'licensed' solar plants stood at 600MW in February.

Gazioglu expects 2017 to be a boom year for solar in Turkey as there is uncertainty around what will happen to the FiT at the end of the year. The connection fees may increase or in the worst case scenario the FiT could be reduced to around US$0.105/kWh. Due to this expected deployment rush, Turkish module manufacturers have a very tight schedule to produce. Gazioglu Solar Enerji production for example was fully booked for some

Algeria's 4GW solar ambitions

Algeria is set to launch a 4GW large-scale solar tender, catapulting it into the forefront of solar nations in North Africa.

The country has solid targets, aiming for 27% of its electricity demand to come from renewable energy by 2030. Of the 22GW of capacity needed, 13.5GW have been earmarked for solar. Meanwhile, 4GW has to be installed by 2020, hence the major tender. It will be held in three phases of 1,350MW each, with projects of average 100MW capacity being selected.

Arkab Mohamed, president and director general of Algerian gas and electricity company CEEG, which is part of state-owned utility Societe Nationale de l'Electricite et du Gaz (Sonelgaz), explained the tender parameters: "The projects will be owned and developed by special purpose vehicle, which will be responsible for financing, EPC works, grid connection and the sale of power. These vehicles will be owned 51% by a domestic investor and 49% by an international partner. Algerian government-owned oil company Sonatrach will hold a 40% stake in all of these SPV, while Sonelgaz and other public or private Algerian companies will hold the remaining 11%. For Algerian private investors the participation in the capital of each company will not exceed 6%. Financing for each project must be provided 30% with own funds and 70% with bank loans."

Winners of the tender will sign a PPA with the electricity distributor SDA, which is a subsidiary of the Sonelgaz group.

"The main actor is the special purpose vehicle (SPV), the project company that has been set up to implement the project," says Malek Drif, co-founder at Africa-focused renewables firm Al-Michkat Renewable Energy. "In several cases, the SPV is usually a subsidiary company with an asset or liability structure and legal status that makes its obligations secure even if the parent company goes bankrupt."

Drif adds that many foreign investors are hesitant because of the 51% to 49% ownership rules.

"Investors need visibility to be able to invest and meet the needs of the market," says Drif. "The immediate challenge is to harness the financial sector's potential to support diversification and economic growth. This will be helped by a broad range of reforms to promote finance. But in Algeria, state banks continue to play an important role in the financial sector."

The country has also made efforts to develop a solar component industry based on its current capabilities in base steel, float glass and electronics manufacturing.

Credit Hichem Merouche, Flickr

Algeria is set to become a regional leader for solar, with plans on the table for a 4GW tender

Back in April 2014, the Algerian government introduced a two-tiered feed-in tariff (FiT) programme, but during the second half of 2016 it chose to opt for the tender model instead of the FiT. Having seen solar prices plummet round the world through the competitive reverse auction model, Bouterfa Noureddine, the newly appointed head of the energy ministry, then announced the adoption of a decree relating to the tender for the 4,050MW of solar this year.

Drif says that the new specifications for the call for national and international partnership were "extremely unfavourable" to local developers as their projects ended up in stand-by. However, he admits that this is exactly the method needed to progress solar in the country, as it does not have the financial resources necessary to carry out an overall programme costing US$8 billion.

The government has expressed intentions of sorting out land availability issues. To reduce development costs, a selection of favourable zones for the reception of projects has already been made by the Algerian Electricity and Gas Regulatory Commission (CREG), the Algerian Electric System Operator and the 48 wilayas (provinces) of Algeria.

"This gives candidates the dual advantage of knowing approximately the cost of the connection as well as the capacities of the source station," says Drif.

Meanwhile, a specific auction mechanism for renewable energy quantities will also be set up specifically for domestic companies.

At the time of writing, local news outlets had reported that the Algerian energy minister Noureddine Boutarfa was expecting the reference price for the upcoming 4GW tender to not exceed DZD4/kWh (US$0.04/kWh), which would be competitive with some of the lowest solar prices seen globally.

time as of April.

The government has opened up anti-dumping duty measures and importing modules to Turkey has become more difficult for now, says Gazioglu. Yet, even Turkey's glass suppliers are struggling to produce enough to keep up.

Turkey is also planning for multiple mega-scale solar parks, with 1.5GW at Nigde and 4GW at Konya. The first tender for 1GW was won by a consortium of local companies including Kaylon and Korea's Hanwha Q CELLS. The project must sell electricity at US$0.0699/kWh. Hanwha must produce cells in Turkey and the group must set up an R&D centre. The project also needs to use locally made cables, inverters and support systems.

These projects are a huge step up from previous large-scale ambitions, given that only last November, Phoenix Solar and its Turkish partner Asunim Turkey brought a 9.1MW PV plant online, which was the largest ever system in the country at that time. On the rooftop PV side, Turkey is targeting 100,000 rooftops by March 2019 under a scheme supported by Günder.

Turkey has of course made headlines round the world for various highly controversial political actions, but the positivity around solar seems to be undiminished.

Turkey has just completed a tender for 1GW of large-scale solar

Credit Solar Frontier

On schedule Saudi tender brings hope

After a couple of damp-squib solar announcements, Saudi Arabia has generated a huge amount of interest among big foreign players following its recently announced 300MW solar tender.

"Saudi Arabia doesn't really have a good track record for renewables policy and certainly for tenders, which is in theory its main mechanism for procuring this renewables capacity," says Victoria Cuming, head of policy, EMEA, at Bloomberg New Energy Finance. "That is why everyone is on tenterhooks to see whether this tender will actually go ahead."

However, with 27 big-name companies – "the usual suspects" as BNEF calls them – shortlisted to go through to the next phase of the tender, it is clear that the industry feels more confident on this occasion.

An initial 500-800MW tender for both wind and solar in 2013 involved a call for interest, which was then followed by silence and then cancellation, says Cuming. Last year there was another tender for two 50MW solar projects that went through a brief qualification period and RfP before being cancelled again.

However, it is encouraging that the newly formed Renewable Energy Project Deployment Office (REPDO), part of the energy ministry, has set out a clear schedule and so far kept to the deadlines, adds Cuming.

The tender will be carried out on a build, own, operate basis with 100% ownership for the winning bidder and no mandatory government stake, which is different to a lot of countries in the MENA region and different even to fossil fuel-based plants in Saudi Arabia.

"The participation criteria were pretty tough including the local content requirement," says Cumming. "That's one of the reasons why the vast majority of the shortlisted candidates are big international players with established supply chains and a lot of experience in doing these auctions and undertaking projects in emerging markets."

Developers will also have to source 30% of their supply chain locally, says Cuming.

Credit Francisco Anzola, Flickr

Hopes are high that Saudi Arabia's latest plans for a solar push will bear fruit after several false starts

REPDO has now qualified 27 companies for the 300MW solar PV project, along with 24 companies for a 400MW wind farm. The qualified companies will now move on to the RFP stage as either managing members, technical members, or both, with the titles based on the group's track record when it comes to delivering IPP projects of this scale.

At the time of the qualifications, Khalid Al Falih, Saudi's minister of energy, industry and mineral resources, said: "The market response to the Kingdom's invitation to its first renewable energy projects has been overwhelmingly positive, demonstrating market confidence in our vast renewable energy potential and investment environment.

For example, Riyadh-based firm ACWA Power, which has been awarded projects at record low prices in the UAE, has received a request for proposals from Saudi Arabia's energy ministry to develop the 300MW solar project in Sakaka, Rajit Nanda.

Bids are due on 11 September, with awards expected as early as November.

Saudi Arabia targets generation of close to 10GW of renewables by 2023, mainly through solar and wind power. After that it aims for 30% of its energy mix to come from renewables by 2030.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Digitalisation, drones and data – Intersolar 2017 rolls into town

Intersolar preview | The need for ongoing innovation is one of the few givens in the unpredictable solar business. Ben Willis speaks to two of the lead organisers of Intersolar Europe about the likely big topics on the show floor this year and what those tell us about industry's continuing evolution

MARKUS ELSAESSER, CEO, Solar Promotion, organiser of Intersolar

PV Tech Power: What will be the big topics under discussion at this year's event?

Markus Elsaesser: At the moment everyone is looking at what they can expect throughout 2017 regarding PV installations around the globe, and especially cost developments. As you know we saw last year an increase in installations of 50%, to 75-76GW; for this year we have seen forecasts around the same number or some that are a little bit higher than last year. So everybody expects that we will see a slight growing market, but some of the big markets have question marks, like China going from 35GW to below 20, and the US probably staying flat; Japan will decline. So everyone is asking: how can other markets absorb the production of China, for example, of those additional 15GW which we probably will not see this year installed in China. There are a lot of expectations that prices will again be under pressure, that prices will go down especially for large power plants. So this is a big question and discussion topic: what we will see this year in terms of capacity and price development.

How will that feed through into the products and services companies will be showing this year?

We will probably see this year many new innovative products to reduce costs for operations and maintenance – software solutions or even sensors to measure the conditions of the power plant, or drones and robots.

Also what we definitely will see more and more are solutions for the integration of large amounts of variable renewable energy into the market. So we are talking about the digitalisation of the energy sector. This is all needed if you have high shares of solar and wind energy in your grid, and if you think about decarbonisation and the Paris [climate change] agreement, we really need to think about solutions for the whole energy system: how can renewables integrate into this modern structure. And we will see a lot of products, a lot of contributions, presentations and speakers focusing on these topics: communication technologies, the integration of storage, integration of charging infrastructure for EVs [electric vehicles] and all of those topics which will be very important for years to come.

How are you adapting the show to better reflect the evolving nature of the renewable energy business that you describe there?

We've already introduced the storage part – EES Europe [co-located with Intersolar] is now the largest storage event in Europe. And we have several forums on the show floor such as the Smart Renewable Energy Forum, where we and our exhibitors present new developments. It's all about how to integrate intelligently renewable energies into the system, into buildings, the transportation sector and so on. We will also have a special exhibition called Energy Lab showing new approaches to integrating diverse technologies. It's a test facility for generating renewable electricity, for storing, power-to-gas, power-to-fuel and power-to-heat.

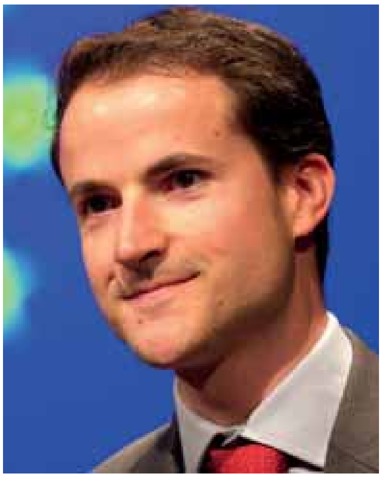
Storage is clearly only growing in importance for the industry. What are we likely to see at this year's show where storage is concerned?

In last three years, since 2015, we've seen a growing number of companies investing into storage systems. What we can observe this year is that there have been a lot of positive innovative developments in terms of energy density, of capacity and of long-term performance guarantees – warranties. A lot of companies now give you 10 years' guaranteed output or at least a certain percentage of guaranteed output. There are also a lot of advances in performance, in quality and security of installations; this was a topic two years back when we saw difficulties with installations and even some systems which went on fire. Even since last year there's been a big improvement in security and performance and guaranteed output.

You highlight the fact that Intersolar Europe is an international show, but what about Europe itself? What will be the talking points about markets closer to home?

We will probably see the German market come back; we together with the German solar associations observe that a business climate index [for solar] is at a seven-year high, which gives us hope that the market after several years will come back. And we also see interesting developments not only in Germany but to drive the market [elsewhere]: sector-coupling, EVs and charging infrastructure. And we will also see soon a tenant electricity power programme, so residents in apartment buildings can achieve savings through [shared] PV systems, maybe combined with small storage applications. So we'll see support schemes for this segment in Germany and in other countries. And I think this self-consumption, the optimsiation of self-consumption systems, will be a driver together with tenant power and sector-coupling.

PIERRE-JEAN ALET, chairman, Intersolar conference committee



PV Tech Power: This is your first year as chairman of the conference. What are the big themes you're expecting will be discussed?
Pierre-Jean Alet: We will continue to have the classical PV technology sessions on cell/module technology; that's what's underpinning the progress of the sector and there's still potential here to reduce costs and improve the competitiveness of PV. There are also all the things that will be discussed related to using PV electricity that I would term the 'value' of PV electricity; that covers energy management, digitalisation of energy, coupling between different energy sectors, forecasting as well, which is a very important topic for market integration.

This concept of value – can you explain a bit more about what you mean there and how that will be reflected in the conference?
One achievement that has been reached by the industry is that if we look just in terms of generation cost, PV is on par in some parts of world with other sources of generation. So that's a milestone, but still we see that's not enough to guarantee that we can displace other sorts of generation. And in a world where subsidies are decreasing quite fast, we need to think more and more about increasing the value for customers. And in particular, if we take the case of Europe, there is a big role for 'prosumers' – individuals and businesses generating and using their own electricity. So for them we really need to make sure that this [PV] electricity we can now generate for low cost meets their needs for energy.

You mentioned digitalisation and big data in this context – what are the main ideas here?
Digitalisation is a big word that can entail lots of different things. One is about the idea that you can trade energy services in a local way with a form of traceability, so prosumers can get remunerated for services they provide to the local grid to ensure it's stable and power quality is maintained. But then we need to find ways to enable that, to have platforms that make this trading and tracebility easy. And that's one part of the things we will discuss in the conference.

The other side of digitalisation is about the use of data. And that in my view is more for larger scale systems and management of the grid. One session we'll have is on forecasting, where the more data you have the more accurate you can be; that's also a key enabler to integrate PV into the electricity market and to help energy suppliers and network operators manage the system. It also has implications in terms of O&M of PV plants – especially for the larger ones. And we see there are players who centralise this operation data and apply techniques to this data to be able to do predictive maintenance and identify faults in a remote way.

You mentioned that 'traditional' topics around cell and module technology would continue to be a key feature of the conference. What do you expect the main discussion points to be here?
The big topic of interest at the moment is bifaciality. There is a lot of activity, a lot of products coming out, also discussions on progress in terms of characterisation and standardisation, and also in terms of modelling so that we can move from the outlandish claims that we may have seen in recent past about the extra power that you can get form bifacial systems to something that is more verifiable.

In terms of cell technology, we can see PERC is really forging ahead at the moment. I think there will be discussion on the role heterojunction technology can play; for a long time [PERC and HJ] have been in competition, with the idea that PERC was more suitable for upgrading existing lines and heterojunction was for new entrants. So I think there will be a discussion on the long-term perspective for both technologies: is PERC the end of what you can do with conventional cell architectures or is there still room for improvements in that direction; or whether we really need to move to a completely new cell architecture to continue the progress on efficiency and costs? ■

Credit Aleo Solar

The business models powering solar's next phase in Europe

Europe | With the decline of solar subsidies in Europe, the industry is under pressure to find new routes to market. SolarPower Europe policy adviser Sonia Dunlop looks at some of the innovative new business models being developed to help ensure solar has a sustainable future

There is much innovation going on across Europe and beyond in new and different business models for solar PV. Over the last 10 years the PV market in Europe has been largely policy-driven – and usually the main business model was dictated by the support scheme in place. Revenues were often guaranteed by the state and therefore low risk, which then opened the door to low-cost finance.

Over the next 10 years, public subsidy will probably play less of a role. The regulatory framework will of course continue to be critical, but this will be driven less by support schemes and more by new and innovative business models and sources of financing.

In this article we will outline some of the work we have doing at SolarPower Europe, much of it part of the EU-funded PV Financing project, to identify what are the existing business models and what are the most interesting variants of these that are likely to make the cut in the next phase of solar PV development.

We recognise however that we will never operate in a political vacuum in the electricity sector and our industry will always remain a highly regulated space. Therefore we also need to put these potential future business models in the context of what existing legislation will actually allow. That is why the PV Financing project has, for seven European countries, published detailed policy advisory papers setting out what the government needs to do at national level to spur solar deployment [1]. And on top of that there are a number of quick wins at EU level that we need to be pushing for – more details on that below.

Innovation in business models will be vital in underpinning solar's future growth in Europe

But first to the two core business models for solar in Europe: self-consumption (with self-ownership) and power purchase agreements. How do we define them and how can they be tweaked to increase profitability?

Self-consumed electricity is cheaper electricity

Four out of five Europeans live in a region where, in theory, the solar electricity they could generate on their roofs is cheaper

than the electricity they buy in from the grid. And that's not even mentioning commercial and industrial applications of self-consumption solar.

Of course in reality it's not as simple as that. How many people are lucky enough to have €6,000 (US$6,533) lying around in their bank account? And how many people don't own their own home?

There are different definitions of self-consumption, but for the purposes of PV we think the most useful is where the power consumer, main investor and plant operator are the same entity. To put it simply, the power consumer owns the system, even if he/she/it had to borrow the money from elsewhere to meet the up-front costs.

This is almost always roof-mounted solar, and we found the most common financing schemes for self-consumption are self-funding, debt and leasing.

Things get interesting when we start playing around with the self-consumption model, for example, applying it to buildings that have more than one power consumer: an apartment block, a shopping mall or a big office block perhaps. This is collective self-consumption. Austria is in the process of bringing in a new set of rules that will allow the occupiers of apartments to self-consume power from an installation on their common roof. This is still in the process of being confirmed, and will probably be conditional on the occupants owning at least a symbolic share of the PV system. France will soon allow collective self-consumption as long as the different occupants form a cooperative or other 'legal entity'.

To help the industry standardise deployment and reduce legal costs the PV Financing project has produced a series of free, publicly available template legal contracts for the most interesting business models in France, Germany, Italy, Spain, Austria, Turkey and the UK. We encourage all who work in solar to have a look and make use of these – they can be downloaded on the website [2].

Being smarter about how we use self-generated power

In the residential segment, it is key that we use new digital technologies to increase self-consumption rates. On average this reaches just 35% across most of Europe – which means two-thirds of the electricity generated by the PV system is being fed into the grid for a (low) export price. The digitalisation of energy and the integration of solar within smart buildings are key opportunities to significantly increase self-consumption rates. Storage, the use of heat pumps and the electrification of heating, flexible demand response and smart appliances, electric vehicles and smart building energy management systems are all catalyst technologies for PV. (See box below on digitalisation.)

But before you can start thinking about 'smart solar' technology combinations, we have to get the basics right.

It is absolutely critical that within the ongoing Clean Energy for All Europeans package, currently under discussion by the European Parliament and the Council of Ministers, we ensure that all EU member states have at least a framework in place for prosumers to pursue self-consumption.

At present Bulgaria, the Czech Republic, Estonia, Finland, Ireland, Luxembourg, Romania and Slovakia do not have a legal framework for self-generating electricity. Consumers should be allowed to become prosumers, and grid charges cannot be designed in a way that disincentivises this. Consumers should also not be forced to become electricity traders or suppliers in order to sell their excess electricity back to the grid, as is the case for some systems in Spain. And prosumers should get at least the market value for the electricity they feed into the grid.

Power purchase agreements: the business of selling solar power

At its essence a power purchase agreement (PPA) is simply a contract between an electricity generator and an off-taker that specifies how much power will be sold at what price for anything between five and 20 years. PPAs can be set with a fixed price for the duration of the contract, a tracker price which applies a pre-agreed discount on the retail or wholesale price or a dynamic discount price where the higher market prices go, the bigger the discount.

PPAs are generally financed with debt, equity or crowdfunding, and the key thing is that the investment decision is shifted to a third party that usually has a longer-term investment horizon than the power consumer.

PPAs cover both roof- and ground-mounted systems. The defining characteristic of a PPA business model is that the owner of the system is different to the power consumer. So a power consumer can consume electricity generated on-site on his building but if the PV system is owned by a third party and the electricity is sold through a contract this is a PPA and not a self-consumption business model.

Residual or top-up electricity can be provided through a second electricity supply contract – which still needs to be expressly permitted at EU level for both domestic and commercial consumers – or through a bundled solar plus balancing contract.

The classic PPA is the wholesale PPA – typically a solar farm injecting into the grid and getting wholesale power prices in return. But there are teams of lawyers all over Europe if not the world dreaming up new and innovative variants of PPAs, some of which allow a generator such as a solar farm to sell to power consumers without any direct link between the two.

The main categories of PPA are on-site private wire PPAs, sleeved off-site PPAs,

The Solar & Digitalisation Task Force at SolarPower Europe

Professor Bernd Engel, SMA Solar Technology

Late last year SolarPower Europe, the European solar PV association, set up a new task force to look at the broad topic of digitalisation of energy and assess how this will impact both existing and new solar PV installations. On behalf of SMA Solar Technology, I am leading the members of our association in this work.

We have already had three meetings to scope out the main opportunities and challenges and are planning on publishing three main pieces of work over the course of the next year.

The first, which we hope to launch at Intersolar, will be a set of commitments from the solar industry on digitalisation. These will cover topics such as interoperability, data protection and working with network operators to provide grid services.

The second will be a set of regulatory asks on solar and digitalisation, which is scheduled for publication at the SolarPower Europe Midsummer Celebration in Brussels on 21 June. This will be a call to action for governments, setting out what policy changes are required in order to implement new digitalised solar business models and revenue streams. This will cover peer-to-peer electricity trading, blockchain and aggregators among other things.

Finally in October we plan to publish a major report on the market opportunities for solar PV within the digitalisation of the electricity ecosystem. Working with our members and specialist consultants, we will tease out where are the key opportunities to deploy more PV, increase revenues for existing installations and make sure that solar is done in a 'smarter' way.

If you are a member of SolarPower Europe, or would like to become one, feel free to get in touch to find out more and get involved in this work.

synthetic PPAs and mini-utility PPAs. Sleeved PPAs are back-to-back PPAs at the meter point from generator to corporate consumer to sleeving utility and then back to corporate consumer. Synthetic PPAs involve the corporate consumer and the generator agreeing a fixed price and hedging against rising electricity prices. In the mini-utility model the corporate consumer sets up its own utility and cuts out the middle man. (More information on all of these is available in the full PV Financing report [3].)

Should all big businesses become mini-utilities?

The mini-utility model is one that requires particular attention from policy makers, both at EU and national level. This is where the generator sells power to a licensed supplier or 'trading SPV' that is wholly owned by the corporate consumer. In this model Google, Unilever or Nestle would set up their own utility to buy power from solar farms and sell it back to themselves. This model is currently in use in Ireland in the wind sector and in the United States.

Regulatory authorities should make it easier and cheaper for mini-utilities who only supply a single corporate entity to get a supply licence and trade on the market.

Even more innovative could be the advent of peer-to-peer electricity trading platforms. Just as Airbnb allows us to sell our spare rooms to each other, and Blablacar allows us to charge each other for rides in our cars, a new platform could allow me to "SellMySolar" to my neighbour. This would be selling via a PPA – the neighbour would buy power at a set price – but you could imagine a day when these PPA contracts were done as automated 'smart contracts' on a blockchain system that bought and sold power based on pre-defined parameters.

The StromDAO outfit in Germany is an example of a blockchain-based peer-to-peer selling platform where consumers can invest in a share of a neighbour's solar PV system and then either 'virtually self-consume' or sell on the excess power. And such a nanogrid, which could be expanded to bigger and bigger regions, could potentially self-balance, thanks to much more accurate accounting of supply and demand.

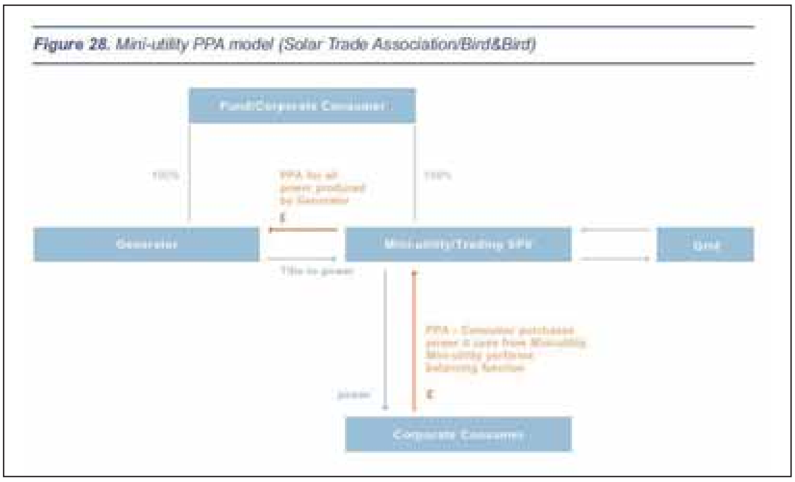


Figure 1. A PPA model for a mini-utility. Source: Solar Trade Association/Bird & Bird

The many shapes and sizes of solar roofs

PV is a highly modular technology. When we talk about the solar market, it is in fact at least nine or 10 different markets: owner-occupied single family residential homes, rented single family homes, multi-family apartment blocks, social housing, new buildings, single occupancy commercial and industrial buildings, multi-occupancy buildings – and finally of course ground-mounted, utility-scale solar farms.

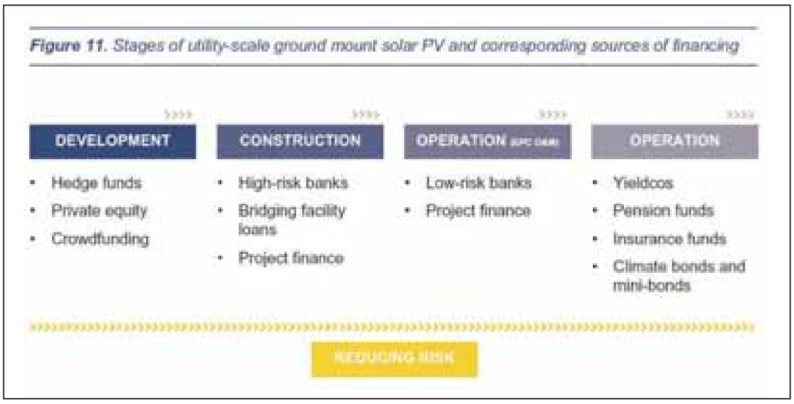


Figure 2. The different types of debt financing in solar PV

The stages of utility-scale ground-mount solar PV and corresponding sources of financing

Each 'application segment' has its own advantages and disadvantages, and needs to be approached in a different way.

The rented building segment is one of segments that has so far been 'hard to reach' in most European markets. That includes both commercial and residential buildings

It is estimated that 150 million people across the EU are tenants, and there the landlord-tenant dilemma often means that neither party has the incentive to invest in PV. The leasing model, where a third party invests in the system and the tenant pays a monthly fee for the use of the system, is one way to overcome this. Mini domestic on-site PPAs are also a way to allow tenants to use solar electricity and save money on bills – this is something that has been used in multi-apartment blocks in Germany within the *Mieterstrom* model. This should be spread elsewhere in Europe too.

And rules that say that the power consumer and system owner have to be the same entity in order to receive beneficial treatment need to be abolished – this is out of date regulation that has failed to keep up with the latest innovations in how PV projects are structured. Getting rid of this barrier will help both the rented segment and multi-occupancy buildings.

Of equal frustration to many solar developers are rules limiting a single solar PV installation from supplying more than one power consumer. The good news here is that Austria is moving to get rid of this, with the introduction of the shared generation facility model where a commonly owned PV system on an apartment block will be allowed to use the wires and cables in the building to sell electricity to the occupiers without being subject to grid charges.

Both here and in the similar German model, smart metering is the essential catalyst: both the PV installation and each individual consumer have to have smart meters installed to properly measure and bill for the power flows.

Money, money, money

Over the last two years of work within the PV Financing project, we have identified all the various sources of finance for solar projects in Europe. Much of this won't be news to readers of *PV Tech Power*. The top level options are self-funding, debt, equity, mezzanine financing, leasing and crowdfunding.

The interesting types to delve into further are debt and crowdfunding. There are many different types of debt, including project finance, on-balance-sheet loans, revolving credit facilities and green bonds. What is particularly interesting is how the type of debt involved in a utility-scale project evolves throughout the lifetime of the project, from high-risk private equity and hedge funds at the development stage to low-risk pension funds and green bonds at the mid-life operational phase.

Crowdfunding equally comes in many forms, even though cooperatives are often the go-to model here. Mini-bonds and peer-to-peer *lending* platforms are becoming more common. The latter shows yet again how digitalisation is a key driver for solar.

