PV POWER TECH

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PLANT PERFORMANCE

How safe is your solar system from cyber-attack?

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Introduction

Over the past couple of years, stationary energy storage has increasingly found itself at the heart of debate over the future direction of travel for solar, particularly in the more mature markets found in Europe. Here, the low-hanging fruit offered courtesy of feed-in tariffs and other subsidies has been plucked and market conditions have become altogether tougher. Storage, however, opens up a whole new range of business opportunities for solar in a post-subsidy world.

Reflecting this, storage takes centre stage in this issue of *PV Tech Power*. Towards the end of June, the Intersolar waggon will be rolling into Munich for its annual outing, and storage looks set to form a major part of the show this year, as it progressively has done over the past few years. The opportunities offered by storage will no doubt be a key topic of conversations at the event, and we take a look at what those might be.

On p.24, we explore how storage is one of a number of reasons to feel optimistic that solar in Europe has a bright future. As trade body SolarPower Europe's CEO James Watson tells us, large-scale storage in Europe is perhaps at a more advanced state of development than people think. While not by any means a finished article as a market, he suggests storage balancing is likely to become a key feature of solar tenders in the not too distant future.

We then zoom in a bit closer and look at how Europe's green energy pioneer, Germany, is weighing up the possibilities offered by storage in the next phase of its energy transition (Energiewende) (p.93). Solar is a shadow of its former self in its spiritual home, but as we discuss, storage at various scales is rising up the agenda as a means of breathing new life into the project.

Then on p.18 we look at some of the technologies being developed to propel the sector forward. Storage technology is at a similar stage to where solar was before the handful of technologies that now dominate won through. We nail our colours to the mast and pick out 20 technologies we think could become disruptors and assess their chances.

Another highlight in this issue is an exclusive in-depth report on a major study by PV Performance Labs into the accuracy of commercially available irradiance measurement instruments (p.44). Instruments such as pyranometers play a vital role in understanding the availability of the 'fuel' of solar arrays – sunshine – without which many vital functions in the design and operation of plants would be impossible. The study is seeking to gain a better understanding of how accurate commercial instruments are as a step towards improving the accuracy of irradiance measurement.

The *PV Tech Power* team will be at Intersolar Europe and EU PVSEC in June. We look forward to welcoming you to our booth A2.251.

John Parnell
Head of content

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HUAWEI
SNEC 2016
ShangHai China
May 24-26
Booth: E6-510
InterSolar Europe
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Booth: B2-530
ALWAYS AVAILABLE
FOR HIGHEST YIELDS
FUSIONSOLAR SMART PV SOLUTION
Higher Yields
Smart O & M
Safe & Reliable


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74


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WORLD'S Most Powerful
Green CIGS Solar Module

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- Royal BLACK color

BOS less

IRR up

LCOE down

Power Gain Factor higher
(More Revenue)

310Wp-330Wp

Cigs-3000 Series

NO. W5-620
国际太阳能产业及光伏工程展 SNEC
05/24~26, 2016

NO. K43
Asean Renewable Energy Week
06/01~04, 2016

NO. A1.140
Intersolar Europe
06/22~24, 2016

Hulk Energy Technology Co., Ltd. www.hulket.com

EUROPE

Storage

Sonnen: Q1 sales figures show 'global demand for storage is real'

Sonnen said it sold 2,600 units of its SonnenBatterie energy storage systems worldwide, an increase of more than 100% over the previous quarter. The privately-listed company was coy about revealing specifics of the figures, but said the US is now its second-largest market outside Germany, with over 50 retailers signing up as partners to sell the products. The US commercial space was the first segment of that country's market Sonnen launched into in mid-2015. At that time, it had sold around 8,000 units in Germany, making it something of a market leader. Sonnen has now launched its residential products in the US as well after racing Tesla into that segment and launching just before Christmas 2015.

Pictured, a SonnenBatterie unit. While it has enjoyed fewer headlines than Tesla, Sonnen reported extensive progress in the US and Germany. Credit: Sonnen.

Germany

Germany could miss solar target for third year in a row

Germany installed just over 50MWp of new PV in February, marking the lowest tally since the federal registry opened and sparking fears the government could fail to hit its own targets for the third year running. The federal government applied the brakes on solar development in 2014, setting an annual cap of 2.4GW to 2.6GW of deployment, from an overall target of installing 7.5GW between 2014 and 2017. The country's regulator, the Bundesnetzagentur, published figures that show that 50,494kWp of PV was installed in February, with no new utility-scale projects included in that amount. By comparison, nearly twice as much – 98,983kWp – was installed in the same month of last year.

Germany's Federal Network Agency awards 128MW of PV in fourth tender

The Federal Network Agency (FNA), Germany's national energy regulator, launched its fourth successful PV tender in April, totalling 128MW of PV across 21 bids. The volume-weighted surcharge value was US$7.4 cents/kWh. A total of 108 bids were received, with 540MW on offer overall. Of the 21 successful bids, 11 were attributed to LLCs, with German engineering companies winning nine contracts through notable names such as Sunera, IBC Solar Projects, ENERPARC and E.ON Energie Germany. One limited partnership also won a contract.

Renewables on the rise for Germany's 'Big Four' utilities, conventional generation suffers

Germany's 'big four' utilities, RWE, E.On, EnBW and Vattenfall, has all referred to the growing importance of renewable energy in their business models in reporting their Q1 2016 results. Together, the four hold about a two-thirds share of the country's power market. Each has made some efforts to realign itself in recent times with the goals of Germany's Energiewende, the national transition away from a nuclear and fossil fuel-powered base load, and while some critics have said the utility giants have been slow to move, RWE and E.On are thought to have been more proactive than their rivals.

UK

UK solar developers lose case against government cuts

The UK Court of Appeal has dismissed claims against the premature closure of the Renewables Obligation support scheme, bringing to an end the long-fought dispute between UK solar developers and the government. The court previously heard an appeal from Solarcentury, Lark Energy and others attempting to overturn a 2015 decision reached by Mr Justice Green, who determined that the government was justified in its early closure of the support mechanism. The appellants however cited an interpretation of wording within the LCF which states the government will honour promises regarding subsidy levels, and that the secretary of state's failure to do so was tantamount to the government acting ultra vires (without authority). Floyd LJ's verdict concludes the case with no more avenues for the industry to appeal.

Green utility buys SunEdison's UK rooftop business

UK 'green' utility Ecotricity has announced the purchase of failed renewable energy developer SunEdison's UK rooftop solar business. The move will see Ecotricity enter the domestic solar market for the first time. Prior to its much vaunted exit of the UK market last year, SunEdison launched its Energy Saver Plan scheme which comprised almost 1,000 separate rooftop PV installs. Dale Vince, chief executive at Ecotricity, said the company expects to resume installs under the scheme in due course. The announcement came just hours after SunEdison filed for chapter 11 bankruptcy in the US following weeks of speculation as to the company's future.

Spain

Spain Supreme Court ruling 'oxygen' for future solar cases

The Spanish Supreme Court has ruled that solar PV companies and investors should be compensated by the Spanish administration over historic amendments to the feed-in tariff (FiT) policy for new installations. The win for solar announced on 29 April was welcomed by law firms and solar stakeholders, who claim it may set

EUROPEAN SOLAR MILESTONES

- **Europe has surpassed 100GW of installed grid-connected solar PV capacity, according to new data from research firm IHS. The continent has risen from 3GW PV capacity in 2005 to 100GW in the second quarter of 2016, mainly as a result of an 80% reduction in costs and a host of supportive regulatory frameworks brought in by countries looking to meet the EU's Renewable Energy Directive, according to IHS.**
- **France's installed solar PV capacity reached 6,549MW at the end of December 2015, according to the latest figures from the French Sustainable Development Commission (CGDD).**
- **The UK has now installed more than 10GW of solar capacity. This comes after solar PV installed during the first six weeks of Q1 2016 hit 340MW, adding to the cumulative solar PV in the UK at the end of 2015 of 9.66GW.**

a precedent for future cases, in a nation where the majority of legal disputes of late have seen solar losing out. Now the Spanish state has been forced to compensate investors and PV promoters after the Royal Decree-law 1/2012 was found to be "surprising, breaking the principle of legitimate expectations" set by the Royal Decree of 2008, which first introduced the FiT subsidy scheme.

Endesa purchases equivalent of 681MW solar in Spain and Portugal auction

Spanish utility Endesa has purchased 410GWh of solar energy in its latest solar auction for Spain and Portugal, which comes to the equivalent of 681MW capacity. The auction closed with a price of EUR39.6/MWh (US$43.82). Endesa said the auction method was reducing the earnings volatility for solar technology and the capacity purchased this week had confirmed the "positive market acceptance" of this mechanism. The next solar auction will be held in June.

Total

Energy major Total pledges to be top three solar player within 20 years

Energy giant Total has said it wants to be a top three player in the solar energy industry within the next 20 years. In April, the firm announced a restructuring, dubbed 'One Total'. The plan involves the development of a gas, power and renewables division. A number of utilities have indicated an intention to pivot towards renewables in a significant way but Total's proclamation is perhaps the most ambitious among the oil majors. The company already has majority ownership in US solar firm SunPower.

Total putting its 'money where its mouth is' on clean energy transition

Total has proposed to buy battery company Saft, which produces devices for the stationary storage industry as well as for transport and other applications. In line with the "friendly" aspect of the takeover, Total is willing to pay a premium on shares, offering to buy them at €36.50 (US$41.58), which is 38.3% above their valuation as of Friday and 41.9% above the weighted average share value over the past six months. Total valued Saft at €950 million (US$1,082 million). The acquisition of Saft is part of Total's ambition to accelerate its development in the fields of renewable energy and electricity, initiated in 2011 with the acquisition of SunPower. The magnitude of the deal suggests it is far more than a CSR venture.

AMERICAS

California

Net metering: Industry slams California grid operator's 'economic justice' attack

Steve Berberich, CEO of California Independent System Operator, slammed net metering as a "subsidy" of wealthy households by poorer ones, claiming it represents an "economic justice issue". California's new iteration of the scheme sought to attach more value to the matching of load with demand. Customers will have to pay interconnection fees estimated to be around US$75 and US$150 to get started. However, three investor-owned utilities, SDG&E, PG&E and SCE have asked the regulator to "rehear" the case.

California passes bill to level residential solar playing field

California's Assembly Utilities & Commerce Committee passed a

SolarCity

SolarCity launches new utility and grid services

SolarCity announced a new set of services targeted at utility and grid operators. The PV provider will be branching into installation, financing and consulting services for utility-scale solar as well as energy storage development. In conjunction, SolarCity will be advancing controls for distributed energy resources, demand response and aggregated grid services.

SolarCity raised a few eyebrows with the annoucement of its move into grid-scale PV services. Credit: SolarCity.

SUNEDISON BANKRUPTCY TIMELINE

1 MARCH 2016: SunEdison pushes back the release of its 10-K while an audit committee investigates allegations made by former executives that leadership misrepresented SunEdison's financial standing.

3 MARCH: Goldman Sachs, Barclays, Citigroup and UBS balk at providing loans to SunEdison for its US$1.9 billion acquisition of Vivint Solar, after delay of 10-K.

4 MARCH: SunEdison and TerraForm Power announce a US$8.5 million settlement and termination of the Latin America Power acquisition.

8 MARCH: Vivint Solar pulls plug on SunEdison merger, citing a 'wilful breach' of the agreement.

22 MARCH: SunEdison shares plunge almost 20% as news of debt restructuring leaks.

29 MARCH: SunEdison moves closer to bankruptcy as shares fall below US$1 for the first time since the inception of the company. A regulatory filing states a 'substantial risk' that the company could go broke.

2 APRIL: SunEdison plans to file for bankruptcy protection. The company's shares are down around 98% over the past 12 months and fall a further 45% in heavy extended trading to US$23 cents each.

3 APRIL: D.E. Shaw Composite Holdings and Madison Dearborn Capital Partners file law suit claiming US$231 million in earn out payments under their agreement.

5 APRIL: TerraForm Global sues SunEdison for US$231 million.

15 APRIL: SunEdison confirms debtor-in-possession (DIP) financing discussions.

21 APRIL: SunEdison officially files for bankruptcy, with listed liabilities of up to US$50 billion.

25 APRIL: SunEdison owes its upstream suppliers more than US$321 million, according to the Bankruptcy Court for the Southern District of New York.

27 APRIL: SunEdison sells 202MW of Chile solar assets to Chilean utility Colbun.

11 MAY: SunEdison yieldcos TerraForm Power and TerraForm Global amend agreements with key lenders to allow them more time to file their financial results and audit.

13 MAY: SunEdison makes further delays in reporting Q4 and full-year statements.

16 MAY: TerraForm Global rejects claims from bondholders that it is in default for failing to provide an annual report.

new bill in April that aims to make rooftop solar systems equally available in all utilities across the state regardless of location; giving consumers a level playing field in terms of access to solar. Traditionally, Californians under a municipal utility had a lesser chance to be compensated under the net metering scheme.

Brazil

Brazil accredits 9GW of solar projects for July auction

Brazil's energy agency EPE has accredited 295 solar PV projects totalling more than 9.2GW of capacity ahead of its reserve energy auction to be held on 29 July. This the fourth Brazil auction with a category for solar PV, following auctions held in November and August in 2015 and the first major auction in 2014, which resulted in the combined award of around 3GW of solar.

Mexico

Solar in Mexico to grow by 521% in 2016 after successful power auction

The results of Mexico's first clean energy auction saw 11 projects earning 1,860MW of capacity. As a result, GTM research predicts solar in Mexico to increase by 521% in 2016, as opposed to the earlier 267% forecast. The winning projects are from a number of developers, including Enel Green Power (992MW), SunPower (509MW), JinkoSolar (241MW), Recurrent Energy (62MW), Sol de Insurgentes (27MW) and Photoemeris Sustentable (29MW). The average contract price was US$50.7 per MWh.

MIDDLE EAST & AFRICA

Iran

Iran includes >30MW solar category in new feed-in-tariffs

Iran has published new feed-in-tariffs (FiTs) for solar PV including a new category for solar projects of greater than 30MW in size, according to the renewable energy organisation of Iran (SUNA). The FiTs were released after a delay in publishing and will be valid until the end of the next Iranian year on 21 March 2017. Overall the tariffs fell by 18-43% for solar, from the initial rates, which were introduced in 2015 for the first time.

Price record

Dubai 800MW tender gets sub-3¢ bid

The latest solar tender in Dubai received a bid of US$0.029/kWh, almost halving the winning bid in the previous 200MW round. The state utility, DEWA, received five bids from international companies with a consortium of Masdar and Fotowatio Renewable Ventures (FRV), now Saudi-owned, offering the lowest tariff. JinkoSolar bid US$0.0369/kWh, beating a bid of US$0.0396/kWh by ACWA Power and First Solar, winners of the previous round along with Spain's Grupo TSK. French IPP and Japanese conglomerate Marubeni bid US$0.0444 and French utility EDF bid US$0.0448/kWh in partnership with Qatari firm Nebras Power. The five bids are now under review by DEWA with both the technical and financial viability under scrutiny. The 800MW, third-phase of the Sheik Mohammed bin Rashid al Maktoum Solar Park is expected to be completed by 2020.

South Africa

Second phase of 175MW PV project completed in South Africa

Solar Capital, a subsidiary of South Africa-based investment and development company Phelan Holdings, completed a 90MW PV project in South Africa under the country's flagship renewable energy programme. South African energy minister, Tina Joemat-Pettersson, launched the second phase of the Solar Capital De Aar project in the Northern Cape province. Combined with the 85MW first phase completed in 2013, the total 175MW capacity of the facility makes it by a stretch Africa's largest operational PV project. The project is also claimed to be the largest in the southern hemisphere.

Saudi Arabia

Saudi Arabia hits renewable reset button with new 9.5GW target

Saudi Arabia confirmed a new 9.5GW renewable energy target as part of its 2030 Vision initiative to move its economy away from a reliance on oil. The plan includes a combination of asset sales, subsidy reforms and the creation of a US$2 trillion sovereign wealth fund. The country famously announced a US$109 billion solar investment plan in 2012 but has seen little in deployment since. Under the new goals, solar manufacturing will also be targeted, and foreign investment in projects will be encouraged as part of public-private partnerships. This model has already proved successful in other Gulf economies, notably the UAE. "Even though we have an impressive natural potential for solar and wind power, and our local energy consumption will increase three fold by 2030, we still lack a competitive renewable energy sector at present," said an English version of the Vision 2030 plan posted on the country's state news website. "To build up the sector, we have set ourselves an initial target of generating 9.5GW of renewable energy. We will also seek to localise a significant portion of the renewable energy value chain in the Saudi economy, including research and development, and manufacturing, among other stages."

Source: First Solar.

The 13MW first phase of the Mohammed bin Rashid Al Maktoum Solar Park.

West Africa

Ghana to update feed-in tariffs to last 20 years

Ghana will soon update its feed-in-tariff (FiT) programme for solar to include the possibility of having contracts last for 20 years, according to Wisdom Ahiataku-Togobo, director of renewables and alternative energy at the Ministry of Power Ghana. He said the FiT for solar PV is due for an update – adding: "Any moment from today, a new set of feed-in tariffs will come out and I believe this FiT is going to take into consideration most of your worries." He said that many developers had raised concerns and asked for a 20-year period for the FiTs instead of the previous 10 years and this is being accounted for in the next update. He also said it was unfortunate that most developers look for credit enhancements from the government, and such developers will be subjected to a tendering process.

2GW green energy corridors planned for West Africa

Clean energy corridors with a combined capacity of 2GW are being planned for the West African region under plans put forward by the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE). Mahamma Kappiah, executive director of ECREEE said the corridor will involve connecting many 10-15MW solar PV plants, as well many other technologies such as wind and hydro. He added: "In the 2GW, we have different contributions from each country. Nigeria wants to take 1GW of it, the rest is shared among other countries, some with 200MW and some 500MW."

Sierra Leone government launches 6MW solar park

The government of Sierra Leone launched a 6MW solar project in the capital Freetown after securing financial backing from the International Renewable Energy Agency (IRENA) and the Abu Dhabi Fund for Development (ADFD). The initial funding for the solar park was cleared in 2014 with the ADFD. The project, worth an estimated US$18 million, is expected to take around 12 months to complete by both the Advanced Science and Innovation Company (ASIC) and Mulk Oasis Gulf Investment (OGI), a subsidiary of Sharjah-based Mulk Holdings.

East Africa

Kenya to construct 55MW solar plant with Chinese government funding

Kenya's Rural Electrification Authority (REA) has approved the construction of a 55MW solar power plant in the East Kenyan County of Garissa, requiring an investment of KES12.8 billion (US$126 million). The solar farm will be financed through concessional funding from the Government of China. The REA will install roughly 210,200 solar panels of 260W capacity each. The project will be able to power the equivalent of 625,000 homes. REA claimed that once complete, this will be the largest solar project in East and Central Africa. It will also create more than 1,000 jobs. Construction will begin in July this year and is expected to be to completed and connected to the grid within a year of starting construction. Meanwhile, UK solar developer Solarcentury has continued its recent international expansion by agreeing to a US$2.5 million solar project in Kenya.

ASIA-PACIFIC

India

World Bank providing US$625 million for India's rooftop solar programme

The World Bank has approved a US$625 million loan for the Indian government's grid-connected rooftop solar PV programme, along with a co-financing loan of US$120 million on concessional terms and a US$5 million grant from Climate Investment Fund's (CIF) Clean Technology Fund. The Solar Energy Corporation of India issued a tender for 500MW of grid-connected rooftop solar PV systems in India. However, a report from the Solar Rooftop Policy Coalition claimed that with a 'business as usual' approach, India is set to reach just one third of its 40GW rooftop solar target by 2022. However, with aggressive market support, India could double its rooftop installation from the current trajectory, to 26GW in the same period. Meanwhile, Gujarat introduced a rooftop solar subsidy.

Grid integration and financing issues to hinder India's 100GW solar target

Grid integration and availability are the key challenges ahead for India's solar sector, according to consultancy firm Bridge to India's latest report. The 'India Solar Handbook 2016', forecast that grid issues are the major bottleneck to the country's 100GW by 2022 target and as a result the country is expected to deploy just 40-60GW instead. Maintaining investment and lending appetite at aggressive tariff levels was another main challenge while policy intervention will be key to sustaining its growth in the sector. In any case the country is still expected to become the fourth largest solar market globally in 2016. Despite the bottlenecks cited, Bridge to India described the sector as in "full bloom" with 25GW of projects under development.

International Solar Alliance targets US$1 trillion investment with launch of first programmes

The International Solar Alliance (ISA) plans to bring US$1 trillion of investment into solar assets within its member countries, according to the first major announcement since the Alliance was launched at COP21 in Paris last December. India energy minister Piyush Goyal and French energy minister Ségolène Royal co-chaired a ministerial side event on the ISA at the headquarters of the United Nations in New York. The ISA also launched its first two initiatives, 'Affordable finance at scale' and 'Scaling solar applications for agricultural use'.

China

China plans 'green certificates' trading market to support renewables

China is planning to create a 'green certificates' market to promote renewable energy and reduce its use of fossil fuel-based power, under proposals from the country's National Energy Administration (NEA). The aim is for power generators to be able to trade 'renewable energy green certificates', which account for the share of renewable energy that they generate, excluding hydroelectric power. The NEA plans for non-hydro-based renewables to account for 15% of the country's total energy mix by 2020, up from 12% at present. Furthermore, power producers are expected to have at least 9% of their electricity generating capacity coming from non-hydro-based renewables by the same year. An NEA statement said: "Renewable electricity green certificates can be traded in accordance with market mechanisms through certificate trading platform."

INDIAN UTILITY-SCALE TENDER TIMELINE

7 MARCH: Karnataka's 1.2GW solar auction invited bids for capacities of up to 20MW in separate taluks (localities), but some developers lost out on capacity even if they bid more aggressively than other successful developers, because they were competing for different taluks. Hero Future Energies (180MW) and Renew Power (180MW) won the highest capacities.

16 MARCH: RattanIndia Power won a 50MW PV project in Allahabad in Andhra Pradesh from the Solar Energy Corporation of India (SECI) with viability gap funding (VGF) of INR7.499 million/MW.

17 MARCH: SolaireDirect won a 75MW solar project in Uttar Pradesh quoting VGF of INR7.435 million/MW.

18 MARCH: Jharkhand's 1.2GW auction saw significant contrasts in bids received, Major winners included Renew (522MW), Suzlon (175MW) and SunEdison (150MW).

18 MARCH: Rajasthan saw the lowest bids so far in the Domestic Content Requirement (DCR) category with Janardhan Wind awarded 20MW by NTPC at INR 5.06/kWh.

18 MARCH: SECI issued a request for selection (RfS) for 100MW of solar projects in Chhattisgarh.

21 MARCH: The Kerala State Electricity Board issued an RfS for 200MW of grid-connected solar PV in what is the state's first utility-scale solar tender for consumer use.

23 MARCH: NTPC issued an RfS for solar developers to set up a 250MW solar PV project in the Kadapa Solar Park in Andhra Pradesh.

China

China PV installs surge past 50GW milestone

China installed 7.14GW of new solar power capacity in the first quarter of 2016, according to the country's National Energy Administration (NEA). Total cumulative solar capacity in the country is now at 50.3GW. The quarterly figure is up 48% compared to the same period last year. Frank Haugwitz, Beijing-based founder of solar consultancy AECEA, said there is more to come – adding: "It is no surprise to see such a high number, because, traditionally Q1 witnesses the final execution of roll-over projects from 2015. As well, in September 2015 a good 5.3GW were additionally approved and their deadline in order to qualify for last year's feed-in tariff (FiT) is the end of June." Another 1GW of projects from the high-spec Top Runner Programme are working to the same deadline. While there has been no official target or quote for PV deployment released for 2016, Haugwitz notes that a vague, unofficial indication of 15GW has been mentioned publically. In 2015, the country installed 5.04GW in Q1 and 15.3GW in total for the year.

Credit: United PV

The surge in large-scale PV in China has created curtailment issues in some parts of the country.

Australia

Concern as Australia redirects AU$1 billion ARENA financing into innovation fund

Australia is redirecting AU$1 billion from the Clean Energy Finance Corporation's (CEFC) AU$10 billion (US$760 million) allocation into a new Clean Energy Innovation Fund (CEIF). The new fund will provide debt and equity to support efforts to bring emerging technologies to a commercial scale, drive innovation and create jobs, under the management of the CEFC and the Australian Renewable Energy Agency (ARENA). Once ARENA has completed its AU$100 million large-scale solar round, it will move from a grant-based role to predominantly a debt and equity basis under the CEIF. Australian Solar Council chief executive John Grimes criticised the new fund claiming that it is a disguised stripping of AU$1.3 billion from ARENA's renewable energy budget funding.

Origin Energy signs PPA for FRV's 100MW solar plant in Queensland

Integrated power firm and utility Origin Energy has signed a 13-year power purchase agreement with solar developer Fotowatio Renewable Ventures (FRV) to offtake electricity from the planned 100MW Clare Solar Farm in north Queensland. FRV will commence construction on the 300-hectare site, located near Ayr in northern Queensland, later in 2016, with operations expected to commence in 2017. The site is currently used for sugarcane farming. Origin now also has the option to develop a further 35MW of capacity at the site. This latest PPA, which runs up to December 2030, follows Origin Energy's signing of a 15-year PPA with FRV for the solar power generated by the 56MW Moree Solar Farm in northern New South Wales in March.

Thailand

Thailand's biggest coal company mulling US$170m Japan PV investment

Thai coal mining company Banpu will invest up to US$170 million in Japan's solar market. The company is interested in seven separate Japanese solar projects with a combined generation capacity of 54MW. These would begin construction this year and come online in 2017, while Banpu is also eyeing projects in China and Indonesia. The announcement marked continued interest in Japan's solar market, which despite being in the process of tapering down its FiTs, is still attractive to overseas investors.

Japan

Japan's government confirms plans for solar tender

Japan's government gave its clearest indication to date of planned rule changes around renewable energy policy, including official confirmation that a tender process is being put before its parliament for the 2017 financial year. The changes are expected to include the introduction of a tender process for large-scale PV projects, longer term assurances of purchasing prices and efforts to streamline the overall measures for renewable deployment. This could include an alignment with the country's ongoing deregulation of its electricity markets; with generators freed up to make direct transactions with electricity retailers, bypassing the wholesale market's pricing mechanisms altogether. After public consultation, the new measures will be put before the country's Diet (parliament) for consideration and if approved will be introduced into legislation when the next iteration of renewable energy laws are introduced in April 2017.

Philippines

'Southeast Asia's largest' PV plant commissioned in Philippines

Singapore-based renewable energy developer and investor Equis has commissioned a 132.5MW solar project, which it claims is Southeast Asia's largest PV plant, in Cadiz City, Negros Occidental, the Philippines. Helios Solar Energy Corporation, a joint venture between Gregorio Araneta and solar IPP Soleq developed the project, which is expected to supply power to the equivalent 167,526 homes with 188,500MWh of renewable energy and is eligible for the Philippines government feed-in tariff scheme. The Cadiz Project brings Equis' operating renewable energy portfolio in the Philippines to four projects totalling 236.5MW capacity.

FACT

India saw US$12.9 billion invested in renewables over the last three years and the share of renewables, excluding hydropower, in India's energy mix reached 5.7% as of February this year, up from 4.97% in 2012/13.

Credit: Flickr/Gopal Vijayarhagvan.

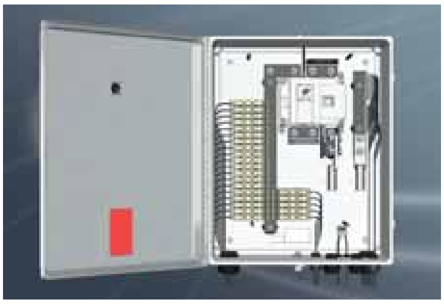
Product reviews

Balance of system | AMtec's disconnecting combiner box features disconnect ratings of up to 400 Amps at 1,500VDC

Product Outline: AMtec Solar Products has launched its new 'Prominence' Series configurable disconnecting combiner boxes, featuring disconnect ratings of up to 400 Amps at 1,500 VDC. The boxes are ETL Listed to UL1741 at 1500VDC and CAN/CSA C22.2 listed at 1500VDC.

Problem: The next generation of utility-scale PV power plants is demonstrating that 1,500 VDC brings down levelised cost of electricity and balance-of-system costs by allowing longer module strings. Disconnecting combiner boxes are now required to meet lower-cost metrics.

Solution: AMtec offers a wide range of additional configuration options including single- or dual-hole output lugs, pre-configured pigtails, voltage monitoring, surge protection, string-level current monitoring, cable connectors and fuse ratings. These heavy-duty, high-capacity components are claimed to offer improved cost savings by reducing the number of overall components needed.



Applications: Utility-scale PV power plants operating at 1,500VDC.

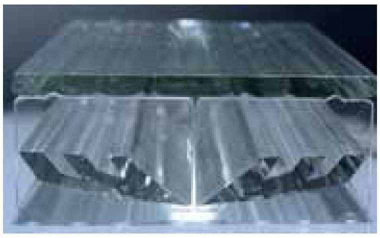
Platform: The new high power capacity combiner boxes are fully customisable with 275A, 325A, or 400A disconnects, and up to 36 strings. Enclosures are available in NEMA 4 steel, NEMA 4X fiberglass or stainless, or 3R. The disconnect switch is fully rated for continuous duty class DC-21, UL98b.

Availability: Already available.

Modules | Banyan Energy offering low-cost low-concentrated PV module under licence

Product Outline: Banyan Energy has developed an optics-based solar technology platform claimed to offer manufacturers, developers and systems integrators an accelerated pathway to ultra-low-cost PV modules and manufacturing. The company's licensing model allows Banyan-designed modules to be easily manufactured in local factories without investment in research and development, reducing production costs and technology risk.

Problem: Banyan Energy claims to bring low-cost solar manufacturing within reach for expansion-minded companies, offering a way for companies to license innovation and keep their R&D spending in check. The patent-protected low-concentration PV module design can help achieve low levelised cost of energy (LCOE), earn strong double-digit returns on their project investments, and shift the industry into a new era of post-subsidy economics, according to Banyan.



Solution: Using Banyan's patented 'Optiwave' technology, companies can leverage their existing production infrastructure to manufacture PV modules for less than 30 cents per watt, well below the current industry cost-per-watt benchmarks for crystalline silicon modules. The optically enhanced, low-cost module architecture is claimed to use 80% less silicon than mainstream solar panels and eliminates the need for module lamination. As a result of the innovations, manufacturers can dramatically increase the capacity of their existing factories for a fraction of the normal cost.

Applications: A wide range of applications, particularly for high-irradiance regions.

Platform: Banyan's Optiwave patented technology is claimed to dramatically reduce module cost by replacing cell area with low-cost concentrator optics. The optics-based architecture is designed into a module with the same footprint as standard silicon modules. In arid, high sun areas, the Optiwave modules are claimed to deliver lower LCOE and better internal rates of return compared to traditional modules

Availability: Currently available.

Products in Brief

Sungrow launches custom-designed string inverter in Japan

Sungrow has launched a custom-designed string inverter in Japan. The SG49K5J has a nominal AC output power of 49.5KW and a maximum efficiency of nearly 99%, according to the company. The SG49K5J is stable in high temperatures, ensuring excellent yields of power generation, and has passed the JIS8502 salt spray test. This test examines if the inverter can work stably in conditions with high salt levels (coastal areas) and humidity in the air, by placing the inverter in a salt spray chamber for a period of 50 days. The SG49K5J also works in numerous bad weather conditions and hostile environments.

Ideal Power's 'SunDial' PV string inverter adds bi-directional third port for energy storage

Ideal Power's new 'SunDial' PV string inverter includes an optional bi-directional third port for direct integration of solar with energy storage during initial installation or any time in the future. This gives solar installers the flexibility to build their project with storage now or plan for its integration in the future without having to replace the solar inverter or add a separate battery converter. Ideal Power plans to target commercial and industrial scale PV installations that want the optionality of adding energy storage or other DC sources in due course.

SnapNrack's MLPE rail kit is UL 2703 certified with Enphase and SolarEdge systems

Under SnapNrack's UL 2703 listing and with the launch of its MLPE Rail Attachment Kit, installers are no longer required to bond optimisers with ground lugs and bare copper. When using microinverters, ground lugs and bare copper are also not required to bond module rows. The kit works with Enphase microinverters and SolarEdge optimisers to directly attach to SnapNrack rails. The kit comes pre-assembled and installs with a single 1/2" socket, utilising standard channel nuts for Snap-In attachment to the rail.

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Product reviews

Modules | Ecoprogetti's A+A+A+ Class certified LED sun simulator tests all new high-efficiency cell technologies

Product Outline: Ecoprogetti has launched its latest sun simulator with LED technology in A+A+A+ Class certified and verified by TÜV. Ecosun Plus is the solution for precise and reliable I-V Curve tests of both standard PV modules and mainly for testing all new high-efficiency PV cell technologies.

Problem: Performing the measurement of the power and I-V Curve of the PV modules is extremely important to warrant customer the quality of the modules. Testing the PV modules with Ecosun Plus technology enables the user to obtain reliable testing results and to guarantee to the customers a high-quality power measurement. All PV modules need to be tested and sorted

according to their power output; Ecosun Plus, with its embedded software, allows users to define and sort the PV modules according to their correct energetic classification.

Solution: The Ecosun Plus' advanced LED technology offers several advantages and innovative features compared to all other sun simulators in the market. The tester uses an LED light source with a 40 million-pulses lifetime and long pulse capabilities: 2-5s, customisable up to 30s and more. There is no recharging time between tests, improving productivity. The system deploys a calibrated pyranometer for accurate irradiance measurements.

Applications: PV module testing for all new high efficiency cell technologies such as PERC, HIT, MWT, bifacial, back-contact and hybrid-silicon solar cells.

Platform: Ecosun Plus is provided with own-developed software with advanced data management features. Ecosun Plus's LED technology is already used in many PV module production industries and also in laboratories for testing the efficiency of the modules.

Availability: Currently available.

Inverters | GoodWe extends 'Smart DT' inverter range with smaller form factor with higher power density

Product Outline: GoodWe has extended its three-phase, dual-MPP tracker 'Smart DT' series inverter range to accommodate a wider number of residential and small-scale commercial applications with three additional models: 8kW, 9kW and 10kW versions have been added to the 4-6kW range.

Problem: Project developers and EPC contractors require more cost-effective technology choices in some projects, particularly for arrays that are larger than a traditional residential system but smaller than a commercial one.

Solution: The Smart DT 8-10kW models

provide three-phase AC output, making system connections for larger homes and small businesses well balanced. The integrated dual-MPP trackers allow two-array inputs from different roof orientations. An advanced control algorithm and distinctive modularity make the inverter access higher power density. Sophisticated technology in circuit topology contributes to higher conversion efficiency, maximising the benefits of the entire system.

Applications: Large residential and small commercial solar PV systems.

Platform: GoodWe engineers have succeeded in adopting new AC capacitors for the models, giving the new inverters an advantage in reliability and life span compared to traditional ones. The volume of a new Smart DT series inverter is 516x474x192mm, 69% the size of the previous DT series. The weight is 24kg, 61.5% of the DT series. Lower volume and weight make installation and transport more convenient. Smart DT 8-10kW models also feature IP65 dust-proof and water-proof rating.

Availability: Currently available.

Inverters | KACO's blueplanet 2200 TL3 central inverter offer fast-track installation in varied environments

Product Outline: KACO new energy's blueplanet 2200 TL3 central inverter is designed for varied of applications and comes as an indoor or outdoor version, or upon request, in a container as a 2.2 MVA or even a 4.4 MVA station.

Problem: Providing central inverters that can be accommodated in a wide range of environments and available as part of an Integrated Power Station (IPS) enables fast, efficient execution of large-scale solar farms.

Solution: The central inverter features the

protection class NEMA 3R and is therefore safe to install outdoors. It is also available as part of an Integrated Power Station (IPS), thus catering for the growing need for fast and efficient execution of large-scale solar farms. The efficiency reaches 98.8% and delivers its full rated power in a broad ambient temperature range from -20 to +50 °C, making it suitable for use in desert-like as well as cold climates. Inverters, medium-voltage transformer and disconnection units for the DC and AC side are mounted together on a single base plate, known as a "skid", to create a ready-to-use, functional unit.

Applications: Utility-scale PV power plants.

Platform: The blueplanet 2200 TL3 is equipped with full digital control. The user interface consists of a large, graphical colour LCD with touch panel. All of the pre-configured country-specific settings have also been incorporated thus allowing for convenient activation.

Availability: From the third quarter of 2016.

System design | PVsyst 6.43 software allows modeling benefits of Ampt string optimisers

Product Outline: PVsyst and Ampt announced that PVsyst's latest software update includes Ampt's DC String Optimizers. The new version, PVsyst 6.43, allows users to model the performance benefits of Ampt String Optimizers in large-scale PV systems.

Problem: PVsyst's software is made for PV system designers to predict the performance of different system configurations, evaluate the results and identify the best approach for energy production. The production reports are also used by project owners and financiers to estimate project revenues from energy generation. The inclusion of Ampt String Optimizers in PVsyst's software update makes it easier for users to simulate the performance advantage of using Ampt in their solar power plants

Solution: Ampt String Optimizers are DC/DC converters that manage power at the string level. They perform MPP tracking on every 3-6 kilowatts (kW) of PV, which is 50 to 300 times more granular than typical central inverter designs. This helps recover system losses from electrical mismatch over the life of a power plant. In addition, systems with Ampt double the number of modules per string, which reduces the number of combiners, cabling and associated labour by up to 50% to save on electrical balance-of-system costs. PVsyst is also now able to model systems that take advantage of inverters with 'Ampt Mode'.

Applications: Utility-scale PV power plants.

Platform: PVsyst is a provider of software to model PV system performance. PVsyst is used by system designers and financial institutions around the world to accurately analyse different configurations within a PV system, evaluate the results and identify the best approach for efficiency and cost.

Availability: Already available.

Inverters | SMA Solar provides first medium-voltage station in a 10-foot container pre-assembled

Product Outline: SMA Solar Technology has launched the world's first medium-voltage station in a 10-foot container for Sunny Tripower inverters, the MVS-STP. The turnkey MVS-STP solution, specifically designed for string inverters, is claimed to simplify the set-up of PV power plants with a decentralised system layout.

Problem: In the past, decentralised PV power plant builders could only create the link needed to connect to medium-voltage grids directly on-site with components that had been delivered individually. Adapting the components to each other, organising overseas and domestic transport, and assembly used to mean long transport and installation times.

Solution: The MVS-STP comes with every component pre-assembled in a 10-foot container with an optimised cooling system. This maintains the advantage offered by the decentralised installation of the string inverters, which are still installed directly on-site. The MVS-STP is suitable for global use, particularly for decentralised ground-based PV systems and large-scale commercial roof systems. This single-source principle makes the connection easier without major effort on-site. Thanks to its low maintenance requirements, PV power plants in remote, difficult-to-reach regions can benefit from the new MVS-STP.

Applications: Wide range of regions, notably in remote areas.

Platform: The MVS-STP is an integrated solution and consists of a transformer, a low-voltage distribution board for connection of up to 30 Sunny Tripower inverters, medium-voltage switchgear, and it works with 600 kVA to 1800 kVA of power.

Availability: Currently available.

System design | SunPower's 'Equinox' residential rooftop system offers 70% greater electricity generation

Product Outline: SunPower has launched its 'Equinox' solar PV system to the US residential market, claiming it to be the first solution in which every major component has been designed and engineered by one company to work seamlessly together.

Problem: Conventional residential rooftop solar design and systems can be complicated and not harmonious, with companies assembling disparate parts and each built in isolation by different manufacturers. A piecemeal approach can result in decreased performance, low-quality aesthetics and longer installation times.