Cash flow models to get new entrants started

Another great resource that has come out of this European Commission-funded project is the cash flow model, which has been built for both self-consumption and PPA projects for each of the seven countries covered [4]. This is available both in a simple web-based format destined for the end-consumer, and in a more advanced Excel form for the industry. All the key variables can be inputted into the model, which also produces sensitivity analyses for the key determining factors such as irradiation and cost of capital.

Change on the horizon

The next years are going to see a lot of exciting change and growth in our sector. New industry leaders are emerging, storage is going to be a key partner and trade wars will wax and wane depending on the mood of our elected officials.

For a more detailed insight into the mechanics of next-generation PPAs, turn to p.47

But what will be really fascinating is how we will apply our minds to selling solar electricity to new and different customers, in new and different ways. They could be corporates like Google and Unilever looking to source power through off-site PPAs, to Mrs. Jones in a social housing block who is struggling to pay her bills.

The PV Financing project has been a useful first step to assess the different business models available in six EU countries plus Turkey. This will evolve further as the industry becomes more experienced and tries new – perhaps more digital – models and find solutions to what have in the past been unsurmountable barriers. We at SolarPower Europe certainly look forward to it. ■

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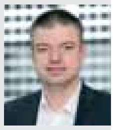

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Corporate PPAs providing the answer in an increasingly unsubsidised sector

Business models | Corporate PPAs offer environmentally minded businesses a means of reducing their carbon footprint and renewable energy developers a new route to market in the face of declining subsidies. Daniel Kaufman offers some insights to buyers and sellers looking to navigate the many complexities of this new market


Credit Apple

The heaving up of the drawbridge for new entrants to the UK's Renewables Obligation (RO) scheme at the end of March signified another milestone in a global trend of shrinking government incentives for utility-scale renewable energy projects. The end of the RO scheme will be followed by the phasing down of production tax credits and investment tax credits that have galvanised the US clean energy market in recent times. Removal or tightening of government support for the solar PV sector is a worldwide paradigm driven by a number of conspiring factors including economic uncertainty, low fossil fuel prices, a significant reduction in the levelised cost of solar PV energy and the success of competitive auction procurement as a method to drive down and achieve record-breaking low tariffs.

But with increasing pressure to reduce their carbon footprint, private sector companies have not stood idly by while governments ice direct support for the decarbonisation of national grid networks. Corporate and institutional electricity customers in jurisdictions around the world have together taken meaningful action to develop their own contractual structures and financial products to pursue strategic and commercial sustainability priorities and to "future-ready" themselves for the disruption affecting the energy sector. More than 40% of Fortune 500 Companies and at least 60% of Fortune 100 companies now have targets relating to renewable energy procurement, energy efficiency or cutting greenhouse gas emissions [1]. The Corporate Renewable Energy Buyer's Principles have been established to promote collaboration amongst 62 major companies when buying renewable energy. Similarly the RE100, a club of 89 of the world's most influential businesses each committed to procure 100% renewable energy, is an example of how the private sector is working to increase the demand for, and delivery of, renewable energy. Last year, Google, a member of RE100, confirmed that it would reach 100% renewable energy coverage of its global operations in 2017. The likes of Google, Apple, Facebook and Amazon are leading the charge; however more corporate giants continue to join the movement, such as Anheuser-Busch InBev who signed up in March this year with a commitment to secure 100% of its electricity (amounting to about 6 terawatt-hours of electricity per year) from renewable sources by 2025.

Corporate PPAs offer companies such as Apple and their suppliers a route to procuring renewably generated electricity to power their operations

Corporate sustainability strategies to decarbonise can involve purchasing renewable energy certificates or procuring green tariffs from utilities (if available), but companies are also looking for tangible ways to demonstrate their environmental commitment and to achieve some "additionality" by bringing new renewable energy projects online.

Captive projects can be on-site as a primary or back-up source of power to mines, processing plants, warehouses, data centres, offices or shopping malls for example. In such cases, the buyer will purchase the power generated by the plant under a "behind-the-meter" power purchase agreement negotiated bilaterally with the seller. They can be built as hybrids in conjunction with conventional power engines and in some jurisdictions it may also be possible to sell on excess power that is not required by the buyer to the utility through net-metering arrangements. Target, the US department store, is currently the top installer of solar power in the US with 147MW installed across 300 stores [2].

Such on-site, off-grid solar PV projects are also popular in many sun-drenched developing countries where businesses and communities are beleaguered by scheduled load shedding, unexpected blackouts, electricity price hikes, forced load curtailment or simply no local access to the national grid. Distributed generation, on-site with a reliable connection, can provide cheap and clean power for the buyers; and for the developer, the negotiated tariffs are invariably better than those being secured under state procurement programmes at the moment. Take, for example, Zambia, where policy support and low-cost finance has achieved solar PV PPA tariffs as low as US$0.06/kWh with ZESCO, the country's main utility company.

Projects however do not need to be built on the same site as the load nor do they need to be connected to the same grid network. An alternative model that is experiencing a significant uptick in popularity, particularly in developed and deregulated markets, is the corporate power purchase agreement (corporate PPA) where companies are able to buy power from off-site centralised renewable energy projects and can claim additionality by demonstrating that the viability for the project would not have existed but for the revenue stream provided under the corporate PPA. In a Corporate Eco Forum survey conducted in 2015, the vast majority of respondents in the United States listed off-site corporate PPAs as their top policy priority with respect to renewable energy procurement. The corporate PPA, the drivers behind it and the contractual structures that are developing are the focus for this article.

The structures

A corporate PPA is a contract governing the purchase by a corporate buyer of all or part of the energy produced by an off-site renewable energy project built, owned and/or operated by an independent or affiliated entity. The term "corporate PPA" actually umbrellas a number of financial and contractual structures that have evolved to promote the bilateral purchase of power between a private seller of power and a private buyer (typically across utility wires) [3].

As the negotiations are between two commercial parties and not with state-owned utilities with standardised processes and documentation, there is a great deal of flexibility and creative opportunity when structuring a corporate PPA transaction. Each will have been molded to fit the corporate buyer's commercial strategy and any subsidies or other state support for renewable energy as well as regulatory requirements for "transporting" power across utility wires. In the last few years the corporate PPA market has been developing increasingly sophisticated models that take account of the different conditions affecting different markets around the world. For the purposes of this article we have boiled the different models down into broadly two types: synthetic/virtual PPAs and sleeved or physical PPAs.

Sleeved or physical PPAs

A "sleeved" or "physical" PPA typically (but not always) involves a direct PPA between the corporate buyer and the seller where the power plant is on the same grid network as the buyer's off-take point and the renewable energy being generated is, notionally, directed to the corporate buyer. Hence the reference to "sleeving". In this arrangement the buyer appoints a licensed utility to physically deliver power on its behalf in return for a fee. In some markets, such as the UK, this will typically involve two PPAs: one with the seller; and the second with the utility acting as the buyer's agent for the management of power delivered by the generator, scheduling and balancing services. Other approaches are available, though. For example, in the Netherlands, a number of corporate energy buyers actively manage their energy deliveries from the wholesale market whilst having a single corporate PPA with a generator.

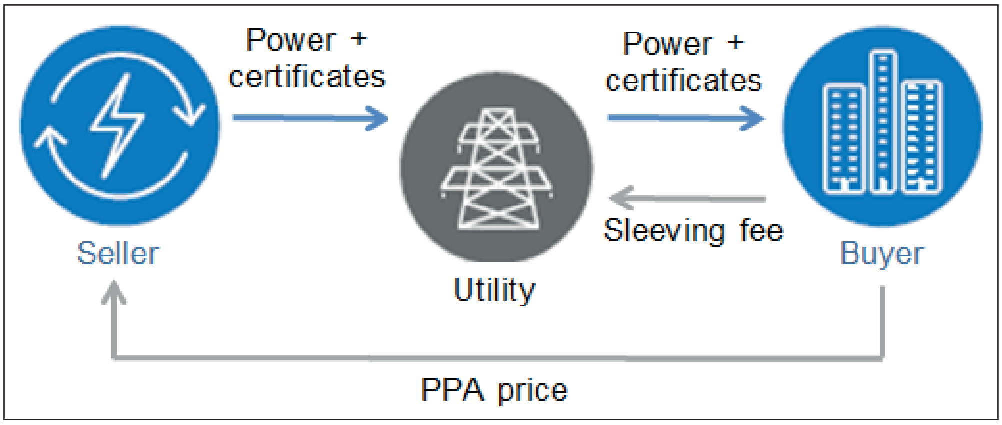
Synthetic or virtual PPAs

"Synthetic" or "virtual" PPAs are actually a financial derivative product under which the parties agree a strike price, with payment flows between the corporate buyer and the seller determined by comparing the strike price against a market reference price. There is no "sleeved" delivery of power to the buyer. In fact, unlike the sleeved PPA the seller and the buyer do not need to be connected to the same grid network (or even to be located in the same country, cross-border synthetic PPAs are some of the most innovative products being developed in the market at the time of writing).

When signed for a 10- or 15-year (or longer) term, in effect they act as a long-term power price hedge and there is a wide variety of possible structures that can be adopted. As a contract for difference, if the market reference price is higher than the strike price, the seller pays the difference to the buyer. If the market reference price is lower than the strike price, the buyer pays the difference to the seller. The volume contracted can be specified in a variety of ways and need not be tied to the actual generation of the project. Synthetic PPAs can also incorporate call, put or collar options on pricing, which gives the corporate buyer the opportunity to buy the right to purchase renewable energy at a certain strike price (a call) or the seller the right to sell to the buyer at a certain price (a put).

Under a corporate PPA however, there is of course no physical delivery of the

Figure 1. Sleeved PPA structure (example with renewable certificates) [3]



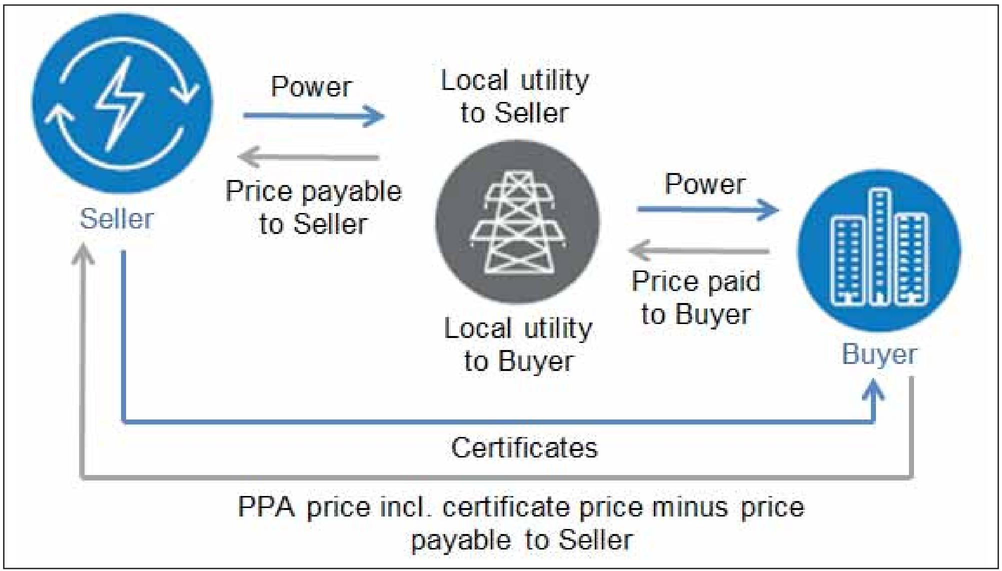


Figure 2. Synthetic PPA structure (example with renewable certificates) [3]

power to the buyer. The connection with the power's clean source is further severed under a synthetic PPA and the intangible nature of the transaction can raise challenges for the corporate buyer who is relying on the arrangement to support its credible environmental, reporting and marketing claims. Therefore, where available, the transaction will also include the transfer to the buyer of renewable energy certificates or "Guarantees of Origin" (in Europe) awarded to the project and/or purchased from the wider market (allowing the seller to sell the certificates issued to it). These certificates will be recorded by the buyer as evidence of the supply and use of renewable electricity and in satisfaction of the renewable portfolio commitments and the environmental impact disclosures that it has to make.

The drivers

We see the following as the main drivers behind the success of corporate PPAs:

Economic

From the buyer's side a long-term corporate PPA can provide a hedge for companies against future fuel and power price volatility. Locking in or capping power prices in this way provides useful visibility over the company's future electricity costs, particularly where uncertainty in the carbon pricing market is present.

From the seller side, a corporate buyer represents an attractive opportunity to diversify asset income streams away from traditional utility off-takers. In these uncertain times, particularly where subsidy support for renewable energy is shrinking and/or future policy is uncertain, a corporate buyer with a good tariff offers a solution that may unlock finance for a renewable energy project that perhaps would not have otherwise been accessible if the project was reliant on a single utility or risky merchant market for its long-term revenue stream.

Sustainability

Since the COP21 climate change summit and the adoption of Sustainable Development Goals in 2015, businesses are under increasing pressure worldwide to reduce their carbon footprint. Sourcing power from renewable projects through a corporate PPA is one extremely effective way of achieving corporate responsibility and environmental goals, decarbonisation targets and creating additionality as a core part of companies' sustainability strategy for the future. Against government regulations and environmental commitments, a corporate PPA can be a valuable tool for demonstrating the company's progress towards sustainability goals related to greenhouse gas emissions reduction and renewable energy consumption. For many companies, direct procurement of renewable energy is a way to connect with an environmentally conscious customer base and, for those companies suffering from criticisms of their own labour and other market practices, it can act as a good distraction.

Diversification

A corporate PPA also allows a corporate buyer to diversify its energy supply sources across multiple technologies and contractual structures to protect against energy availability concerns. It also allows companies to develop partnerships with a new pool of reliable and experienced counterparties and potentially to access regional development funding. From the seller's perspective, it allows for diversification of revenue streams away from traditional utility off-takers and the potential to develop an investment pipeline in new and emerging markets that may not have otherwise been possible.

In general, buyers are robust and creditworthy companies and so corporate PPAs may allow sellers to access development financing and a lower cost of debt as well as streamline their own development costs through the production of standard terms and conditions for the PPA, construction and O&M documentation (rather than adopting the government or utility standard procurement documentation that will be different in every jurisdiction).

The challenges

It would be remiss, however, not to mention the challenges that corporate buyers and sellers will encounter when venturing into this complex market for the first time.

On the buyer side this may be entirely uncharted territory. This may be the first time a renewable energy procurement strategy has been considered and will require due diligence into the following issues: the local regulatory landscape; the attitude of policy-makers (current and future); competition restrictions and utility protectionism; long-term power price forecasts; and the various counterparties and projects available in the market with whom a suitable partnership can be struck.

Having considered all of the above, the buyer must build a strategy around its own anticipated energy demand during the term of any corporate PPA. Solar power is of course intermittent, therefore if a sleeved corporate PPA is chosen, a utility must be found that can provide services to manage the scheduling and balancing risks for an acceptable fee. There are also accounting implications of entering into a long-term corporate PPA which can, depending on the structure and wording, be categorised as a lease under the International Financial Reporting Standards. The effect of this may require the corporate PPA to be recorded as a liability on the buyer's balance sheet, which can impact gearing ratios, debt covenants or other KPIs.

For sellers there are also difficulties to be faced. Finding a suitable buyer counterparty may be easier said than done. There is a relatively small (but growing) pool of corporate buyers; finding one with a strong enough credit rating or ability to provide credit enhancements, such as letters of credit or corporate guarantees, is fundamental to the bankability of the project. In fact lender and buyer interests are often

not aligned and one of the developer's main tasks is to find a structure and terms that work for all. Fixing a long-term tariff is naturally a risk for the seller too as unforeseen changes in the cost of developing a project (e.g. delay, change in law, currency fluctuations) can eat into the revenue required by lenders and shareholders. Sellers will also need to have a deep understanding of the market and the applicable regulatory framework; for first movers in emerging and uncertain markets this can be risky and so careful due diligence must be undertaken.

In some markets, financing large-scale energy project development has been hampered in recent years by the effect of global financial crises, subsequent Basel III restrictions and political and regulatory uncertainty. Traditional limited recourse project finance debt tenors are typically 15 years or more. But long term equals high risk, and as a result some international commercial banks in certain jurisdictions have, at least temporarily, cooled off in their appetite for long-term debt and started to interrogate project economics more carefully.

Financing options have evolved to address this. A good example is the emergence of mini-perm financing as used on the recently awarded 1.1GW ADWEA Sweihan Solar PV project in Abu Dhabi. A mini-perm loan typically involves a shorter tenor of seven to 10 years covering both construction and a period post completion with a requirement on the borrower to refinance prior to maturity to avoid an event of default, aka a "hard" mini-perm. A "soft" mini-perm may have a longer tenor but incentivises the borrower to refinance earlier on by increasing margins and applying a cash sweep in the mid-term. This puts some risk on the developer to predict the availability of favourable refinancing terms in the future before the ratchets and cash sweep are applied. A long-term corporate PPA with a good tariff and strong corporate buyer(s) may work well with a mini-perm and could be structured to offer very attractive conditions for refinancing at the appropriate time.

Project bonds are another financing vehicle that developers and corporate buyers should consider when structuring partnerships and projects around a corporate PPA. Green bond issuance, particularly from the private sector, has grown rapidly (perhaps as a result of subdued appetite for traditional project finance in certain markets) in recent years. The pursuit of the private sector for climate conscious and responsible investment, the availability of robust corporate buyers offering a creditworthy, fixed revenue stream and the (flex)ability to structure a green bond to maximise the environmental and sustainability benefits for corporate and institutional investors all make bond financing an interesting option for forward-thinking companies looking to invest in or refinance solar PV projects with corporate PPAs.

The future

Despite the shrinking subsidies, the falling costs of solar power and increasing pressure on companies to decarbonise (and to tell the world that they are doing so) means that corporate appetite for solar power investment will continue to grow using the methods described and undoubtedly through innovation of fresh and novel transaction models. The shifting market towards distributed generation in both developed and developing economies, and the combination of solar PV with other technologies including the biggest disruptor in this sector, battery storage, will create new opportunities for tie-ups under corporate PPAs in jurisdictions where this was previously not possible.

> "The shifting market towards distributed generation and the combination of PV with other technologies including the biggest disruptor in this sector, battery storage, will create new opportunities for tie-ups under corporate PPAs in jurisdictions where this was previously not possible"

A good example of recent innovation is the emergence of multiple buyer structures. A corporate buyer with low energy demand, little experience and/or a poor credit profile will have minimal bargaining power with a developer of a solar PV project. A club of such buyers, however, by aggregating their demand and their balance sheets, presents a very different counterparty risk profile to a potential seller and their lenders. Approaches using this model can involve multiple PPAs with different buyers for a single project, or the development of a buying group that will enter into a single PPA for the benefit of all members. In the case of the latter, these buyer clubs can offer a great deal more flexibility with the option for individual buyers to opt in and opt out (subject to appropriate controls and fees) during the term.

In March we saw financial close for the 102MW Krammer onshore wind park in the Netherlands where Google, AkzoNobel, DSM and Phillips joined forces as buyers from the plant developed to power their Dutch operations. Even more recently, the South Australian Chamber of Mines and Energy (SACOME) won approval from the Australian Competition and Consumer Commission for 19 big industrial users to band together to negotiate low-cost long-term electricity contracts with renewable energy generators, having tired of the price hikes and short-term contracts offered by the state's retail oligopoly.

What is clear is that in the face of these developments, utilities will also have to innovate to avoid being left behind. The success of corporate PPAs and growing demand for renewable energy is placing pressure on them to look at their business model again and find new ways to maintain market position and recover revenue streams that are being lost to off-grid or sleeved corporate buyer arrangements. Certified and competitively-priced green tariffs are one way utilities can directly service their carbon-conscious customers but more green products are required. There is little doubt that in this dynamic sector there are more and more opportunities for companies and utilities alike to develop new products and transaction structures that will fuel the solar PV economy despite shrinking government support and subsidies. ■

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Solar reporting – where does the data come from and who needs it?

Reporting | The growing range of stakeholders in the solar business, from the owners of small rooftop systems to pension funds, require timely and adequate information on asset performance, but to varying levels of detail. Edmée Kelsey looks at how the industry is rising to the increasingly onerous reporting challenge

Credit First Solar

The investment appetite for solar PV seems insatiable: the total global installed base of solar PV is estimated to be at around 300GW today. Early investors in the industry were assuming higher perceived risks in return for higher investment returns. Investment in solar PV is now becoming more 'mainstream' and is attracting new investors and new service companies. Investors have gained more comfort to support their investment decisions, because there is a lot more experience data available today, compared to a few years ago. It is one thing to rely on the claims of cell efficiency of panel manufacturers, but it is a completely different thing to have a history of actual operational data available to support those claims.

Different market actors need different data and different reports. Some require very deep technical data on a real time basis and others are happy with a periodic high-level overview on the financial performance of their investment. Although the industry has become a lot more professional in recent years, reporting is still a cumbersome process.

Where does the data come from?

To answer that question, it is interesting to have a look at the evolution of solar data since the early days of the industry. Initially data was mainly available through web portals provided by manufacturers of inverters, combiner boxes, meters and data loggers. These manufactures were addressing an emerging need in the industry. They were differentiating their product by packaging it with a monitoring system. This was a great first step to visualise performance data and alarms, and create reports.

But the industry soon discovered the limits of those monitoring systems: for investors who own multiple solar projects, it is a hassle to log in to multiple web platforms on a daily basis. In addition, many industry participants soon requested additional data points or customisation of those platforms to meet their needs. Since inverter companies make their profits on their hardware solution, the improvement of software has never been their top focus.

This is why a new breed of independent monitoring providers jumped at the opportunity by creating hardware-independent monitoring solutions. These monitoring solutions claim they are "hardware agnostic". They are able to acquire data from multiple hardware solutions and multiple renewable energy sources. They will standardise the data sets so that investors can create portfolio reports and compare the performance of solar plants against each other.

The breadth and depth of data from PV portfolios and the range of players demanding information create reporting challenges for the solar industry

Until recently, investors in larger PV systems had less of a need to standardise, simply because their portfolios have not been large enough. They are typically relying on data from O&M service providers, who draw the data from the SCADA system on site. The issue with the SCADA systems is the challenge to view performance data remotely. Apart from cyber security concerns, these SCADA systems are also highly customised, so integration with a monitoring system often requires additional investment. Any investor who is interested to see real time or near real time data from a portfolio of large-scale solar plants should budget for a cloud-based remote monitoring solution.

As the industry continues to grow, it is attracting attention from players from different industries. New entrants believe that their experience with big data and IoT (internet of things) can bring additional efficiency and insights to the solar industry. They are planning to bring down the cost of monitoring through more efficient data acquisition and more modern data models. These IoT players are likely to have a lower cost structure because they can amortise the software development over much larger data sets, since they are not just developing a solution for the solar industry. Cost consideration will be extremely important, especially if monitoring requirements go to down to panel level data, in which case the data sets will grow exponentially. In addition, these new entrants are applying knowledge of neural networks and machine learning to build sophisticated "event handlers" that can create automated tickets based on highly customisable algorithms.

The data reported by the various monitoring systems is mainly technical in nature. The reports will analyse if the plant was under or over performing based on the actual irradiation measurements. They can analyse the production lost to downtimes. More flexible monitoring solutions can also calculate complicated custom performance ratio guarantee formulas stipulated in O&M agreements. But it is still a far cry to get from this technical data to cash-flow planning or calculation of investor returns.

Who wants reports and what type of information do they need?

There are many different stakeholders in the industry and they all have vastly different reporting needs. Their information requirement will usually vary by the type of involvement they have.

The doctor or dentist: An example of an affluent homeowner who invested his personal funds in solar panels on his home. He will have made this investment for a combination of reasons, such as supporting the environment and to save money on lower utility bills. He will love to flash out his smartphone at parties and show off the performance of his home's solar panels on a mobile app.

The school: Many schools have adopted solar to save money. But they will have also considered the educational component and may have incorporated solar into their curriculum. They typically have a large digital display in the school entrance hall to show the current solar electricity production and the lifetime production.

The supermarket or department store: Until recently most companies' main driver for investing in solar has been that they are using solar for marketing purposes. They want to be perceived as helping the environment and will want to show their clientele how much CO_2 emissions they have saved.

The O&M service provider: Real time alarms and alerts are the core data source for O&M service providers. Based on the alarm type, they will decide if they need to dispatch a service technician to investigate the problem. O&M service providers are typically paid to "keep things running". They may have availability guarantees and performance guarantees in their contracts. But the financial implications of their decisions are not part of the scope of their work. So if they need to decide to dispatch a technician to one of two plants with the same problem and same capacity, they will most likely first go to the plant that is closer or has stricter guarantees, not to the one with a higher feed-in-tariff.

Financial and business reporting for asset managers is a headache, but software is becoming increasingly sophisticated

The NOC: Larger O&M service providers and independent power producers (IPPs) will have a network operations centre (NOC), a room filled with monitors and trained staff. This NOC will monitor millions of alarms a day and will have a set of analytic tools to evaluate performance of the solar plants in depth. The staff at the NOC will be able to produce very technically oriented reports and make recommendations for performance improvements.

> "Reporting is still one of the major pain points in the solar industry. Most modern monitoring systems can produce customised technical performance reports. But where things get a lot harder is in translating kilowatt-hours into euros or dollars"

The IPP: The IPP is quickly becoming the most vertically integrated player in the industry. While they invest other people's money, they will typically also invest themselves or have retained ownership in the project. They are involved in the development, construction and operation of the solar plant. While they traditionally only performed asset management, they are now increasingly involved in O&M activities directly. IPPs are very data hungry. They need data and reports for many different reasons. The performance of their own portfolio provides a great feedback loop to their development team and will help make smarter hardware choices. In modern IPPs, the asset managers will have P&L responsibility for the project companies that own their projects. This gives the asset manager the responsibility for the overall management of the projects in such a way that they generate maximum cash with minimum risks. The management of the IPPs will require extensive internal reporting to manage their business. Investors in the IPP will require monthly reporting of financial and technical performance of each individual project company and also on the portfolio as a whole.

The bank: The reason banks are involved in the solar industry is that they want to realise a margin on their loans. They are not particularly interested in the technical performance of the plant, but need to have comfort that the plant is producing according to the financial forecast. Because the bank is not participating in any financial upside, their main focus is on minimising risk. If the plant is underperforming, they will see this as a risk that needs to be mitigated. Their reporting requirements are focused on the cash returns of the solar project and how the cash is able to service their debt. They typically need reports on quarterly or semi-annual intervals. In each case they will need to see comparisons of the actual cash generated versus a variety of budgets and they need the calculation of ratios that are part of the loan agreement, such as the debt service coverage ratio.

The pension fund: Traditionally pension funds have invested in solar in an indirect manner, i.e. via a third party investment fund or an IPP. Some pension funds are starting to invest directly. But operating solar assets is not their core business, so they typically outsource this to an independent asset manager. The pension fund will have invested in relatively low-risk projects. As long as they meet the expected IRR, they will not be very interested in in-depth technical and financial reporting. But because risk minimisation is very important to them, they will require frequent risk reporting. They need to monitor regulatory and contractual compliance very closely to safeguard their investments.

The exchange traded investment fund: Depending on what stock exchange this investment fund is traded, there will be many specific reporting requirements. These funds will typically have external audits to prove that they are compliant with regulations. Compliance reporting is becoming increasingly important for those funds. Another challenge that publicly traded companies face is that they will need to close the financial month end very quickly, sometimes on the third or fifth business day. For many solar projects, the actual revenues will not be known yet at that point, because they are waiting for utilities to provide utility statements or feed-in tariff payments. In this case the publicly traded company will need to book an accrual that they will later need to reverse when actual data comes in. Another level of complexity for financial reporting.

The utility: For many utilities solar is still a very small segment of their total generating capacity. They will already have many different departments in place, which each will pick up part of the activities of a solar asset manager. Because of that "fragmentation" of the solar asset manager's job, it will be challenging for them to get a complete overview report of all aspects of a solar project. As long as the solar business is still relatively immaterial to their overall business, this may not be an issue.

How are the reports created?

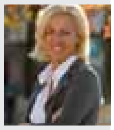
Reporting is still one of the major pain points in the solar industry. It is mainly a manual recurring job. Most modern monitoring systems can produce customised technical performance reports. But where things get a lot harder is in translating kilowatt-hours into euros or dollars.

In the early feed-in tariff regimes, this was relatively easy: you just multiplied the kilowatt-hours by the applicable tariff and that was it. Today most solar projects have more market-based pricing, which adds a whole new level of complexity. Solar projects sell their generation based on time-of-day-based PPAs, benefit from reduction of the utility's time-of-use capacity fees, will sell green certificates, renewable energy obligations, will sell solar energy on day ahead markets, be involved in energy price hedges and so on.