Solution: SunPower's 'Equinox' system has been designed to deliver 70% more electricity generation in the same space over 25 years with 70% fewer visible parts, all backed by one company with one warranty. This is intended to provide the most efficient and reliable residential solar power system available that also complements the aesthetics of a building.

Applications: US residential rooftops.

Platform: The system incorporates SunPower's solar panels, with microinverters pre-integrated into each solar panel. The microinverters also allow for system designs that safely conceal wiring. The SunPower 'InvisiMount' mounting system is engineered to be hidden beneath solar panels. SunPower's 'EnergyLink' ecosystem, a Smart Energy management platform, tracks energy production and consumption in real time, offering an intuitive user interface. A 25-year product and power warranty exists for the entire solar array.

Availability: Already avaialable in the US.

20 energy storage disruptors

Storage | Andy Colthorpe and Ben Willis profile some of the companies and technologies making waves in the fast-changing world of stationary energy storage

The term disruptor is thrown around a lot these days in a world rapidly facing digitisation and the fight to stay relevant is becoming ever more competitive in energy storage. While technological breakthroughs are always exciting, to paraphrase an old saying, there's a lot that can go wrong between filling a cup with liquid and putting it to your lips. In the race to commercialise technologies and business models for a mass market still in its infancy, the real disruptors in energy storage aren't just in the lab, they are making a real difference in houses, commercial buildings and on and off the grid.

We have carefully selected 20 such technology and service providers for this feature, with commentaries by energy storage market analysts Logan Goldie-Scot at Bloomberg New Energy Finance (BNEF) and Brett Simon of GTM Research.

"When assessing new companies, we are not looking for great ideas which are simply impossible to implement or are ahead of their time," Goldie-Scot says. "We are looking for companies that are currently addressing big opportunities, with innovative solutions and have proven track records.

"One way of assessing them is by looking at potential to scale, innovation and momentum. Many energy storage technology companies are clearly innovative but have yet to show they can scale, and momentum is often lacking. The ones that tick all these boxes are incredibly impressive."

KEY

Residential

Commercial & Industrial

Utility-scale

Off-grid

1

Company: **Redflow.**
Technology: **ZCell**

The world's first residential flow battery seemed a surreal proposition to some but the device received its real-world launch in late March. Australian company Redflow is targeting its domestic market for solar self-consumption.

Falling feed-in tariffs (FiTs) and high energy prices are making behind-the-meter storage an increasingly attractive proposition. Australian tech entrepreneur Simon Hackett's company believes flow batteries, considered too bulky for residential applications in other countries, could work Down Under, where population density is considerably lower than most developed nations.

Prior to the launch of the household system, Z Cell, which comes with a standard 10kWh of energy storage, Redflow focused on "off-grid and fringe-of-grid applications", GTM Research's Brett Simon says. Flow battery technology still needs to be proven, according to Simon.

"The release of a first residential flow battery is fascinating but I am not yet convinced that it will displace lithium-ion in that segment," Logan Goldie-Scot at BNEF says, adding that while flow batteries can be effective in longer duration storage applications, the more lucrative applications are shorter duration, making commercialisation a tricky task.

2

Company: **Tesla.**
Technology: **Powerwall and Powerpack**

US EV manufacturer Tesla's debut play in the stationary storage sphere needs little introduction. The company's CEO Elon Musk announced the Tesla Powerwall and Powerpack products to an expectant public in 2015, since when the hype has shown little signs of going away.

Available for residential, commercial and utility-scale applications, Tesla claims its products raise the bar on cost-competitiveness by virtue of the production scale it expects to achieve at its Nevada Gigafactory. Some have questioned the trumpeted price advantages, particularly for the Powerwall, claiming that total system costs are much higher than Tesla admits.

"Tesla has historically installed a significant number of systems in California, and Tesla expects substantial cost reductions once the Gigafactory reaches scale, though it remains to be seen if Tesla can actually deliver on these claims. Nevertheless, other battery vendors are projecting similar cost trajectories, and it remains to be seen how well Tesla will compete against established vendors," says GTM's Simon.

3

Company: **Sonnen.**
Technology: **SonnenCommunity**

Germany's market leader in residential energy storage with more than 10,000 systems sold, Sonnen has quickly identified that commoditisation of battery storage could impose aggressive competition on providers. The company's goal is to be seen as an energy services provider as well hardware vendor.

After running a series of trials including aggregated virtual power plants in its homeland, Sonnen last November launched perhaps its most daring and innovative 'product', Sonnen-Community. The scheme lets Sonnen battery system owners – and non-system hosts who can join for a fee – trade the surplus energy in their systems, using the grid as a virtual large-scale battery.

"[The] SonnenCommunity platform offers an intriguing opportunity for customers to trade electricity with one another, though this programme is still in its early stages," Simon says. This makes the company one of the few "pioneers" of aggregating behind-the-meter residential storage, adds Goldie-Scot says. Both Goldie-Scot and Simon say that it will be interesting to see if Sonnen can and will take the idea to other markets it is active in such as North America and Australia.

4

Company: **S&C Electric.**
Technology: **PureWave**

S&C Electric's family of energy storage-management systems, PureWave, offers solutions from 25kW up 100MW for commercial, utility and off-grid applications.

The company has been involved in some significant pioneering trials around the globe, allowing it to gain valuable experience proving the case for storage in a variety of settings. These include a project in Texas that links four separate micro-grids and a variety of generation source, including PV, as well storage. The company has also built one of the largest battery projects in Europe to date, a 6MW/10MWh system in the UK.

"S&C has so far been focusing on larger systems, and recently completed a 7 MW project with Half Moon Ventures in the Town of Minster, Ohio which will provide multiple services including frequency regulation in the PJM market, T&D deferral, power quality improvement, and peak demand shaving," says GTM's Simon.

5

Company: **Panasonic.**
Technology: **Smart Towns**

A new Zero Energy Homes (ZEH) standard will be mandatory from 2020 in Japan, where as many as 1 million new houses are built annually. Tesla's Gigafactory competitor-collaborator Panasonic and other Japanese firms have long been selling complete kits for residential PV customers, adding storage as backup or self-consumption solutions more recently.

Panasonic is even engineering, designing and building its own 'smart town' near Yokohama. The company's next gen home PV offerings will also include management systems to enable trading of power. While this is still an early-stage function, Japan's electricity market is in an ongoing process of liberalisation which extended to retail sales in April.

Panasonic is already one of the world's biggest battery vendors, Simon says, with production volume giving it an "edge in battery cost". "Smart Home is still a young concept, but may offer additional opportunities for residential energy storage," he says, also referencing recent activities by the company in solar-plus-storage for homebuilding companies in Canada.

Goldie-Scot meanwhile says that although Panasonic is trialling residential storage with utilities in Australia, "it is not clear it is proactively pushing into the [residential storage] market as quickly as some competitors".

6

Company: **NGK Insulators.**
Technology: **NaS Battery**

Japanese firm NGK Insulators was an early mover in the storage business through its sodium-sulphur (NaS) battery and has around 3GWh installed worldwide now, including the world's largest battery system in Japan. Sodium-sulphur is a form of molten salt technology that is particularly suited long-duration applications.

Despite the early toehold the company has gained, lithium-ion batteries appear to be the latest technology of choice for grid-scale storage projects, according to a recent study from Lux Research. Meanwhile, flow batteries are also waiting in the wing as an alternative long-duration technology.

BNF's Goldie-Scot says: "Between 2007 and 2010, NGK had 66% market share

for stationary energy storage. However, it has only won a couple of projects recently, albeit large ones such as the 35MW-280MWh project in Italy for Terna. If flow batteries are able to scale up effectively, this will pose a major challenge to NGK which has long been the only available option for customers looking for long-duration energy storage systems.

7

Company: **Sunverge.**
Technology: **Solar Integration System**

While others have also trialled virtual power plant (VPP) functions for aggregated residential behind-the-meter storage, US company Sunverge has made headlines for related activities that include attracting significant investment – around US$20 million – from Australia's biggest utility, AGL, in the first quarter of this year.

CEO of the Australian Renewable Energy Agency (ARENA), Ivor Frischknecht, said the partnership "will accelerate the roll out of a state-of-the art grid integrated battery storage solution to Australia's large household storage market".

The company executed its first VPP project in Canada earlier this year, in which the technology's capabilities in reducing peak demand, providing frequency response and other services to the network will be trialled in 20 houses. These will be able to 'time shift' their solar energy for the Powerstream project in Ontario, which applies time-of-use pricing to residential customers.

"These [virtual power plant] projects

are in the early stages, but the results may offer new business models for utilities and additional opportunities to provide grid services with aggregated behind-the-meter storage," Simon says.

BNEF's Logan Goldie-Scot meanwhile says AGL's strategic investment into Sunverge "could position it well in Australia as well [as the US]".

8

Company: **Aquion.**
Technology: **Aqueous Hybrid Ion battery**

Aquion's Aqueous Hybrid Ion battery uses sodium-ion technology (essentially saltwater) and is claimed to be one of the cleanest batteries on the market. Aside from flow and NaS-based batteries, Aquion's is another technology that sits firmly in the long-duration camp.

The company has been particularly successful in securing early-stage funding to develop its technology and is targeting a cost of US$160 per kWh when it eventually scales up production. However, without only a few significant deployments under its belt, the jury is still out whether it Aquion will fulfil its early promise.

"Aquion continues to attract VCPE funding and has secured nearly US$200m to date. The company remains very early stage though and has only deployed a small number of relatively small projects," says Goldie-Scot.

Simon adds: "Aquion's technology has typically been deployed in markets where electricity prices are high, such as a project under development in Puerto Rico. Aquion's aqueous battery technology still has only a handful of commercial deployments. Aquion has significant cost reduction goals."

9

Company: **Green Charge Networks.**
Technology: **Greenstation**

Anticipating the now seemingly inevitable growth of EVs and fast DC chargers at commercial premises like supermarkets, municipal facilities and hotels, Silicon Valley's Green Charge Networks is using energy storage to mitigate demand spikes from EV charging in its home state of California and elsewhere.

The company looks to be building up scale quickly. It has a partnership with ChargePoint, which has over 22,000 EV chargers in operation, a manufacturing deal with Flextronics and works with US utility Duke Energy and REC Solar. It is also among those repurposing '2nd life' EV batteries with Nissan.

French utility company Engie (formerly EDF Suez) acquired an 80% stake in Green Charge in May.

"This is the first major utility deal for a majority stake in an energy storage company to date," Goldie-Scot says of the Engie acquisition, adding that while Green Charge's 'no upfront cost' model is capital intensive, being bought out Engie will give it a US$10 billion balance sheet to lean on. Goldie-Scot believes Green Charge has about 48MWh of storage deployed or under construction.

"It's shared savings model can make storage for peak demand management attractive for customers with particular loads and in markets with the right tariff structure," Simon adds.

10

Company: **ViZN.**
Technology: **Zinc-iron flow battery**

ViZn is another producer looking to make its mark in the long-duration flow battery market. Its technology, based on zinc-iron chemistry, is available in various configurations, and is aimed larger scale end of the market, for utility, micro-grid and off-grid applications such as mining. The company recently took a big step forward in proving out its technology when it was chosen to supply a 2MW/6MWh grid-balancing system in Ontario Canada.

"Flow batteries are an emerging technology, and still need proof of commercial bankability," says GTM's Simon. "As costs fall, the technology may become more appealing for long-duration (3+ hour) applications. ViZn's flow battery technology is a non-acid medium, which aims to eliminate the pump and component erosion found in other flow batteries and thus improve lifecycle system costs and performance. ViZn has a strategic manufacturing partnership with Jabil."

Goldie-Scot adds: "This company is in a similar boat to Aquion: it has attracted a fair amount of investment but has yet to have a meaningful impact on the market."

11

Company: **Ideal Power.**
Technology: **Sundial**

Having made its name as a provider of power converters, including acting as equipment provider to Sharp's US commercial storage offerings, targeting China's C&I sector and supplying 125kWh magnetic power converters for large-scale projects, Ideal Power has also now launched Sundial, an all-in-one inverter tailored to be integral to solar-plus-storage solutions for businesses.

SunDial is a fully isolated PV string inverter with an integrated PV combiner, disconnects and a built-in Maximum

Power Point Tracker (MPPT). The product is aimed at the commercial sector and comes in a 30kW model, using the company's patented Power Packet Switching Architecture.

"[Sundial is] a solar PV string inverter which includes the option to add a bi-directional component to allow for energy storage integration, offering the option to install energy storage upfront or later as a retrofit to an existing solar PV system," GTM's Simon says.

"The multiport conversion system offers greater opportunities for solar-plus-storage, and shows an acknowledgement of a future behind-the-meter market where pairing storage with solar PV becomes common."

12

Company: **RES.**
Technology: **RESolve**

Multi-disciplinary renewables engineering firm, RES, has become one of the early movers in constructing large-scale storage project, with 88MW under its belt already and another 200MW under development.

At the heart of the projects it undertakes is its proprietary 'RESolve' control system, which integrates the energy storage unit with the renewable generation source, and both of those with the grid. RESolve has been designed to allow the overall system to offer a variety of grids protection and support services and thus to benefit from multiple revenue streams.

"RES has built up significant experience with projects in 10 or so different areas, across a number of applications relying on multiple revenue streams," says Goldie-Scot. "This experience will no doubt prove very valuable for future projects.

"The RESolve platform has mostly been applied for frequency regulation applications thus far, but is being utilised for other applications in a few project," adds Simon.

13

Company: **Younicos.**
Technology: **YCube**

One of the trailblazers in software-based battery management to enable multiple applications, the German-US company grew out of a research lab rooted in Germany's solar and wind industries.

The first company authorised to provide primary frequency control with batteries in Europe, Younicos has executed numerous utility-scale grid services projects in Germany. The company has also launched its own range of hardware: the Y.Cube is a plug-and-play system that combines a lithium-ion battery with Younicos' power conversion system.

"The Y.Cube plug-and-play [integrated power converter and storage] system can work with multiple technologies and is modular," GTM's Simon says.

While Logan Goldie-Scot agrees that Younicos has been another leading-edge company, it faces a battle to remain at the front of the pack as the industry ramps up.

"Younicos is one of the leading energy storage software providers and system integrators. It has struggled to compete for some of the larger tenders recently though, losing out to integrated solutions providers and developers such as AES, RES and Invenergy that have their own software platforms."

14

Company: **Saft.**
Technology: **Intensium li-ion battery**

French company Saft made the news recently when it agreed to a US$1 billiion buyout from oil and gas giant Total.

Prior to the acquisition, the company had involved in various trial projects around the world, supplying its lithium-ion batteries to a number of projects focusing on renewable integration in remote areas, such as islands, where electricity prices are high. Projects include a 1.2 MW installation for a remote community in Alaska, a system for renewable integration at the Anahola solar PV plant in Hawaii, and a recently awarded contract for 10MW of energy storage in Puerto Rico.

BNEF's Goldie-Scot says of the deal: "This is the largest ever M&A deal for an energy-storage provider. Within energy storage, only a few deals for battery-materials suppliers have surpassed it. Despite this, the acquisition is unlikely to disrupt the sector significantly. Total will gain a foothold in the market but the company will not go head-to-head against larger manufacturers, such as LG Chem, Samsung SDI, Tesla and Panasonic, in terms of volumes.

15

Company: **AES.**
Technology: **Advancion**

AES' Advancion system is designed to function as an alternative to peaker power plants, providing grid support at times of high demand. The fourth generation of the Advancion was unveiled at the end of 2015, offering greater power density and introducing the 'Advancion Node', a new modular building block for its storage systems.

AES is expanding internationally with projects underway in the UK, Netherlands and Chile. It recently said it was looking to add the Philippines, India and the Dominican Republic to that list by the end of the year. AES operates one of the largest battery storage fleets of any company worldwide, with some 384MW of assets operational.

"AES is moving towards greater standardisation with the Advancion platform, which is likely to lead to reduced costs and faster deployment times," says Simon. "AES' partnerships with leading battery manufacturers also give it an edge in terms of all-in system pricing."

16

Company: **AMS:**
Technology: **Hybrid Electric Buildings**

It seems likely recent investors like Arnold Schwarzenegger have faith that Advanced Microgrid Solutions (AMS) CEO Susan Kennedy understands issues driving the US market – Kennedy was once chief of the California Public Utilities Commission (CPUC), with ever-increasing distributed generation on its networks.

As well as a large-scale portfolio that includes a 3.5MW project for a water treatment plant in California, the company is targeting the distributed grid market with aggregated commercial storage installations that also serve utility functions. The company is likely to get its chance to build further experience with a 50MW award

of mandated behind-the-meter storage under long-term capacity contracts from utility Southern California Edison (SCE).

AMS claimed it could be purchasing up to 500MWh of Tesla Powerpacks, so confident was AMS in the technology's suitability, Kennedy said.

"Advanced Microgrid Solutions pursues a hybrid approach, deploying a portfolio of projects across multiple customers' sites which can be leveraged to provide grid services for local utilities while also providing services to building owners such as demand charge management," GTM's Brett Simon says.

"It remains to be seen whether Engie's acquisition of Green Charge Networks will impact AMS, since the utility is also an investor in the latter company," Goldie-Scot says.

17

Company: **Greensmith.**
Technology: **GEMS IV**

A big winner in the early-stage US market of 2014 with as much as a third of 61.9MW deployed at grid scale and behind the meter that year utilising its control platform, GEMS, Greensmith appeared to keep pace with the market, with the software-driven system now in its fourth version.

Announcing some big grid-scale wins in 2015, the company attracted investment from E.On at the end of the year.

While the company provides turnkey systems, it also provides software-as-a-service. This emphasis on software extends to interactive storage modelling and forecasting tools included as part of the GEMS IV platform. Greensmith claimed to have reached a 70MW "milestone" in deployments at the beginning of April.

"Energy management software provides opportunities to maximise value of energy storage.[Greensmith is] Involved in several utility-scale projects in the US where [its] software has been applied for multiple applications, across different technologies," GTM's Simon says.

"The company has developed a good reputation for being a leader in energy storage software and integration," Logan Goldie-Scot confirms. "Although its activity has been limited to the US, it's been involved in some fascinating projects and has an impressive range of solutions spanning multiple applications."

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Company: **Geli.**
Technology: **Internet of Energy**

Growing Energy Labs Inc (GELI) is one of the few pureplay software providers finding a foothold in the US market.

It is debatable whether Geli is the first to coin 'Internet of Energy' as a phrase, but the company uses it to describe its

software and networking solutions for energy storage. It has caught the market's imagination enough to attract US$7 million of investment from Shell Technology Ventures (STV) in April.

Geli has also been awarded a grant from the US Department of Energy Advanced Research Projects Agency – Energy (ARPA-E) to control more than 100 distributed energy assets and demonstrate an automated transactive energy market. It also has a partnership with solar inverter maker Tabuchi Electric and a four-way tie up with global electrical supplies specialist Gexpro, LG Chem and Ideal Power.

"Geli's partnership with Gexpro positions them to have greater behind-the-meter opportunities as Gexpro increases its energy storage activities," Simon says.

"Geli stands out from other software companies in that it is explicitly a pureplay software company, and is looking to license that software to others, or to enable customers to use its online tools to inform their decisions," Goldie-Scot says.

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Company: **Enphase.**
Technology: **AC battery**

Much was made over possible rivalry between Enphase and Tesla as both did their best to build up anticipation for their entry into the residential battery market. After a wait-and-see 2015, Enphase's battery for home systems, which comes in a modular 1.2kWh design, is now available for installers to order in Australia

and New Zealand.

Priced at around AU$1,150/kWh (US$838/kWh), the bi-directional device's AC coupled configuration means it can be retrofitted to existing solar systems and installed in just over an hour and a half, the company claims.

With lithium iron phosphate battery materials supplied by Japan's Eliiy Power, it comes with a 10-year warranty and is expected to launch in the US late this year before a rollout to selected European markets in 2017.

"Enphase announced a trial project with SA Power Networks in Australia at the end of 2015 to gain insights on how energy storage can be utilised for load management and explore new business models for utilities," GTM's Simon says, adding that the company "may have the opportunity to pursue energy storage offerings for existing solar PV customers using Enphase products".