Financial and business reporting needs to incorporate and analyse the project's revenue and cost information and to compare it against the original investment case. Currently this information lives in "data silos": information systems that do not talk to each other, like monitoring systems, spreadsheets and accounting systems. The creation of reports requires a lot of copying and pasting from one system to another.

Solar asset management software providers like 3megawatt are there to help. These cloud-based software solutions will provide integration of the various monitoring systems with spreadsheets and accounting systems to create different reports for different stakeholders. It is not a completely automated process yet. But the industry needs to get this right quickly to address the every increasing reporting requirements of the various market participants. ■

Author



Edmée Kelsey is founder and CEO of 3megawatt, a software solution provider for the renewable energy industry. 3megawatt has developed BluePoint, the largest and fastest growing enterprise-class asset management platform in the industry. BluePoint is designed to automate and control the entire renewable asset management lifecycle. Kelsey was the former CFO of Main Street Power, where she closed project financing for over 100 distributed solar PV projects and was responsible for the asset management of those solar assets. She was also formerly a VP at the investment bank JP Morgan and managing director of a clean energy corporate finance advisory firm.

Understanding the energy yield of PV modules

Module yield | Varying climatic conditions across markets and the individual characteristics of PV technologies undermine accurate predictions of module energy yield using conventional methods. Markus Schweiger, Werner Herrmann, Christos Monokroussos and Uwe Rau describe how a calculation of module performance ratio can be used to accurately assess the efficiency of different PV module technologies in different climates and thus the likely return on investment from a project

Between 2004 and 2016 a sum of US$1,161 billion was invested in PV systems [1], and there is currently approximately 200GW of PV capacity installed worldwide. By 2050 a globally installed PV capacity of around 4.6TWp is expected; this in turn implies a global investment market of some US$225 billion per year on average through 2050 [2].

A major part of this investment is represented by the price of PV modules, which is determined by their output power rated at standard test conditions (STC), specifically an irradiance of 1,000W/m^2, a module temperature of 25°C and a spectral irradiance according to IEC 60904-3. Real outdoor operating conditions, however, are in general considerably different from STC conditions, as demonstrated in Figures 1 and 2 for optimal mounting conditions. The relevant standards for specifying the energy rating of PV modules are IEC 61853 parts 1 to 4, but not all parts have been published yet [3,4]. The energy yield estimation for various PV module technologies, using simulation tools, exhibits high uncertainties as a result of the limited availability of sufficient PV module performance data.

It is therefore essential to have a detailed understanding of all the factors that impact on the energy yield performance of PV modules. Such knowledge will provide a scientific basis for making accurate yield estimates for different technologies and for optimising energy yield performance for different climates. For the upcoming multi-GW installations of 125GW/year on average, each percentage of uncertainty results in significant investment uncertainty with regard to capital expenditures.

Energy yield performance as a key factor for the return on a PV investment

Consider a PV power plant with 100MWp nominal power (for STC) at a location with a moderate specific energy yield of 1,500kWh/kWp and a levelised cost of electricity (LCOE) of US$100/MWh; this means US$150,000 extra revenue for each per cent of additional energy yield and year of operation (if emerging interest earnings are neglected). This would essentially mean US$3.75 million more revenue per 1% increase in energy yield after 25 years of operation. Furthermore, assuming a new market of around 4.4TWp as mentioned earlier, and while keeping the specific energy yield, lifetime and LCOE constant, the result is an astonishing US$165 billion surplus in revenue per 1% of energy yield, which could be achieved by choosing capable PV modules. Besides the chance for investors to maximise their net profit by considering the energy yield performance, this relation also bears a certain investment risk for the PV industry if the long-term performance is lower than expected, and if investors are not able to accurately calculate the expected income.

Figure 1. The test sites operated by TÜV Rheinland for PV module characterisation and energy yield measurements (clockwise from left): Cologne (Germany, moderate climate), Tempe (Arizona, dry continental climate), Chennai (India, tropic climate), Thuwal (Saudi Arabia, dry desert climate with sand deposition) and Ancona (Italy, Mediterranean climate).

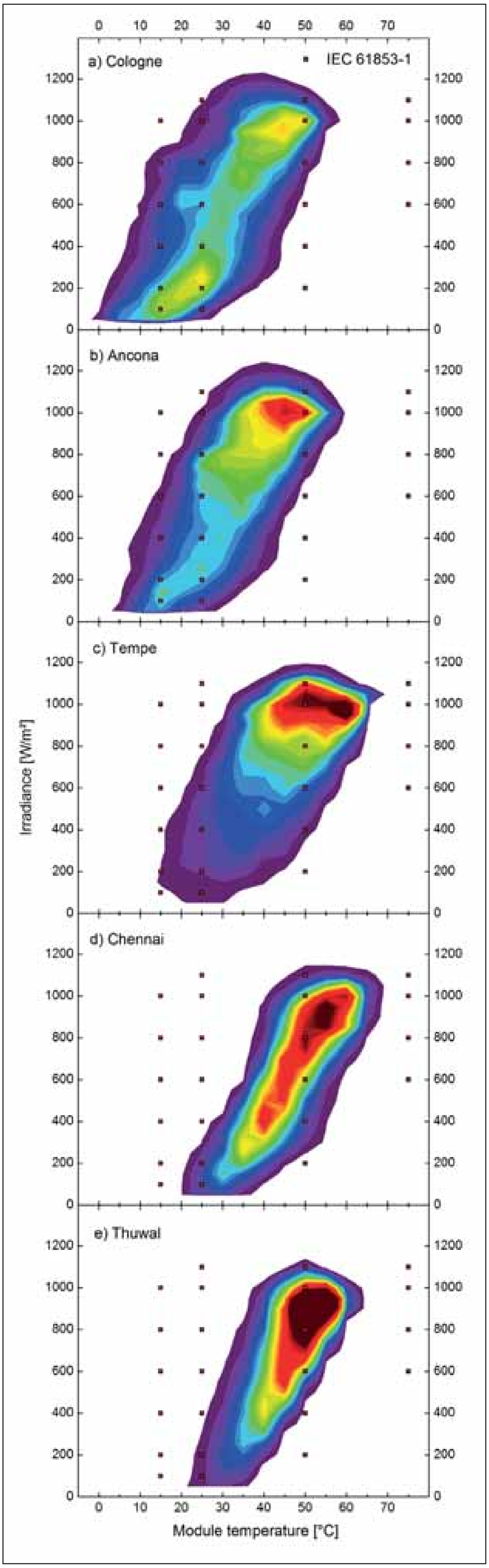


Figure 2. Generated electrical energy of a crystalline PV module in five different climates as a function of module temperature and irradiance on an annual basis, compared with the measuring conditions of IEC 61853-1 energy rating matrix (red dots). Colour range: 0.1–2.6%; colour increment: 0.1%

From absolute yield to specific yield to module performance ratio

The energy yield of PV modules deployed in different climates is a complex topic involving interdisciplinary knowledge of cell physics, module properties and meteorological aspects. To find a pathway to the underlying correlations, some general definitions therefore need to be discussed first.

The absolute energy yield (EY) of PV modules is defined in watt hours (Wh). Because of the different efficiencies and designs of PV modules, it makes sense to calculate the specific energy yield in watt hours per watt peak (kWh/kWp), by dividing EY by the nominal power P_{STC}; this allows a comparison of the energy yield performances of different types of PV module. Besides P_{STC} the second factor dominating energy yield is solar irradiation (H); this strongly depends on geographic location, local mounting conditions of the PV power plant and annual fluctuations. When choosing a pyranometer as a reference irradiance sensor, H is almost independent of environment-related impact factors, such as angle of incidence, spectral shifts or temperature. Thus, to compare and elaborate only technology-driven performance factors, the module performance ratio (MPR) is the best-practice method and can be calculated as:

$$MPR = \frac{EY}{P_{STC}} \cdot \frac{1{,}000\,\mathrm{W/m^2}}{H}$$

The MPR is suitable for investigating the efficiency of PV modules in different climates compared with STC efficiency, as well as for comparing different technologies and climates. As the local weather conditions cannot be changed (unlike the global climate), differences with respect to technological origin are of special interest for optimising PV module performance and for selecting suitable products for a certain climate. The amount by which the value of MPR differs from unity represents the losses in real outdoor operating conditions compared with STC efficiency. The MPR facilitates a relative comparison in percentage terms between different technologies and climates; it includes all the offset relevant influences on energy yield performance due to inaccurate nominal power, temperature losses, non-linear module performance depending on irradiance *G* (low-irradiance behaviour) and spectral effects, as well as the losses due to soiling and angular behaviour (as illustrated in Figure 3). The MPR is identical to the performance ratio (PR), commonly used for PV systems, when system losses, such as wiring, module mismatch or invertor losses, are not considered. Uncertainties of less than ±1% can be achieved when choosing P_{STC} as stated by the manufacturers as a constant basis for MPR calculations.

Underlying database and investigations performed

Since 2013 the performance of 15 different PV module types within the nationally founded 'PVKlima' R&D project has

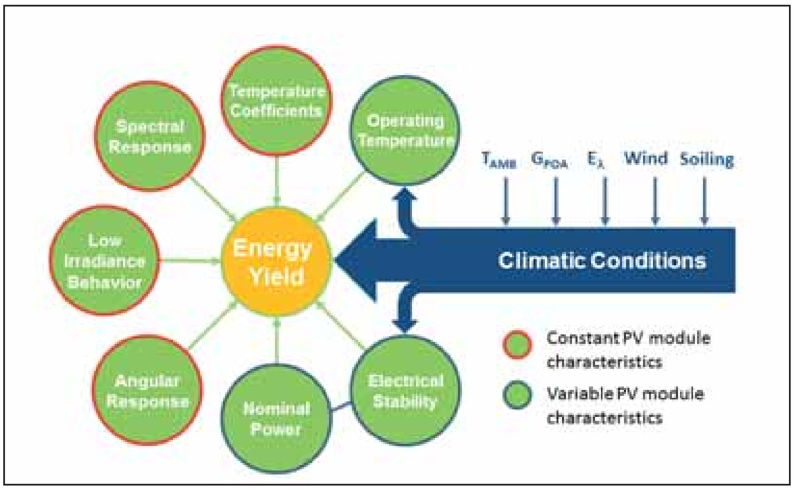


Figure 3. Factors influencing the energy yield of PV modules

航天机电 HT-SAAE

High-Efficiency Mono-Crystalline PV Modules

Hyper C

Better Choice For Higher Efficiency

PERC cell
Back surface passivation
Higher power output

5BB cell
Lower series resistance
Higher module efficiency

Microcrack protected /PID protected
Triple EL tested for high quality control
Applied anti-PID cell and high reliability encapsulation material

300W
Output power can reach 300W and above for 60-cell module

21.2%
Cell efficiency level for mass production up to 21.2% and above

7%
Output power increase of 7% per unit area
(compared with 280W)

4.7%
A 4.7% BOS reduction per Watt
(compared with 280W)

*48pcs, 50 pcs ,60pcs,72pcs modules and other options available

Solar Silk Road, Paving The Way
To The Future

Shanghai Aerospace Automobile Electromechanical Co., Ltd.
Web: www.ht-saae.com
E-mail: pvmarketing@ht-saae.com

FORTUNE 世界 500	Bloomberg TIER 1	60YS	10 million+	1.8 billion+	100+	600+
		Based on nearly 60 years experience in solar technology R&D by CASC	10 million+ USD R&D investment per year	Corporate ' s total assets is over 1.8 billion US dollars	Over 100 independent intellectual property rights for cell & module	Established over 600 PV power plants in China and overseas

* All above information on technical parameters is for reference only. HT-SAAE reserves the right to modify.

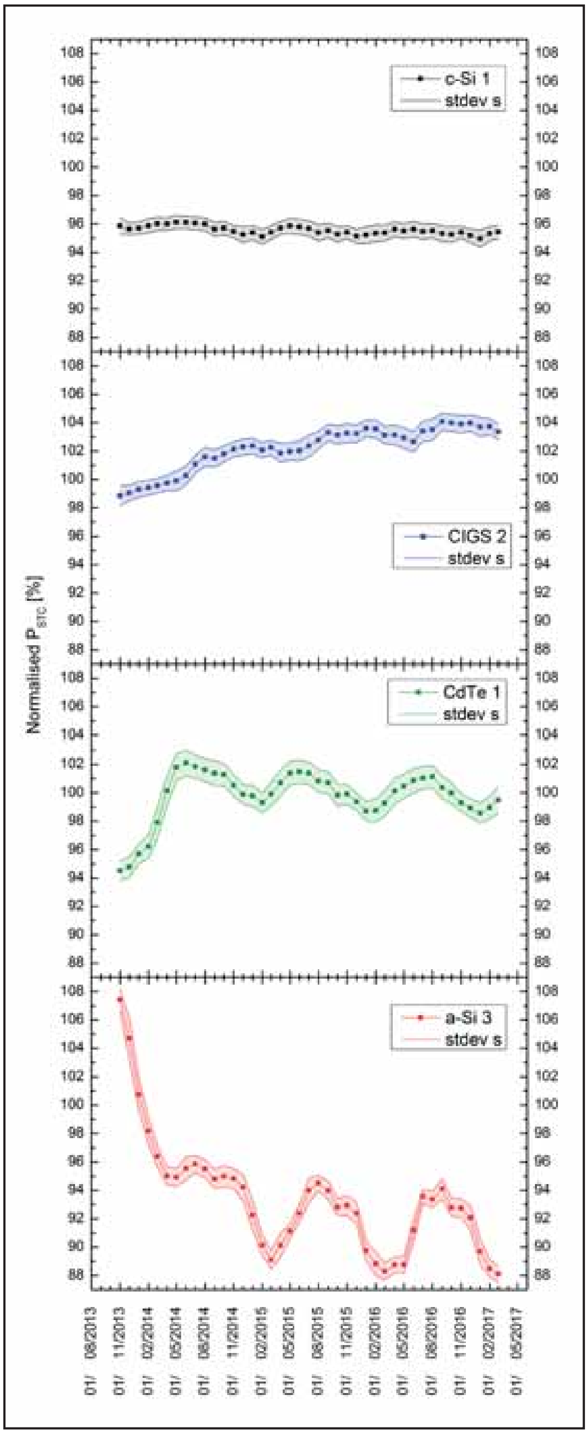


Figure 4. Monthly averages of STC-corrected nominal power for four PV module types, normalised to stated nominal power, for the Ancona test site in Italy (uncertainty: ±2.5%)

been undergoing systematic analysis. The tested modules were:

- Five different crystalline silicon (c-Si) module types from three different manufacturers.
- Four $Cu(In,Ga)Se_2$ (CIGS) modules from four different manufacturers.
- Three cadmium telluride (CdTe) module types from two different manufacturers.
- Three amorphous silicon (a Si tandem) module variants from three different manufacturers.

The five different c-Si module types comprise three polycrystalline and one monocrystalline PV modules with heterojunction cells, and one monocrystalline module with back-contacted n-type cells. The polycrystalline samples are equipped with different front glasses: one sample with standard float glass, one with an antireflection coating and one with deeply structured glass.

Comprehensive tests with regard to energy rating and energy yield were performed in the laboratory and outdoors; five test sites, each in a different climate zone, were therefore constructed (see Fig. 1). The annual in-plane global solar irradiation was 2,386kWh/m^2 in Saudi Arabia, 2,360kWh/m^2 in Arizona, 1,860kWh/m^2 in India, 1,556kWh/m^2 in Italy and 1,195kWh/m^2 in Germany. These test sites allow the generation of the PV module and environmental data sets needed to understand the real-world performance and long-term reliability of PV modules. Thus it was possible to generate an understanding (that so far is unique) of PV module performance under real operating conditions in different climates.

Nominal power at STC and monitoring of electrical stability

To understand the energy yield of PV modules, it is necessary to first begin with the most challenging aspect from the metrology point of view: the determination of STC power and the monitoring of its stability during outdoor operation.

To get a deeper insight into the various seasonal effects on module performance, an elaborate current–voltage (*I–V*) curve analysis was employed. After the *I–V* curves of all samples were measured using a sampling rate of 10 minutes, corrections of temperature and irradiance according to IEC 60891 [5] were applied, in combination with a spectral mismatch correction obtained from measured spectral irradiance data according to IEC 60904-7 [6]. These corrections are necessary in order to create constant operating conditions for time series analysis which would not otherwise be achieved outdoors.

Figure 4 shows the monthly average STC power for four samples representing four technologies. The test site in Italy is used as a model case for the discussion of some fundamental PV module performance characteristics.

With the application of this correction method, all environmental influences are accounted for and can be directly compared. The method allows the influence of temperature and spectral irradiance on fill factor *FF*, short-circuit current I_{sc}, open-circuit voltage V_{oc} and P_{STC} to be analysed independently of each other.

Starting with c-Si, mostly stable P_{STC} power values were found within more than three years of outdoor exposure for all climates. Typical long-term average degradation rates of less than –0.5% per year can be confirmed. For heterojunction PV modules, higher rates of about –1.0% per year were observed, mainly related to

> "The most important pieces of information for investors are the results based on the pure STC power as stated and sold by the manufacturers"

a decrease in V_{oc}. The c-Si 1 sample shown in Figure 4 exhibits an approximately 4% lower value than the P_{STC} stated on the label. It is noted that the stated results are subject to a measurement uncertainty of ±2.5%, which should be borne in mind when interpreting the results.

The nominal power of CIGS PV modules revealed significant performance changes due to metastable cell processes; the consolidation phase of these processes can take longer than a year. Changes in power are related in equal proportions to *FF* and V_{oc}. The depicted CIGS 2 sample in Figure 4 exhibited an increasing P_{STC} of around +4% compared with the label specification. Some of the other PV module types resulted in more than a –10% deviation from the label value after three years of operation; this depends on the manufacturer and not just on the technology.

The tested CdTe PV modules also revealed metastable processes that significantly affected P_{STC}. After an initial performance increase of up to 8%, which takes several months (depending on local temperature conditions), the nominal power exhibits annealing processes between summer and winter, leading to a P_{STC} oscillation with an amplitude of approximately ±2%; this oscillation disappears in hot climates, such as those found in Tempe or Chennai. The annealing

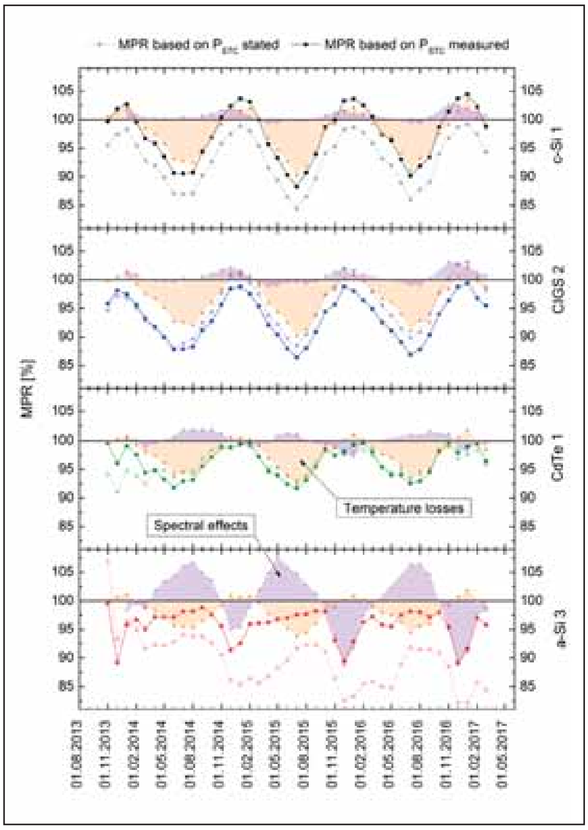


Figure 5. Monthly module performance ratio based on stated P_{STC} for four PV module types, compared with the MPR based on monthly measured P_{STC}, for the Ancona test site in Italy. A deviation from 100% means yield losses or gains; the temperature (orange) and spectral effect (purple) contributions are indicated

process is assumed to achieve a constant state in these hot locations for the whole year. Changes in power are related mainly to *FF*. The average stabilised P_{STC} of the CdTe 1 sample shown in Figure 4 fits quite well with the stated P_{STC} values after three years of operation; however, PV module types with more than a –10% deviation from the label value after three years of operation were also found.

The performance of a-Si PV modules revealed the well-known (but not fully understood) Staebler–Wronski effect, with initial stabilisation of around –10% to –15%, depending on module type. As in the case of CdTe, the performance reveals a summer and winter oscillation of about ±3%, which could also be observed for hot climates. The time constants of these effects are again temperature driven and mainly related to *FF*. The average stabilised P_{STC} of the depicted a-Si 3 sample is about –9% lower than that stated by the manufacturer. Long-term degradation rates are superimposed onto these metastable effects. One module type completely failed the long-term test; two out of four samples ceased operation after just a few months of operation.

It remains unanswered here whether or not the technology-specific stabilisation procedures stated in the new IEC 61215 [7] series of standards are suitable in order to achieve reliable, stabilised P_{STC} values. All the results on stability can be reviewed in Schweiger et al. [8]. Now that the P_{STC} values of all PV modules have been verified, the discussion about climate-related influences can continue.

Origin of climate-related performance differences for PV module technologies and major findings

As mentioned above, PV modules have different low-irradiance behaviours, different temperature coefficients, different operating temperatures, different spectral and angular behaviours and also different soiling behaviours when different front glasses are used. These factors, combined with site-specific climate conditions, result in significant performance differences on the basis of the nominal power measured at STC. As pointed out, the nominal power can deviate significantly up or down from the stated values as a result of binning policies, measuring inaccuracies (±2% in the laboratory) or stability issues, such as light-induced degradation (LID), potential-induced degradation (PID), or metastabilities for thin film.

Given the impact on investment of just one percentage point difference in energy yield performance, the most important pieces of information for investors are the results based on the pure STC power as stated and sold by the manufacturers. Within this project, a significant difference in the energy yield performance was observed between the best- and worst-performing PV module types: up to 23% in India, 21% in Arizona, 14% in Germany and 12% in Italy. After compensating the effects related to nominal power mismatch discussed earlier, an annual difference in yield of 16% in India, 19% in Arizona, 8% in Germany and 9% in Italy remained; the results for Saudi Arabia are still under investigation.

For comparable standard crystalline only, the latest investigation of 24 c-Si samples indicates a technological-origin-related difference of at least 5% (implying again correct and stable nominal power values). This value increases greatly for certain PV modules incorporating special technologies affecting energy yield performance, such as in the case of bifacial PV modules or some thin-film technologies.

Seasonal performance behaviour under investigation

To investigate the origin of the above-mentioned significant differences in annual yield results, an evaluation of short-term MPR values provides a first impression of the physical background. It is a fast and easy way to obtain insights into module performance, which is also the reason why it is used most frequently as a monitoring solution for PV systems, needing just one reference irradiance sensor. The potential, however, is limited, since all influencing factors are superimposed onto just a single value.

For the MPR calculation, the maximum power point was tracked with a sampling frequency of 30s, and a ventilated pyranometer served as a reference irradiance sensor. Figure 5 shows the monthly average MPR values of representative samples in Italy based on stated P_{STC}, together with the compensated MPR based on measured P_{STC}, as well as temperature losses and spectral irradiance influences. This plot is used again as the model case for the discussion of some fundamental performance characteristics of different PV module technologies.

As discussed earlier, the performance of c-Si PV modules (black dots, Figure 5) is mostly stable. Nevertheless, the plot of monthly MPR values for c-Si shows the strongest oscillations by season, with maximal MPR values in winter; the reason for this is the high relative temperature coefficient γ, with typical values of –0.35%/K for high-efficiency modules and –0.42%/K for standard cells. The maximum in winter can be reduced for modules of each technology with poor low-irradiance behaviour due to the lower average irradiances on winter days. The influences of spectral effects on c-Si are low. An offset of the MPR curves can occur in the case of PV modules with inaccurately stated nominal power on the label or datasheet.

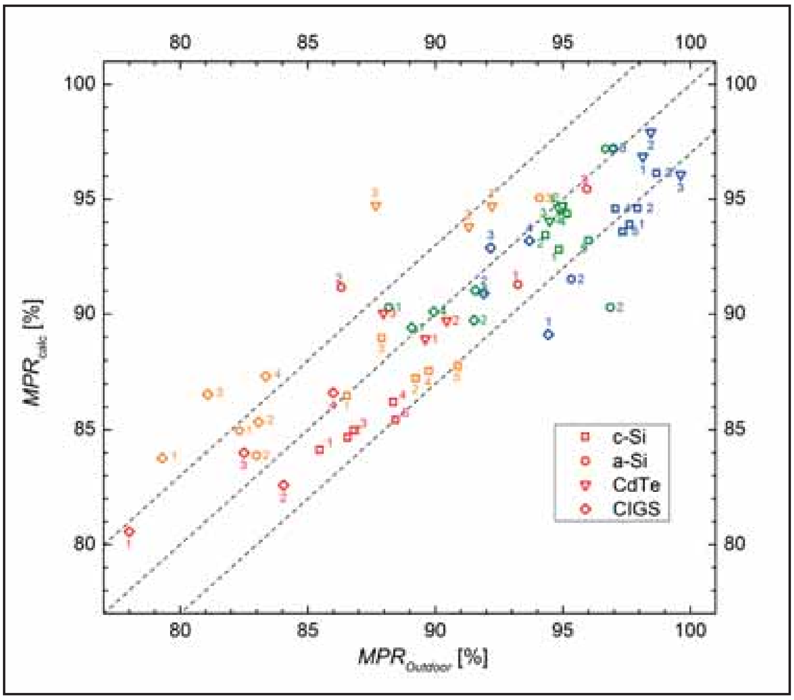
Almost the same performance behaviour can be observed for CIGS samples (blue dots, Figure 5); the spectral response signals and temperature behaviour are comparable to those for c-Si. The oscillations between summer and winter can be slightly lower for the samples with better temperature behaviour or poor low-irradiance behaviour. Any potential gains due to a better temperature coefficient can be lost again, however, as a result of higher average operating temperatures. The CIGS 2 module shown in Figure 5 indicates the effect of an increasing P_{STC} over the

years due to metastable behaviour, as demonstrated earlier, which can be either positive or negative for PV modules of this type.

CdTe samples (green dots, Fig. 5) show less oscillation by season, but still exhibit maximum MPR values during the winter months. The reasons for the lower amplitudes can be found in the significantly lower temperature coefficient γ of typically –0.29%/K, and in the spectral gains in summer. The difference between summer and winter is further reduced because of the metastable behaviour, as shown earlier.

In the case of a-Si samples (red dots, Fig. 5), the MPR values during the first few months are dominated by Staebler–Wronski degradation, followed by temperature annealing observed in the summer months. Compared with c-Si, small oscillations between summer and winter are achieved. In contrast to all other cell technologies, the maximum MPR values are reached in summer; the reason is a combination of small temperature losses, again due to low temperature coefficients γ (typically in the range of –0.26%/K to –0.39%/K, depending on manufacturer), gains due to thermal annealing, and significant spectral gains in summer. For some samples, high losses due to poor low-irradiance behaviour in winter were observed. It is noted that the performance of some a-Si samples did not reach a stable level after more than a year of outdoor exposure.

Figure 6. Module performance ratio MPR_{Calc}, calculated using weather data and indoor measurements, plotted versus the measured $MPR_{Outdoor}$ based on energy-weighted average outdoor power (blue: Cologne; green: Ancona; red: Tempe; orange: Chennai)

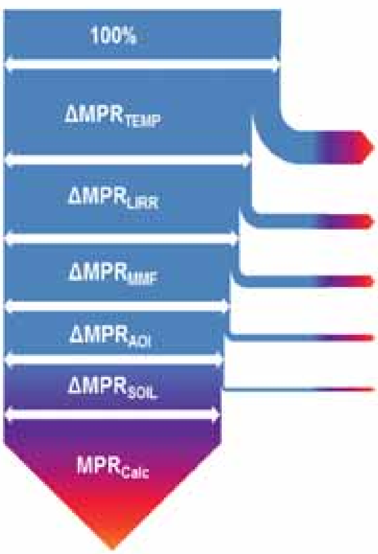


Energy rating of PV modules using linear performance loss analysis

A linear performance loss analysis (LPLA), as described in Schweiger et al. [9], can be used to quickly, accurately and inexpensively predict the MPR of PV modules for different climates. Simple reference environmental data sets and energy rating data, in accordance with the IEC 61853 series, measured in the laboratory serve as input data. An energy yield prediction based on calculated MPR_{Calc}, with a deviation of ±3% from measured $MPR_{Outdoor}$ values, can be achieved, as illustrated in Figure 6; this deviation is assumed to be mainly due to the influence of P_{STC} measuring uncertainties on the $MPR_{Outdoor}$ results. The approach takes into account all the relevant factors that have an impact on energy yield, such as module temperature, low-irradiance conditions, and spectral and angular effects, as well as soiling.