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Company: **Nissan & Eaton.**
Technology: **V2G and 2nd EV life batteries**

One of several partnerships exploring the repurposing of second life EV batteries, Japanese car company Nissan's partnership with engineering giant Eaton on second life batteries and vehicle-to-grid (V2G) is notable for the scale its participants could achieve.

In addition to a technology partnership which has developed a control centre for dispatchable behind-the-meter energy storage resources, the pair is launching xStorage, a residential storage system for the UK. While there are potential drawbacks to using second life batteries, such as the unpredictability of remaining life span, the units could be sold as cheaply as US$4,500 for a 4.2kWh battery repurposed from Nissan's popular LEAF EVs.

The range of major announcements from the collaborations so far is completed with a trial of vehicle-to-grid technology in Britain. Owners of 100 LEAFs and electric goods vehicles would be able to sell surplus electricity from their vehicles into the grid.

Honourable mentions

In addition to the above list, there are hundreds of companies doing exciting things, either from a technical or business point of view. Some of those include Stem, which was another big winner in California's utility mandates and operates on a similar basis to AMS in providing both behind- and front-of-meter benefits. SimpliPhi Energy, a provider of off-grid systems which came out of the movie business, supplying energy solutions to location shoots, now claims to have dealt with thermal runaway in lithium batteries. Ultracapacitor maker Skeleton Tech has been one of the recent big magnets for VC cash. A small German company, ASD Sonnenspeicher, claims to have developed a system for placing stationary storage batteries in parallel circuits, allowing for simple scalability, while US start-up 24M has been pinpointed by some analysts as having what looks like an effective, energy-dense variation on lithium battery chemistry in pre-commercialisation stages. Meanwhile, for all the excitement over next-gen batteries and growth in the US market for them, North America's most used energy storage provider is Trojan, maker of advanced lead acid devices.

Five reasons to be cheerful about the European solar market

Credit: Younicos

Market drivers | Shifting generation mixes, a regulatory re-write, the fall in technology costs and simultaneous rise in technical capabilities are transforming the European energy market. Status quo solar may not have terrific prospects but there are plenty of reasons why it has a central role to play in Europe's energy future. John Parnell reports

Europe would likely consider itself the crucible in which the present day solar industry was forged. It can certainly claim its share of cost-cutting technical breakthroughs. The feed-in tariff (FiT) programmes of Italy, Spain, Greece and especially Germany, meanwhile, drove GW-scale demand sparking the emergence of more manufacturing and a globalised supply chain that saw prices plummet further.

Shifts in manufacturing patterns, popularity that proved too rich for the public purse and a deep recession that amputated power demand have all contributed to European solar's current challenges. Those are well documented, unpredictable and unfavourable policy changes, trade barriers. These are the stories that cross into mainstream media and feed what, we'll argue, is a false impression of solar's future prospects in Europe.

Let's set the scene first. The European Commission is currently deciding on its 2030 climate and energy package. A 27% goal for the share of renewables by 2030 is on the table but that does not track very far from what the continent is headed for anyway. A suite of policies targeting the development of a single energy market, secure supply and reduced demand are all in development. Meanwhile, a number of nations are suffering with oversupply, aging infrastructure and far from ideal conditions to tease out the investment required. At the same time, the financial and carbon cost of technology is shifting expectations. Low prices have left utilities in financial dire straits. Change is afoot but the appetite for risks would appear to be low. It's a tough market to operate in.

Despite all of this, many of the unique characteristics of solar offer it distinct advantages in what is likely to be a new-look energy market.

The rapid evolution of storage in Europe, where several grid-scale pilots are underway, is one reason for optimism over the future of solar in the continent

Simple economics

The levelised cost of electricity for solar is falling. In Europe, plummeting, wholesale electricity prices have perhaps taken some of the drama out of those reductions, masking the progress solar has made and the impact it could have.

"It's very well-known how solar costs have come down the curve in the last few years but even now the evidence base is pointing to a further shift and significant reductions in cost," says Phil Grant, a partner at the Baringa Partners energy consultancy. "Recent auctions in the Middle East have demonstrated where the clearing prices for auctions have come in. That is a step change I think. It's hit the US, it's hit the Middle East; are we going to see some benefits in the European market? That's when I think things get interesting."

Further cost reductions are coming, but while those filter through, a dramatic shift in the relative costs of solar and socket electricity could come via the latter.

"We are at an historically low period of power prices in Europe so relatively against the known costs that we see today, renewables do look expensive and require subsidies, but you have to recognise that we are at a low point in the last 10-15 years of power prices. Demand is being suppressed, there is over-capacity generally across Europe, we've had very benign weather conditions over the last few winters and we're in this world of pretty low power prices." This could change very quickly says Grant, pointing to how gas prices have fluctuated in recent years.

"[With] the closure of older forms of generation capacity, sharper weather changes, very suddenly we can jump from a world of €30MWh to €50MWh at which point the cost of renewables looks much more competitive," he adds.

Appreciating these costs in the context of present day pricing is easier when looking at power purchase agreements where the price paid by the off-taker can be held up against not the wholesale rate, but the going rate they pay a utility company. If that sector is going to stimulate significant demand in Europe, the economic opportunity and the fringe benefits need to be explained to the public sector bodies, big corporates and industrial operations that would be interested in such arrangements.

Christopher Burghard heads up First Solar's sales operation in Europe. He says there is no single driver for corporates to procure solar power.

"I don't think there is a general rule, businesses may have different reasons for investing in renewables. One might simply be that it is a good investment. If they can marry something that yields them a decent return, at a time when there aren't too many options to invest with good returns as an SME, with hedging the cost of an important input for them, that is one option.

"Another might be that they are paying a lot of money for electricity or they have a fundamental view that electricity prices are going to go up and they believe they can make a good bet today for the future. They will have a third party come in and invest for them while they harness the benefits of an advantageous PPA. Others simply view it as part of a CSR strategy that doesn't cost any money and provides a benefit to them," he explains.

Further efficiencies are on offer for PPAs using a private wire connection without the grid limitations and connection fees.

Ikea is one of a number of corporate embracing solar for a combination of brand and economic reasons

Credit Ikea

Storage

Storage is the perfect bedfellow for solar but significant and well-documented hurdles around regulation, cost and the underlying business model remain. The good news is that pilot schemes are well underway in several countries. The UK is expected to consult on a possible incentive scheme for network operators and the European Commission has the tricky 'how to classify storage' question in its sights.

Grant believes the question of how to define energy storage in a way that investors can be at ease with is possible and perhaps only a few years away.

"There's an awful lot of pumped hydro storage plant across Europe; conceptually, battery storage is playing a similar role, so it's not an unsolvable problem. What is more complex is if you're co-locating with solar: does the output of the battery qualify fully as green power? That is a more complex question and it needs a unified approach across Europe to address that. Otherwise you are going to get distortions, particularly on the continent as to how batteries are treated. I think there is a role there for the European Commission to provide some leadership and guidance on how you define that."

In a consultation on its renewable auction scheme, the UK government put forward a dual classification for storage as a system that can convert and store electricity and also act as a generating unit when that energy is converted back to electricity.

Grant describes storage as relatively simple from an operations perspective but harder to grasp from a business perspective, with arbitrage between high and low prices and a host of grid services on offer, but with a value that is harder to define. Solving this problem will go a long way to resolving concerns about pricing.

"Our analysis shows that purely on an arbitrage basis, it is quite hard to justify that investment today so you need those other services to top up your revenues," says Grant. "Given the cost trajectory of battery storage following perhaps a similar learning curve with solar, in four years' time you'll have purely merchant batteries that don't have to offer grid services, they purely monetise on the basis of wholesale arbitrage."

SolarPower Europe's CEO James Watson believes that while not the finished article, energy storage is more developed than people may think.

"It is already happening. National Grid is tendering for 200MW of storage in the UK; this is not a government organisation this is a private company and we are going to see more solar and storage which will drive both technologies," he says. "Storage is a natural partner to solar and there is already a lot of behind the-meter storage underway in Germany. Utility-scale developments are now emerging rapidly. We expect to see more tenders for solar that include a balancing solution as part of the requirements so the tenders themselves will stipulate for storage," predicts Watson.

"The more solar-plus-storage that comes on the grid the more people will see this as a really great option and we will move away from the mentality of 'coal is cheap'," he adds. "It takes more CO2-intensive generation offline and provides balancing services.

Solar and base load

The most common argument presented as the reason for large-scale solar's bleak future is the overcapacity issue. Why indeed would additional plant be added to an oversupplied network?

It is a fair point but one that fails to acknowledge, or perhaps give fair weighting to, the desire among European states to adjust their generation profile. The Union is expected to strengthen its 2030 renewable energy package from the current 27% to something beyond 30%. Watson says SPE is pushing for 35%. NGOs are pressing for 40% and above. This will form a key component of the EU's commitments under the Paris climate agreement, which, while not perfect, appears six months on to be triggering some response.

France and Germany are looking to decrease and entirely remove nuclear power from their mix respectively. The UK has pledged to shut all its coal power stations down by 2025, albeit with offshore wind, nuclear and gas the current preferred choice as replacements.

The three largest economies in Europe have shown that there is an appetite not make do with "enough" capacity, but to have the right kind of generation capacity and put policies in place to pursue that. To take the UK example, solar may not be the top-billed replacement now but by 2020, the appeal of solar and storage backed by clear regulations and with attractive economics may well change that situation.

"We have overcapacity in the power market but we somehow need to decarbonise at the same time," says Watson. "So there is a trend of saying yes we need to get rid of coal, and some people also say gas: this is the direction we're going in to get rid of the hydrocarbons and replace them with the technologies which are best for society, which are the cheapest and the greenest. We're in a transition period where solar will continue to develop in a sustainable fashion but that's not about feed-in tariffs; it's going to be about the technology, and greater exposure to the market through transparent tenders."

Digitisation of energy

This is a harder concept to define, but it is a central tenet of the European Commission's energy policy reset. It is about the technologies that power it, the services they enable and the impact that has on customer behaviour. It incorporates better visibility on billing, optimisation of self-generation (and storage) and a data-driven grid that has more in common with a modern IT network than a dumb system of cables that is closer to a Roman aqueduct. It enables demand response services, improved grid management and more interaction between customers and power providers.

Energy prosumers and increased carbon awareness from consumers and corporates will drive demand for measurable, traceable, flexible electricity from the cleanest and cheapest sources as and when they present themselves.

"Digitisation is a must for an energy system that is driven by renewables," says First Solar's Burghardt. "The smarter the plant, the better the plant can be steered and controlled and therefore integrated into the need that it serves. That's critical.

"Dispatchable, conventional power has the advantage that you can just turn power on or off; here you are talking about a system with environmental benefits, big fuel cost hedging benefits and so big energy security benefits too. The system has no fuel at times and you can maximise the benefit of that through storage, through better intelligence; that is to say, an intelligent grid, intelligent interoperability with that grid and intelligent consumption patterns. The larger that market, the better the functionality," adds Burghardt, segueing perfectly into the next theme.

The Supergrid and the single market

Plans to better connect Europe's disparate national grid systems and create a single energy market have obvious benefits for solar. A bigger market smooths out the imbalances of supply and demand. Germany's periods of negative power pricing and curtailed renewable capacity would be at the very least reduced.

While the opportunities this creates for solar, storage and indeed all renewable generation are clear, the design of this new better integrated pan-European grid could end up diluting the demand that created it.

Existing (dark blue) high-voltage lines, those planned for completion pre-2020 (mid-blue) and those planned for after 2020 (pale blue). Adapted from Platts and European Commission data

"There is a problem here that is going to need a framework to solve," explains Grant. "Interconnectors have developed economically based on price differences between markets. Price differences occur because of some structural difference between market A and market, and power flows from A to B. As you get more renewables in one market it can increase the price differential between it and adjacent markets and that sends a very strong price signal for new interconnector investment to take advantage of that arbitrage between markets. But as you layer in more interconnections you reduce the economic signal between markets and that is one of the challenges here.

Grant says this framework needs to trade off better integration of renewables with additional interconnectors, but without eliminating the price differentials that attract the investment to pay for them: "There is a role for a framework that protects interconnector investment in the event that we have so much interconnector capacity that it destroys, or cannibalises, the price signal that incentivised it in the first place."

The prospect of a British exit from the EU could also further complicate the situation with electricity trade between the UK and the rest of the EU subject to tariffs. Ireland, which is connected via the UK at present, would be cast adrift from the network while Norway's substantial hydro capacity would be partly disconnected from the continent and the potential new connection to Iceland's geothermal and hydro power.

Changes

The scale of change in the European energy market is unprecedented. The retreat of nuclear and increasingly untenable position of coal will have huge impacts on demand for new capacity. The continuing shift from utilities and oil majors (not just to ring fence their fossil fuel business but taking bigger bets on solar projects and investing in PV and storage manufacturers) means there is a new pool of highly organised, well-financed operations taking an interest in the evolution of power markets.

So many of these changes play into the hands of solar. By old standards, the future for solar looks bleak. Looking forward, PV will have a central role in the evolution of the European power market and the companies that position solar within the context of these changes are the ones that will prosper. ■

Keeping up with the Joneses

North America | The US is leading the charge for solar in North America, but its next-door neighbours, Canada and Mexico, are also pressing ahead with plans to boost deployment. Danielle Ola reports on the policy developments expected to underpin the growth of solar in the two countries

OCI Solar Power

The US solar market is expanding at an exponential rate, thanks to a booming residential PV market and continued realisation of the utility sector's double-digit gigawatt project pipeline. Recently celebrating one million solar installations nationwide, the US now boasts a total installed capacity of 27.4GW, enough to power 5.5 million homes. Its neighbouring North American counterparts, Canada and Mexico, have some way to go to catch up, with total installed capacity at over 2.5GW and 104MW, respectively.

In 2015, the US installed 7,260MV of solar PV. On a comparative development timeline, Mexico is currently in 2004 in terms of US installed capacity by that year. At that time in the US, the fastest growth in the country was the commercial PV market, but in Mexico, utility-scale solar is expected to take a front seat.

Both Canada and Mexico had been lacking in appropriate energy policies that could adequately serve their growing solar markets, and began to see significant industry growth once new renewable-friendly legislation was in place. For Mexico in particular, this also meant a framework that could cater to an emerging market.

"The turning point really was the energy transition," says Mohit Anand, senior analyst at GTM Research, referring to a wave of regulatory reforms recently introduced in the country. "Prior to that, there wasn't a policy that was suitable for an early stage market; especially in a developing country like Mexico because it didn't give the kind of confidence that financiers need."

The reforms have made the country, for the first time ever, a competitive market. "It really is liberalisation in the truest sense of the word," says Anand. "Pre-liberalisation it was a fairly stuck-up, monolithic, monopoly-oriented market."

Meanwhile, according to Patrick Bateman, director of market intelligence and research at the Canadian Solar Industries Association (CanSIA), despite Canada's leading solar province, Ontario, surging ahead of the rest of the country has been slow to embrace PV. "The reason why Canada as a whole has been slower than the US is twofold: the first one is that electricity and resources are very much a provincial and territorial jurisdiction in Canada and we haven't had a lot of federal leadership on those files over the last decade. The second reason I would say is that in the US they have excellent federal tax policy over the last decade that has really accelerated the solar industry there," Bateman says.

Solar in Mexico looks set to take off following the country's successful first tender earlier this year

Below we profile the two countries and look at the drivers as well as the remaining obstacles for their solar industries.

CANADA

A lack of national-level policies

The unique constitutional fabric of Canada dictates that each jurisdiction has its own set of regulatory guidelines and processes. This poses a barrier for a streamlined approach to energy policy – despite it being a predicament that neighbouring America has clearly found surmountable, according to Dan Woynillowicz, policy director at Clean Energy Canada, a clean energy and climate policy think tank.

"Similar to the US, the bulk of jurisdiction and decision-making around electricity policy in Canada occurs at the provincial level and not the federal level," Woynillow-

Innovation makes APsystems a global solar leader

INSTALLERS' CHOICE | With over 250MW installed at the end of 2015, APsystems continues its unprecedented growth in all regions.

Thanks to its strong MLPE portfolio, APsystems ranked no. 2 in global market share among microinverter suppliers by shipments in 2014.

APsystems was first to market with a dual-module microinverter, the YC500, offering outstanding power while lowering balance of system costs for residential installations. It's now a flagship product, the microinverter of choice worldwide for installers who want reliability and fast installation.

Always forward thinking, APsystems also introduced the world's first true 3-phase microinverter, bringing all the advantages of microinverter technology to the commercial segment for the first time.

How does APsystems lead the industry?

Savings in component and assembly costs at the point of manufacture have allowed APsystems to maintain a price point highly favorable to customers, with solar technology unmatched by others in the microinverter arena. APsystems microinverters are built around a highly programmable FPGA chip, allowing each unit to be built with about 30 percent fewer internal components than other microinverter offerings.

As the market tests new technologies and platforms, the advantages of solar microinverters remain. These include ease of system design and installation, the safety of low-voltage DC for installers and building owners, and the lowest LCOE for consumers.

APsystems notes that the overall market for Module Level Power Electronics, including microinverters, is extremely strong around the globe. A leading analytics firm recently noted that sales of microinverters and related products should top 2 gigwatts by year's end, and predicted the microinverter segment's share of the larger MLPE market could triple by 2018.

"The microinverter proves itself on countless rooftops around the world, every hour of every day," says Zhi-min Ling, President & CEO APsystems Global. "It's a technology that is here to stay, and APsystems will be here to push it forward."

With over 250MW installed at the end of 2015, APsystems continues its unprecedented growth in all regions around the globe; significantly increasing its sales and support staff in the EMEA region, adding new product certifications in Brazil, achieving major customer wins in emerging solar markets like South Africa and will soon be celebrating a new office opening in Mexico.

APsystems locations around the globe are offering installers a new power paradigm with a proven power electronics architecture that increases solar harvest and ensures maximum output for residential and commercial solar arrays. APsystems remains committed to innovation, keeping microinverter technology at the forefront of the industry and putting more power and efficiency into every solar array.

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icz says. "A significant difference between Canada and the US is that in the US there has still been a lot of federal engagement to try to encourage development of solar energy; we really have not seen that in Canada."

For the last 10 years, Canada has had a Conservative federal government that mostly wound down some of the existing programmes supporting renewable energy, which contrasts with the prominent support given to solar in the US, such as the US Department of Energy's SunShot Initiative.

"[The US] has had more on the innovation and early deployment side of things," adds Woynillowicz. "They've also had the solar investment tax credit (ITC) as well, which has played a significant role in encouraging solar in the US."

New policy drivers for renewables

The new government under prime minister Justin Trudeau has made promises to shake off Canada's reputation as a laggard on climate change, with designs for it to emerge an 'energy superpower' by fixing the country's reputation as a carbon bully in international climate negotiations.

"The federal government has actually identified increasing the use of renewable electricity as a key piece of what needs to happen within the energy system to achieve the greenhouse gas reductions that they committed to in Paris," says Woynillowicz.

These promises have as of yet to translate into legislation, but the government has embarked on a cooperative process with the provinces to develop a Climate Plan for Canada, which provides for fuel-switching and emissions regulations on coal-fired generators.

"In addition to making the tax treatment more favourable as with oil and gas, we'd like to see tax treatment become more competitive like that in the US," says Bateman.

Examples of renewable energ policy have only been seen in dribs and drabs, highlighting the piecemeal policy framework of the country. For now, the future of clean energy rests on the cumulative effect of some of the other pieces, rather than any single overarching policy.

Ontario

"Generally speaking, when you speak of solar energy in Canada, it is really referring to solar energy in Ontario," says Kevin Allan, vice president of sales and marketing for Grasshopper, Ontario's largest residential solar company.

Today, the province has enhanced the competitiveness of solar by phasing out coal in its entirety – which is one of the most significant environmental actions in North America as a whole. It has installed well over 2,000MW of solar to date. Under its Long Term Energy Plan, Ontario expects clean energy to comprise half of all installed capacity by 2025.

Some industry analysts reconcile the pivotal turning point for Canada's solar industry with the launch of Ontario's Green Energy Act (GEA) in 2009. Just a year prior, there was 5MW of solar installed nationally, and in 2009 that increased tenfold and from that point forward there were several hundred megawatts installed every year. The GEA gave rise to Ontario's feed-in tariff (FiT) programmes which really drove the first real wave of solar in the country.

The province has since switched from this approach to a competitive procurement process under the Large Renewable Procurement (LRP) programme. Under Phase I in March this year, 16 contracts totalling 455MW of renewable energy capacity were offered. Of those, seven were solar (139.85MW) at a weighted average price of US$156.67/MWh.

The next round of contracts will be bid for in summer 2016. A total of 930MW is on offer, with 250MW specifically allocated to solar.

Alberta

Meanwhile, the province of Alberta has recently unveiled a series of policies that could eventually see it emulate Ontario's lead on solar. Last November the provincial government set a target to phase out coal by 2030 and effectively triple its share of electricity generated by renewables over the same period.

So far Alberta has only installed a lowly 9MW or so of PV, and the new policies so far contain no specific carve-out for solar. But CanSEIA believes under the province's climate leadership programme, in which its ambitions are framed, solar could meet up to 15% of its power needs by 2030, resulting in up to 4,300MW of new capacity being installed in that time.

Already some large projects are beginning to come forward in the Alberta. In Vulcan County, EDF EN Canada is planning a 100MW project, which is set to be operational autumn 2018. Sucor, BluEarth Renewables and GTE Power are other names that are also proposing large solar farms. Between them, including the Vulcan farm, there are a total of eight separate projects that could produce up to 352MW of energy.

Saskatchewan & British Columbia

Southern Saskatchewan and southern Alberta have some of the best solar resource in Canada – approximately 1,500kWh/kWp installed, according to Bateman.

The province has committed to generating 50% of its power through renewables by 2030. That is approximately double what the province has – creating a huge opportunity for wind and solar and other renewables over the coming years.

It has also committed to initiating the procurement of 60MW of utility-scale solar starting this year. The impending outcome of these procurements will serve as a benchmark to determine what scale and pace the province moves forward with solar after that point.

British Columbia, on the other hand, is one of the provinces with a lot of hydro power, so whilst significant annual growth is expected, it will start from a very small base. "It's an up-and-coming province for sure, but Saskatchewan and Alberta are going to be breaking the 100MW mark in the next few years, whereas British Columbia will be a slow burner," says Bateman.

Obstacles for Canadian solar industry growth

A lack of overarching policy stimuli can be pinpointed as the main reason why solar has not taken off in Canada in the way it potentially could, alongside competition in a highly saturated energy market rich in hydro and amortised coal.

On the manufacturing side, Canada arguably lacks a lot of innovation support relative to the US or some European nations like Germany. Some industry experts go as far to say that the Canadian financial sector is nowhere near advanced enough in its understanding of electricity markets and how to manage and mitigate some of the opportunities and risks associated with them.

But with the pricing recently seen in Ontario's competitive tender, Bateman believes others may sit up and take notice of what is possible with solar.

"I think that 2015 will be viewed as a turning point for the solar industry in Canada – with the price discovery from the LRP," he says Bateman. "Policy makers, regulatory and utilities will really begin

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Dual-side Power Generation: 10%-30% additional power generation
2016 New Characteristics:
30-year Power Output Guarantee
1500V System Voltage: meets 1500V system voltage requirement, reduces system costs by 10%,
305W Super High Power Output (based on 60-cell module)

Credit BluEarth Renewables

BluEarth Renewables is among the developers eyeing solar projects in Alberta

to take a more serious look at solar than they have done in the past. I think that, combined with some of the new policies at the federal level, will really bring solar into the mainstream."

MEXICO

A new regulatory framework

At first, Mexico's new regulatory framework was met with cautious scepticism. Energy programmes had been in place for the last two to three years, with a renewable energy portfolio consisting of a combination of net-metering, self-supply schemes and small power producer schemes.

While sound in their own right, these power schemes did little to ignite Mexico's solar industry. The energy reforms at the end of 2015 overhauled the state-owned electricity provider, Comisión Federal de Electricidad (CFE), and constructed a wholesale market from scratch to encourage competition through private-sector participation.

Through these reforms, Mexico's young solar energy market finally had an adequate framework in which to grow. Under the energy transition there are now tenders with a fixed 15-year power purchase agreement (PPA) with CFE. The auctions provide opportunities for solar companies to also move into the clean energy certificate (CEL) market.

The new framework, though promising at its outset, was shrouded with uncertainty as solar developers and financiers alike were dealing with a wholly new set of rules. This was to be expected, especially with something as slow and large-scale as an energy infrastructure, where any significant regulatory changes will result in a lag in the financing and investment space. Financial institutions needed to take the necessary time to understand the new paradigm.

"Because of [those constraints], there was a period of lull in Mexico," says Anand. "The pipeline in Mexico coming out of the previous paradigm was close to 7GW of solar projects whereas we were initially forecasting no more than about 400MW or 500MW for this year. That was emblematic of the fact that the industry was really grinding to a halt to take its time to understand the implications of solar changes in the new paradigm."

Investor interest

But if the reception of the country's first long-term energy power auction is anything to go by, it can be concluded that the new paradigm works, and is backed up by substantial investor confidence.

The overall volume of power awarded was 4,019GWh. Solar came out on top, securing 74% of the overall energy awarded, bagging 1,869MW at a rate of US$50.7 per MWh.

Enel Green Power (EGP) was the auction's biggest winner, securing around almost 1GW of contracts. In fact, seven out of the 11 winners including EGP were key international PV companies: SunPower (509MW, including projects by subsidiary Vega Solar), Recurrent Energy (62MW), Vega Solar (740GWh), JinkoSolar (241MW), Photoemeris Sustenable (29MW) and Sol de Insurgentes (27MW).

The turnout was much higher than the Mexican government had anticipated: in total: 227 bids were made by 69 participants. As a result, GTM Research predicts solar in Mexico to increase by 521% in 2016. Mexico has just announced its second tender, ensuring demand for the foreseeable future.

Moving forward, the PPA has been assessed to be bankable, with banks vetting it in the past. There was initial doubt over the viability of the PPA prices, given how they were some of the lowest prices globally.

GTM's Anand characterised the aggressive pricing as an upside for solar: "That clearly shows that within the developer community there is room for squeezing margins to optimise the extent to which they can really make these projects viable."

The auction was very much in the direction of utility-scale projects, with GTM forecasts for utility-share of the market at over 80%. At the same time, the distributed generation space is quite a healthy part of an emerging market like Mexico, at 15-20% of the energy mix. This however is dependent on net metering to make it viable, and as things stand, there is no explicit mandate for this yet.

The big unknown that reamins is whether the implementation of the 3.4GW planned between January-March 2018 will happen in a timely manner.

"Will it be able to execute on time? Will it be able to execute in a manner that is financially attractive for the developers? What are those margins by the end of it for all of them? All of that will determine whether this whole kind of 'rush' is viable or not," says Anand.

Things are heating up in Mexico already, with EGP confirming three PV projects almost immediately after its win, under a US$1 billion investment for the construction of the plants. In addition, Chinese PV giant Canadian Solar is developing a 63MW plant in Aguascalientes, which is scheduled to be connected to the grid in September 2018. JinkoSolar made its debut out of the Chinese market with three solar projects in Mexico, two in Yucatán and one in Jalisco, totalling 188MW.

"It is a good venture for JinkoSolar as Mexico is a new market," says Asier Aya, project development director, Latin America, for JinkoSolar. "It is one of the larger markets on volume counts and also CFE is a very bankable up-taker. So the volume, and the fact that there is a stable PPA you can finance, and the prospect of several auctions in the next few years, made it one of the most attractive markets."

As for the future, GTM predicts a cumulative 9.3GW between 2016 and 2020 and a compounded growth rate of 41%. In fact, if many of the potential trials in the market play out, on the upside, the market for 2020 could be as much as 4GW for that year alone. ■

West Africa solar takes first steps forward

Regional overview | The second Solar and Off-Grid Renewables West Africa event in Ghana in April heard mixed views on the progress of solar in the region. But with the first projects reaching completion and others moving forward, brighter times seem to be around the corner. Tom Kenning reports

Credit: Tom Kenning

The opening of a new module assembly plant in Ghana suggest an anticipated uptick in demand for solar in West Africa

Despite the commissioning of the largest solar PV plant in West Africa this year, the total installed capacity in the region stands at a scanty total of 33MW. The sector has continued to be held back by lengthy delays in the early stages of project development, high costs of capital and the poor financial health of major utilities. However, a host of ongoing government tenders may have paved the way for genuine movement in the coming two years. Meanwhile, the region's long-standing power deficits continue to uphold a strong case for solar deployment. PV Tech attended this year's Solar and Off-grid Renewables West Africa conference in Accra, Ghana, for an insight into the region's utility-scale solar ambitions.

One year ago, many hopes lay in Ghana as the torch-bearer for solar in West Africa but the introduction last April of a 20MW cap on project sizes by the government and persistent off-taker issues have hampered progress. Instead, it was Nigeria that took centre stage this year by showcasing multiple large-scale projects in its pipeline and a significantly higher solar target than any of its neighbours, set at 1,343MW by 2020 – well above Mali's goal of 308MW and Ghana's 218MW. Grid constraints will be a major barrier to large-scale solar in several West African countries, but Nigeria should be able to cope for some time.

"Nigeria's grid can take 1GW of solar with no issue. Come 2GW it will require some structural readjustments to accommodate it," says Longe Yesufu Alonge, head of power procurement and power contracts at state-owned body Nigerian Bulk Electricity Trading (NBET).

Meanwhile the submission to parliament of Nigeria's National Renewable Energy and Energy Efficiency Policy for passage into law is a major step for large-scale deployment of renewable energy in the country, adds Abubakar Sani Sambo, chairman of the Nigerian Member Committee of the World Energy Council (WEC). If passed, the law would help create an energy development fund to incentivise use of renewables and support Nigeria's feed-in tariff.

Sambo also lists a host of large-scale projects under consideration in the country including Canadian developer SkyPower Global and Saudi-based FAS Energy's plans to build 3GW of PV in Delta State, having signed agreements with state and federal governments for the US$5 billion project. Meanwhile, two other US companies signed agreements with the Nigerian government for 1.2GW in different regions for US$2 billion. French oil company Total also intends to build 1GW of projects.

Nevertheless, despite an extensive list of large-scale projects in development, including around nine projects of 50-100MW capacity, Janos Bonta, senior investment officer, structured finance energy of Dutch development bank, FMO, says there are substantial challenges in negotiating power purchase agreements (PPAs).

"Nigeria is a big market with multiple initiatives," says Bonta. "Nevertheless we followed the market for many years. Projects are delaying and PPA negotiation is quite painful and long, and it makes projects very expensive."

Due to the build-up of delayed projects awaiting contracts, Nigeria is unlikely to start any tendering process until late next year, says Justin Woodward, co-founder and chief development officer of JCM Capital. Furthermore, if approaching Nigeria as a new developer, it can also take a long time to standardise procedures around contracts, as there is inconsistency in the regulation at present, he adds.

Other issues highlighted by delegates include the fact that while solar resources are highly favourable to projects in the north of Nigeria, many of these locations carry a security risk. Furthermore, the cost and difficulty of acquiring land varies from state to state, calling for due diligence, patience and management of expectations.

Another key issue is the high cost of financing, which is part of the reason why long PPA negotiations make projects even more expensive.

Large-scale outlook

Looking at the wider African region solar resources are plentiful, but the speed of progress will not be uniform across the countries. This has given rise to innovative proposals such as using solar for cross-border energy trading between the West African Power Pool (WAPP). According to a report launched at the event by the United Nations Environment Programme (UNEP), multiple PV plants located within 5km of the grid in Ghana could have their energy exported to neighbouring countries in order help integrate the intermittent power coming into the grid.

Interest in the large-scale market is growing, says Bonta, as it is complementary to base load during peak hours and it can be realised in remote areas with a shortage of power relatively quickly compared to other technologies. However pricing remains on the high side.

"In order to be successful in developing solar at minimal cost and optimal speed, scale, standardisation and competition are required," says Edore Onomakpome, investment officer at the International Finance Corporation (IFC).

This means projects of greater capacity than 25MW must be installed to improve the wider market conditions. It also requires establishing bankable contract template documents that will effectively reduce the overall transactional cost for developing these projects, she adds. Meanwhile, greater competition between developers is necessary to bring down tariffs. Such competition also requires a certain level of transparency.

"When you are navigating small grids and small projects, it becomes extremely expensive and quite inefficient to attract the large-scale developers that are necessary to drive down costs," says Onomakpome.

Ghana

Contracts for larger projects in Ghana, for example, were being negotiated on a one-on-one, project-by-project basis, which limits the transparency and the level of competition in the contract signing, which again drives up costs.

Onomakpome also says that Ghana suffers from an oversupply of brokers, without experience or strong balance sheets, who are focused on developing as many projects as possible and then flipping them to the larger developers at a premium – usually for around 20-30% of the overall project cost. "Ghana does have its thinking cap on and is walking in the right direction, but there is still a lot to go," she says.

The multiple hurdles left for the Ghana market may seem odd, given that it saw the largest solar project in the region come online this year. The 20MW plant built by China-based power firm BXC Ghana, a subsidiary of Beijing Fuxing Xiao-Cheng Electronic Technology, should have been a strong milestone for large-scale PV development. However, Wisdom Ahiataku-Togobo, director of renewables and alternative energy at the Ministry of Power Ghana, cites the fact that BXC had funded the plant without credit enhancement from the government, claiming it was "unfortunate" that most other developers do look for such supports and must be subjected to competitive tender processes instead.

Ghana even saw the launch of a 30MW PV module manufacturing plant in Kpone, a commercial hub just outside Accra. The facility, developed by Strategic Power Solutions, a subsidiary of Strategic Security Systems International (3SIL), is totally unique to the region and suggests an expectation of demand in the coming years.

In any case, the period of time necessary to carry out PV projects remains long and debilitating. None of the hopeful projects last year have moved forward, says Bonta, because government has changed its policies and is not willing to give the necessary guarantees. This comes partly as a result of the weak off-taker, the nation's main utility Electricity Company of Ghana (ECG) (see box, previous page).

Utilities

The poor financial credibility of utilities is one of the perennia troubles for solar in West Africa because financiers of PV projects want guarantees that off-takers will be able to pay for any solar energy produced.

For example, IFC's Edore Onomakpome says: "The Electricity Company of Ghana (ECG) as it stands is not currently a bankable credit utility and a lot of developers even on the thermal side have required that ECG provide some form of liquidity support."

However, recent electricity tariff hikes in Nigeria and Ghana are helping by making consumers pay a commercial rate for electricity. This not only provides much needed capital for the utilities themselves, which have been used to delivering energy at minimal prices for years, but it also sets the stage for solar to eventually be able to provide power at cheaper rates.

While utility credit ratings are an issue, the off-take of intermittent power also introduces fresh challenges.

It is difficult to give an off-taker comfort that solar energy produced is dependable, says Chana Gluck, general counsel of solar and social development company Gigawatt Global. Utilities in West Africa are used to guaranteed annual energy outputs, but these guarantees are not applicable to renewable energy, which is dependent on prevailing meteorological conditions.

ECREE director Mahama Kappiah says a number of promising tender processes in West Africa are underway

Credit: Tom Kenning

To add to the concern, Ghana's power sector has been in crisis for several years, after its generation dropped drastically and has made blackouts incessant since 2012, when the term "dumsor", meaning "off-on" became a popular household saying.

"The way going forward is actually very difficult for developers and slow," says Bonta. Ghana has seen multiple initiatives delayed due to off-take risk, uncertainty on liquidity, termination risk, grid capacity and unclear policy on project capacity caps. Nevertheless, Bonta says FMO is more optimistic about certain projects going forward.

Governments' progress

Solar is not the sole preserve of Ghana and Nigeria of course, with Bonta singling out the Ivory Coast as having a particularly good private power framework in place, where the government is willing to give guarantees for the off-take risk, which streamlines the development of projects. Meanwhile, Mali, Burkina Faso, Benin and Senegal all have several early-stage initiatives with potential.

Promising tender processes are at various stages in several countries, says Mahama Kappiah, executive director of the Economic Community of West African States (ECOWAS) Regional Centre for Renewable Energy and Energy Efficiency (ECREEE). This includes a completed tender for two projects of up to 75MW in Mali, five projects up to 67.5MW in Burkina Faso and one project of 10MW in Togo.

"The ultimate goal is a tender process," adds Woodward. "It will drive the tariffs down in the future."

Clean energy corridors with a combined capacity of 2GW are also being planned for the West African region under plans put forward by ECREEE. Kappiah says the corridor will involve connecting many 10-15MW solar PV plants, as well many other technologies such as wind and hydro.

Meanwhile, many new projects including larger-scale projects are in the pipeline, some of which were initiated by government IPP tenders.

Small-scale solar

While the utility-scale sector faces continued delays, the small-scale solar opportunity in West Africa is gathering pace, and with some of the weakest and smallest national grids and hardest to access populations, this small-scale industry perhaps makes more sense in Africa than in any other region.

Unfortunately solar-based products are suffering an image problem in Nigeria where cheap imports and poor maintenance have seen persistent failure of solar street lamps and other products. As a result communication about the ownership of solar systems and the importance of maintenance over time in hot dusty conditions needs to be improved.

How to secure payment from consumers for small-scale and distributed generation solar has also been a major challenge. At all scales the up-front cost of solar is often the biggest hurdle in Africa.

Off-grid solar specialist Nova-Lumos, which provides residential solar systems, has come up with a solution that relies on a pay-as-you-go (PAYG) model. This allows consumers to use mobile payments and transfer cash via text messaging to pay for power in advance. It also alleviates a major hurdle for solar firms in Africa, namely the high upfront cost of PV systems.

"If you want to be able to finance and pay for the systems via the customers, most people do it by phones and most companies rely on third-party solutions such as mobile money, which is very available in places like Kenya – not so much in West Africa or Nigeria where we operate," says Ron Margalit, head of impact financing at Nova-Lumos.

The solar company is working in partnership with MTN, Nigeria's largest telecommunications provider, so that customers can use their existing airtime balance with MTN to buy electricity from Nova-Lumos, paying for daily, weekly or monthly instalments. The solar systems can only operate on days for which electricity has been purchased giving a greater level of security for the panels.

Margalit adds: "There is definitely a need for some more risk-orientated financiers, whether it would be DFIs or multilateral development banks or impact funders to come and take the initial risk of financing. The biggest challenge of this sector would be eventually how to [get] commercial oriented and institutional investor funders."

Small-scale solar in West Africa has huge potential but faces hurdles such as financing

Gambia Ghana and Nigeria have also introduced or are planning to introduce feed-in tariffs for renewable energy, says Kappiah, but this has brought limited results so far. Meanwhile Cape Verde, Gambia, Ghana and Senegal have seen limited uptake of their net metering schemes.

The outlook for solar in West Africa is clearly mixed, but there is a sense that some projects that have been in development for several years may start coming up in the next two years. Progress remains slow and market will need more competition to really take off.

Location	Capacity	Stage of development
Burkina Faso, Zagtouli	33MW	Financing secured
Mali, Segou	33MW	Under construction
Senegal, Bokhol	20MW	Under construction
Sierra Leone, Newton	6MW	Financing secured

Table 1. West African projects in later stages of development. *Source: ECREE.*

For an in-depth account of West Africa's first utility PV power plant, turn to p.75

Emerging market briefing

By Tom Kenning

Large-scale solar flourishing in the Philippines

The Philippines has seen a flurry of projects being connected to the grid in the early stages of 2016, mainly as part of a rush to install plants before the 15 March deadline set by the government to qualify for the feed-in tariff (FiT).

The country is continuing to be a standout performer among Asia's emerging solar markets and is moving at great pace. Last year it saw around 122MW completed, but that figure has already been exceeded several times over so far in 2016.