The approach also allows a quantification and comparison of the various influencing factors for different PV module technologies and for different climates, as illustrated in Figure 7. The energy yield of PV modules is affected by five individual loss factors; the mechanisms correspond

Figure 7. Quantified loss mechanisms influencing the MPR of PV module types c-Si 1, CdTe 1 and CIGS 2 in different climates on an annual basis



	c-Si 1				CdTe 1				CIGS 2			
	Cologne	Ancona	Tempe	Chennai	Cologne	Ancona	Tempe	Chennai	Cologne	Ancona	Tempe	Chennai
ΔMPR_{TEMP}	-2.3%	-3.9%	-8.9%	-9.6%	-1.5%	-3.5%	-6.7%	-6.2%	-2.9%	-4.5%	-8.8%	-9.1%
ΔMPR_{LIRR}	-1.2%	-0.8%	-0.4%	-0.5%	0.0%	+0.2%	+0.3%	+0.6%	-3.6%	-3.1%	-1.8%	-2.4%
ΔMPR_{MMF}	+1.3%	+0.5%	-0.8%	+1.6%	+2.3%	+0.9%	+1.1%	+5.3%	+1.4%	+0.3%	-1.1%	+1.8%
ΔMPR_{AOI}	-3.5%	-2.4%	-2.0%	-2.9%	-3.5%	-2.4%	-2.0%	-2.9%	-3.5%	-2.4%	-2.0%	-2.9%
ΔMPR_{SOIL}	-0.5%	-0.5%	-3.7%	-2.1%	-0.5%	-0.5%	-3.7%	-2.1%	-0.5%	-0.5%	-3.7%	-2.1%
	-6.2%	-7.2%	-15.9%	-13.5%	-3.1%	-5.4%	-11.1%	-5.3%	-9.1%	-10.3%	-17.4%	-14.7%
MPR_{Calc}	**93.9%**	**92.8%**	**84.1%**	**86.5%**	**96.9%**	**94.6%**	**88.9%**	**94.7%**	**90.9%**	**89.7%**	**82.6%**	**85.3%**

to loss terms ΔMPR for different climates, which can be singled out. The loss mechanisms which influence the MPR of electrically stable PV modules are: temperature (ΔMPR_{TEMP}), low irradiance (ΔMPR_{LIRR}), spectral effects (ΔMPR_{MMF}), angular losses (ΔMPR_{AOI}) and soiling (ΔMPR_{SOIL}).

The losses due to soiling and angular effects are almost constant for PV modules with standard untreated front glass. Soiling losses (ΔMPR_{SOIL}) are highest in Arizona, although higher soiling rates can be expected in Saudi Arabia. The soiling rate is highly dependent on the period under consideration, and long-term averages are needed.

The losses due to angular effects (ΔMPR_{AOI}) are highest, compared with overall available energy, in Cologne, with up to –3.5%. In addition to the advantages gained in light transmission, lower angular losses can be achieved with deeply structured glass (–2.8%) or an anti-reflection coating (–1.6%). For deeply structured glass, however, higher soiling rates must be considered.

Relative losses due to low-irradiance behaviour (ΔMPR_{LIRR}) are also highest in Cologne, with up to –3.6%. The low-irradiance behaviour for constant spectral irradiance conditions is technology driven, but also depends on the individual manufacturers. The behaviour is dominated by wafer recombination losses, and module internal serial and parallel resistance in combination with operating voltage and current. The performance between different manufacturers may vary significantly. A satisfactory low-irradiance behaviour for constant spectral irradiance conditions means an efficiency drop of less than –5% at 100W/m^2 relative to STC; this can easily be tested in the laboratory.

Losses due to temperature (ΔMPR_{TEMP}) are highest for c-Si, with up to –9.6% in Chennai. Better values can be achieved with thin film when the advantages due to low temperature coefficients are not lost because of higher operating temperatures.

The influence of spectral irradiance (ΔMPR_{MMF}) on c-Si is low on an annual basis. The highest impact on energy yield can be found for CdTe (up to +5.3% in Chennai) and a-Si.

For other mounting conditions with orientations that differ from optimal or those with reduced ventilation, as in the case of building-integrated PV (BIPV), other loss factors must be assumed.

Conclusions

Because of cost and time pressure, consideration of the energy yield performance of PV systems is often of secondary importance when constructing PV plants. Optimisation of the yield is necessary, however, for successful investment. Significant differences were observed in the energy yield of PV modules available on the market – up to 23%, depending on power rating, technology and climate.

The results have shown that a combination of indoor tests and reference climate datasets is sufficient for estimating, within ±3%, and comparing the energy yield performance of different PV module technologies. The long-term stability of electrical power, however, must still be tested in the field.

The ultimate owner of the PV power plant should consider a well-defined module performance ratio before making an investment decision. The competitiveness of solar projects can be enhanced by PV modules with reliable long-term performance and optimal energy yield performance suited to the climate of the installation location. ■

Acknowledgement

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Taking PV design software to the next level

System design | As PV projects get bigger and more complex, plant design programs are rising to the challenge. Sara Verbruggen looks at how some of the latest innovations in design software are helping developers win the competitiveness game

Specialist software design tools for simulating PV plant layouts and yields can shorten design time significantly and resolve engineering challenges, helping to reduce soft costs.

But providers are also responding to the needs of the industry with software tools that simulate with greater accuracy super-sized ground-mount projects, half a gigawatt or more in size, as well as provide modelling that factors in the economic impact and value of connected systems and loads, like storage and electric vehicles (EVs).

Historically developers of large-scale solar PV plants have had two main tools at their disposal: the engineering tool AutoCAD, used in computer-aided design of anything from road infrastructure to furniture, and PVsyst, for the project's energy modelling.

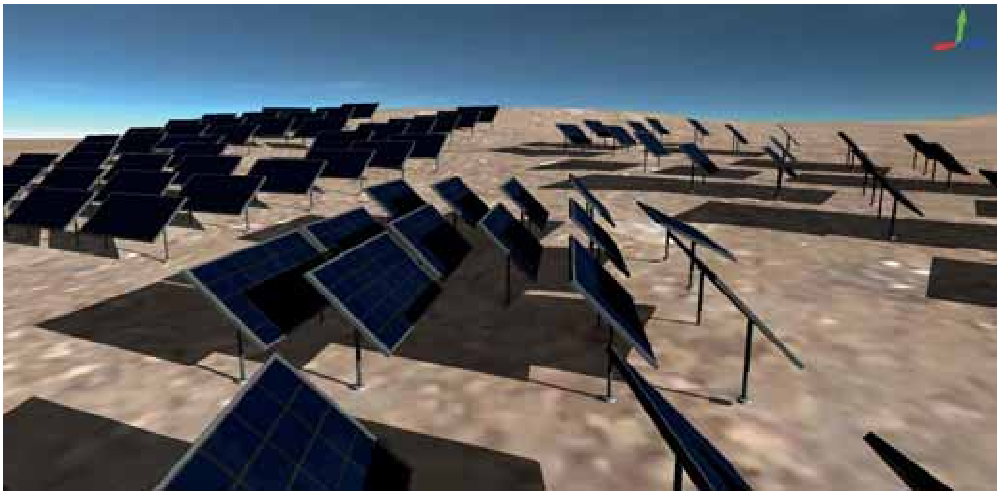
But as the PV market has grown and the industry faces pressure to reduce costs in PV plant development, construction and operation, more software programs that can design PV plants and take into consideration impact of a wide range of influencing factors, from specific module or inverter types and models to shading, have arrived enabling developers to rapidly simulate PV plants.

New functions

An established provider of PV plant simulation and design tools is Germany's Valentin Software, which introduced its PV Sol tool in the late 1990s. Users of the software include developers, installers and also banks, for ensuring bankability of projects.

Recently the company has enhanced its offering by launching PV Sol Premium, which is able to model PV systems and projects in 3D by taking into consideration shading and the impact this has on the plant's output and yield.

The premium offering can produce designs with a maximum of 5,000 modules, equivalent to a 1MW plant. However, where



Credit Meteodyn

a developer wants to design a bigger plant, to take into consideration shading, this can be done by using PV Sol to model several smaller plants and combine these, using PV Sol Premium for any shaded areas.

PV Sol is also able to produce designs not only of PV systems, such as commercial rooftop, but simulations that factor in a building's loads, or on-site EV charging, as well as battery storage for projects where self-consumption of PV-generated electricity needs to be optimised.

One client, a shipping/logistics business, operating throughout the night, is interested in installing a rooftop solar PV system at its premises. The firm operates a fleet of battery powered forklift trucks that can be recharged with electricity from the solar panels during the day. The software results provide economic modelling for the solar PV array down to how many kilowatt hours each forklift truck will use, supplied by the solar, versus the cost of these kilowatt-hours, from the grid.

To simulate PV projects and the yields and output of plants, PV Sol software imports climate data from Meteonorm, site data from Google Maps and has a database of different PV modules, inverters, battery storage systems, EV makes and tariffs.

PV design software is becoming more sophisticated, in step with the requirements of solar developers

The software produces an aggregate simulation based on the performance metrics of the modules and other system components fed into it, along with assumptions based on the actual electrical behaviour of the components, plus data on loads and grid connections, to produce a simulation that is closer to how the physical plant might actually perform. More recent developments include a battery simulation.

Most projects are run through PV Sol on its own or through a second software, usually PVsyst, for a "second opinion" assessment of bankability, according to Valentin Software's managing director Steffen Lindemann.

Credit Valentin

Innovations in PV design include being able to simulate the incorporation of batteries

Utility-scale design

Vertically integrated module and component producer, developer and asset manager SunPower has spent the last few years refining its approach to simplifying the building of large and utility-scale solar PV plants by standardising components that are constructed in modular blocks. The US company launched the latest version of its Oasis Power Plant in September 2016, with additional features to optimise the design of utility-scale PV plants.

The earliest stage of developing a large-scale PV project requires selecting the right site. Developers usually have to use available satellite images, and send people out to sites to photograph and survey them. But as PV plants have grown in size, sometimes to hundreds of megawatts in size, this approach becomes impractical.

"The other option is to hire a small plane and take images from above, which can cost around US$30,000 to hire," says Matt Campbell, vice president, power plant products, at SunPower.

SunPower's answer is to use drone imaging. High in the sky, drones scout potential locations, flying over hundreds of acres of land in a matter of hours to record images and assess topography.

"In 2016, when surveying sites for large-scale PV plants in Mexico, one guy with a drone was able to survey two sites a day, rather than the weeks it can take with conventional methods," says Campbell.

The images are fed into SunPower's proprietary software to create bird's eye view images of potential sites, containing more detail than satellite images are able to capture; for example picking out creeks, gullies, rocks, old buildings and other potential obstacles. Other important information can be fed into the company's software to build up a complete map of the site, including gradients of areas, to show where there are parts of the site that may be too steep for some types of trackers, as well as other constraints, such as transmission lines.

SunPower uses drones to speed up the surveying of potential PV sites and aid the design process

Once all the necessary information is inputted into the software for processing, it produces a range of site layouts with maximum output and best financial results, based on multiple parameters, all in a matter of hours. The parameters include DC to AC energy loss, clipping loss, lowest levelised cost of energy (LCOE), lowest engineering, procurement and construction (EPC) cost, as well as net present value (NPV). Big data and algorithms are used to crunch all of the data and information required to come up with suitable sites and designs.

"Traditionally when assessing sites, NPV has been the determinant metric, but as we move more and more to auction-based systems and lower power purchase agreement (PPA) prices, then LCOE is probably going to be the key metric when assessing sites to take forward for development," Campbell says.

The software enables the overhead image of the site to become the interface for the project through its entire duration and the resulting plant's operational lifetime. SunPower can make its software available to EPCs so they can also refer to the site's map and any updates.

To prepare for construction, roads can be added to the site map as well as the location of a substation, inverter cabinets and cabling. A drone can be flown over the site during regular intervals throughout the construction period, reducing on-site management time, monitoring the rate of construction process and updating inventories and delivery schedules.

According to Campbell solar plants should be thought of as factories. "A manufacturing plant's operations and output is optimised with management information software (MIS). Why shouldn't it be possible to optimise all stages of the solar plant's construction?" he says.

Once the PV plant is operational the map and the software updating it is still important, for example, to show which portions of the PV plant are more prone to soiling so the cleaning can be adjusted accordingly with the area most prone to soiling cleaned more regularly. As the site map is updated in terms of areas cleaned it, O&M costs can be more accurately calculated.


Credit SunPower

Highest output at the lowest cost

Folsom Labs is a west coast US software developer that launched its solar PV simulation and design tool in 2014. At the time the aim behind HelioScope was to provide the industry with PV design software that was simpler and faster to use while ensuring the projects it simulates provide all-important bankability, aiming for the highest output at the lowest LCoE.

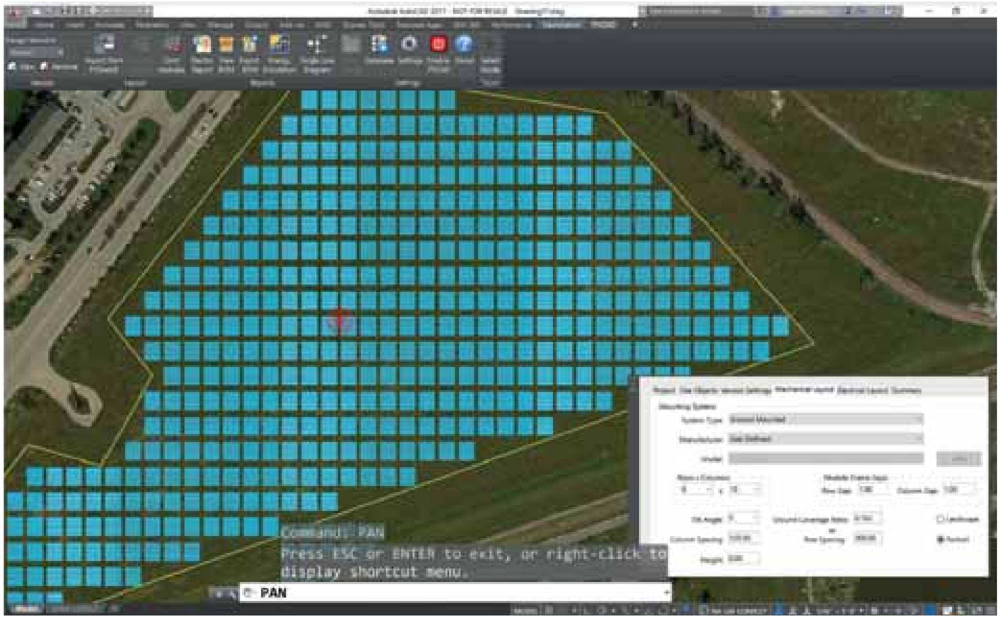
The user selects a suitable project site, such as through Google Maps, and produces a design based on inputs of different components, including modules, inverters, cabling and mounting. The software also combines with weather forecasts and runs simulations based on all the data in order to accurately predict the system's performance in terms of output.

This core design can then be adapted, with different components, to see the impact on results, including shade modelling and analysis.

"The incumbent PV design software took a module multiplied by however many and then applied a 'haircut' for the losses. When we launched, the value proposition for HelioScope was that it was a bankable granular component-level modelling software. But what we have found since then is the demand has been for a poor man's AutoCAD. By that I mean a solar PV-specific design tool for non-engineers," says Paul Grana, co-founder of Folsom Labs.

He cites a typical mid-sized solar firm, where there might be two or three engineers and a team of several sales representatives. "When one of the sales team sets up a meeting with an owner of five properties who wants to put solar on their roofs, the sales rep comes back and needs the engineer to produce five designs. HelioScope gives the sales team the ability to produce engineer-calibre results," says Grana.

With HelioScope a sales person can produce designs, meet with the client, and



Credit PVComplete

PVCAD combines the main attributes of AutoCAD design software with solar modelling capabilities

if the client wants to change something – removing trees from a site for example – to maximise the array area and increase output, then these types of changes can be made on the fly. "This fits in much more with the sales process, which tends to be very dynamic," says Grana.

The breakdown of projects using the software tool is about 40% commercial, 40% residential and 20% utility scale. But the highest traction is in commercial.

"A racking supplier on the east coast of the US said that of their 30 largest customers, there is 100% usage of HelioScope. That's a good indication that we are the market standard in commercial," according to Grana.

The company is prioritising adding new features for a residential version of HelioScope though some of the refinements will also feed into making the software more user-friendly for utility projects.

"One way we've modified the offering is to factor in the different building and safety codes that are different for residential buildings than for commercial. We've also tweaked features to allow individual modules to be clicked and dragged to move about in the layout, as required by this market."

The company has also customised a document aimed at homeowner customers. The reports HelioScope generates contain lots of detail, in terms of losses due to various factors, which is extremely useful for engineers but unnecessary for a sales pitch.

Grana says: "For homeowners we've streamlined the proposal to show cost, payback period, images and details such as what their typical bill might look like after installing solar. It's all backed up with underlying module-level physics."

One of Folsom Labs' main customers is Caterpillar which has gone public about plans to roll out solar internally and also supply dealer partners that are constructing solar PV projects and supply all the components necessary for building PV-hybrid microgrids.

Over 50 Caterpillar dealers globally are signed up to use HelioScope. "Caterpillar told us their dealers would also appreciate a similar proposal tool, based on a simple yet robust financial programme, a document that can be used in the sales process."

Getting a utility-type project such as a solar PV microgrid developed usually requires face-to- face meetings with different stakeholders, such as landowners, utilities and permitting departments. Each often has different questions, but crucially they all benefit from a simple, non-engineer level of document, according to Grana.

"It can change dynamically for the different stakeholders involved in the project, which can be very useful. For example a developer is facing a series of constraints: the utility will have a limit to the maximum power that the grid can take; the municipality will have restrictions on how the land can be used, such as setbacks from property boundaries and roads and line-of-sight restrictions, while the project owner may have budgetary constraints or financial return requirements.

"Plus, different technologies will be more or less effective at satisfying all of those requirements. Developers will use HelioScope to update their design and financial model on-the-fly, as they learn more information about new restrictions," says Grana.

Around 40% of Folsom Labs' customers are outside of North America, mainly in India, South Africa, Latin America, Australia and Turkey.

"We are seeing demand where new markets with growing demand are the norm. In these markets developers want to grow revenues aggressively but not necessarily grow their teams of staff."

The utility-scale proposal tool version, which includes features for solar trackers, is going to be launched later this year. Expanding the functionality of the software to include storage is also in the pipeline.

"We are very aggressive about API tie-ins , making sure that our software is compatible with other relevant software that investors and developers use. We have financing modelling, but HelioScope is compatible with the software used for financing calculations. Energy Tool Base is one such example of compatibility. When we add storage capability, we will still support API tie-ins to storage design software tools. It's important they all play nicely together," Grana says.

New players, new solutions

Another west-coast software start-up, PVComplete, has created its PVCAD software design and modelling tool to be entirely compatible with AutoCAD by adapting the software for the specifics of the PV industry, through a royalty agreement with AutoDesk, AutoCAD's developer.

The advantage is that commercial and utility-scale PV plants of any size, with yields modelled, can be designed on one piece of software. "Almost anyone who is an engineer or is trained to draft will be familiar with AutoCAD from working with it as a student. In the cases of other PV design and modelling tools, there is an added step between exporting back and forth between two different types of software plus, you have to pay for each one. That's not the case with PVCAD," says Claudia Eyzaguirre, a co-founder of PVComplete.

PVCAD taps into databases of thousands of different modules, inverters and racking and mounting components. "Because the layout and geometry is influenced by the type of racking, in the past a developer would have had to go to the racking supplier first and requested a layout. If you were not a regular client you could be waiting for a couple of days. With this type of software it's instantaneous," says Eyzaguirre.

Such software removes the rule-of-thumb approach. "You can design a project using one type of module and calculate its energy yield, and then see instantly it changes when you input another type of module. You can see your optimal design based on different tilt angles. You can see immediately how energy production is impacted, whereas before engineers would have to do long calculations and build in contingencies," Eyzaguirre says.

From wind to solar

Another new player on the scene is the French firm Meteodyn, which having cut its teeth in the wind energy business, has now developed a software simulation tool for solar projects.

Meteodyn develops applied meteorology software and is a leading provider of wind software for resource assessment in complex terrains. The company's PV software offering spans solar resource assessment as well as modelling of utility-scale solar PV power plants.

Optimising the Gala solar plant through design

SunPower used its combination of surveying and design technologies to good effect in the design of its 56MW Gala project in Oregon, US.

The project site is 480 acres, so it was surveyed in a half day using a drone. SunPower claims to be able to survey an average of 1,000 acres per day, depending variables such as the time of year and site conditions.

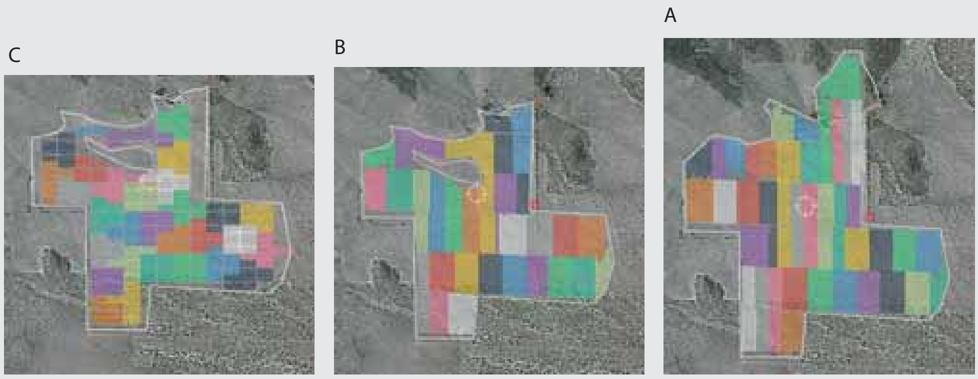
SunPower's proprietary software, GEO, allows users to input their preferred or target site parameters and then choose which unique design iteration is best suited to the specific project. They can adjust site boundaries, site density (GCR), and DC/AC ratio to optimise for specific outcomes such as highest DC capacity, target AC capacity, target year-one energy, highest yield, lowest levelised cost of electricity and highest net present value.

A given project may see anywhere from 10-100 user simulations, each of which results in a unique power plant design. But each power plant design is the result of billions of layout iterations processed by GEO's design algorithms. Depending upon the size of the project, it may take 20-30 minutes to run 10 simulations.

The 480-acre Gala site is oddly shaped and a portion of the site was going to be too steep to build on. With a generic linked tracker and standard efficiency modules (315W), SunPower would have been able to build 50MW (DC) on a reduced land area due to slope tolerance restrictions (image C).

With the new Oasis tracker and P-Series modules (345W), SunPower could build 65MW (DC) on the same reduced land area by taking better advantage of the oddly shaped land with a more configurable tracker and also the higher efficiency modules (image B).

With the new Oasis tracker and P-Series modules (345W), SunPower could build 81MW (DC) by taking advantage of the steeper land areas (image A).



Credit SunPower

SunPower was able to make best use of the 480-acre Gala project site in Oregon using its proprietary design technologies in conjunction with its tracking and module hardware

Similar to other solar PV design tools Meteodyn PV will simulate projects based on geographical position, component-optimising parameters such as azimuth and inclination angles, and distances between arrays. But the software includes some new features, including topographic data the company has accumulated, as well as data based on wind speed at specific sites, to define the temperature of the module, which can affect output, especially in hot climates. Increasingly as developers in markets such as Australia and India, co-locate wind and solar PV generation, Meteodyn offers a compelling one-stop-shop for resource measurement and plant design.

"With the renewable market growing, lots of companies from the wind industry have started to work in solar PV, so it was easy for us to talk to them and share a vision on what they really need in a solar resource assessment software," says Cyrille Vezza, who is in charge of business development for Meteodyn's PV software. The tool will be launched at Intersolar Europe 2017. Its beta users have done some tests and comparisons but the company will not be releasing results for a few months yet, according to Vezza.

Global demand for solar PV continues to grow. But with new regions, more complex terrains and sites, plus intense pressure to deliver projects cost-effectively as incentives are removed, it is no surprise the software design field is drawing more providers to provide developers, banks and other parties with more options than were available even just a few years ago.

What's particularly good news is the number of third-party software programs that are coming onto the market. While SunPower has investigated significant sums in developing its software, it is proprietary. With third-party engineering firms becoming more prevalent in the US market, or where developers retain a core in-house team of engineers, but take to contracting out engineering support needed for large projects, reliance on user-friendly, third-party PV design and modelling software will increase. ■

Sara Verbruggen is a freelance journalist

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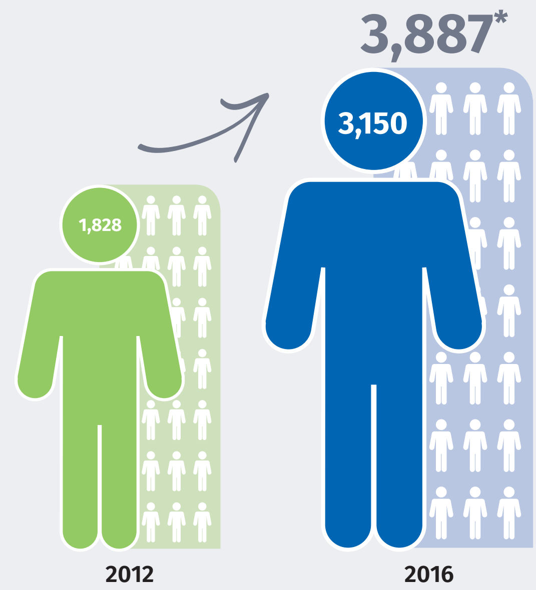

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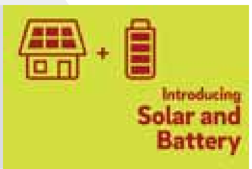

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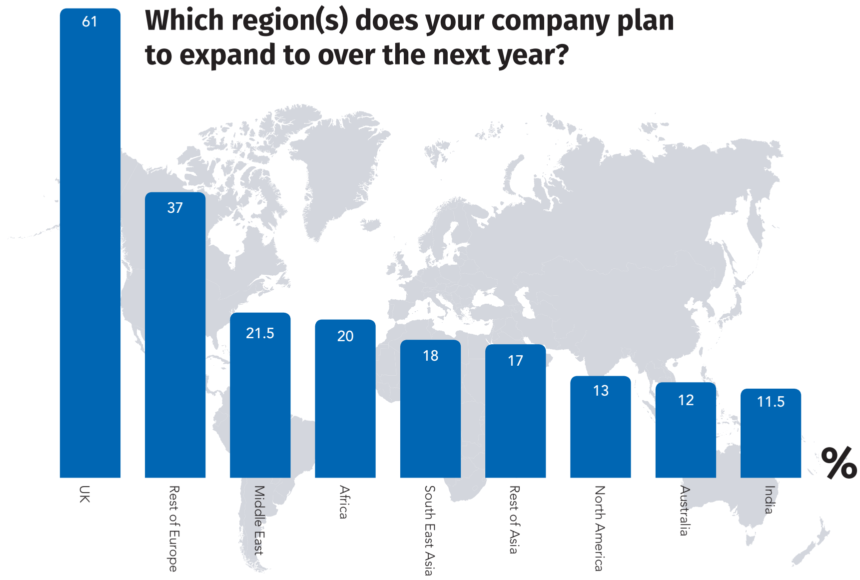

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“The Energy Storage Summit is fast becoming the **industry standard** annual event attracting the **key players** in this field. Delegates are made up of a good cross section of developers, investors, technology providers, advisers and network operators and policy regulators”

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Light-induced degradation newly addressed – predicting long-term yield loss of high-performance PV modules

Module degradation | Light-induced degradation has long been recognised for its negative effects on the performance of crystalline silicon solar cells. Researchers from Fraunhofer CSP explain how with the advent of advanced materials and cell technologies such as PERC, new tests and standards are required to minimise the impact of the phenomenon on plant reliability

Light-induced degradation - a reoccurring issue

In addition to installation and maintenance costs, long-term energy yield is most important for the operation of PV power plants. The long-term yield is determined by both module efficiency and long-term performance. Thus, modules have to pass several standardised tests to fulfil well-defined reliability criteria. While standard tests are suited for the latest technology at their time, new technologies often require new tests for long-term reliability assurance.

Long-term power degradations, such as light-induced degradation (LID), are basic menaces for economic PV system operation. LID is an important degradation phenomenon effecting solar cell and module efficiency. It can cause an efficiency loss up to 15%rel under illumination in the first years of module operation. Manufacturers have achieved control over this defect in standard crystalline silicon solar cells with aluminium back surface field, keeping LID below 3%rel [1]. In general, the LID sensitivity of solar cells can be limited by using an adapted, optimised solar cell production process.

However, these cell processes respond sensitively to variations in the silicon material used for cell production (e.g. contaminations from crystallisation processes). Furthermore, the measures to prevent LID reduce the process parameter window leaving less room for other optimisations. LID also seems to be a serious issue for new high-performance solar cell technologies: lab tests and field data analysis have shown light-induced degradations of 3-5%rel for mono-crystalline passivated emitter and rear cell (PERC) solar cells and 7-15%rel for multi-crystalline PERC-cells [2]. The degradation rates depend strongly on environmental and operation conditions such as temperature or electrical operating point (MPP, VOC, ISC). In contrast to previously known types of LID, the degradation process in PERC cells may last much longer (over several years).

Hence, the growing market for latest technology modules, particularly PERC, demands a critical review of existing standard tests. Improved LID assessments for PV modules are required based on realistic, accurate and reliable accelerated life testing procedures.

Fraunhofer Center of Silicon Photovoltaics CSP supports the industry by applied research in this field. It provides research services from testing and quantifying the LID sensitivity of cells and modules, over root cause analysis, to optimisation of the passivation process for LID mitigation.

LID occurs for all cell technologies

The phenomenon of of solar cell degradation caused by illumination has been under investigation for more than 40 years [3]. Different chemical processes reducing the solar cell efficiency are known. Often, they are induced by a shift in the Fermi level due to an increase in excess carrier concentration. As the increase in excess carrier concentration is related to the incident irradiation, this process is quite generally termed light-induced degradation (LID). However, the same effect occurs by inducing a current to an unilluminated solar cell which as well causes an increase in excess carrier concentration.

Well known LID mechanisms are the activation of boron-oxygen complexes

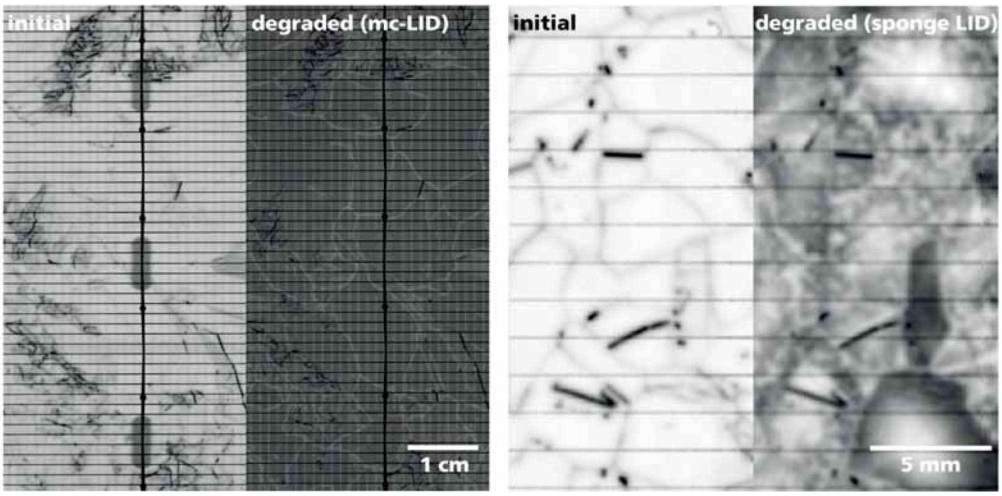


Figure 1. Light beam-induced current mappings of a mc-LID sensitive PERC solar cell before and after degradation (left) and of a sponge-LID sensitive solar cell (right). The different lateral appearance allows the determination of degradation type. The cells were processed in an intentionally modified cell process leading to high LID sensitivity

(BO-LID) and the dissociation of iron-boron (FeB-LID) pairs [4, 5]. However, also other metal contaminations as chromium and copper cause LID [6, 7]. Recently, two new LID defect types were detected: sponge LID on "high performance multi" (HPM) and mc-LID (also termed "LeTID") on multi-crystalline PERC [8, 9]. A distinction of these different LID mechanisms is possible by the degradation rates, the subsequent regeneration process, the material impurities of the wafer material and the lateral appearance (example shown in Figure 1).

Boron–oxygen complex activation (B–O LID)

Light-induced degradation has first been reported on monocrystalline boron-doped Cz silicon solar cells, which suffer up to 10%rel in efficiency under operation. At elevated temperature regeneration occurs subsequent to the degradation [10], increasing the cell efficiency again until the initial efficiency is partly or entirely regained. The defect mechanism as well as the kinetic behaviour has been under investigation for several decades now. However, still the scientific discussion is ongoing. Currently, there are several explanations for this LID effect. The main and most prominent explanation is a formation of so called B-O complexes under light or carrier injection [7]. This B-O degradation is also the most prominent LID and often meant by the general term 'LID'. Depending on the material and the operating location during field operation the degradation may take months until saturation.

Iron–boron pair dissociation (FeB LID)

The defect formation of FeB-LID is well understood. In the dark, positively charged iron atoms link to the negatively charged boron atoms due to Coulomb interaction. These complexes have shallow energy levels and do not reduce the cell efficiency. The shift in the Fermi level under illumination causes the neutralisation of the iron ions, which consequently separate from the boron atoms. Interstitial iron causes a much higher charge carrier recombination under solar cell working conditions [5]. Thus, the dissociation of iron-boron pairs causes a severe efficiency loss in iron-contaminated cells within the first minutes of illumination.

mc-LID or LeTID

mc-LID was first noticed on p-type mc-Si PERC solar cells leading to an efficiency loss of up to 15%rel. Standard Al-BSF and mono-Si PERC cells are less affected. In contrast to other LID mechanisms, it occurs at elevated temperatures above 50°C only. Therefore, Hanwha Q CELLS suggested the name light-and-elevated-temperature-induced degradation (LeTID) [2]. mc-LID differs from the above discussed mechanisms by occurring on much longer time scales as it takes days in the lab and years during operation. Subsequent to the degradation, regeneration sets in. However, during field operation the regeneration will not start in the 20-year warranty period. It is believed that a metallic impurity causes the degradation. However, the root cause of degradation is still under investigation. Recently, a high Cu concentration was detected with element analysis at mc-LID sensitive mc-PERC cells, indicating that Cu plays a role in mc-LID [11].

Sponge LID

Sponge LID is a fairly new degradation mechanism with the root cause still being a topic of research. It can occur on HPM-Si material. This new wafer type with small grains but only few dislocations leads to an efficiency gain of about 2.5%rel. Sponge LID can over-compensate this gain and saturates within a day in the lab, inducing an efficiency loss of up to 10%rel [8]. Under outdoor conditions the degradation takes a few weeks.

Effect of LID in the field under operation

For conventional Al-BSF modules, light-induced degradation typically occurs within the first year in the field with a power reduction in a range from 0.5% to 3%. With respect to module warranty, module manufacturers often simply subtract the anticipated power loss from the initial power measurement and label it accordingly. Nevertheless, for PERC modules much higher losses of between 7%rel and 15%rel were reported [2]. There are also PERC modules showing very low LID losses (1%rel) by modification of the wafer growing recipe and the solar cell production as LID strongly depends on the material and solar cell manufacturing process parameters.

Typically, not all cells within a module are affected equally (see Figure 2). However, one can show by electric simulations that even few degraded cells can decrease the performance of the PV module considerably (see Figure 3). This is based on the fact that the current in a cell string is limited by the current flow through the degraded cells. Thus the module current and therefore the module power (at MPP condition) are significantly affected even if only few cells in a module are degraded. Based on field data, it has been found that these power losses can be directly translated into yield losses if the appropriate temperature and illumination conditions are taken into account.

LID testing

Testing and standards on module level

Light-induced degradation affects the efficiency of PV modules during their complete lifetime. Therefore, quantifying LID is an important task for yield

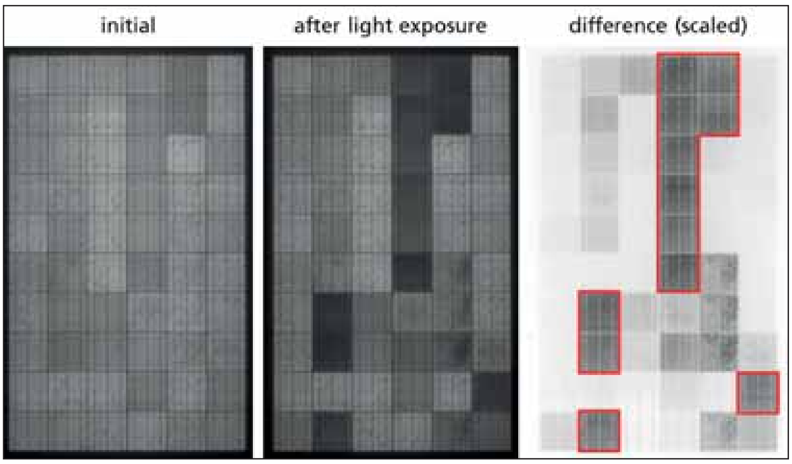


Figure 2. Electroluminescence images of a module before light soaking (left), after 20 hours of illumination with AM1.5 (middle) and the difference between the two – scaled and inverted (right)

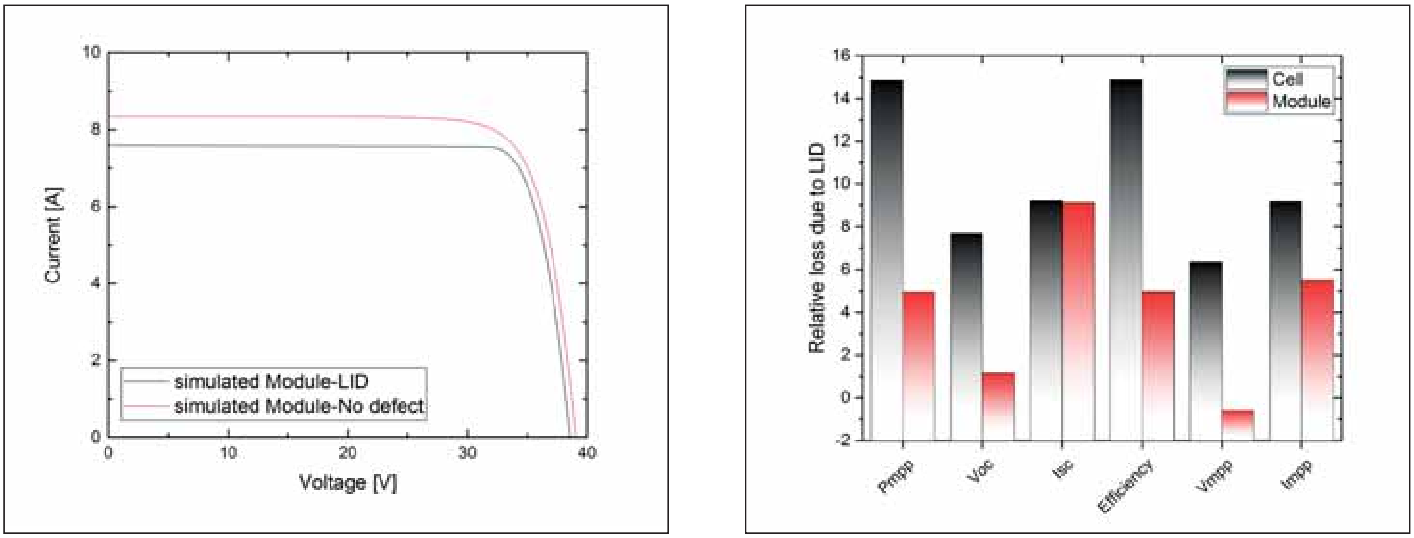


Figure 3. Electric simulations of module parameter losses when 12 cells in a 60-cell standard module show significant LID. Left: IV-curves of a module before and after LID. Right: Relative changes in electrical characteristics of cell and module after light induced degradation

simulations and cost-effectiveness of PV systems. The LID stabilisation test is used for two purposes: first for initial stabilisation in order to check the manufacturing label values by flash testing; and second for assessment of LID after final stabilisation. According to norm (IEC 61215-2:2016) final stabilisation is not required for crystalline PV modules anymore. This made sense for standard crystalline BSF modules since the LID effect was considerably small and occurred during the first hours of operation. However, this is not always the case for specific LID types in PERC technology modules with their particular degradation kinetics. Therefore, Fraunhofer CSP highly recommends the application of final stabilisation tests in LID testing of modules.

The LID stabilisation test consists of a sequence of light exposure intervals of equivalent irradiance dose (>5kWh/m^2). During light exposure the module performs at its maximum power point (MPP) and is kept at constant temperature (50±10)°C. After each interval the module is flashed. If the difference in module power of the last three flashes is smaller than a threshold value defined by the norm the stabilisation is regarded to be finished and the accumulated total irradiance dose required is determined. If not, the procedure is repeated and the next light exposure interval is applied. If the performance loss succeeds 5% after stabilisation the module failed the standard test. However, already a degradation of 5% would have a drastic impact on the levelised cost of energy (LCOE). Thus checking for LID before the investment is even useful when installing certified modules.

Requirements of testing PERC technology modules

There are two problems arising when the degradation rates are small. At standardised conditions (50°C, MPP) it could take up to 1,500 hours (two months) until maximum degradation is reached [2]. This is much more time- and material-consuming (e.g. lamps) than for standard back contact cells with test durations of about 60 hours and makes this test hardly affordable. Since the degradation is slow, it may happen that within the last three intervals of light exposure the difference in power is small enough such that "stabilisation" is detected while in fact it is not reached yet. This way, the measured power loss is underestimated.

Fraunhofer CSP therefore suggests LID indoor testing at elevated temperature (80°C) and under open circuit voltage (VOC). Both effects accelerate the degradation and compensate the effects mentioned above. However, a quantitative correlation with outdoor performance based on acceleration factors and temperature dependence is the subject of ongoing research.

Outdoor LID tests can be performed in a similar way. The irradiance is measured by a reference cell mounted next to the module. The module performs at its maximum power and only irradiance levels above 500W/m^2 are considered for calculating the total irradiance dose required for stabilisation according to norm. Again, open circuit conditions and a thermal isolation of the modules for achieving higher module temperatures can accelerate the degradation significantly. Accordingly, for reproducible and comparable outdoor LID evaluation the definition of standardised test conditions is mandatory.

Fraunhofer CSP is working on these R&D issues beyond standard norm testing within various projects. In particular, various light-soaking chambers as well as a module-level LED sun simulator are used to expose PV modules to various light wavelength, temperature and operation conditions. The LID behaviour of PV modules is characterised through I-V measurements and also through quantum efficiency measurements at module level.

Degradation tests during operation

Testing the long-term reliability of PV installations is not only a task for R&D departments. Also plant owners can evaluate the reliability of their modules during operation. Knowledge of current problems and possibilities for rectification are important for risk mitigation as well as increased yield and production feedback. Thus, low-cost and precise module-level monitoring is needed, for early detection of LID and other performance-reducing issues during operation of a plant.

For these investigations the voltage is usually measured at inverter or string level in a PV system. Yet, voltage measurements from a string during

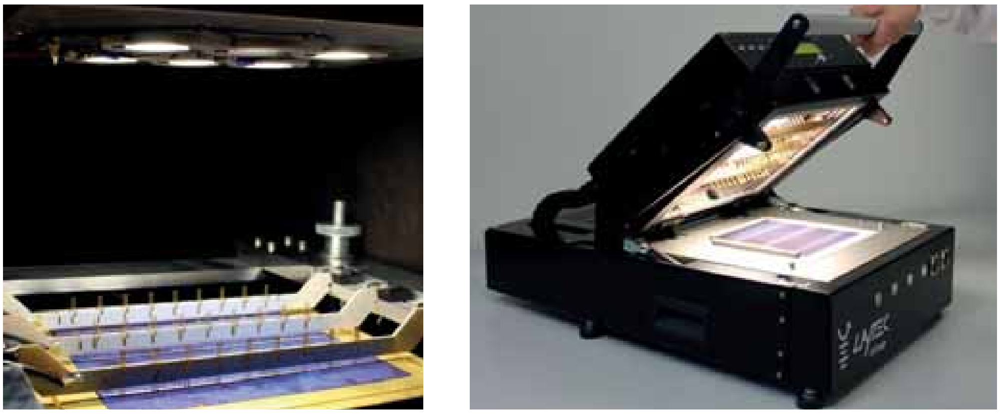


Figure 4. Left: LED-based test set-up at Fraunhofer CSP. Right: Commercially available LIDScope by LayTec AG

operation can be precise, but they are insufficient to detect and evaluate losses that occur on single modules. String voltage is the average of all voltages of strings which are connected to the same MPP tracker. An average voltage value gives no insight into the location and nature of a problem. An alternative for a more detailed evaluation is the SunSniffer technology.

The SunSniffer technology has been in field use for seven years. Its core is a sensor in each junction box and it is seamlessly integrated into PV systems, with data transmitted via powerline communication, thus no additional cables are required. It measures temperature and voltage in each module with ±1% accuracy. In combination with the power measurement data of the strings and the data of irradiation sensors, these data are analysed by an artificial intelligence algorithm. As result, the deviations are recognised and specific patterns can be detected and assigned to certain types of errors [12]. Measurements are made in intervals down to 30 seconds. However, these intervals are non-static, as the system calculates and determines the concrete interval necessary.

LID is detected by its specific voltage and temperature pattern and is automatically recognised. Still more investigation is needed to ensure detection at its earliest appearance. To further improve automated detection, the complex LID pattern needs to be scrutinised more deeply. Permanent module-precise measurements and their analysis enable continuous refinement of these filters and further comprehension of this phenomenon. For scientific reasons, it would be beneficial to have all modules with PERC cells being measured on a constant basis in order to better understand and maybe even find indications to solve LID. Plant owners would benefit equally.

Degradation tests on cell level

LID tests can already be performed at an early stage of production by investigating the solar cells. This is important for accelerated solar cell developments and quality control during module production. At Fraunhofer CSP, LID test set-ups are developed allowing quantitative and user-friendly LID reliability tests (see Figure 4). These set-ups are suitable for accelerated LID testing as well as simulating field conditions. Two set-ups have been developed based on (1) advanced LED techniques and (2) electrical carrier injection. Both carrier injection by light or by electrical currents lead to the same effect. Using advanced LED techniques, IEC standard module test conditions can be applied to solar cells, mini-modules, or individual components. The second set-up is optimised towards a robust LID test for mass-production circumstances. Electrical carrier injection offers a reliable, robust and controllable degradation procedure that is easily operable and independent from environmental influences. The system is commercially available from Laytec AG, the LIDScope (Figure 4, right).

Mitigation strategies

There are several strategies to mitigate LID: (i) selecting proper wafer material; (ii) optimising solar cell and module production; and (iii) introducing a production step to avoid LID.

Selecting proper wafer material

Most LID defects can be traced back to the wafer material [7]. Hence, a proper choice of wafers can minimise light-induced degradation. For example, to mitigate B–O-related degradation it's important to choose wafers with reduced boron and/or oxygen concentrations. Degradation effects in multi-crystalline silicon solar cells (FeB-LID or mc-LID) can be reduced using wafer material with fewer metal contaminations.

Optimising solar cell and module production

Adaption of the solar cell process can lead to a reduction of various LID types [13]. For example, optimisation of firing conditions reduces the extent of degradation on mc-Si PERC cells. Subsequent

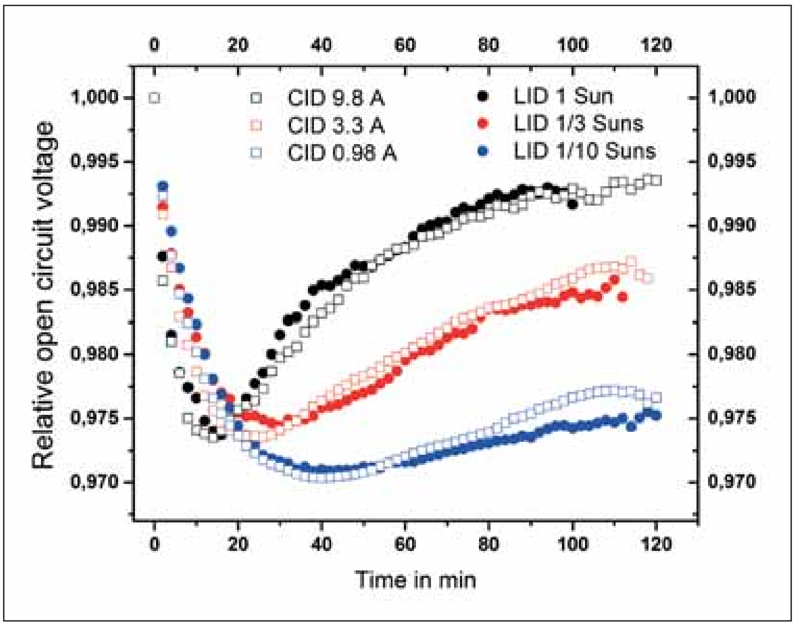


Figure 5. Comparison of LID and CID for different intensities at 140°C on boron-doped Cz silicon solar cells showing B-O LID [16]

treatments can also be carried out, such as illuminated annealing or a second firing step. However, these approaches are lavish and have several disadvantages i.e. no complete avoidance or avoidance to an unknown extent and negative influences on the solar cell efficiency and other parameters.

Introducing a production step to avoid LID

A promising technique is so-called regeneration, which is a subsequent process step within the solar cell production that passivates the LID defects [14, 15]. Typical degradation-regeneration curves are shown in Figure 5. The passivated defects are stable under field conditions. Generally, light and elevated temperature is used to perform regeneration. Several furnace manufacturers, such as centrotherm photovoltaics AG and Despatch Industries, have introduced solutions to the problem. These regeneration processes have the disadvantage that an individual cell treatment and an in-situ process control are not possible. Fraunhofer CSP has investigated an alternative method with more process flexibility. This process is based on an electrical current-induced regeneration for industrial application [16]. The regeneration process can be carried out using forward biasing and increased temperature (Figure 5). The key is a correct control of both temperature and carrier injection. This process is assumed to be more flexible, controllable, scalable and cost efficient than current methods.

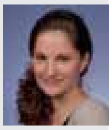
Summary

LID is a critical topic for plant owners, since it can permanently reduce the efficiency of modules by up to 15%rel. Particularly high-performance solar cells are affected, as unresolved LID types have been detected on new material and cell processes. However, this degradation effect can be reduced or even avoided by optimising the cell process or passivating the LID defects. To achieve that Fraunhofer CSP is working on root cause analysis of new LID phenomena and on optimisation of passivation methods. However, LID tests throughout the value chain, as well as dedicated LID test standards in module quality control, are advisable to guarantee long-term reliability of photovoltaic installations. ■

Authors

Dr. Marko Turek studied physics at the Dresden University and received his PhD in the field of condensed matter theory at the University of Regensburg. At Fraunhofer Center for Silicon Photovoltaics (CSP) he leads the team for the electrical characterisation of solar cells. His research focus is on the loss analysis of solar cells, advanced characterisation methods, and the development of new test methods and devices.

Dr. Christian Hagendorf is head of the research group, "Diagnostics of Solar Cells", at Fraunhofer CSP. He obtained his PhD at Martin-Luther-University Halle-Wittenberg, Germany in the field of surface and interface analysis of semiconductor materials. He joined Fraunhofer CSP in 2007 and established a research group focussed on defect diagnostics in crystalline and thin-film photovoltaics. Research interests include optical, electrical, microstructural and trace elemental characterisation of solar cells and modules.



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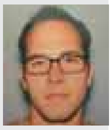
Rico Meier studied in the "International Physics Studies Programme" at the University of Leipzig. Since 2010 he has been working in the reliability of solar modules and systems group at Fraunhofer CSP. His research focuses on development of new ultrasonic methods for advanced material characterisation.

Hamed Hanifi received his MSc degree in electrical power engineering from Brandenburg University of Technology. In 2015, he has started his PhD work in the module technology group of Fraunhofer CSP in the field of simulation and optimisation of PV modules for desert applications.



Marcus Gläser received a bachelor degree in solar technology (photovoltaics) at the "Anhalt University of Applied Sciences" in 2011. After his master degree in sustainable energy systems at the Otto-von-Guericke University in Magdeburg, he started as a PhD student with Fraunhofer CSP in September 2014 working on the carrier induced hydrogen passivation of bulk defects in crystalline silicon solar cells.

Dominik Lausch received a diploma degree in physics from the University of Leipzig, Germany, in 2009. During his studies, he was with the company Q-Cells SE on various subjects, including his diploma thesis about pre-breakdown effects. In 2012, he received a PhD degree in natural science from the University of Halle (Saale), Germany, in cooperation with the Fraunhofer CSP and Q-Cells SE. His dissertation explored the subject of the influence of recombination active defects. He is now team leader at Fraunhofer CSP.

Ingmar Kruse has been developing innovative technology since the early 1980s. In 1983 he founded his first company IPT Image Processing Technologies. He studied business administration in Nuremberg and computer science in Atlanta, USA. As his businesses expanded internationally he signed a deal to build Apple computers under licence in 1995. Ingmar holds miscellaneous patents for technologies in the printing and renewable energy industry. Since 2002 he has been in the photovoltaic industry.

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Project briefing

IRAN'S FIRST LARGE-SCALE SOLAR PROJECTS

Project name: Persian Gulf and Amir Kabir
Location: Tehran, Iran
Project capacity: 7MW each

With United Nations sanctions lifted on Iran in spring 2016, the solar industry was just one of many that pondered the risks of entering this previously restricted market. Just a year later and the Middle Eastern giant can already boast its first two large-scale solar plants, with the project rights developed by local firm Aftab Mad Rah Abrisham, but delivered and wholly funded by German PV specialist Athos Solar.

The two plants, located near the capital Tehran, have a combined capacity of 14MW and are named Persian Gulf and Amir Kabir. Both are spread over 10 hectares each in the province of Hamedan and look set to pave the way for Iran to go big on solar. Statistics from Renewable Energy Organization of Iran (SUNA) in March showed that 34 companies had already signed long-term power purchase agreements (PPAs) for nearly 370MW of solar projects.

Many solar firms have described Iran as a tough country to do business in, so putting up the first ever large-scale plants came with some unique challenges.

Regulation

Many of the classifications and regulations in place in Iran are largely the same as in other countries, says Christian Linder, managing director of Athos Solar.

For example, developers need to use land that has the least ecological value and must remain environmentally sensitive in the construction phase. "They examine the site after you have finished construction [to check] if you have polluted it in some way and it's quite similar to what you see in Europe on regulation," adds Linder.

Nevertheless, regulation is still one of the biggest bottlenecks in Iran since the ministries are not as experienced when it comes to allocating the right customs rates and deciding whether to import equipment or source locally.

"I wouldn't call it problems, it's more like missing experience," says Linder. "Usually the expectations from investors nowadays are that such a site is built within three to four months. This is a very tight timescale if you want to sort out questions with various authorities."

Furthermore, while the Iranian population is well educated and well trained, it also enjoys multiple religious holidays and other breaks during the year, which can disrupt attempts to communicate with authorities and progress with projects. Trying to get confirmations through letters and contracts can also be confusing.

"This is very different culturally," says Linder. "Usually it's a given that agreements are written contracts. Here culturally the gentleman's word or agreement is sometimes more the legal document; even with authorities."

Linder says it would be an interesting development if larger international investors came to Iran and had to deal with misunderstandings over written emails, contracts, word of mouth and indeed legality. This is not to say that Iran does not also suffer the same troubles of development in other countries such as adapting to alternating conditions in winter and summer.

100% equity

The lack of international investors and a generally cautious approach to the historically troubled country, gave rise to one of the most unique factors of the Athos Solar installations. They required nearly €20 million (US$22 million) investment, with the full 100% equity coming from Athos Solar. This is the only way that projects can be financed in Iran at present, says Linder, with financing via banks not yet possible, he claims.