For example, international downstream solar specialist, Conergy, completed and connected 201MW of solar projects with capacity spread across multiple regions. The new projects bring Conergy's total in the Philippines to 274MW,which is more than half of the 500MW quota the government had set for PV under FiT programme.

"With the deadline passing, the 500 MW FiT quota that was set by the government has been used up," says Alexander Lenz, region head, Asia Pacific for Conergy. "However, due to the expensive generation mix of the country as well as the increasing demand for electricity, we see investors looking to build based on bilateral PPAs. The next FiT quota is expected to be released around the end of this year."

Lenz says the FiTs for both utility-scale and rooftop solar, as well as a net metering scheme for rooftop PV, are the main drivers for solar development in the Philippines, however, the development process is "lengthy and highly bureaucratic", he adds. There are also foreign ownership restrictions for power projects in place.

"Conergy is optimistic about solar prospects in the Philippines," Lenz adds. "We are actively pursuing some 180MW of projects in 2016 and 500MW in the next two years."

Similarly, Singapore-based renewable energy developer and investor Equis recently commissioned a 132.5MW solar project, which it claims is Southeast Asia's largest PV plant, in Cadiz City, Negros Occidental. Helios Solar Energy Corporation, a joint venture between Gregorio Araneta and solar IPP Soleq, developed the project.


Credit Equis

The Philippines has seen a flurry of solar projects being completed

The Cadiz Project brings Equis' operating renewable energy portfolio in the Philippines to four projects totalling 236.5MW capacity

"We increase our ability to bring costs down for consumers whilst advancing the efficiency and reliability of renewable energy in markets reliant upon imported fossil fuels," says David Russell, Equis chief executive.

Swiss firm Syntegra Solar also commissioned four projects totalling 98MW overall in Negros, meanwhile another 57MW were installed near Tarlac city and Mindanao.

How the Philippines will fare in its next phase depends on the next FiT cuts and how the tariffs are affected, but it should remain a key market in Southeast Asia over the coming year as demand for electricity continues to grow.

Financing Iranian solar aided by lifting of sanctions

Iran's economy relies heavily on the hydrocarbon sector, but a study led by the German solar association BSW-Solar has outlined the strong potential for solar PV. Meanwhile the recent lifting of various economic sanctions on Iran will also help to improve the financing challenges of entering this Central Asian renewable energy market that is very much in its infancy.

According the report, 'Enabling PV in Iran', the country faces increasing energy demand that cannot be met solely by conventional energy sources, and it has abundant solar resources.

While solar hopefuls in Iran have struggled with high inflation rates, limited access to international finance and highly subsidised electricity, the nation did bring in its first feed-in tariff (FiT) for solar in 2015, with attractive rates.

PV was never part of the sanctions against Iran, says David Wedepohl, spokesperson for BSW-Solar, however, project development was extremely difficult because there were no financing options available.

Under Iranian sanctions, governments such as Germany were not providing the export guarantees necessary to cover companies' entering politically unstable countries. Nevertheless, Germany will now start providing these guarantees once Iran has paid off its debts.

Iran published new FiTs for renewable energy in May, reducing the solar subsidy by between 18-40%, but adding a new category for projects of greater capacity than 30MW. This will be valid until the end of the Iranian year on 21 March 2017.

"There are a lot of companies that are confident that at the price offered, it is worthwhile building systems there," says Wedepohl. "As this is a new market, the companies going in are going to be pioneers. Of course that takes a certain risk."

Wedepohl adds that it is natural for the FiT to come down in line with the decreasing price curve being seen for solar PV across the globe. However it is important not to cut the FiT too quickly.

Iran's current PV market is extremely small, with only a few experimental systems at universities, but the long-term potential is clearly there.

"We have found the locals very open to the idea even though it is an economy heavily dependent on hydrocarbons," says Wedepohl. "Like many other players in the region, including the Emirates, they are looking to

Turkey set for long-term growth

Turkey has proved a popular market as opportunities in Europe dry up

Credit Halk Enerji

Turkey has laid strong foundations for growth in its solar sector and is seen by many as being poised for long-term growth.

"Turkey's independence from subsidies means it is naturally competitive already," says Jinko Solar's general manager for Europe, Frank Niendorf. "They have relatively high electricity prices, which allowed very nice development in the unlicensed market segment below 1MW systems. With Turkish entrepreneurs, this segment took off significantly last year."

Niendorf says there is a good chance Turkey will reach 1GW cumulative capacity this year, which is significant considering it was built up over two to three years. However, investors need to be aware of certain political changes, which are always possible on the regulatory side, he adds.

Turkey was connecting around 10MW to the grid per week in Q1 2016, says Yalçın Adıyaman deputy general manager of Turkey-based EPC firm Halk Enerji.

"A lot of international companies want to enter into the growing Turkish PV market while other European markets shrink," he adds.

Turkey has a feed-in-tariff of US$0.133/kWh as well as local content incentives and no VAT if the developer has an investment certificate, says Adiyaman. This makes PV investments highly attractive with IRRs beyond 10%. Furthermore, there are no exchange risks as the FiT is based on the US dollar and payments are secured by the Turkish government.

"Taking low interest rates of many central banks into consideration, PV projects in Turkey are an interesting alternative to generate sturdy and low-risk cash flows," he adds.

Adiyaman claims there are no active policies that are holding back solar in the country. Nevertheless, he says: "The complex and changing regulations slow down PV investment to a certain degree, but the more PV projects implemented the better the players within this industry will manage the processes including public bodies."

The market is growing healthily and is unlikely to witness market distortions that have been seen in other markets in Europe when policy makers have supported PV strongly in the very beginning and pulled back on very short notice, adds Adiyaman. These distortions elsewhere put many international competitors in a critical financial position, which also restricts business development in other countries.

There has been a lack of transparency around Turkey's 'unlicensed' market rules, and an import tax on certain solar modules was introduced at the end of last year. Still, Germany-based firm Juwi Group recently announced it would be developing 18 unlicensed solar plants for Koyuncu Group totalling 18.6MW overall and located in Konya and Nevşehir.

However, advancements have not been the preserve of solar developers, as in April the market saw another strong driver with Turkish firm Marsan Marmara Holding announcing it would produce solar panels for export as well as the domestic market, with the launch of its 230MW capacity facility due in July.

Meanwhile, after Trina Solar recently supplied 40MW of modules to Tegnatia in Turkey, Rongfang Yin, assistant vice president, regional head of the module business unit of Europe and Africa at Trina Solar, said: "It represents an important milestone in the promising Turkish market and we are looking forward to supporting and accelerating the much-needed deployment of solar PV in Turkey."

Credit Christiaan Triebert, flickr

The lifting of sanctions in Iran could give a boost to solar

diversify their economy; they are looking to diversify their energy supply.

"It is a market that has a huge potential, just because there are so many resources. Land prices are ok because it is a large country, but we don't know how the framework is going to work out.

"It is very hard to predict. We did this report because we think the market is going to develop. It is going to be an interesting market to invest in."

Predicting Iran's solar future will obviously be more realistic once its first major project has been installed, but it is unclear when that could be.

Local reports in April suggested that a group of Italian investors had signed a deal with officials in the province of Qazvin to build a 1GW solar PV plant, with the project divided in to 100x10MW sections. Such a project would be an enormous milestone, but it remains only an agreement.

Wedepohl suspects that the government's focus will be on the large-scale solar sector for now due to the highly subsidised power prices for end consumers, however, the FiT is also levelled at its most attractive for small-scale <20kW systems at around €0.21/kWh, which is very attractive compared to many other markets worldwide.

It will surely take time, but with sanctions lifted, Iran may be a market to watch closely in the coming years.

New Argentine president paves way for solar

After a lengthy period of radio silence regarding solar developments, Argentina finally emerged with a strong renewable energy policy with plans to build a trust fund of ARS12 billion (US$844 million) for renewable energy this year and start work on competitive bidding.

Argentina's new president Mauricio Macri has opened up the market to international investors, says Manan Parikh, solar analyst, Latin America and Caribbean, at GTM Research. Macri has created a favourable environment and part of that is down to the new energy law. The target is 8% renewables by 2017, which projects out to around 3.4GW. The country is also likely to auction out around 1GW capacity in May.

Argentina has rolling blackouts across major cities and has had to import electricity from Bolivia and Chile so the future is bright for clean energy.

"There is still plenty to clarify in terms of regulation," says Parikh. "There are definitely going to be some bumps on the road."

In February, Macri announced plans to establish a solar plant of up to 3GW in Northern Argentina with investment support from the federal government. The renewables promotion scheme, named 'plan Belgrano', will benefit 10 provinces of northern Argentina.

However, Parikh says: "There have not been any developments in terms of exactly where those projects will take place or any specifics on the companies."

Elsewhere, the government of the province La Rioja signed a letter of intent with German firm Photovoltaic Park to develop three solar parks with a combined capacity of 700MW in separate parts of the province costing US$1.4 billion overall.

Energy generated would be fed into the Sistema Interconectado Nacional (SIN) network. If implemented, the plans will start with two projects in Villa Union (300MW) and Chamical (100MW) and a third east of the capital city La Rioja (300MW).

Governor Sergio Casas, said: "We have already presented to the president and the ministers of interior and energy the concrete possibility that La Rioja can produce over 1,400MW between different forms of generation, wind, solar and hydro with the Blanco river in the mountains. In this way it will be changing the profile and the matrix of the province."

Credit Wikimedia Commons

Argentina's new president Mauricio Macri has signalled his support for renewables

Within two years, the province plans to be a net exporter of energy by consuming less power than it produces.

Again this 700MW agreement is only part of a memorandum of understanding. "With a country that is just getting started in the solar world like Argentina, while these are big numbers, you should take those will a grain of salt," says Parikh.

There is some more solid development in the region of Santa Fe, which recently started net metering policies.

For a country that has seen almost negligible PV deployment, the three recent announcements can only be seen as a positive sign for the industry, even if these early intentions are left unfulfilled.

"There is definitely now a movement on also the state and regional level in being more conducive to solar," adds Parikh.

Green bonds and solar investment: what's the future?

The Solar Star projects in the US were funded by a bond issuance of US$325 million

Credit: BHE Renewables

Future finance | Green bonds have the potential to unlock vast new sums of capital for the deployment of solar and other low-carbon infrastructure. Katie House looks at how a relatively new concept is rapidly evolving into a potentially major source of clean energy finance

Green bonds first appeared in the market in 2007, with initial issuance from development banks including the European Investment Bank (EIB) and the World Bank. Issuance really began to ramp up from 2012. Some US$2.6 billion was issued in that year, US$11.5 billion in 2013, a tripling to US$37 billion in 2014 and continuing growth with issuance reaching US$41.8 billion in 2015 (Figure 1).

All up, in less than a decade the green bond market has become established. While still small in the context of the US$100 trillion global debt markets, green bonds are firmly on the post-COP21 Paris agenda looking at climate finance options and a vastly increased role for the private sector.

Predictions for what 2016 will bring have come from various market observers; Climate Bonds Initiative forecasts US$100 billion-plus of issuance, Swedish bank and green bond issuer SEB predicts from US$80-100 billion, Moody's and HSBC weigh in with more conservative estimates of US$70 billion and US$55-80 billion respectively.

Whichever estimate you look at it is clear green bonds are on the up. They have huge potential to help fund the necessary transition to a low carbon economy, be it clean energy, efficient water management, green buildings, climate-friendly transport and other low-carbon infrastructure. Renewable energy, including solar power generation, is an obvious sector to be financed with green bonds.

What are green bonds?

Green bonds are regular bonds that carry a 'green' label. Bonds may be labelled green if the proceeds from the issuance are to finance or refinance projects that deliver positive climate benefits. Green bonds are backed by the issuer's entire balance sheet. Figure 2 demonstrates the variety of project types that green bonds have been issued for. Renewable energy accounted for 45.8% of green bond issuance in 2015 with the bonds predominantly financing or refinancing solar and wind power assets.

The green credentials of a bond are based on the projects or assets linked to its issuance, not the green credentials of the entity issuing the bond. This means that a wide range of issuers can issue green bonds including bonds for solar energy, whether they are a national government, a city or municipality, development bank, commercial bank, or a corporation.

'Green' has issuer and investor benefits

The overarching benefit and aim of issuing a green bond is the environmental and climate benefits it delivers. However, there are additional benefits to both the issuer and the investors above what is gained by a regular bond.

Investor diversification: Because of the green label, green bonds attract a more diverse pool of institutional investors than issuers typically gather. The green label is attractive to asset managers who have sustainable mandates from the pension and retirement funds whose investment portfolios they manage. Issuers are often keen to achieve this diversification amongst their bondholders as this can widen their potential pool of capital providers in any future offerings.

Bond oversubscription: Currently, demand for green bonds outstrips supply. Issuers of green bonds are seeing oversubscription for their issuances sometimes resulting in green bonds being upsized.

Increased transparency: With green

bonds, investors benefit from heightened transparency on where their money is invested. Issuers are becoming increasingly aware of the need to be accountable on how bond proceeds are used. Annual reporting on how proceeds are allocated is a common feature of green bonds.

Low-cost capital for infrastructure: Green bonds are a useful finance tool for delivering low-cost capital for infrastructure projects. Infrastructure projects are often large scale, requiring upfront capital expenditure, which then generate long-term, relatively stable returns. If the infrastructure has inherent emissions-reduction characteristics, like clean energy or mass transit systems, it can be financed in part by green bonds. If climate resilience and adaptation features are incorporated into the design and build it can become even more attractive.

CSR & PR: A final benefit that green bonds deliver is in terms of social licence. Both issuers and investors can use green bonds to promote the fact that they are acting on climate change and behaving in a socially responsible way.

New standards are part of the story

Green bonds were created to fund projects that have positive environmental or climate benefits. It is up to the issuer to label the bond as green. However, many investors are keen to see some kind of verification that the projects funded are delivering substantial environmental or climate benefits. The Green Bond Principles and the Climate Bonds Standard can provide such assurance.

The Green Bond Principles are voluntary best practice guidelines for labelled green bonds. They focus on transparency of use of proceeds, the process for project evaluation and selection, management of proceeds and reporting on use of proceeds. The principles are governed by a membership secretariat made up of green bond issuers, investors and intermediaries.

The Climate Bonds Standard is an investor-screening tool that assesses and certifies the environmental integrity of green bonds, allowing prioritisation of green bonds with the confidence that the funds are delivering climate change solutions. A suite of sector-specific criteria, solar criteria being one of these, detail what assets are eligible for certification. Third-party verifiers assure that a green bond adheres to the Climate Bonds Standard (see box, left).

Sean Kidney, CEO of Climate Bonds Initiative, explains why solar criteria for green bonds are necessary: "Solar energy seems like a straightforward fixed asset to include in our definition of a low-carbon economy, but we needed to address questions around potential environmental impacts, fossil fuel back-up plants included in some plants, and supply chain manufacturing, to make sure we have all bases covered."

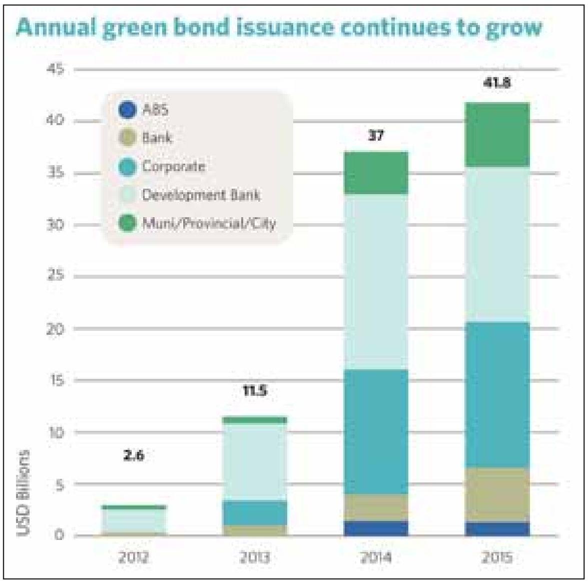


Figure 1: Growth and development of green bond issuance

Climate Bonds Standard & Certification Scheme: Solar Criteria

The Solar Criteria were developed by a technical working group (academics and experts in the field), and an industry working group (organisations and individuals working in the field). The proposed criteria were then submitted for public stakeholder comment before being approved by the Climate Bonds Standard Board. These criteria are now available for certification under the Climate Bonds Standard and several certifications have already been completed.

Eligible projects and assets

Eligible projects and assets relating to solar energy generation are those that operate, or are under construction to operate, in one or more of the following activities:

1) Solar electricity generation facilities
2) Wholly dedicated transmission infrastructure for solar electricity generation facilities

Eligible projects and assets that have activities in solar electricity generation facilities shall have a minimum of 85% of electricity generated from solar energy resources.

Further details on the development process and the specific technical criteria are available on the Climate Bonds Initiative website (www.climatebonds.net).

Solar and green bonds

The International Energy Agency (IEA) forecasts that the sun could be the world's largest source of electricity by 2050. Solar PV systems could be generating up to 16% of the world's electricity by 2050 while solar thermal electricity could contribute an additional 11%. Many other analysts predict solar uptake will be even higher as further technological development improves efficiency and lowers costs. Green bonds can finance this increased capacity.

Green bonds can be, and have been, used to finance solar projects in a number of ways. Some examples we have seen to date are:

1) Solar pure-play issuance
2) Solar asset-backed securities
3) Solar within a bigger green bond issuance

Solar pure-play issuance

Organisations that deal only in solar energy are the obvious issuers of solar related green bonds, these organisations can be referred to as solar pure-play issuers; they purely deal in solar. US-based Solar Star Funding LLC is one such issuer. In March 2015 Solar Star issued a US$325 million bond to fund its 579MW solar projects. The bond was upsized by US$10 million due to investor demand. Although Solar Star did not label its bond as 'green' it easily could have done.

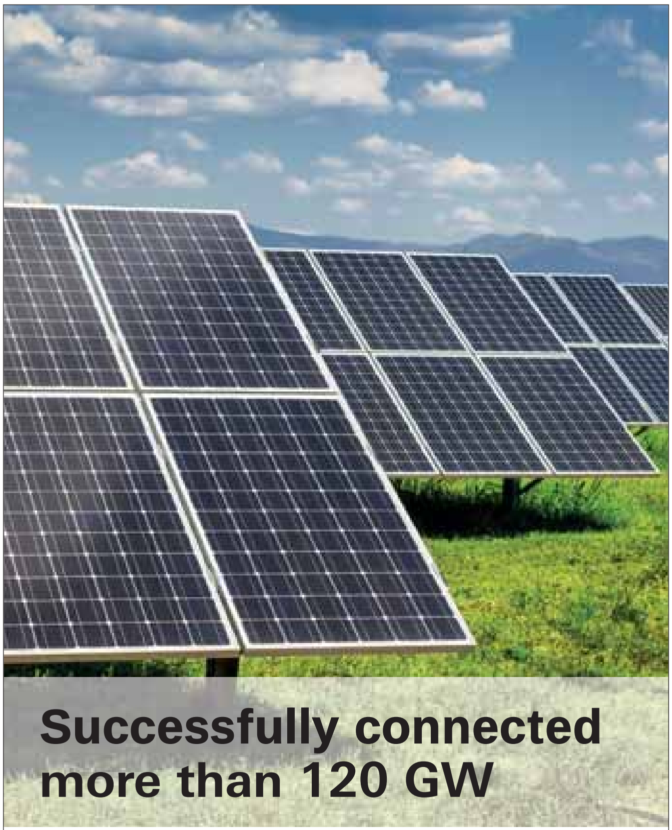
In addition to labelling bonds green, issuers may choose to get their green bond third-party certified. This provides assurance to the investor that the environmental credentials of the bond are robust.

Belectric, a UK based solar power technology and construction expert, did just this when it issued a £4.6 million (US$6.6 million) certified green bond to refinance the cost of developing and constructing the 3.8MWp Willersey Solar Farm. Bureau Veritas, the global inspection and certification services provider, verified that the green bond complied with the Climate Bonds Standard to provide assurance to investors.