The projects' history started with Tehran-based Aftab Mad Rah Abrisham, a wholly owned company initiated by two business partners from Iran and Ireland, both living in London. As an Iranian special purpose vehicle (SPV), it developed the project rights in early 2016. Later in the autumn, 99.9% of the shares of Aftab Mad Rah Abrisham were sold to a German holding company ,"DISEG", which is 95% owned by Athos Solar and 5% owned by the two men mentioned above. Athos went on to build the project during winter 2016 using an approved EPC firm also from Germany.

One bottleneck in this case was project rights, says Linder, but the partners who developed the site did an excellent job to get the site ready, he says.

However, Linder adds: "The biggest bottleneck – obviously you need to have trust and equity together so that you can finance the whole project on your own."

This risk-taking approach of offering full equity was ultimately the main reason that Linder gives for Athos being able to get ahead of the pack to deliver the country's first utility-scale PV plants.

The projects receive a feed-in tariff (FiT) during the 20-year PPA of €0.16-0.17/kWh.

Credit Huawei


Credit Huawei

By Tom Kenning

The two projects benefit from a higher FiT as the subsidy is split into two categories – above and below 10MW for individual projects. A category for more than 30MW was later added in May last year.

Asked about how Athos sought to bring the overall levelised cost of electricity (LCOE) down as low as possible, Linder says the firm did not prioritise cost reduction, but focused more on meeting its international quality standards to construct a plant that delivers the expected production figures for the next 25-30 years.

The 20-year PPA is with SUNA, but Linder says it's more accurate to call it a 19-year PPA as the contract time starts at signing of PPA and it takes nine to 12 months from PPA signing to complete grid connection.

The site

Ralf Weidenhammer, who is also a managing director at Athos Solar, says site levelling was necessary particularly with the desert ground. In such conditions, if it rains the water stays on the ground, so it becomes essential to have drains or ditches built in to get the water off the site. On the flip side, the desert conditions also bring a lot of dust so Athos is currently evaluating the best possible operations and maintenance (O&M) approach for removing dust off the panels.

"Water consumption is obviously an issue in a desert so therefore we see it as a challenge to have clean panels on one hand and not to waste too much resources in terms of fresh water," adds Weidenhammer. "We currently see it would be most efficient in terms of input and output to use water to clean."

The plants faced restrictions on the size of the plot of land that could be used (10 hectares) as well as a restriction on the maximum export on the AC side. These two factors determined the 7MW size of both plants. Athos had to use low-grade land on which to build the systems. Athos used a local surveyor for evaluation of the landscape and a yield report produced by a German provider.

"We have taken care to start an early communication with all local stakeholders like the farmers and people living in the village around to keep them informed on the development," says Weidenhammer. "In terms of environmental factors, we used the same standards as we use in Germany or the UK, which covers all local requirements and goes in some points beyond this. Keeping the dialogue with the local stakeholders is of major importance."

The Athos executives say that they also received great support from the local governor's office to realise the project. Meanwhile, the German EPC will be in charge of O&M in connection with local partners and site security was handled by Aftab, the Iranian SPV. Athos also commissioned Iranian companies both for preparatory land works and for electrical works.

Components

The projects include 40,000 modules from China-based manufacturer Canadian Solar, while inverters were supplied by Huawei. Both companies are Athos Solar's long-standing suppliers and business partners. The modules are 72 cells with a frame that makes them capable of handling heavy snow loads as well as desert conditions, says Linder. Robust modules were important as the projects are pitched at 1,800 metres altitude and temperatures can range from -20°C to +40°C.

Athos Solar decided against using trackers as the company wanted to keep the project setup as simple as possible, opting instead for a fixed mounting structure from Germany with three modules in portrait formation.

There were several issues during the construction phase, starting with a time-consuming process to get a German export licence and the Iranian import licence. Other challenges included organising the logistics, customs and VAT charges and customs clearance process, lead times on local products such as transformers and ensuring that requested quality standards were met. These factors were particularly important given that the majority of the project components had to be imported to Iran.

"Communication with local suppliers is sometimes difficult due to the lack of communication skills in English," says Linder. "But we want to point out that we did receive quite a lot of help from authorities and Iran is really very much interested in getting on track with green energy."

Both plants were connected to an existing 11kV power line – one connection was done via a ground cable and the other line was constructed on poles. Athos was asked to replace existing poles and install a new wire over a distance of 4 kilometres.

In early February 2017 the two plants officially commenced operations, with both German ambassador Michael Klor-Berchtold and Iranian energy minister Hamid Chitchian present at the ceremony and main TV news reporting on the same evening.

Iran's solar future

The plants were completed within nine months of first contact with the Iranian developer and Athos Solar now plans further projects in Iran. The firm is expecting to complete its next project in the region in around August this year and it is looking for equity investors to secure a better return on investment than going through the bank finance route.

"The overall plan, which the [Iran] government has set up, is to achieve 5GW in solar by 2020," says Linder. "We think by the end of the year they might have finished 250MW in total and after that might be able to do 1,000MW [per year]."

The outlook is clearly optimistic for a country whose market was all but impenetrable just a year ago. But the signs are good: in late April power firm Ghadir commissioned a 10MW solar plant in province of Isfahan with trackers. It remains to be seen whether the momentum can be maintained. ■

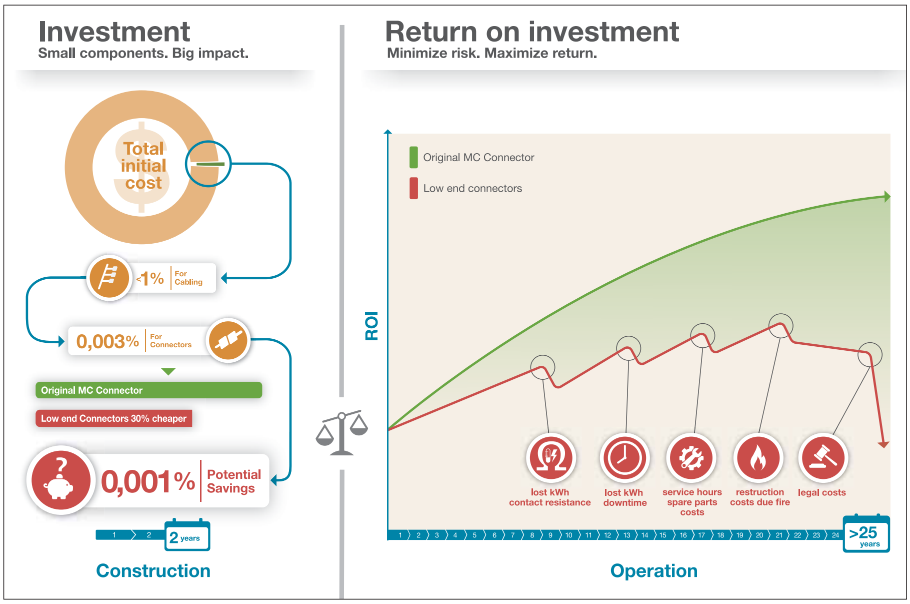
Small components, big impact:
the bankability of Stäubli Electrical Connectors

Bankability is today critically important in the PV business and has become an essential benchmark with substantial influence on investors, banks and other financing institutions. In order to ensure the deciding factors for the long-term success of a PV system, bankable project partners must be acquired. Careful selection of bankable products and components to be built into the system is also a core topic, as these have considerable impact on the bankability of the PV project.

The components for cabling (connectors, junction boxes, cables) often play only a minor role in the calculation as they amount to less than 1% of the total initial costs (capex), for connectors an even tinier percentage (approx. 0.003 %). In sum, potential savings are small – but choosing low-end over quality products may have serious consequences for the efficiency and the profitability of a PV system.

Those apparently minor components can have an ultimately decisive influence on the risks and on the return on investment of a PV project. Saving a few dollars in the short term could greatly increase a project's operations and maintenance costs (OPEX). Furthermore, the risk for power losses, a (partial) system failure/downtime, or even a fire may increase significantly during the operation phase.

As a pioneer and global market leader for connectors, Stäubli Electrical Connectors (formerly Multi-Contact) has amassed over 20 years of experience in the photovoltaics industry. To date, we have more than 150 GW of installed photovoltaic capacity, amounting to approximately 50 % of the global cumulative PV capacity, that has been successfully connected using our original MC4 connectors. This figure demonstrates the reliability and highest quality of our products.



Small components, low costs, low saving potential, but with high risk potential and impact on the ROI of a PV plant.

The core of all Stäubli connectors is the innovative MULTILAM advanced contact technology. Thanks to their constant spring pressure, MULTILAM louvers ensure continuous contact with the contact surface and constantly low contact resistance. This provides for safe and long-life operation whilst reducing downtime and service cost significantly. Furthermore, risks for power loss and hotspots or fire that may lead to enormous reconstruction costs are reduced to a minimum.

By choosing Stäubli, you benefit from profound expertise, extensive support by a global network of trained staff and experts as well as long-life components that keep your PV installation up and running efficiently and safely. Stäubli therefore is your reliable partner when it comes to fulfilling the requirements of bankability and guaranteeing a sustainable return on investment in the long term.

Further information

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About Stäubli

Stäubli is a mechatronics solutions provider with three dedicated activities: Connectors, Robotics and Textile. With a global workforce of over 4,500, the company generates annual turnover surpassing 1.1 billion Swiss francs. Originally founded in 1892 as a small workshop in Horgen/Zurich, today Stäubli is an international group headquartered in Pfäffikon, Switzerland. Worldwide, Stäubli operates twelve industrial production sites and 29 subsidiaries, expanded with a network of agents in 50 countries, delivering innovative solutions to all industrial sectors.
www.staubli.com/en/profile

About Stäubli Electrical Connectors

Stäubli is a recognized specialist for advanced contact technology and sophisticated solutions with a product portfolio ranging from miniature connectors up to high-power connectors for power transmission, test and measurement, transportation and many other industries. In Photovoltaics, Stäubli is global market leader with its MC4 connector components. The core of all Stäubli electrical connectors is the unique MULTILAM contact technology.
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Module technology under the microscope

Modules | PV module technology is more advanced and more varied than at any other time. Having pulled together a throng of senior PV technology experts for our PV CellTech conference, PV Tech's head of market research, Finlay Colville, discusses with John Parnell the need to match these advances with a dedicated event this November

Finlay Colville at the inaugural PV CellTech conference in Malaysia

It's always nice when someone tells you directly that you can't do something to set out and prove them wrong.

PV Tech Power, its sister website pv-tech.org and their publisher Solar Media were told in the early phases of planning the inaugural PV CellTech conference, that pulling together a string of CTOs and R&D heads from the some of the biggest firms in the cell processing supply chain would not be possible. Following the event's second outing in March 2017, we have now done it twice.

Dr. Pierre Verlinden, chief scientist at Trina Solar, Qi Wang, chief scientist at JinkoSolar and Dr. Markus Fischer, director of R&D processes at Hanwha Q CELLS, are among the names that have joined us since. In November his year, we will be putting together a similarly stellar line-up catering for everything that manufacturing a PV module involves once the cell is complete.

"There hasn't been this type of event before," says Finlay Colville, chair of both conference and head of market research at PV Tech. "Our experience from doing the PV CellTech event in the last couple of years is that this is a high-tech industry so showing data to back up the claims and predict future trends is absolutely critical and I'm convinced that module suppliers will gravitate towards this event as being an excellent forum to talk about their products."

The motivation for the conference is rooted in the additional complexity, sophistication and sheer variety of technologies that could theoretically differentiate identical sets of cells rolling off the same production line.

"Similar to cells, modules have really moved on in the last four to five years. It used to be that module assembly was a very low-tech, low-barrier-to-entry part of the value chain. A lot of the work was manual. Now modules are 60-, 72-, even 90-cell [formats]. We will have 72-cell modules exceeding 400W by the end of next year. Multi-busbars on the modules have really driven another level of power increases and there is a significantly greater level of automation on the production lines as well," explains Colville.

"We're starting to see glass-glass, new types of glass, new materials, bifacial modules...Actually keeping track of that, which manufacturers are genuinely producing state-of-the-art modules in terms of power performance and reliability and consistency with the cells they are using, is a huge issue now compared to a few years ago. Back then everyone's module factory was the same and a lot of people were buying cells from just a small group of players."

Changes

These changes in technology are not trifling either. These are not niche developments springing up in isolated pockets. Recent research by Colville has shown that by 2018 the ratio of mono versus multi modules will be around 50:50 (see Figure 1).

The International Technology Roadmap for Photovoltaic (ITRPV) forecasts a less dramatic but more varied shift in the make-up of chosen encapsulants out to 2025. Likewise for module interconnection materials, backsheets, frame materials, metalisation, busbars…the list goes on.

Bifacial modules are waiting in the pipeline to begin grabbing significant share from markets where conditions on the ground, literally, make the additional expense pay back for investors. Trina Solar and SolarWorld are already bringing these to market.

Marketing

While there is never any shortage of people willing to line up and explain why their product is in fact the best, PV ModuleTech shifts the onus on to the technology and bold claims will be backed by data.

As the number of routes to increased power and efficiency grows, with differing side effects for other performance and reliability indicators, the event will look to provide a more transparent approach to assessing the relative merits of these.

"If you look now at how module suppliers back up their claims of being the best there really are very few platforms on offer. Obviously they have marketing collateral that they bring out through their websites, through trade shows, datasheets, brochures, but that is all done in-house. It's not done in an independent platform or forum. The trade shows and the related exhibitions are always 100% marketing platforms as well, so really an independent event to provide that third-party voicing of why modules are performing in a certain way and how the quality, reliability and consistency is there is something that almost all module suppliers would jump at; the industry is dying to get qualified, technology-driven data analysis from an independent source about how modules are put together, the materials used in them and the performance.

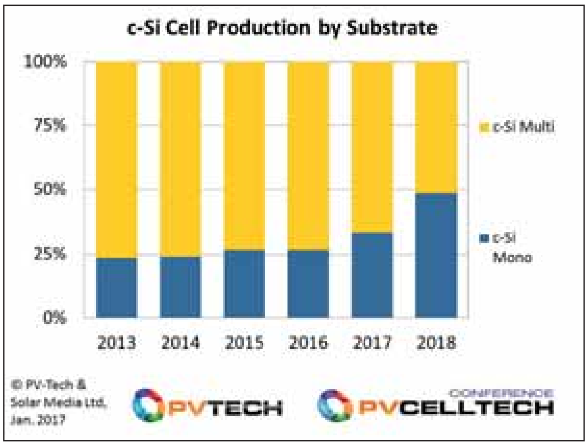
"PV CellTech was designed to fill this gap between the big solar exhibitions that have side events that are unregulated and badly attended ,and the highly academic events like PV SEC and IEEE that are largely there for the academic community to talk about blue-sky research or what is going on in the universities and research institutes.

"If you look at the module side, there is nothing like this and again we have this gap between the big exhibitions demonstrating modules and the module research spoken about at the academic conferences. Again, it's about identifying the overlapping technology with the commercial manufacturing. The key questions are what is happening in the real world and what are the technical issues important to the commercial success of module design and supply."

Benchmarking

As end-market demand and manufacturing capacity have ballooned in recent years, the legacy systems for ensuring a manufacturer was legitimate have become obsolete. Most manufacturers with anything approaching a reasonable amount of capacity are able to make claims that, on paper at least, put them shoulder to shoulder with the largest and most sophisticated manufacturers. This is, in part, the motivation for the conference.

"There isn't a benchmarking process that dives into quality and performance supported by data. There are numerous ranking systems by third parties that have never built a module, never supplied a module and are not in the module supply arena. There are many ranking systems that use weird and wonderful algorithms to generate a top 10, but rarely have these ranking systems been of any use. We've had companies going bankrupt within 12 months of appearing in some ranking systems," Colville points out.



The changing balance of mono versus multicrystalline silicon production in the coming year. Source: PV Tech & Solar Media

"So it's really about having an absolutely independent platform for companies to explain, whether or not they are supplying 50MW of very high-spec modules for the Japanese residential market or it's a company supplying multi-gigawatt volumes to utility-scale companies. These are very different types of companies and they will have absolutely mastered what's important in terms of the module design. But ranking systems try to commoditise and standardise the industry as opposed to really breaking out which modules are best for which environment."

Commodity no more

It is becoming an increasingly difficult argument to consider solar panels as an undifferentiated commodity. Whether it's the increasing data from older assets, and so the scope to identify lost revenue from underperforming plants, or simply the growing choice on offer for different end uses in different geographies, investors are better educated on solar technology than they have previously been.

"The recent pace of technology change in the last few years means a lot of the investment community are asking suppliers, 'Are your modules mono- or multi-? Are they 60- or 72-cells? Are your modules in the US market next year coming out in 400W? Is your module production being specified for residential markets or have you got dedicated 1,500V modules to be used specifically for harsher environments in India and the Middle East?'

"We've got the investment community asking those questions because they realise that a module is not a module. It's not a standard product across all manufacturers," says Colville. "The module suppliers and the whole supply chain of materials and equipment are having to address which are the best modules and why. Not only on the roof or on the ground, but also across different countries, and I think that the investment guys absolutely want to know who has got the modules that will allow the company to grow globally and not be just confined to certain smaller parts of the market or just certain countries because their modules are not going to operate in warmer or more humid environments."

Networking

Part of the attraction of drawing together such a large group of senior PV technology executives is the focused networking opportunity on offer.

"PV ModuleTech will be a dedicated two-day event not in China, not in the US; we've chosen Malaysia again, and over the two days, the only issue on the table is modules. Module quality, module performance, module materials, equipment, certification…That means you end up with a few hundred of the top people globally driving the module improvements, that are behind the certification, the people that are producing the vast amount of modules being used. When you have the key stakeholders together in the same place for a couple of days so the scope for networking and business opportunities is absolutely immense. We saw that at PV CellTech, because of that environment, and we expect the same again."

That is of course, assuming we can get everyone together in the room. We don't think anyone would bet against us this time around. ■

How we put it together

Finlay Colville explains the approach used to ensure PV ModuleTech connects the dots between technology and real-world commercial success.

"Fundamentally, it's a dedicated upstream conference specific to modules. What we're doing internally at PV Tech is a number of surveys and internal research to really identify the top 10 or so categories that are important for module supply. Then we've identified leading experts in each of those ten categories to form a technical advisory board. It is the technical advisory board that then sets the agenda and also determines which companies are the best ones to be invited to stand up and talk about their modules or technology or materials. The next stage is ensuring that we have a senior level technology driven senior executive to talk. It's not a platform for sales and marketing people to convince the audience why supplier a is better than suppliers b,c and d. We make sure we find the right person from within the company as the speaker. So, in terms of the speakers, it is invite only. That means it's altogether a different type of event to one where you have sales and marketing people, often region-specific, basically trying to convince the whole audience that they are the best."

The 'PV System Doctor' – smart diagnosis for photovoltaic systems

O&M | Every photon and electron lost in a PV system represents unrealised revenue. The Solar Energy Research Institute of Singapore has developed a holistic diagnosis package – the PV System Doctor – to identify and cure underperforming PV power plants in real time. The team behind the service explains how it helps maintain a healthy PV system and ensure expected returns – or even surpass them

Do you know how many photons are converted into electrons in your photovoltaic module? Do you know how many of those electrons get lost in the inter-connections and the inverter until they finally reach the revenue meter? Every photon that does not generate revenue reduces the 'health status' of your PV system.

Solar PV has seen an unprecedented growth over the past couple of years with the global installed capacity reaching nearly 290GW by end of 2016 [1]. However, like any other industrial technology, PV systems are also vulnerable to failures [2] due to anomalies in PV modules, other system components or inadequate system design leading to a performance reduction or even a complete breakdown. These negative consequences will lead to unachieved expected returns, which negatively affects investors' confidence to further finance the growth of the global solar deployment.

The need for cost competitiveness and rapid scaling of the industry has caused a number of installation companies to compromise on quality, thereby providing sub-standard products and designs for the installation of the systems. A small underperformance in PV systems, however, cascades to higher revenue losses when analysed over the operational system lifetime [3]. In addition, such sub-optimally performing assets also cause operation and maintenance (O&M) cost to go up, reducing the return on investments even more. Therefore, regular maintenance of PV systems is imperative to ensure optimum operational quality. However, in reality, O&M services are widely employed on an 'as-needed' basis where the owners only react when the systems are in distress. The installation companies usually provide standard O&M services after commissioning such as visual inspections, electrical checks, repair or replacement of damaged components, conditional monitoring of data and occasionally infrared imaging of modules.

It is essential for the industry though to adopt innovative methods to detect actual or nascent underperformance of PV systems for continued growth of the industry and to keep risk premiums for investors at affordable levels. To ensure optimum quality of PV assets and help system owners to maximise financial gains, the Solar Energy Research Institute of Singapore (SERIS) has launched a new industry service – the 'PV System Doctor'.

Motivation

It is often underestimated or not known how severely any deviation from the expected PV system performance affects the cash flow of the project.

Figure 1 shows the cash flow projections of a 1MWp commercial rooftop system in Singapore as an example. Since the city-state does not have monetary support schemes such as a feed-in tariff for renewable energies, the net present value (NPV) considers SERIS' most-likely future electricity price scenario [4]. Based on an initial performance ratio (PR) of 80%, the system would yield an NPV of ~US$500,000 over an assumed 20-year lifetime, with a project internal rate of return (PIRR) of ~12% and an equity internal rate of return (EIRR) of ~18%.

Figure 2 visualises the financial impact on the project cash flow for different degrees of underperformance. A small deviation of 5% in PR (75% instead of 80%) leads to cumulative NPV losses of nearly US$90,000 (i.e. -17% of its expected level), and a reduction of between one and two percentage points in the expected IRRs.

This underlines the need for advanced and innovative O&M services such as the PV System Doctor for early detection, and quick and cost-effective rectification of underperformance of PV assets.

The PV System Doctor

The PV System Doctor is an advanced and innovative O&M service that provides a comprehensive 'health check' for PV systems. The service aims to provide timely identification of underperformance in PV assets and to proactively evaluate solutions to mitigate risks and prevent revenue losses.

Target users are typically PV system owners and operators, investors and insur-

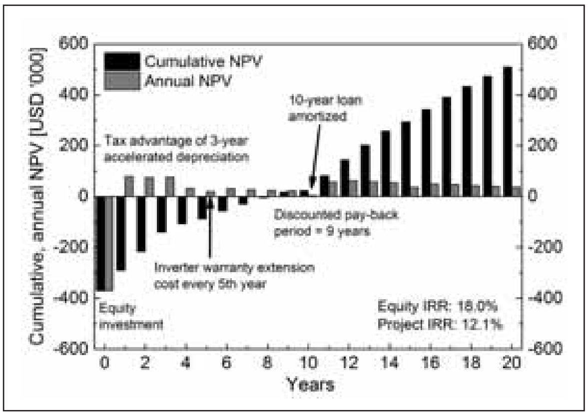


Figure 1: Annual and cumulative NPV, EIRR and PIRR of a 1MWp PV asset on a commercial rooftop in Singapore. NPV = net present value, EIRR = equity internal rate of return, PIRR = project internal rate of return

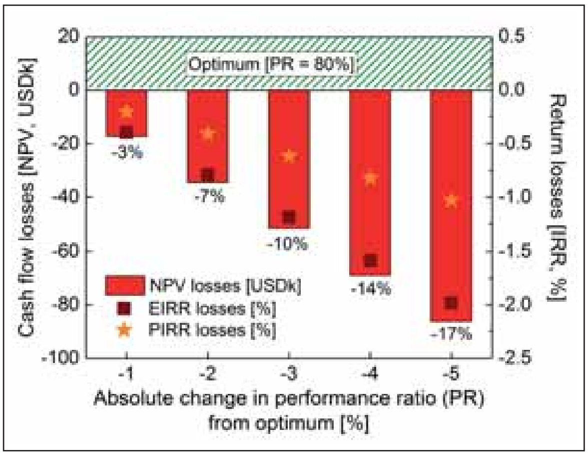


Figure 2. Cumulative NPV losses, EIRR and PIRR reduction due to absolute changes in PR compared to the originally expected value of 80%

ance companies. The three main reasons for calling the 'PV System Doctor' are:

Regular health checks, i.e. periodic independent assessment of PV system performance and benchmarking against expected yield;
Preventive maintenance, i.e. in-depth analysis of PV system performance, including on-site assessments of critical system components;
Detection of actual system faults or suspected underperformance, i.e. independent evaluation of system faults and root-cause analysis of suspected underperformance of PV assets.

The PV System Doctor is comprised of the following professional services that can be employed as an individual service or as a package by interested clients:

- Real-time monitoring of individual strings or system.
- Advanced on-site diagnostics using innovative imaging techniques and IEC-compliant PV system checks.
- Independent financial assessment.

SERIS provides a comprehensive diagnostic report for all these services that includes the recommended rectification works and their cost-benefit analysis.

PV System Doctor services

Real time monitoring of PV strings or systems

For this purpose, SERIS has developed and now is able to offer state-of-the-art performance monitoring solutions for PV installations, from small rooftop systems to ground-based utility-scale installations. The monitoring solutions from SERIS are customisable as per clients' requirements and can provide comprehensive data ranging from meteorological parameters (irradiance, module temperature, wind speed and direction, rain gauge, spectrum etc.) to DC and AC performance of individual strings or systems as a whole. The real-time monitoring of systems and meteorological parameters has been offered by SERIS since 2011 using robust data acquisition hardware with a data transmission and stability of 99.9%. The data is available to the customer through an intuitive graphic user interface (GUI) coupled with big data analytics, on SERIS' secured customer portal.

SERIS' monitoring solution integrates the meteorological data such as irradiance and module temperatures, and DC and AC data from PV strings or system for continual assessment of performance ratio. The monitoring hardware also has the capability to interact with the installed inverters for verification and/or control. This enables early fault detection by continuous benchmarking of:

- String performance against each other;
- System performance against simulated behaviour under optimal conditions;
- Plant performance against peer installations.

Only with such comprehensive analytics is it possible to detect any underperformance and develop rectification strategies in a timely manner.

It is noted here that the early-fault detection can also be carried out by using data from any type of existing PV monitoring system that is already in place, meaning additional investments in hardware may not be required.

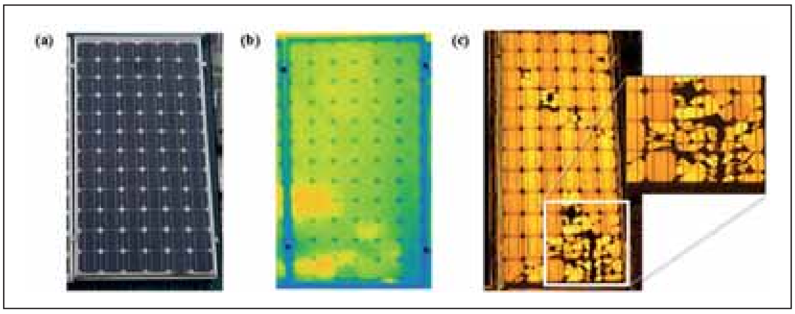


Figure 3. Representative comparison between (a) visual image (b) infrared (IR) image and (c) daylight electroluminescence (DEL) image of a PV module with severe micro-cracks

Advanced on-site diagnostics of PV systems

Remote monitoring solutions can provide an insight into the quantitative aspect of the PV modules or systems as a whole. However, the root cause of losses in a system often remains a question unanswered without an on-site inspection. Therefore, it is essential for the system doctors to carry out certain on-site diagnosis to find the reasons for the underperformance and develop solutions to improve the health status of the PV systems.