Solar asset-backed securities

Solar projects, especially individual rooftop arrays, are very small-scale projects in infrastructure terms. Asset-backed securities (ABSs) allow aggregation, where individual, small and medium size projects can be pooled or combined to reach the scale for which bond financing is appropriate. Securitisation involves turning receivables from assets like mortgages or equipment leases into bonds. These are sold to investors, who receive the repayments due from the assets.

A recent example of this is Australian company FlexiGroup that issued a certified green asset-backed security for rooftop solar PV. FlexiGroup will refinance existing residential rooftop solar PV systems and other solar equipment accounting for



Successfully connected more than 120 GW

around 19,000 customer contracts.

This security was certified under the Climate Bonds Standard with assets deemed eligible under the Solar Criteria. What was really exciting about this issuance was that the certified green notes closed five basis points lower than non-green notes issued at the same time by FlexiGroup and backed by the same wider pool of consumer receivables.

Commenting at the time Sean Kidney from Climate Bonds alluded to the future possibilities: "Australia already has one of the highest rates of rooftop solar density and a diverse ABS market. There is enormous potential for this green ABS to be the first of many."

Solar within a bigger green bond

ABN AMRO issued a certified bond in June 2015. Proceeds of the €500 million (US$556 million) bond are being used to finance and refinance mortgage loans for new residential buildings, "green loans", for financing solar panels installed on residential buildings as well as commercial real estate loans for the construction and financing of energy efficiency buildings.

In another high-profile example, Silicon Valley tech giant Apple issued its first green bond earlier this year. In an issuance of US$1.5 billion proceeds are for mixed uses including financing of green buildings, energy efficiency, renewable energy, energy infrastructure, water efficiency, recycling and pollution reduction. The renewable energy portion will finance solar and wind projects and associated energy storage solutions.

Apple's green bond was issued to help the company fund measures to reduce the climate impacts of its operations. It is a prime example of a non-solar player issuing a green bond and funding solar energy for its own needs via a diverse pool of low-carbon projects.

Where to for the market?

The green bond market has started to diversify in currencies and ratings; signs of a maturing market. Green bonds have been issued in 23 currencies, several high-yield green bonds have been issued and emerging markets are entering the market.

The growth of green bonds in emerging markets is an important development, as these economies are where most of the low-carbon and climate-resilient infrastructure must be built in the coming decades to meet global climate targets.

Broad standards and definitions as to what constitutes green are an important consideration for institutional investors, particularly as the market grows in size and diversity. Recognition of standards such as those the Climate Bonds Initiative administers and harmonisation between national regulators to ensure market integrity around green definitions will give impetus to issuers and buyers.

More green issuance from corporates would give green bond markets added liquidity and depth. The corporate bond market is enormous, the major source of debt capital. Apple is a prominent example where bond issuance has a solar component. Issuance from other S&P500 companies or leaders amongst the FTSE or Nikkei indices would have a positive ripple effect through international bond markets.

Lastly, the market needs regulatory action from governments that frames and promotes market directions. Broad measures like clean energy targets and carbon pricing to specific incentives are needed to promote clean energy uptake in the built environment, transport and energy-intensive processes. A reduction in fossil fuel subsidies must also be part of the policy agenda.

From helping structure markets, encouraging private sector action and setting the directions, governments and regulators have a vital role.

Are big investors getting serious?

Much of the international discussion since the Paris climate conference has centred around the need for the private sector to dramatically increase climate financing, in part to help nations achieve their stated NDC goals and hold to the 2°C target.

The most credible of the forward energy forecasts recognise that holding warming to this target requires a dramatic scale up of clean energy production over fossil fuels. Within this mix, solar has cost, technology and efficiency gains yet to be realised and will benefit from grid, energy control and storage improvements.

Leading investor bodies realise that the pace of change in solar uptake will not accelerate through market action alone. On Earth Day, global investor associations, the Terrawatt Initiative and the Green Infrastructure Investment Coalition (GIIC), representing over US$60 trillion of assets under management, issued the New York Solar Investor Statement, pledging their support to the objective of the International Solar Alliance (ISA) target of US$1 trillion investment into PV power generation assets in member countries by 2030.

The short-term commitment involves working with the ISA to support the swift mobilisation of US$120 billion of capital in solar investments. The goal is to create investment structures that meet the risk and yield requirements of institutional investors, and the promotion of suitable financial instruments that will accelerate investment in solar to the capital levels outlined above.

In plain language it means working with nations to develop new solar energy opportunities and project pipelines. Green bond financing, solar bonds and new forms of solar securities will be part of the investment mix

Climate finance and solar

Global green bond markets need to grow into the hundreds of billions in annual issuance, with financing for clean energy comprising a large proportion of these new bonds.

Climate finance success will in part be defined by how quickly we can fund the solar component of the world's clean energy needs. ■

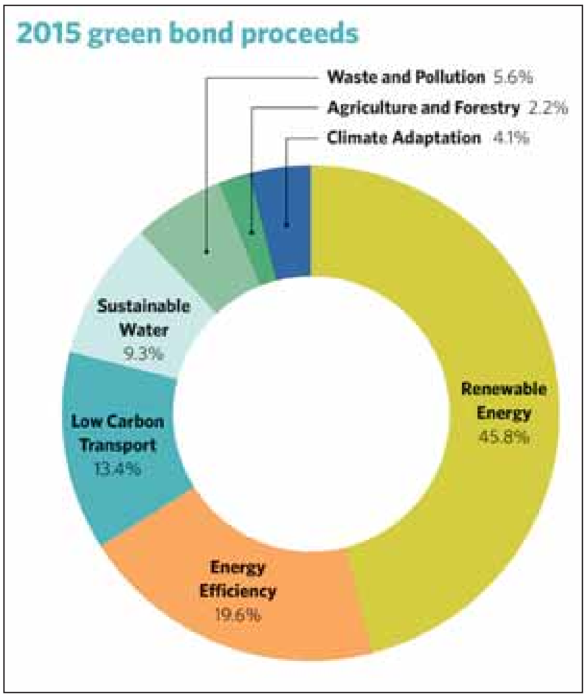


Figure 2: 2015 Green bond proceeds

Author

Katie House provides research and communications support within Climate Bonds Initiative, predominantly for the Climate Bonds Standards scheme. The Climate Bonds Initiative is working to mobilise the global bond market for climate change solutions.

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In pursuit of accurate irradiance measurements

Part 1: Sources of measurement error in pyranometers, photodiodes and reference cells

Resource assessment | Measuring solar irradiance is an essential part of the PV plant life cycle, but the many instruments available for performing this function behave in very different ways. In the first of an exclusive two-part article, Anton Driesse and Joshua Stein detail a major study they are leading that is seeking to characterise the accuracy of commercially available PV sensors

Sunshine is the fuel for PV power plants. And even if the fuel itself is free, the equipment and infrastructure for collecting and converting this fuel are anything but free. Nothing seems more natural, therefore, than to measure the amount of fuel flowing, in order to check on the operation of those PV plants. *Easier said than done!*

Solar irradiance measurements provide essential information at all stages of the PV system life cycle. Historical measurements are used for selecting sites, designing systems and securing financing. In order to fine-tune the planning, long-term averages may be supplemented by higher-resolution measurements in the period before construction. When it is time to commission a system, the need for irradiance measurements is particularly acute; without them it would be impossible to tell whether the modules were performing as per manufacturer claims. But the story does not end here. Only a stable independent irradiance measurement will permit the detection of long-term changes in system performance, be they changes caused by the modules or by some other component in the system. As PV arrays age, decisions also need to be made about upgrades, replacements, expansion and decommissioning. Irradiance measurements put everything into perspective.

If irradiance measurements are so useful and important, then it stands to reason that they need to be accurate. PV plant electrical power output can be measured using different classes of instrument, depending on the accuracy required – for example, 0.5% or 0.2%. And similarly, different classes of irradiance sensor are available, providing variable degrees of measurement accuracy; the problem is, their accuracy is about an order of magnitude worse than that of the power measurements! Most analyses which involve irradiance therefore have the uncertainty of their conclusions dominated by the uncertainty of the irradiance measurements. The effect of these uncertainties depends on how the data are used. Some errors average out when the total insolation is calculated over long periods (e.g. day, month or year); other errors may cause significant biases in long-term estimates and lead to poor decisions or lost revenue.

> "Irradiance measurements put everything into perspective"

Credit: Dan Riley

Figure 1. Forty-two irradiance sensors mounted on a dual-axis tracker at Sandia. All signals from sensors, as well from reference instruments, were recorded once per second and continuously for two months, in various sensor positions.

Clearly, there is a need for more-accurate instruments to measure irradiance, but today's PV plants must make do with the instruments that are currently available. In 2014, therefore, PV Performance Labs launched a study called PVSENSOR to evaluate a broad range of commercial sensors in order to better understand the sources of measurement inaccuracy of each type. The premise is simple: if an instrument is strongly influenced by temperature, to take one example, then its accuracy is going to be worse when operating at very high or very low temperatures. If that temperature dependency is known to be systematic, then a correction of the measurements is possible, leading to a reduction in uncertainty. On the other hand, if the dependency is not systematic, then the temperature range over which the measurements were taken can be transformed into an uncertainty estimate. Alternatively, for certain types of analysis, the data could be filtered to include only a limited range of operating temperatures, which would reduce the uncertainty of the analysis results.

In addition to temperature, several other factors affect irradiance measurement accuracy, including: 1) the directional response (effect of the angle of the light hitting the sensor); 2) the spectral response of the sensor; 3) the dynamic response (how quickly a sensor responds to changes in light level); and 4) the linearity of the response with respect to irradiance. The objective of the PVSENSOR study is, therefore, to evaluate how a variety of secondary factors influence instruments for measuring irradiance, and, to the extent possible, to determine how these influences are systematic or predictable. With such knowledge, it becomes possible to analyse PV system performance data in a new way. Irradiance data is no longer generic, but associated with a time, a place, an instrument and operating conditions. Together with an in-depth knowledge of the instruments, this contextual information permits a quantification of systematic errors and uncertainties in both irradiance measurements and performance metrics.

The first part of this two-part article presents the instruments under evaluation, and describes the characteristics that were evaluated, as well as the methods used for this study.

The sensor selection

The total irradiance received by a flat surface, such as a PV module, is referred to as the *global* or *hemispherical irradiance*. When the sky is clear, a large fraction of the solar radiation arrives directly from the sun, and the remainder is scattered by the atmosphere and/or reflected by the surroundings. When the sun is obscured by clouds, the scattered, diffuse radiation is dominant. While the diffuse component can be measured separately, most sensors used in PV systems measure only the total global irradiance, which includes both components; therefore all the sensors in this study are of this type.

Three fundamental sensor categories are represented:

Thermopile pyranometers: These instruments have a black surface under a glass dome; the surface absorbs the solar radiation and produces a small voltage in proportion to the internal temperature rise. The samples used were of the highest-quality class, called *secondary standard*, and of the lowest-quality class, called *second class*.

Photodiode pyranometers: A miniature PV cell hidden under a translucent

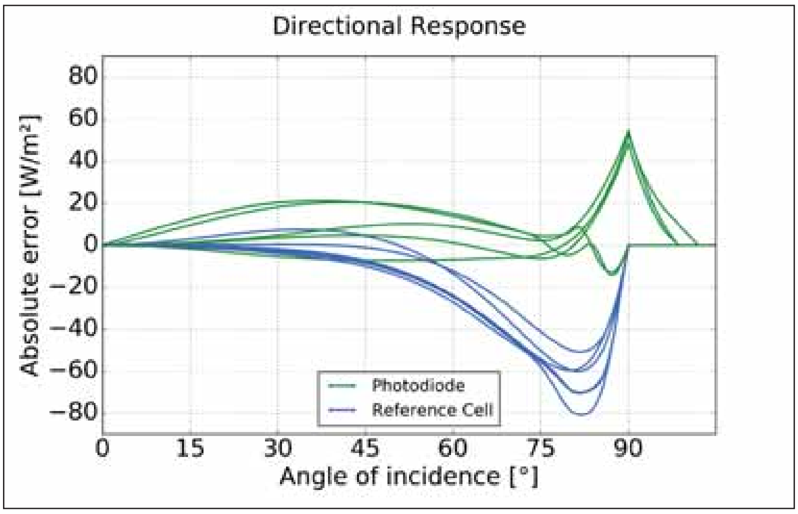
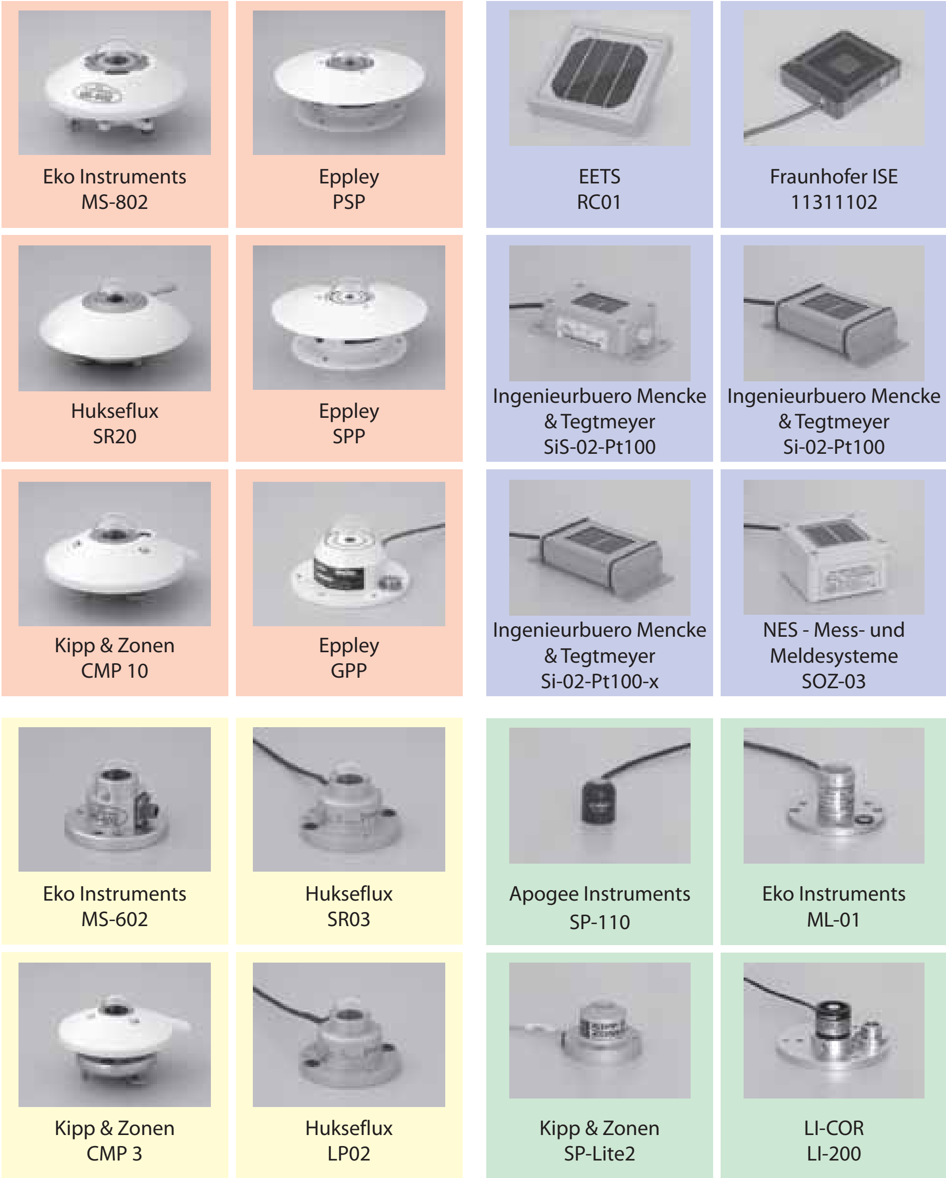


Figure 2. Directional response of the photodiode pyranometers and reference cells, measured indoors. The error values shown are for a beam irradiance of 1,000W/m2, shining at the angle indicated. The characteristics of the flat glass reference cells are very different from those of the shaped diffusers of the photodiodes. The three convex diffusers show positive errors, even beyond 90°.



Red: Secondary standard thermopile pyranometers
Yellow: Second class thermopile pyranometers
Blue: Reference cells
Green: Photodiode pyranometers

Table 1. The sensors tested in the PVSENSOR study, grouped by category. Images © Anton Driesse

diffuser inside the body of these sensors produces a current proportional to the absorbed irradiance. They are designed to behave as much as possible like thermopile pyranometers.

Reference cells: This category also uses the current generated by a PV cell, but the cells are large, and the physical construction and optics are more similar to those of a small PV module.

As shown in Table 1, sensors in each category were chosen from different manufacturers in order to capture a representative cross section of the commercial sensors in use today. Two units of each type were procured, for a total of 42 sensors.

Measurement facilities

Indoor testing was carried out in the winter of 2015, primarily at the Joint Research Center (JRC) in Ispra, Italy, to isolate specific factors, such as temperature dependencies, spectral response and dynamic response; directional response was measured at PV Performance Labs facilities in Freiburg, Germany. The first phase of outdoor testing took place in summer 2015 at Sandia National Laboratories (Sandia) in Albuquerque, New Mexico, USA, with all sensors mounted on a dual-axis tracker (Fig. 1). The sensors were monitored continuously for two months – several periods in a horizontal position, several periods tracking the sun, and sometimes undergoing experiments. A period of extended monitoring in a fixed-latitude tilt, both at Sandia and at PV Performance Labs (PVPLabs) in Freiburg, Germany, during 2016 will complete the data-collection effort.

Measured characteristics

Directional response

The *directional response* refers to the way the instrument responds to light arriving from different directions. It is also referred to as *angular response*, or *cosine response,* because the intensity of a narrow beam of light arriving at a flat surface is reduced by a factor equal to the cosine of the angle of incidence. This is easily understood as a flashlight held at an angle to a surface illuminates a larger area more dimly.

An accurate measurement of the available irradiance therefore requires the angular response to be a perfect cosine function. A flat glass surface, such as the front of a PV module, reflects more light at higher angles of incidence, and in reference cells this reflection causes an underestimation of irradiance at higher angles of incidence. Different textures on the glass surfaces and on the interior PV cell surface lead to different angular responses between reference cell models.

Thermopile pyranometers all use glass hemispherical domes, so no matter which direction the light comes from, it travels through the glass perpendicularly to reach the receiving surface. Deviations from the perfect cosine response for these instruments may be caused by slight imperfections in the construction or geometry, or by internal reflections. Photodiode pyranometers use a specially shaped translucent diffuser to collect the light. The designs usually trade off positive and negative errors to achieve an average directional response that approaches the ideal cosine response. Certain instruments use both a glass dome and a diffuser, but these are not included in the current instrument set.

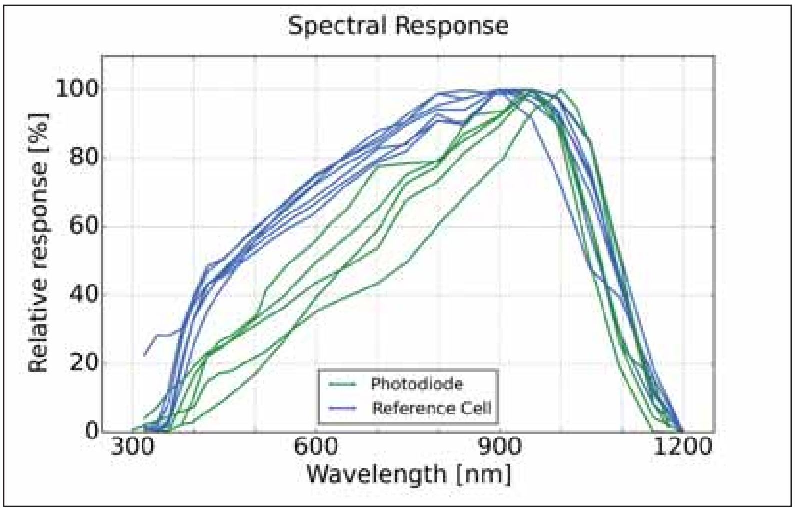


Figure 3. Spectral response of the photodiode pyranometers and reference cells. The photodiodes differ more among each other than do the reference cells, and their narrow response curves are actually somewhat less suitable than the reference cell response curves for measuring broadband irradiance.