Standard O&M contracts include IEC-compliant services for visual and electrical checks. In addition, qualitative measurements of the PV modules are occasionally carried out using infrared (IR) imaging. The IR images capture unusually high temperatures in operating PV modules ("hot spots"), providing hints about defects in modules. However, it is very difficult to detect macro- or micro-cracks in the modules, which gradually will lead to power losses. Therefore, in addition to providing these IEC-compliant services, SERIS'

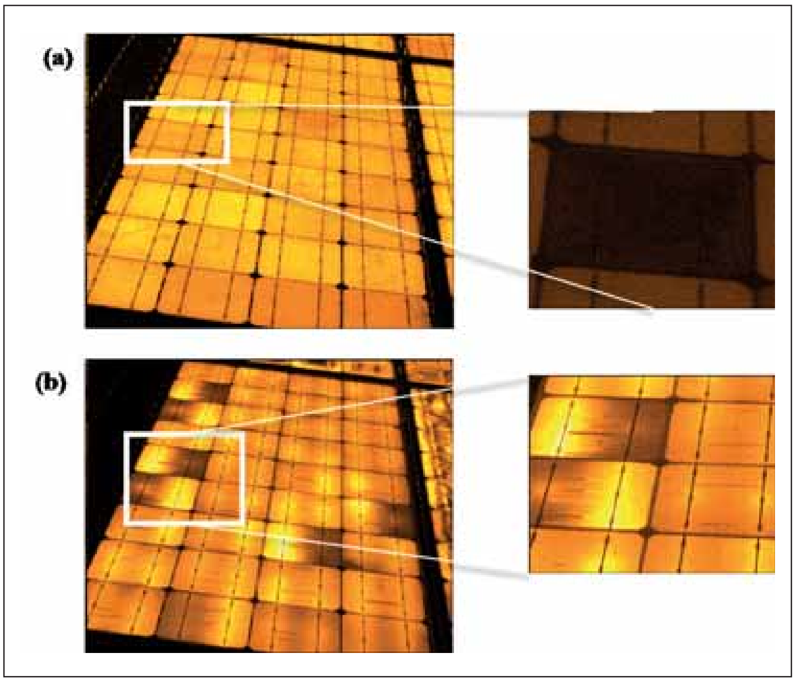


Figure 4. Comparison between (a) DPL image (contrast adjusted) and (b) DEL image captured for a PV module on-site in a 10-year old PV system in Singapore

PV System Doctor also employs highly specialised mobile daytime luminescence imaging technique to inspect the quality of PV modules either individually or as a complete string without removing them from the frames or from the site. The daytime luminescence system is an in-situ, non-destructive technique that provides information on material or electrical defects in PV modules or strings. The technique is capable of performing both daytime **electro**luminescence (DEL) and daytime **photo**luminescence (DPL) imaging.

Figure 3 shows a representative comparison between optical, IR and daytime electroluminescence (DEL) imaging of a module with cracked cells. These images have been captured on-site at the same time under identical irradiance conditions for comparative analysis. It can be clearly observed that the DEL image provides a much greater wealth of information compared to the IR image, which does not show any abnormally high temperatures of the affected areas.

The DEL technique employs electrical excitation of PV modules or strings, thus causing radiative recombination of injected carriers as photons emit from the surface of the PV cells. The intensity of the emitted luminescence is dependent on the electrical and resistive properties of the cell, thus areas of high series resistance result in low luminescent areas. This helps in mapping out bright and dark areas, thus identifying various defects in the PV modules. The DEL technique allows the detection of a multitude of defects such as micro-cracks, electrical shunts, broken contacts and interconnects, and many more.

On the other hand, the DPL technique employs sunlight as an excitation source to generate carriers. The material impurities or anomalous material compositions cause a loss of carriers in the flawed regions, thus affecting the emitted photoluminescence signal. DPL allows identification of material quality of the cells of the module, intrinsically or mechanically induced shunts and potential induced degradation (PID) defects.

Figure 4 shows a representative comparison between DPL and DEL images captured on-site during daytime for a PV module installed in a 10-year old PV system in Singapore. The DPL image shows darkened cells, which indicate the degrading material quality of the cells whereas the concentrated dark areas near the busbars and fingers of the cell in the DEL image show the electrical interconnection faults in the cells of the PV modules. Such defects lead to underperformance of the affected PV modules and eventually cause yield losses in the PV system.

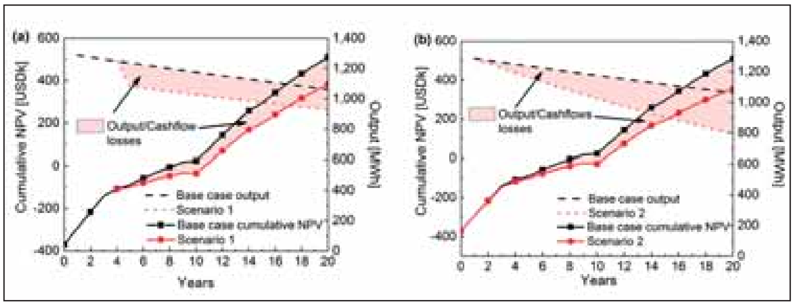


Figure 5. a) Cumulative NPV profile impact from a 50% underperformance of 25% of the modules, b) Cumulative NPV profile impact in case of accelerated degradation (2.5% p.a. as opposed to 1% assumed in the yield assessment), e.g. due to soiling and/or poor maintenance

Independent financial assessment

The possible root causes of sub-optimal performance of PV systems greatly varying from component defects to design-related issues or poor installation. A report on the long-term performance of PV systems [5] by the International Energy Agency (IEA) discussed real-world systems where performance ratios were significantly below optimum. While a nine-year old system in Germany, for example, had a PR as low as 50%, severely suffering from degradation of the PV cells, another 13-year old system in Italy experienced several unplanned outages, causing the annual PR to fluctuate significantly from 25% on the low side to 70% on the high side. Such underperformance in PV systems, if not detected and rectified within an appropriate time frame, can lead to significant revenue losses over the operational life of the system.

Using the 1MWp rooftop example as discussed before, two different scenarios of system underperformance are illustrated in Figure 5 to visualise their negative financial implications, in case no rectification work was implemented:

a. Scenario 1: A collective underperformance of 25% of the installed PV modules (only reaching 50% of the rated power anymore);
b. Scenario 2: Degradation of the PV system by 2.5% (rather than the 1% as assumed in the original yield assessment), e.g. due to excessive soiling and/or poor maintenance.

While the first scenario results in a sudden drop in output in year five, the second scenario shows how a small deviation in degradation might appear small in the beginning but, if left unchanged for the whole lifetime, can cause similar substantial losses in cash flows as in scenario 1. Thus, the scenarios highlight the requirement of a preventive approach to O&M using real-time monitoring systems that can alarm the project owners to request for a timely health check of their PV systems. In addition, for existing underperforming systems, a detailed cost-benefit analysis will be performed to decide whether potential rectifying measures are worth to invest in.

While real-time monitoring and early detection of underperformance can help to reduce unplanned outages, a probability-based technical risk impact assessment (Figure 6) can also be conducted to mitigate

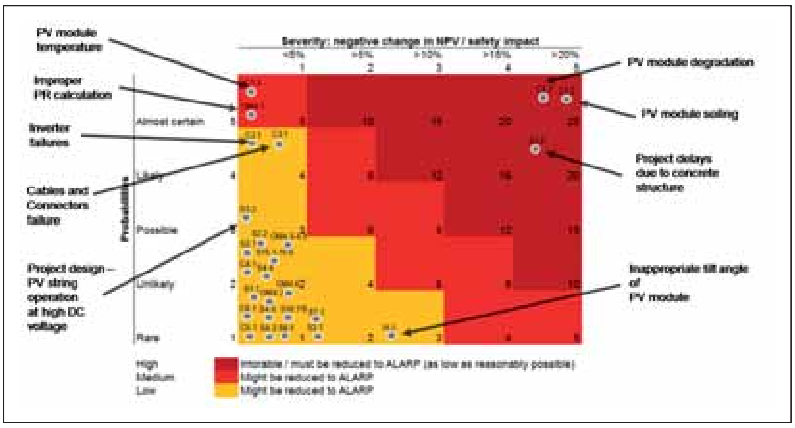


Figure 6. Example of a SERIS probability-based impact assessment of various technical risks illustrated in a mapping matrix. Method adapted from [6]

potential system underperformance in the future. All possible technical risks need to be identified, categorised and mapped based on their probability of occurrence and severity. The latter should not only be in quantifiable units (for example change in NPV or change in EIRR) but also in non-quantifiable units, such as safety impacts etc.

Conclusion

To allow a steady growth of sustainable investments in the PV systems industry, it is critical to maximise production with as little downtime and degradation as possible, over the entire operating life of PV assets. The complete financial value chain from upstream to downstream PV industry relies on the performance of these PV systems. In response to these needs, SERIS has developed a unique capability – the "PV System Doctor", a preventive and innovative O&M service that can contribute to realise and even surpass these goals. ■

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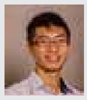
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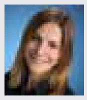
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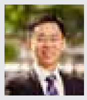
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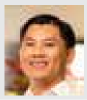
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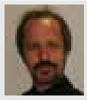
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IEC 61724-1: what's it all about?

System monitoring | The international standard guiding the monitoring of PV systems has been revised to include greater emphasis on accuracy. Will Beuttell of EKO Instruments explains some of the key aspects of the revised standard and how it will help satisfy the maturing PV industry's appetite for better quality data on plant performance


Credit EKO Instruments

While many countries have raced over the last decade to install PV), the community developing the standards has struggled to keep pace. In addition, the larger projects have required greater amounts of data and analysis to track system efficiencies. As these projects have become larger, so has the risk associated with financing and ensuring profitability. How can you assure investors that the project is producing the financially needed power as predicted if the sensors and metrics are ambiguously defined and/or vaguely understood? What could be causing your project to under- or perhaps over-perform? High fidelity data is needed, but in what format and how can you get it?

If you were an owner of multiple sites, would a small commercial site report match your utility-scale project? One monitoring company may provide variables that are not needed or in other cases lacking when compared to another. With this high amount of variability in monitoring information, a detailed standard was needed. The International Electrotechnical Commission (IEC) in 1998, published a standard labelled 61724:1998, and while it has served some purpose, a more mature industry requires greater direction and precision than in the past. This article seeks to shed some light on the recent changes to the IEC 61724 standard especially as it pertains to section one (IEC 61724-1), 'Photovoltaic system performance-monitoring'.

The need for better data

Most of the changes to the standard include additional information on measurements, which has facilitated a clear and welcome monitoring system classification. By providing this classification system, all stakeholders can assess the quality of their monitoring efforts as well as decide what modifications to the monitoring system will yield in tangible results. The adherence to this classification system should be explicitly stated in a declaration of conformity. This declaration is used in the final commissioning and due diligence of the project. As an EPC, a plant owner, or an ISO, you now know your monitoring system is at a particular level of justified performance.

Besides the simple calculation of performance ratio, standardised monitoring systems provide stakeholders with information about trend analysis and potential faults or problem areas, as well as insight into alternative configurations and placements of various instruments to help them gain the information and validation the plant needs. The original 61724 standard understood the basic connection of many variables such as irradiance and power output as well as their coupling to one another, but there was a limited understanding of the variability in the quality and performance of the instruments/sensors as well as the data those sensors provide.

While the case for higher accuracy is perhaps intuitive for utility-scale projects, what is large in one region may not be in others. California Independent Service Operator (CAISO) making a broad requirement may not be extrapolatable to the solar industry in Japan. Therefore, one approach cannot work for everyone. Going from 1MW to 100MW is an entirely different effort and any vagueness of specifications could cause problems down the road, costing thousands or millions to the owners. However, placing strict requirements of high-level monitoring on a commercial project may result in an unjustified cost for measurements. The IEC standards group realised this situation and defined distinct levels of classification to help maximise the monitoring of all projects.

Standards for the accuracy of sensors is one of the key aspects of the new IEC 61724-1

Classification

As mentioned earlier, part of the major improvements to the standards was the establishment of a course classification system. This system defines three levels or classes of monitoring systems with emphasis placed on the following areas:

- Accuracy of individual sensors and measurements
- Frequency at which the measurements are made and data recorded
- Recommend number of measurements based on the size/scale of a project
- Requirements for servicing and maintaining the instruments (cleaning, calibration, etc).

Once a monitoring system is installed, users can perform whatever analytics they

choose as long as the system provides them with the needed data. Each monitoring system classification provides a guideline as to what analysis a user can expect to perform. Each monitoring system class places higher requirements on these areas as well as the accompanying data analysis. Similar to the variation in PV project cost using these monitoring systems, there is a variation in cost for the monitoring system. The IEC standard committee took this into consideration for the classification system. Information on the required measurements can be found below in Table 1.

From lowest cost and requirements, you have class C, which represents the basic accuracy required by IEC, followed by the medium accuracy system of Class B. Lastly, at the top, is the premiere Class A system. The only consistently required values across the classes being reported are solar irradiance and ambient temperature. As your classification level increases, so do your requirements for measurements, calibrations and maintenance. Table 1 provides insight into what applications plant operators can perform or achieve with each class of monitoring systems with IEC 61724-1.

Each class has a particular user group that will find the requirements more in line with their project efforts and goals. Starting with class C, we can see this to be the minimum requirements to having a successful monitoring system. Smaller commercial and primarily residential users will find this approach best for their application. With having only a basic system assessment, the user is free from additional hurdles and able to install less expensive instrumentation. While not the most accurate, the user will still be able to correlate system performance based on the prescribed inputs but with reduced confidence compared to the higher classification systems. Class B yields better accuracy but requires additional measurements and analysis. Most likely this level will not be used for residential applications but for small commercial and very small utility projects. Class A requires the highest level of accuracy of measurements and analysis. This class would be reserved for the projects and clients most interested in validating their design and detecting trends towards assuring a financially successful PV project.

Parameter	Symbol	Units	Monitoring Purpose	Required? Class A High Accuracy	Class B Medium Accuracy	Class C Basic Accuracy
Irradiance						
In-Plane Irradiance (POA)	G_i	$W \cdot m^{-2}$	Solar resource	√	√ or E	√ or E
Global Horizontal	GHI	$W \cdot m^{-2}$	Solar resource, connection to historical and satellite data	√	√ or E for CPV	
Direct Normal Irradiance	DNI	$W \cdot m^{-2}$	Solar resource, concentrator	√ for CPV	√ or E for CPV	
Diffuse Irradiance	G_D	$W \cdot m^{-2}$		√ for CPV with <20x concentration	√ or E for CPV with <20x concentration	
Circumsolar Ratio	CSR					
Environmental Factors						
PV Module Temperature	T_{mod}	°C	Determining temperature related losses	√	√ or E	
Ambient Air Temperature	T_{amb}	°C	Connection to historical data, plus estimation of PV temperatures	√	√ or E	√ or E
Wind Speed		$m \cdot s^{-1}$	Estimation of PV temperatures	√	√ or E	
Wind Direction		degrees		√		
Soiling Ratio	SR		Determining soiling-related losses	√ if soiling losses expected to be ≥2%		
Rainfall		cm	Estimation of soiling losses	√	√ or E	
Snow			Estimation of snow-related losses			
Humidity			Estimation of spectral variations			

Source: IEC-61724-1

Table 1. Irradiance and environmental measurements required for each classification.

Irradiance measurements

Why so much new interest or emphasis on the irradiance measurements? For years, irradiance sensors as part of required weather stations have troubled the industry and at times been problematic in the monitoring system. While some companies strived for low-cost solutions some companies wanted highest accuracy but no one could agree on how many sensors would yield real results. Problems became more evident when high-quality monitoring systems were installed in locations but with an irradiance sensor that had serious limitations due to the specific sensor technology. Certain technologies have different strengths and weaknesses. Some sensors have angular response or spectral issues, others have issues with thermal offsets, and the range of response times can vary by approximately two orders of magnitudes (0.3 seconds to 30 seconds @ 95%).

For almost 30 years, the International Organization for Standardization (ISO) and the World Meteorological Organization (WMO) have established a course classification system for these solar radiometers. Each class defines specifications for properties of the sensors that contribute to overall measurement uncertainty. ASTM will soon follow in creating their own classification system. Having quality measurements aids in developing a dataset that allows the decision makers to effectively optimise their power generation periods. While forecasting offers to potentially answer this problem, you must start with quality measurements of solar irradiance.

Now that higher accuracies and reduced uncertainties are required for better monitoring systems, the use of high-quality thermopile detector pyranometers is explicitly defined and needed. ISO 9060 gives more detailed information on the classification of pyranometers. In this document, the standards community sought to provide insight into the performance areas of the devices and to classify the sensor into three groups. From lowest to highest quality you have second class, first class and secondary standard. There is no primary standard for pyranometers so if you want the best you

Table 2. Number of sensors to be deployed for the respective PV project size. Depending on the classification (A, B, or C) the user will need to install all corresponding irradiance measurements in the necessary numbers shown

System Size (AC)	Number of Sensors: Irradiance Measurements	PV Module Temperature Measurements
< 5 MW	1	6
≥ 5 MW to < 40 MW	2	12
40MW to < 100 MW	3	18
100 MW to < 200 MW	4	24
200 MW to < 300 MW	5	30
300 MW to < 400 MW	6	36
400 MW to < 500 MW	7	42
≥ 750 MW	8	48

Source: IEC 61724-1

go with the ISO secondary standard. The same idea applies for the WMO classification of pyranometers. From Table 1, opposite, you can see that the Class A monitoring systems require a much higher quality sensor for measuring irradiance than the Class B and Class C systems.

The user of IEC 61724-1 will also see the suggestion – and in certain cases, a requirement – for adding a heater and ventilator to the pyranometers. This is an additional add-on. Depending on the manufacturer the cost can vary. Since the standard does not require a pyranometer to have heaters, ventilators and tilt sensors installed internally, all major manufacturers can still comply with IEC 61724-1. This is an important issue to avoid when writing standards. If the standards harm the industry by requiring equipment that is not easily available then the standard will simply be less successful. Most major manufacturers have heaters and ventilators available as external add-ons. Historically it has been considered a best practice to install your pyranometers with a ventilator heater combination [1]. In the case of projects that adhere to this standard, the ventilator will be very helpful at mitigating the effects of soiling and precipitation, especially frozen precipitation. The benefits of heating and ventilating can be seen below.

The heater removes frost and snow while the ventilator help reduce thermal offsets of the sensor by keeping the sensor closer to ambient temperature. Ventilators could also remove dew and soiling of the pyranometer outer dome. The heaters would not usually be operated continuously but instead would be switched on, based on conditions. IEC 61724-1 also requires Class A system to use inclinometers with digital outputs as well as GPS receivers for making pyranometer orientation measurements. While the pyranometer specified can be a high accuracy device, if it is installed improperly then the improved measurements are lost due to user error. Inclinometers and orientation equipment will be important as the problems caused by misalignment are rather large [2]. The issues caused by these alignment errors have been known for quite some time as evident in Figure 1. Fortunately, these positioning devices are easily available in the industry. By levelling and orienting your sensors properly as well as keeping the optics clean and clear, you will reduce user errors, decrease your measurements uncertainty and increase the fidelity of your data.

As mentioned earlier, the classification of irradiance sensors has greatly improved in this version of the standard. In addition, the classification places new requirements on the recalibration periods and cleaning schedules. Calibrations are critical to maintaining the highest level of confident performance throughout a project's lifetime, thus having the highest accreditation of calibrations from the beginning is needed. Class A irradiance sensors under IEC 61724-1 need to be recalibrated annually.

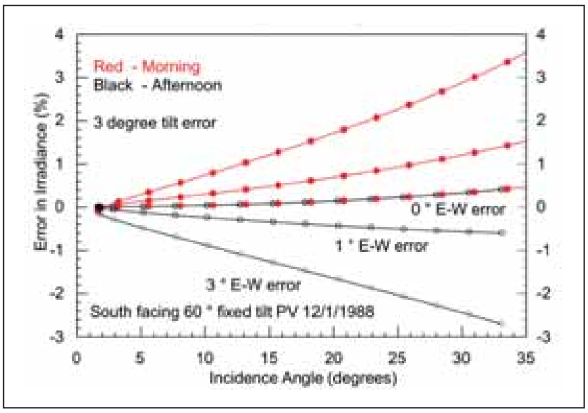
In addition to recalibration, properly maintaining a clean sensor is important. Usually this means wiping the dome and removing the deposited material. Sometime water is needed to lift off the material. Rarely if ever is alcohol or some cleaning solution is needed. Depending on the location the sensors are deployed in, rain can provide some ability to clean the sensors but in other cases the rain can actually deposit more material. This all must be considered by the site operators and the operations and maintenance (O&M) companies. This rain or dew also affects the measurements. Frost too can occur, which is why IEC places a requirement for ventilators and heaters.

Clipping and curtailment

Curtailments and clipping are large concerns for renewable energy projects. Fossil fuel generation uses a model where the fuel costs are relatively fixed and the power can be made at any time. Renewables have no cost for fuel so there are no saved expenses by not being in operation, and in the case of solar, there is only a portion of the day where you can achieved peak power. Accurately predicting and planning for produced power helps grid operators maintain stability and help plant owners achieve profitability. Through adherence to improved metrics via IEC 61724-1, the PV industry should be able to reduce the number of issues that occur while operating a PV site.

While it has been somewhat common to oversize inverters, having more accurate site data will aid in predicting the amount of energy available as well as gained or lost due to inverter capabilities. In the case of a time of use pricing structure, the oversized array-to-inverter ratio will help produce more power during periods of higher payment.

If curtailment is a problem then this standard should help in reducing the frequency and duration of the curtailment period, all adding to the overall profitability of the solar project. While the improved



Credit EKO Instruments Japan

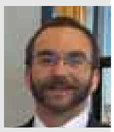
Figure 1. Levelling error in irradiance measurements

accuracy of the data through adherence to IEC 61724-1 is nice to see in real time, the calculated metrics using that data are more important as they provide operators the ability to more accurately know current and to predict future power production. This prediction, if more accurate, will help regions reduce curtailment by reducing the conventional power generation source contribution to the baseload due to the inherent variable generation of PV. While additional resources will also be needed such as increased storage capabilities, this increase in highly accurate data is a critical first step. IEC 61724-1 provides much more detail on the required metrics to accurately show plant power output.

In summary, we will need to see how the industry adopts this standard completely. As for the USA, it seems every region has its own rules. Perhaps the standard will bridge those gaps and create some consensus on how to measure and report data. Hopefully moving forward, the industry does not change so much that the standard becomes obsolete too soon.

The new standard is available from webstore.iec.ch.

Author



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O&M in storage: optimisation and maintenance

Battery storage | Operations and maintenance is becoming an important subset of the fast-maturing solar industry but is not yet as clearly defined in the less developed storage business. Andy Colthorpe reports on how efforts to get the most out of battery systems are focused on optimising assets to provide maximum value across a range of markets

Credit Younicos

In solar PV, operations and maintenance (O&M) is big business. In mature markets such as the UK and Germany, where the booming construction phase of the utility-scale PV segment has quietened down, providing cleaning, security, monitoring, forecasting and a whole range of other services has breathed new life into the industry. Analysis firm IHS has forecasted that in North America alone, the O&M market will be worth a billion dollars by 2020, while GTM Research claimed in 2016 that the global utility-scale solar PV O&M market for that year was close to 182GW in total.

Operations and maintenance, in the sense we would apply the term as a service industry segment of solar, simply does not exist for battery storage systems. Third-party maintenance of large-scale battery storage systems is unheard of, with fault repair the responsibility of system integrators and manufacturers. This means the maintenance aspect is more a question of troubleshooting as and when necessary, and while different project developers or system providers have different strategies to do this, it's generally a simple case of automated fault-finding and cloud-based alerts.

O&M in energy storage is primarily about maximising the value of batteries across multiple value streams

O versus M

Adriana Laguna, low carbon technology manager with UK distribution network operator (DNO) UK Power Networks, is responsible for overseeing O&M for the Smarter Network Storage project, a 6MW/10MWh large-scale front-of-meter battery system that has been trialling the use of energy storage for peak shaving and grid services. Laguna says that maintenance of even such a large plant is mostly restricted to a six monthly check up to ensure optimal performance.

These include "the calibration of the batteries to identify the battery degradation levels, software upgrades, inspection and relevant work on the power conversion system and all connected electrical equipment such as the Uninterruptible Power Supply (UPS) systems installed on site," Laguna says.

Similarly, Phil Hiersemenzel, communications director at storage system integrator Younicos, says that a lot of maintenance is "software updates and things like that", adding that while this makes it seem like a routine set of activities, where projects are remotely monitored and problems fixed either remotely or on-site, it remains a vital part of the project's lifecycle.

"I think it's very important that you have it (maintenance), it ensures the availability of your asset and maximises that so it's very important. But not all important things are sexy!"

Meanwhile, it's in the 'O' of O&M that we find some of the most interesting activity going on – in other words in the operation of a battery storage plant, determining what it actually does, what services it provides, when it exports to or charges from the grid, whether it 'stacks' one or more services on top of each other for diversified and multiple revenue streams, can ultimately determine what the energy storage system earns in economic terms, which stakeholders it benefits and how long it will be capable of doing so.

"From the start point with the battery there are a lot more permutations of things happening," says David Hill, director of business affairs and corporate management at UK demand response aggregator and latterly battery energy storage operator Open Energi.

"The strategy is very different to solar – because solar's just on one strategy: export when you can and get as much subsidies as you can, or if it's subsidy-free you're still looking for a contract with an off-taker to take everything at a certain price. Whereas the economics of a battery mean you're trying to operate within as many different types of market as possible to recover the capital invested."

The price of lithium-ion batteries has dropped drastically since they were first made commercially available at the beginning of the 1990s. But although the price drops in some ways mirror the downward trajectory seen in solar panel pricing, batteries are still a relatively expensive asset. This means deploying a battery for time-shifting solar production, or for backup power alone, is not hugely economically viable, outside of certain territories such as islands and remote areas with existing high electricity prices, fossil fuel import costs and/or lack of reliable grid power, where solar can be made dispatchable and immediately more competitive with a battery attached.

> "The economics of a battery mean you're trying to operate within as many different types of market as possible to recover the capital invested"

Luckily, the versatility of batteries as a kind of 'Swiss Army Knife' for the grid means that they can provide multiple 'stacked' services – which mean a 'stack' of revenues can be accrued as well. Open Energi is responsible for the day-to-day operations – but not maintenance – of Europe's first commercially installed Tesla Powerpack, a 500kW system in England co-located with an existing solar farm. As Hill points out, it's the commercial strategy of a project that defines the O&M of a battery storage asset.

A balancing act

The key crux of O&M for battery energy storage systems is the balance between extracting maximum economic value from the asset and extracting use from it, ensuring the battery does not wear out. With the emphasis on the former, Hill says that for energy storage installations in the UK and many other territories, the most lucrative use of the battery is in frequency regulation markets, in Open Energi's case to keep frequency of power in the grid as close to 50Hz as possible. On top of frequency response contracts, commercially installed batteries commonly also provide peak demand reduction services to reduce grid power consumption onsite, while they can potentially also be used in capacity markets and for energy trading. All of these uses will have different operating parameters and economically optimal windows, but the key thing is not to overdo any of them or bring them into conflict.

"What you're trying to do is maximise the value over a period of time, because that battery will have been bought with some sort of understanding of a return on investment (ROI) or an IRR. It might require four to five years under that strategy to pay off the capital and you've probably signed it on a deal of 10-15 years so what you want to do is make sure that battery last 15 years, basically," Hill says.

"The main issue there is degradation. Every single time you charge and

Credit S&C Electric

The UK's Smarter Network Storage battery projectin Leighton Buzzard has been able to play a role at local and national levels

discharge the battery, it degrades the lithium-ion cells."

So a battery has to be used carefully and within the parameters defined by the battery or whole storage system manufacturer/integrator. As Hill points out, flexibility is often built into the batteries by manufacturers who might oversize them deliberately to give the operator a little room to breathe, while for his company's part, building on its experience in demand response, Open Energi automates the running of its plants as much as possible.

"We've built our whole R&D team around real-time machine-learning control algorithms that can optimise many different types of assets in relation to a range of constraints… We've developed a lot of sophisticated software that can optimise output against a range of constraints, be it state of charge, throughput on the battery, a physical connection from the field, all these different things."

The other aspect of this balancing act is the type of contract entered into when a project is delivered. For instance, in the case of the Smarter Network Storage project, Adriana Laguna says that as a grid-scale trial project, the battery is "primarily designed to support the local distribution network during periods of high electricity demand and keep the lights on" in the local area.

"Operationally, during these time-windows the technical considerations are a priority over the economic considerations, as the plant cannot be utilised for the provision of other high-value services and can stay idle for a prolonged period of time.

"Nevertheless, the last two years of operating the SNS, we have identified synergies between providing local network relief and reducing congestion at a national level complementing both technical and economic considerations," Laguna says.

O&M for a commercial fleet

Larsh Johnson and Gabs Schwartz, chief technical officer (CTO) and marketing director respectively of US intelligent commercial energy storage provider,

> "The [energy storage] industry is also 10 years behind solar in terms of market penetration, and so even though maybe at some point we will see separate, independent O&M providers, I don't see that happening for the next 10 years"

Stem, agree that energy storage O&M is far more about 'O' than 'M'.

"Storage, compared to almost any other energy technology, is not really a hardware-based value proposition. Once the storage system is there, it's basically just an empty battery that has the capability of storing a certain amount of energy, "Schwartz says.

"What makes it valuable is the operation of it, pretty much second by second every day, for the entire life of the asset – a smart brain if you will, telling it exactly when to charge and discharge in order to provide its intended value; you can call that the 'O' of the O&M but we think of it as the entire business that we're in."

While to the end customer, the greatest value of Stem's systems is in reducing the demand charges that can make up as much as 50% of a commercial or industrial energy user's bills, the company's systems could be providing five or six different services "throughout a 24-hour day or 30-day monthly period". While this core function remains the system's priority, if a system was only reducing demand charges, it could be idle as much as 85% of the time, Johnson says. For some of the rest of that time it can be supporting the grid with ancillary services, alleviating grid constraints or trading in capacity or wholesale markets. Stem has two teams that take care of the bulk of the 'O', albeit running as many automated processes as possible.

"We have a network operation centre that's monitoring and using our software tools to detect any issues that require some kind of maintenance or field visit or any kind of tuning or adjustment of the system; that's sort of an operational team," Johnson says.

"At the same time we also have a data science group. Their job is to be looking at the data coming back and using data science techniques to mine that for clues as to how we can continue to improve the operations and then they use that to enhance or redevelop our algorithms to accommodate that new learning that they've come through from monitoring and observing the systems over the several million operating hours."

Stem has also made a name for itself in aggregating its fleets of installed behind-the-meter systems. Johnson and Schwartz say that this has several benefits from an operational standpoint, both technically and economically.

"Here's the benefit of having a large fleet – you have diversity in the system and so, what we see is the diversity in the different sites allows us to configure the system and set the rules and use the artificial intelligence processes to continually improve the way we optimise value across these multiple sites and in our offerings. As we do that, we're taking advantage of the fact that not all fleet participants are in the same place doing the same thing at the same time. That gives us a lot of flexibility around what we do. We typically see 80%+ state of charge across the entire networks and so we're able to use that flexibility," Johnson says.

A question of maturity?

One other obvious difference is the maturity of the respective 'parent' industries. While batteries have been around for over a hundred years in their modern form, their use for stationary storage and solar storage is relatively new. To put it bluntly, solar has more than 10 years of experience as a 'mainstream' industry, with mass manufacturing and scaled deployment. From the ground-mount boom of the early 2000s, to markets that are now maturing, offering O&M as a standalone service has grown as an industry in its own right. Everything from the use of novel brushes and robots for panel cleaning to cloud-based security can quite legitimately be bundled into the provision of O&M, often by a third party to developers or project owners.

For instance, as detailed in *PV Tech Power* Volume 8, solar O&M has grown up to the point that trade association Solar Power Europe created an O&M 'taskforce' in 2015, to create quality benchmarks for the provision of these services, and to standardise approaches where feasible. Similarly, Sandia Labs and the National Renewable Energy Laboratory have drawn up a series of best practice documents for the US market along with the Sunspec Alliance.

In contrast, no such documents exist for energy storage – as yet, although best practice guidelines such as DNV GL's GRIDSTOR are starting to emerge. More critically, in terms of the differences between solar and energy storage O&M, maintaining and operating an energy storage system, be it grid-scale or commercial, is rarely contracted or sub-contracted to a third party. Younicos' Phil Hiersemenzel says that with the differences in configuration and applications each battery system is used for, the level of knowledge of each system required means that it is perhaps better left to the various project partners and the battery manufacturers themselves – at least for now.

"One difference between batteries and solar is that in solar it's a lot more of a commodity – batteries are a commodity too, but they're more specific in terms of what each battery looks like. The [energy storage] industry is also 10 years behind solar in terms of market penetration, and so even though maybe at some point we will see separate, independent O&M providers, I don't see that happening for the next 10 years. Batteries are being deployed in too specific ways.

"If you do it smartly, you can leverage batteries to do many things. But that also means you need to make sure they behave as they should and that in turn implies that you have people who have knowledge of the actual system. It could be a third party but they will have to spend a lot of time gaining the knowledge that the people who installed the system already have." ■

Credit SMA

Battery O&M requires in-depth knowledge of individual systems

Storage triumphs at Aliso Canyon

Credit AES Energy Storage

Grid storage | A natural gas leak in California in 2015 raised the prospect of widespread power outages in Los Angeles until a rapid procurement of large-scale storage projects saved the day. Danielle Ola reports on how storage's stock has risen since this unexpected opportunity to demonstrate its capabilities in bolstering grid networks

In the summer of 2016 , Southern California witnessed an environmental disaster when a major leak was detected at the Aliso Canyon natural gas storage field. The leak prompted a shutdown of the facility and left power generators in the region braced for blackouts, with plants providing nearly 10,000MW of peak-time power to the Los Angeles Basin forecast to be affected.

Time was of the essence, prompting California governor Jerry Brown to declare a state of emergency in January 2016. In order to mitigate any predicted power disruptions, regulators called for alternative measures, with energy storage at the forefront of those plans, alongside solar PV, solar thermal, energy efficiency and demand response.

It was then up to regulators and utilities to calculate what and how much additional generation was needed to fill the projected shortfall in peak energy capacity. Peaking capacity is a service that has historically been provided by thermal generators, but in this instance utilities needed to act much more quickly, and batteries were a solution that could be deployed quickly enough. This freed up utilities to start procuring batteries. And procuring lots of them.

The big battery test

In a landmark resolution, the California Public Utilities Commission (CPUC) in May 2016 expedited direction to utility Southern California Edison (SCE) to procure energy storage projects on an emergency basis. Likewise, San Diego Gas & Electric (SDG&E) issued a 'request for offer' (RfO) to expedite energy storage projects that they had already had in development.

"We had already pre-qualified a number of those bidders and as a result we could move very, very quickly," says Josh Gerber, SDG&E energy storage and smart grid expert. "We still had to get the contracts completed, get projects identified and ultimately built, but it was really because we already had that RfO in process that we were able to mobilise things so quickly."

One of the storage projects in California commissioned following the Aliso Canyon leak

In a similar vein, SCE was already running a procurement process, and was able to ask involved bidders with 'shovel-ready' projects to ask if they could meet the timelines proposed. These projects would have to be commissioned in record time, with SCE imposing a 31 December 2016 deadline and SDG&E 31 January 2017.

Rapid procurement

"In between May and July 2016 we identified the sites and selected the contracts," says Gerber. "We ultimately submitted that to the regulators by 18 July and got approval to proceed one month later on 18 August."

In total, the two utilities sought to procure just over 100MW of storage (250MWh+) through projects ranging in size from 2-30MW – with the vast majority of it being longer-duration, four-hour systems. Utilities were looking for suppliers who could mobilise the resources necessary to

put the project together expeditiously, as well as those with a solid track record of experience to implement a safe and reliable system. The main system suppliers selected were AES, Greensmith Energy, Tesla, Powin Energy, GE and Western Grid Development.

Contractors were given just a few months to advance their projects and have them grid-ready, putting significant pressure on a process that under normal circumstances could take years, according to Powin Energy president Geoff Brown.

"From the date the RfO came out in late May, to when the batteries and inverters were fully installed and ready to go in December, was less than six months from start to finish. It was the work of our director of engineering applications, Stephan Williams, to be able to get the project through the permitting process, the land leasing process, the engineering and construction process.

"Any of those typical processes should take six months alone, and to do all of them simultaneously shows a lot about what the technology is capable of."

The Aliso Canyon storage procurement did indeed show what energy storage was capable of, setting records for both the fastest grid-scale storage deployment and the world's largest lithium-ion battery facility. With the four-hour duration projects, it also demonstrated energy storage is capable of offering economic capacity products, in addition to shorter-duration products, and that storage has the ability to provide valuable functions for utilities in the electricity market.

'World's largest'

AES Energy Storage was the powerhouse behind the largest battery storage facility built to date. When combined with the other mammoth battery plants built by Tesla and AltaGas, the three constitute around 15% of the entire battery storage capacity installed across the planet last year.

AES delivered two projects for SDG&E – the 30MW/120MWh Escondido project, just north-east of San Diego, and the 7.5MW/30MWh El Capon project. Both projects were sold under an EPC contract and used four-hour lithium-ion batteries in modular containers.

The 30MW project – the world's largest grid-scale lithium-ion facility – was contracted in just three weeks, according to the company, with the entire system being delivered in approximately six months.

"Obviously the short timeframe was challenging," says Kate McGinnis, AES market director for the Western US. "We were able to overcome those challenges through our collaborative working relationships. We had actually started working with our suppliers early in the spring when it looked like there was going to be the possibility of a procurement. That early work helped to shape our knowledge of how much and how fast we'd be able to deliver a project."

"In the case of Escondido, there were five billion pounds of batteries that had to be delivered to the site – it was over 100 truckloads of just the batteries," adds Gerber, highlighting the scale of the projects.

> "Any of those typical processes should take six months alone, and to do all of them simultaneously shows a lot about what the technology is capable of"

'World's fastest'

Leader in energy storage software and solutions, Greensmith Energy, secured the title for the world's fastest grid-scale energy storage deployment. Its 20MW/80MWh project in Pomona was deployed in a record four months – a couple of months earlier than any of the other projects' impressive feats.

Greensmith handed over the regulatory process to Canada-based energy infrastructure company AltaGas, who was the project developer and owner of the San Gabriel facility.

Greensmith's CFO and COO Jim Murphy notes that the main technical obstacles in delivering the project were around supply chain "traffic jams". Otherwise, the process for this 20MW project was not materially different to its other ventures.

"The process was just condensed from a timing perspective," says Murphy. "Keep in mind, Greensmith has delivered 18MW sites in about six months in the past. For Aliso Canyon, the construction subcontractors required significant amounts of overtime as AltaGas had the teams operating on a 24-hour basis to meet the deadline. At one point there were over 200 electricians working on the project, completing wiring and battery installation."

Technological advances

It was a smaller project that SCE mandated Oregon-headquartered Powin Energy to build. The 2MW/8MWh Grand Johanna project is a perfect example of one of the benefits of the technology, in that project sizes can be customised to fit the specific need and application of any individual site.

"A distributed deferral application does not really need 20MW of capacity, you can have a longer-duration, smaller power system come in and provide exactly the requirement that is needed for an optimised cost," says GTM Research senior storage analyst, Daniel Finn-Foley. "So being able to scale things so precisely and so effectively is a big benefit for energy storage."

For its project, Powin preassembled lithium-ion phosphate electrochemical battery packs with its battery management software for use at the 35,000sq ft warehouse in Irvine. And it is its patented technology that the company credits for

Credit Powin Energy

Powin Energy commissioned the 2MW/8MWh Grand Johanna storage facilitiy within just a few months of being given approval for the project

Credit Greensmith Energy

Engineers worked around the clock to complete a 20MW battery storage facility in San Gabriel with AltaGas

executing such a rapid procurement.

"In large it was all possible because of the type of technology we are using," says Brown. "It's low impact, inside a warehouse and doesn't have all sorts of permitting challenges. From a land acquisition perspective it was a relatively…I wouldn't say easy process, but it's not leasing out 10,000acres like you would need to do on a wind project. It's just fundamentally different."

This exemplifies why energy storage batteries were an ideal solution to fill the electricity shortage void. Battery projects are fundamentally lower-impact than traditional wind or solar projects and therefore permitting thresholds are lower. And considering just how many batteries can be stacked in a warehouse, space was not as big an issue as it might be with other technologies.

"The patented technology that we have at Powin did allow us to do a lot of pre-commissioning work before we were completely online," says Stephan Williams. "And I don't know that other competitor technologies have that capability. Our technology therefore allowed us to get a bit of a head start and it was great to have that technical element with this timeline."

Powin uses an auxiliary power source to balance their batteries – as opposed to your standard EV-style balancing system which uses the batteries themselves – which enables batteries to essentially be micro-charged, increasing or decreasing the voltage on a much smaller level.

"By the time it was toward the end of the year and crunch time, we already had our batteries balanced relative to each other. That gave us like a 100 metre head start in a 400 metre race," says Brown.

A new blueprint?

After thousands of batteries were individually unwrapped, ribbons were cut and executives took their bows, constituents of California's LA Basin area could safely run their aircon units or cook dinner and run laundry simultaneously without the threat of a peak power shortage.

Largely thanks to California's energy crisis, but also improving economics and state- and federal-level policies, the business case for US energy storage has never been stronger.

"Energy storage is still a relatively nascent industry when it comes to grid-side or front-of-the-meter applications," says Finn-Foley. "So to be able to demonstrate several different capabilities at once during a capacity shortfall that was clearly unpredicted, that was really a big deal."

That being said, did the massive grid-scale deployment provide a blueprint for how procurements should be done in the future?

What it did prove is that storage can be deployed at pace, which makes it different from many of the other typical electrical generation resources that have been deployed in the past.

"This probably gives the industry a test case that this is something that can be used in these emergency situations but also in the normal course can be deployed with a shorter planning horizon than is typically used," says Gerber. "I don't think that it is going to be the norm right away, but I do think that we'll see more like this in the future."

Whilst this might be ideal, there are however some complexities with the proposition that procurements of this kind should be the new norm. With energy storage, there has to be both a need and a sound business case for it. It is not necessarily for the industry to do anything other than demonstrate that the technology is viable, and that will play a part in its being increasingly accepted and asked for by grid operators and utilities. The latter will procure storage when the value proposition makes sense in comparison to the other options available – and that is when at-scale deployments will be seen across the country.

It might be ideal to conduct future procurements in a similar fashion as Aliso, but not realistic.

"Putting a developer's hat on, all our lives would be a lot easier if we just waived a lot of these permitting and interconnection rules and made procurement faster," says Brown. "There probably is some merit to that, but I can't overstate how much SCE, CAISO and the city did for us in being able to make all this happen. They made it a real priority and pushed off other projects and other work that they had on. I think it would be easier to say, yeah; let's do this on all projects. But that probably minimises the amount of work and extra effort that SCE and CAISO had to do."

A valuable alternative

Even if there is not yet the business case for future procurements to be done at the same pace and scale as Aliso Canyon, the episode did prove that such projects have a very clear value proposition for utilities.

"It may mean that utilities even move to procure more than they've been mandated to," says IHS senior storage analyst Sam Wilkinson. "It may help to increase the outlook for the US market in that sense, but I think it all just hinges on evidence of the business case that will make other areas of the States more comfortable and confident in the technology."

"Look at energy storage as a new tool in the utility and the developer's tool belt and it has a lot of advantages that traditional generation doesn't have," adds Brown.

The Aliso Canyon leak demonstrated that energy storage can be a solution to extreme and unpredicted events. And if that continues, energy storage could even be seen as a one-size-fits-all solution. However, that is not enough to mould a business model around. Ultimately, this procurement was a demonstration of energy storage's capability, but in order to really be a mature industry, energy storage has to be able to participate in markets on its own, and that is going to be the next big step. ■

What storage proved in the Aliso Canyon saga

Timing

One of the biggest successes was obviously timing. There were, between the initial RfO and commissioning of projects, as little as just a few months. That is the kind of timeline it takes to merely get an environmental permit for a new natural gas peaker plant. The fact that such large-scale projects were able to get off the ground successfully in such short timeframes proves that energy storage can be a very flexible grid solution in a very short order.

Further, it readied a solution that utilities did not even have before. Using batteries on this scale was an idea that has always held far-reaching potential, but the execution was not something that engineers and policymakers had ever attempted.

"It all just really adds up to shattering that concept of needing years to build an asset that actually will have a really big and positive impact on a larger electrical system," says Williams. "That coupled with how fast the price of energy storage is dropping is starting to make heads turn."

Longer-duration storage

This emergency storage procurement was evidence of batteries being able to participate in longer-duration applications, as traditionally the large-scale battery storage market has been dominated by frequency regulation applications, which typically use shorter-duration systems.

"Now, because of the significant cost reductions that we're seeing for batteries, longer-duration systems are making economic sense," says IHS' Sam Wilkinson. "That's why we get the four-hour systems like this that are providing peaking and systems like those that have been announced in the UK recently for capacity auctions as well."

Competitive pricing

Such longer-duration projects were only possible due to aggressive pricing, which demonstrates the ability for storage to be cost competitive.

"It comes down to cost – as battery pack prices decline, it is going to be a lot easier to justify longer-duration, higher-capacity projects," says GTM's Finn-Foley. "The more capacity you have, the more solutions you can provide. I do think that we are going to be seeing fewer 2-5MW projects."

The cost of batteries on a kWh basis has been falling very quickly; with prices of battery system costs dropping 10-14% in the last year alone, according to GTM Research. "Every time you add an hour, you add another number of MWh of batteries, and therefore that US$/kWh is very important," says Wilkinson. "As that number has fallen something around 50% in the last two to three years, it is much more affordable to buy longer-duration systems."

In terms of pricing the projects in this procurement, whilst able to demonstrate to regulators that the systems were very cost competitive compared to previous offers, utilities indicated that there was a significant premium that they paid to have the projects expedited.

Germany showing the way for storage

Market update | As with solar, Germany has been one of the leading early adopters of storage. Andy Colthorpe speaks to analyst Valts Grintals about the key drivers emerging for storage in this pioneer country

Germany's energy storage market seems to be in good health, with just over 50,000 residential system installed to date and a number of large-scale projects getting the go ahead or already in action. While the federal elections later this year may bring some big changes, at the moment the country seems to be staying the course of its Energiewende ('energy transition') process. Although work remains to be done on decarbonisation and in coupling the heat, transport and energy sectors, the early stage energy storage market is showing promise. Delta-ee analyst Valts Grintals discusses his research and analysis of the German market.

PV Tech Power: What are the key trends you are seeing in the residential storage market?

Valts Grintals: The annual market in 2016 reached around 24,000 units [sold], which is actually higher than expectations, indicating that customers are really warming up to installing storage even if the economics are not there yet. There has been significant growth from 2014 to 2016 and we see in the future the market slowing down a bit but still growing, so an annual market growing up to around 30,000 units by 2019 and then after that higher growth again as the economics become more appealing, [with] paybacks below 10 years.

Really the market is driven by growing electricity prices, customers wanting to play their part in reducing the carbon footprint and becoming more self-sufficient, having less reliance on utilities. I think within the next five years storage will become part of the standard PV installation. We see within the next few years half of new PV installations also adding storage. As for the retrofit market, we see that starting to develop a bit more after 2020, once the cost of the batteries is low enough.

Do you think providers like Sonnen that have tried to do something different with SonnenCommunity [a peer-to-peer energy trading platform]is a quicker way to change the economics and how do you view that kind of offering?

It's a really interesting business model. At the moment I think Sonnen is just trying to grow its customer base to reach a certain number, to have this aggregated capacity to actually tap into different value streams like PCR [primary control reserve] or participating in the wholesale energy market. So they're really trying to position themselves as an energy supplier almost. By having this [newer] SonnenFlat proposition, where customers with SonnenBatteries installed can pay a flat monthly fee for their energy [while Sonnen nets revenue for grid services], this is a business model that right now, they primarily are just investing in to get a bigger customer base. As it develops their main aim is to tap into different value streams in Germany and I think they're launching that in Australia as well. So from their side, I think it's a longer term investment in the future.

At the moment what does a typical or average German residential storage system among the 50,000+ already installed look like?

Really it's a wide range of capacities. I think most of the installations are between 4kWh to 8kWh. In the UK you would assume to have slightly smaller systems because PV installations are slightly smaller and demand in the UK is lower than in Germany. People in Germany installed bigger PV systems so will need bigger storage units. It ranges between how big is your building and what is your electricity demand, but I think in terms of power, most systems are about 3kW.

It depends on how the system is sized according to demand but the average assumption is that it goes up to 60% self-consumption if you have an integrated PV-plus-storage system. If you go for a bigger storage system or increase the size of the PV you can go higher but there's a trade-off in how cost-effective it is to actually do that.

It seems quite competitive already. Who are some of the bigger players and what are your expectations?

I think Sonnen will have a good position in Germany especially. The market is still fragmented because a lot of players are launching products [including] companies from Spain or Austria that are seeing this opportunity in Germany because there's actually a market where you can sell some units. I think Sonnen will be leading, I think Fenec has a good market share as well, LG Chem is well-positioned in a lot of the markets including Germany, E3/DC has a good position at the moment as well in the German market. As the market grows, it will change and it will depend on who has the best business model really.

What is happening in the commercial and industrial (C&I) segment?

There will be C&I customers who have PV and use slightly bigger storage units than residential scale to improve their self-consumption, because electricity prices are still high for smaller C&I customers.

Overall, from a capacity standpoint it's the smallest section of the market, it's still only emerging but we see it growing quite a lot. It will still be the smallest part of the market even by 2020, 2021, but it will have good growth starting off with the smaller scale C&I segment. It actually makes sense in a lot of cases.

Then, in the longer term there will be the opportunity for bigger


Credit LG Chem

A battery storage park in Feldheim, Germany, co-located with wind turbines. Integrating large volumes of renewables into the grid will be a key long-term driver for storage in Germany

scale industrial applications on peak shaving, as demand charges in individual German regions are high and expected to grow.

So are the economics already working out for C&I customers?
It's very similar in terms of how the market will develop in the shorter term, starting with smaller C&I customers and early innovators, to how the residential market has been developing right now: early innovators installing storage to improve their self-consumption as well as to be greener.

In the longer term, as we see how the peak demand charges develop, it improves the economic case for storage, so this would be additional value that storage can easily tap into and has been proven to work in the US and has been also of quite significant value at least for now in the UK as well.

Even though overall the German grid is in a good situation, there are regions where there is high peak demand and you get charged a lot, whereas in some regions high peak demand has less of an effect. Overall though, demand charges are going up and the value in using storage to avoid those charges will improve.

Delta-ee's research forecasts commercial installations to exceed 10MW per year in the next three years. What limits that market potential?
To make a good business case for the value the customer needs to get from the storage, there's a lot of effort, a lot of bespoke analysis, that goes into deploying relatively small amounts or small capacity or small amount of units, at least at the moment because there is no standardised solution. It's really hard to create a standardised solution if the market is developing and there is a lack of certainty as well about how demand charges will look, what you can participate in as a C&I customer.

What are you seeing in the utility-scale segment?
The market topped after 2016 or [has] gone down a bit. The key driver for installing big-scale storage was PCR and a lot of the installations in the pipeline thought the value of PCR will go up. The assumptions behind how much money they will make from PCR did not meet reality; the value of PCR actually went down, which kind of slowed down the market a lot after 2016.

In the long term, there will be a drop in 2017, but then it will have steady growth after that because of renewable energy integration being the key driver for installations.

I think there's quite a few large capacity wind [projects] and there is a big opportunity to have storage installations co-located with those; as they run out of the feed-in tariffs (FiTs) they will need something else, so that wind energy can be used to participate in wholesale markets, for example. Where storage comes in is as a replacement to the FiT. That's where we see storage coming in further down the line: for renewable energy integration and to prevent renewable energy curtailment and integrate into the grid.

In our view, around 500MW of cumulative capacity of front-of-meter batteries will be installed in Germany by 2021, with the biggest traction coming in 2016 because of the PCR installations.

Is the design of things like wholesale markets in Germany good for large-scale storage?
I think it's still slightly behind the US where they're trying to solve the issue of the wholesale price settlement timeframe. As you decrease the settlement timeframe it enables storage to be one of the rare technologies that can respond to that price signal, so if you have half-hour price signals it needs to compete with gas etc. As it goes below five minutes, storage becomes the technology that you can maximise the benefit from.

With utility-scale projects, as with other countries we've seen the growth of revenue and application-stacked projects. Is that something that's made its way into Germany's utility-scale sector?
The big difference is that they don't have that many values to stack in Germany. PCR is almost bundled values; it's like frequency response plus a capacity market, to use a UK example. The UK has this fragmented market that allows you to stack things together. In Germany, the main value is PCR or renewables integration, so there's no stacking; the focus at the moment is on providing one value. In the future it might change.

I think in the long term, renewables integration is a key value for storage and we will see longer duration storage in front of the meter, because there's a lot of buzz in the UK around stacking different values but there's also not a lot of long-term certainty – FFR (firm frequency response) might change, TRIAD (commercial time of use mechanism) might go away, DuOS (grid fees) will change. Even though you can stack different values there's a lot of uncertainty.

In Germany it's actually easier from an investment perspective because you know or have more certainty around the value in renewables integration or self-consumption improvement, in PCR as well.

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Thin-film solar production to collapse to seven-year low in 2017

Manufacturing | Thin-film production looks set to hit a low this year, but this doesn't spell the end of the dream yet, writes Finlay Colville

The production volume of solar PV panels based on thin-film deposition of semiconductor materials on large-area glass panels is set to hit a seven-year low in 2017, according to the latest PV Manufacturing & Technology Quarterly report published by Solar Media. Given that legacy roadmaps for solar PV cell technology until 2010 were predicting that thin-film manufacturing was to dominate the solar industry by 2020, something has clearly not panned out as many expected.

End of a dream, or a new start for an established technology?

Thin-film emerged in the research labs in the 1970s, and was seen as a viable and attractive alternative to silicon. By the time we got to the 1980s, MW-scale lines were in operation, with manufacturing lines producing a-Si, CIS/CIGS and CdTe variants, on both glass panels and flexible substrates. While the efficiencies were lower than c-Si, the prospects of low-cost manufacturing and deployment benefits were seen to outweigh this.

By the time we reached the early 2000s, First Solar and Solar Frontier emerged as leading producers, with a myriad of thin-film followers and competitors. The landscape was diverse, but the investment community latched onto thin-film as a technology that was being predicted to potentially make c-Si redundant.

While this was happening, silicon feedstock pricing had fallen by an order of magnitude. China embraced silicon cell production, and in the space of a few years, the dreams of more than 100 companies that had gone into thin-film production were evaporated. Fast-forward to 2015, and we end up with two thin-film producers of note: First Solar and Solar Frontier, each with GW+ capacity levels and competitive products from a performance and cost standpoint.

During 2016, thin-film effectively saw a second major round of investment announcements that probably leaves many wondering how 2017 production levels could possibly fall to a seven-year low. So, let's explain this now.

First Solar made the bold decision to set in motion a plan to move to a panel size some three times lager than the current Series 4 panels, triggering capex levels akin to building a 10,000MT polysilicon factory. This effectively makes 2017 somewhat of a transition, in terms of lines in Ohio and Malaysia being stopped ahead of the new Series 6 equipment being commissioned. Coupled with the high backlog of Series 4 sitting on First Solar's books mid-year, production levels from the industry's largest thin-film producer by some margin will be lower than over the past several years. This alone is a major factor in the overall thin-film numbers being down.

While First Solar is actively upgrading technology, Solar Frontier is seeing a very different outlook for its CIS manufacturing in Japan, and this forms the other big driver to lower 2017 productivity.

Solar Frontier had grand plans for CIS production, with frequent announcements of overseas plant aspirations and global project development activity. However, years of negative operating metrics has seen the company retreat back to the domestic Japanese market, idle capacity, and look for new module variants to have a differentiated offering by the end of 2017.

And then we have China

Everything goes in cycles, and we currently have a major boom in Chinese thin-film equipment ordering, much to the delight of European equipment suppliers that had ten years ago been supplying production equipment to the likes of Avancis, Solibro and many more in Europe.

Announcements, orders, equipment revenue-recognition and factory-acceptance; these are all must-have prerequisites ahead of mass production success, but they are of course absolutely no guarantee of success. We will know more in 2018, or 2019. Until then, the Chinese thin-film announcements and tool deliveries are worthy of tracking, but they don't really change anything in terms of productivity in 2017.

Credit First Solar

First Solar's technology upgrade is one reason behind the low levels of thin-film production expected this year

What about 2018-2020?

For First Solar, 2018-2020 will be the period where we will know how successful the Series 4 to Series 6 transition is. So far, First Solar has come good on almost every technology upgrade promise for its Series 4 lines and its efficiency increases over the last three to four years are staggering. It's a great reference point for Series 6 being successful, but there are many other things that need to fall into place, both at First Solar, but also across the wider industry as a whole and in particular where the GW offerings from the likes of JinkoSolar are by the end of 2018.

Potentially, an uptick in thin-film production from Solar Frontier and the China entrants should probably be seen as incremental, and less impactful compared to what First Solar produces during 2018-2020.

Therefore, while production levels will be at seven-year lows in 2017, the thin-film sector and optimism is anything but in decline, and with a few headwinds and manufacturing successes, could see massive growth by the time we get to 2020. On the other hand however, it may not.

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