The directional response of the photodiodes and reference cells was measured in the lab by mounting them on a rotating platform, shining a constant narrow beam of light on them, and measuring their output. Outdoors, a similar procedure was carried out on the large two-axis tracker at Sandia on a clear day. A sample of the results is shown in Fig. 2.

Spectral response

Once sunlight has entered the instrument through the glass plate or dome and/or diffuser, it is absorbed by the sensor element. In a thermopile instrument a flat black surface is used, which absorbs virtually all the light that reaches it equally, even towards the ultraviolet and infrared regions. Thus the temperature rise that is produced internally is a true representation of the complete energy content of the light, regardless of wavelength. In fact, the limiting factor for the spectral response of pyranometers is usually the glass dome, which is opaque at wavelengths greater than 2,800nm in the infrared region. A small portion of the ultraviolet light is also blocked.

In a PV cell or photodiode a current is produced roughly in proportion to the number of photons that are absorbed. However, those photons need a minimal energy level to produce current, and so the infrared light at wavelengths above 1,100nm (for Si cells) does not generate any current, and is not measured. In contrast, the light at shorter wavelengths has excess energy, which is also not converted to current. The spectral response is the measure of how the instrument response varies with the wavelength of light.

Measurements of spectral response require sophisticated lab equipment. The measurements in this study were carried out indoors at the JRC for one instrument of each photodiode and reference cell model. The results are presented in Fig. 3: these curves are not directly useful, but they can be combined with the outdoor spectral measurements to calculate how much measurement error they cause, which is referred to as the spectral mismatch factor.

Dynamic response

PV cell and photodiode current is generated quasi-instantaneously in response to the incident light; these sensors can therefore report very fast fluctuations, such as those that occur with passing clouds. Since thermopile pyranometers measure a rise in temperature, their reaction time is slowed by the thermal mass of their sensor element and the degree of thermal isolation from the rest of the instrument mass. In consequence, their output signal may take anywhere from under 1 second to more than 15 seconds to stabilise after a change in irradiance. This means that individual readings of irradiance taken during changing conditions will lag behind the actual values. However, if those readings are averaged over periods of several minutes (or longer), then positive and negative measurement errors produced by a slow response will also average out.

> "A thermopile pyranometer output signal may take anywhere from 1 second to more than 15 seconds to stabilise after a change in irradiance"

The large-area continuous solar simulator at the JRC was used to measure the thermopile response times. Fast transitions from light to dark and from dark to light were created with a motorised shutter, and the instrument signals were recorded 20 times per second to produce the profiles shown in Fig. 4.

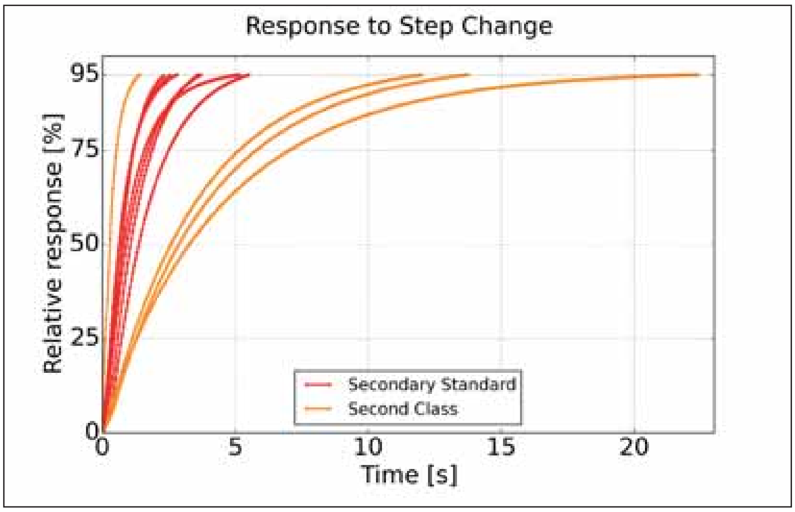


Figure 4. Dynamic response of the thermopile pyranometers, measured indoors, showing the time needed to reach 95% of the final value after an abrupt change in irradiance. Some lines cross, meaning that a faster 95% response time does not always imply a faster 99% response time.

Linearity

Every instrument is expected to produce a signal that is proportional to the measured irradiance, so that doubling or halving the irradiance also doubles or halves the signal.

Any deviation from this leads to measurement error. In a thermopile pyranometer various non-linear principles are at work, such as radiant heat transfer and the Seebeck effect, but over the normal range of operation the instruments are fairly linear. In a photodiode or reference cell the light-induced current is also nearly linear, but the way that current is measured – usually using a shunt resistance – can lead to a non-linear instrument response.

The linearity of the photovoltaic sensors was measured using a flash tester in the JRC lab over a range of 100 to 1,100W/m^2, while keeping the temperature and spectrum constant. Fig. 5 illustrates the results.

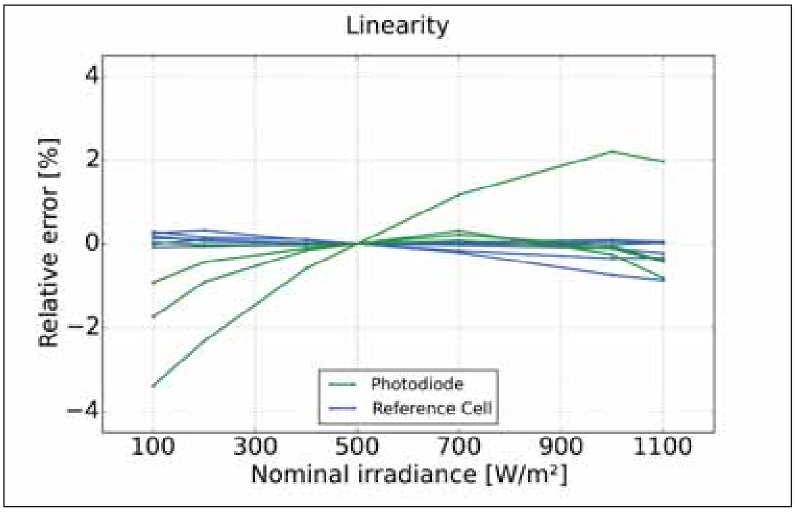


Figure 5. Linearity of the photodiode pyranometers and reference cells, measured using a flash tester. Several photodiodes draw attention with their pronounced non-linear profiles, while most of the reference cells show barely perceptible trends.

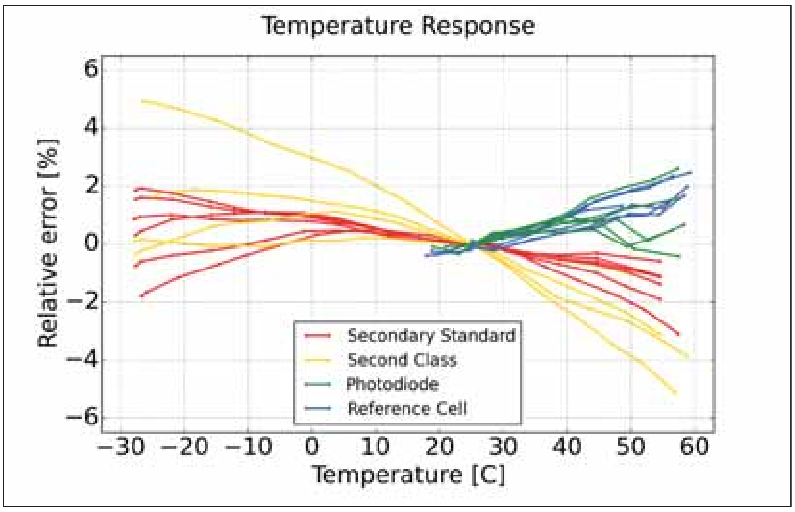


Figure 6. Temperature response of all instrument types measured in climate chambers. Reference cell output signals are usually corrected for the positive linear temperature dependency that is seen here. The opposite temperature effects for photodiode and thermopile pyranometers will accentuate the discrepancies between them.

Temperature response

Both thermal and photovoltaic sensor types have responsivities that vary with temperature, and these effects are quite pronounced. For the thermal instruments the responsivity tends to decrease with temperature, but in the more accurate models a compensation circuit is built in to counteract this effect. For some models a correction function is provided by the manufacturer so that the measurement errors can be further reduced. In PV reference cells the influence of temperature is the opposite, and even stronger; a temperature sensor is therefore built in, and a correction is usually made using a single temperature coefficient provided by the manufacturer. The correction is not perfect, though, since a change in temperature also changes the spectral response of the cells; thus the net effect of temperature also depends on the spectrum of the sunlight being measured. This is the subject of a parallel investigation by PV Performance Labs in collaboration with the National Renewable Energy Laboratory (NREL) in Golden, Colorado, USA.

Temperature response must be measured under carefully controlled conditions. The thermopiles were evaluated at the JRC in a large climate-controlled chamber with continuous light exposure over a range of –25 to +55°C, and the photovoltaic sensors in a smaller chamber with a flash tester over a range of 20 to 55°C. The combined results are shown in Fig. 6.

Thermal offsets

Thermal offset effects only appear in thermopile instruments. As already mentioned, the output signal measures a small temperature difference created by the warming effect of sunshine. But warm surfaces lose heat by radiating energy outwards to colder objects, and pyranometers are no exception. Heat lost towards the cold, clear sky reduces the output signal, thus leading to an underestimation of the measured irradiance, and this reduction even produces negative signals at night when there is no solar irradiance. This is the so-called *thermal offset A*. Double-glass domes, domes made of sapphire or quartz, and ventilators are all strategies for reducing this effect. There is also a *thermal offset B*, which is observed when the air temperature (and consequently the instrument body temperature) changes quickly, as might happen when there is a change in the weather.

The offset B signals of the thermal instruments were observed at the JRC lab in the climate chamber, and the offset A signals during night-time measurements outdoors at Sandia.

General considerations for instrument selection for PV system performance monitoring

Part two of this article will present a more detailed analysis of the measurements, but some useful observations can already be made on the basis of a general understanding of the sensor characteristics.

Before selecting an instrument to measure plane-of-array (POA) irradiance, the most important question to ask is: what will the measurements be used for? There are a variety of overall performance metrics that can be calculated – for example power, efficiency or performance ratio – and for each of these one can look at the peak, mean or median value, or the distribution of values, over different time spans. Most performance metrics can be evaluated in two ways: one is the *absolute* performance

for a certain point or period in time, and the other is *changes* in performance from one point or period to another. Knowing the absolute performance for different periods gives insight into changes as well, but it is possible to measure changes in performance *without* knowing the absolute performance.

To detect changes in performance, especially over short time spans, a sensor that behaves similarly to a PV array is very convenient. As the signal of such a sensor correlates closely with array output power under normal operation, even small abnormal changes stand out more readily. Commercial PV reference cells do not share all the characteristics of all PV modules, but among the available irradiance sensors they are the most suitable for this purpose. Photodiode pyranometers share the similarity in spectral response (at least with crystalline-silicon-based PV modules), but their different directional response means that their measurements will have cyclical daily and seasonal differences to PV array power output, which may mask defects or degradation.

"There are many practical considerations that play a role in maintaining high measurement accuracy over the long term"

Of course, daily and seasonal fluctuations are not a mere measurement artefact. The absolute performance of a PV array changes in response to many of the same factors discussed above: irradiance intensity, spectrum and direction, and temperature. In order to evaluate *how much* PV array performance fluctuates with these conditions, irradiance measurements that are minimally affected by these factors are needed. For this purpose the thermopile pyranometer category is the most suitable, and the best individual instruments are the ones which are least affected by these (or other) external factors.

With regard to individual instruments, the measured characteristics are important, but there are many practical considerations that should not be ignored when making a selection. Ease of mounting, alignment and replacement, quality of connectors, physical robustness, resistance to soiling, and availability of repair and calibration services all play a role in maintaining high measurement accuracy over the long term. The best choice will therefore not always be the same choice.

Conclusion

Thus far it has been shown that there are clear and measurable differences between the categories of irradiance sensor and between individual models that are commercially available. The results presented are primarily based on measurements taken indoors, where it is easiest to isolate specific characteristics. In the outdoor tests the tracker was used to exercise some control over the operating conditions, but multiple effects are still observed at once. These data are used to confirm the indoor observations.

The next step is to combine the measurement errors caused by individual factors in order to arrive at total error estimates.

Twenty-one irradiance sensors mounted at fixed-tilt for long-term measurements at Sandia. The other 21 instruments are operated in a similar manner at PV Performance Labs in Germany.

Total errors will vary by location and system orientation, as well as by time period under consideration; therefore such analysis would ideally be carried out on a case by case basis for the specific sensors in use and for the specific analysis required. In part two of this article the combined errors will be shown for each instrument in this study, using typical PV systems and performance analysis types.

Acknowledgements

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Joshua Stein is a distinguished member of the technical staff at Sandia National Laboratories, and works in the area of PV and grid integration. He currently develops and validates models of solar irradiance, PV system performance, reliability and PV interactions with the grid. Joshua leads the PV Performance Modeling Collaborative at Sandia and is a member of the IEA PVPS Task 13 Working Group on PV performance and reliability.

State of the art in PV yield assessments

Resource assessment | Studies modelling the yield from a PV power plant are an essential element in the planning and operation of a project, but come in many shapes and sizes. André Schumann breaks down the key components of a successful yield assessment and argues the need for a greater level of standardisation in the process of producing one

Credit: SolPEG

Random combinations of the word groups "yield/production/energy", "analysis/assessment/estimate/forecast" and "report/study" are prevalent in the photovoltaic market for one and the same thing. There are various providers for this kind of service but no general standard. In order to ease orientation in this confusing situation this article points out the crucial quality criteria a reliable yield study should meet.

Yield reports should not be considered as a necessary evil that the bank or investor demands. They provide the essential input for financial modelling either for newly built or resale plants. If this information is not based on the necessary level of accuracy and transparency the investment may be precarious.

The exact determination of the expected yield is as significant as its presentation in clear and reproducible documentation. As already pointed out in prior publications [1, 2] the most important quality criteria can be summarised in the four key factors displayed in Figure 1.

"Done by experts" implies that the yield analysis and its documentation should be carried out by independent, qualified and well experienced specialists.

Yield assessments are an integral aspect of the PV power plant business

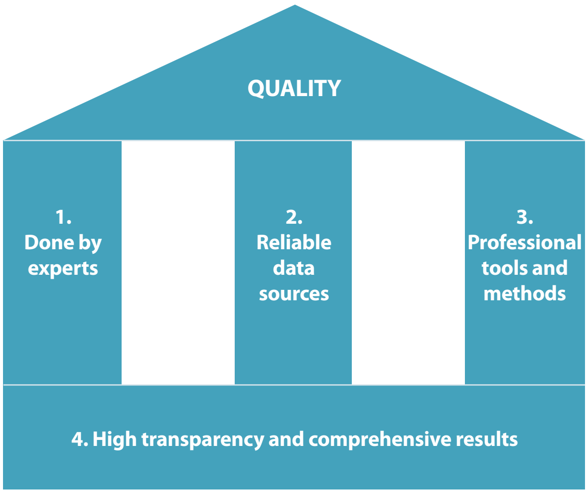


Figure 1: The four quality key factors of yield studies.
Source: SolPEG.

"Reliable data sources" refers to valid and detailed technical specifications of the used components as well as to the qualified use of multiple meteorological and geological data sources.

"Professional tools and methods" describes that the yield simulation process is carried out in at least hourly steps based on validated models and settings that have been tailored to the specific project and components.

"High transparency and comprehensive results" means a clear and reproducible description of all relevant details of the site, the PV system, the used meteorological data as well as the process and outcomes of the yield simulation, including a step-by-step analysis of all losses with corresponding uncertainties and assumptions.

In the subsequent sections these quality criteria and the overall process displayed in Figure 2 are described in more detail following the recommended structure of a yield report.

Site characterisation

Following generally established procedures the documentation should begin with a description of the given situation. Besides the documentation of the most important general information, like geographical coordinates, the focus should be on site aspects that may influence the yield and lifetime of the PV system, such as near and far shading objects, exposure to wind, soiling conditions, topography and atmospheric peculiarities (salinity, alkalinity, acidity, humidity etc.). Information is preferably given in tables, supported by aerial views and pictures. The most independent site assessment is obtained if the yield assessor visits the site personally. Nevertheless,

Credit All images, SolPEG

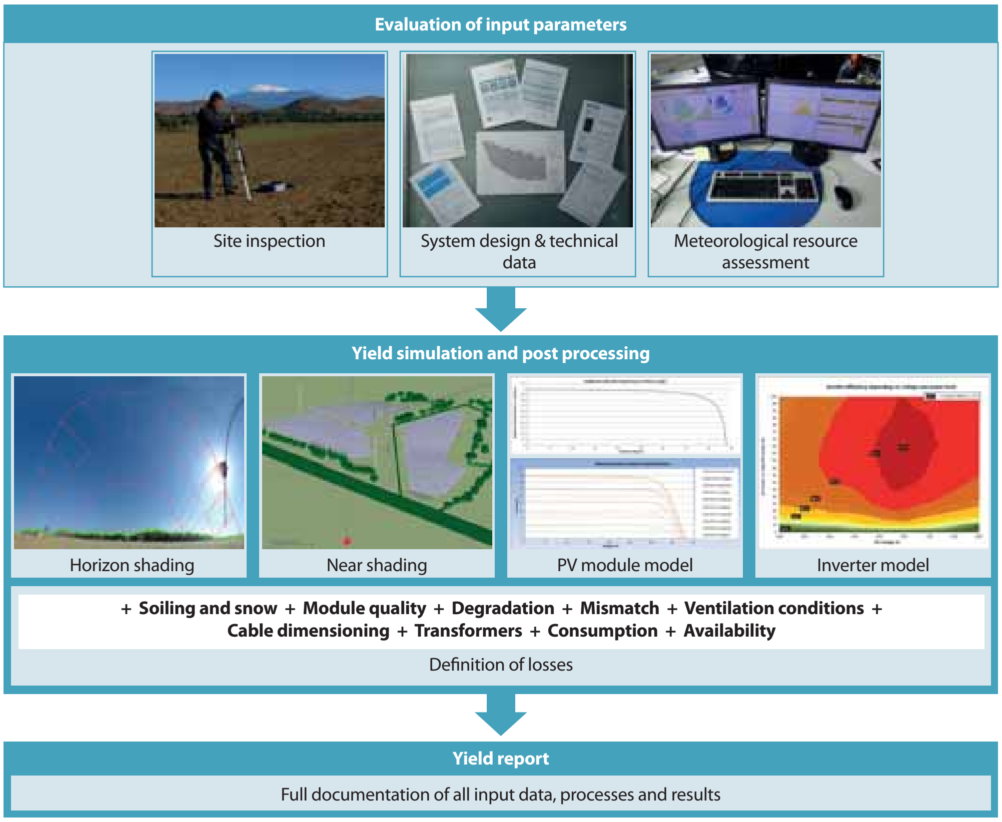


Figure 2: Process chart of a professional yield study

other provided documentation (such as photography) combined with researched information usually allows a detailed and valid judgment. Also, planned modifications, for example of the terrain and shading objects, should be mentioned.

PV system details

The second aspect of the given situation that the yield assessor needs to analyse and describe is the (planned) PV system. Again, tables allow the clearest and most compressed way to present, for example, the number and types of used modules, inverters, transformers and their interconnection. Also the planned layout, including orientation (tilt, azimuth, tracking ranges), module alignment, table configuration, row distances and shading angles, needs to be listed and displayed. Furthermore all general and yield-relevant technical data of the main components should be given, for example the temperature and irradiance-level dependency of the PV module performance, as well as the power and voltage level-depending efficiencies and temperature behaviour of the inverters.

Meteorological resource assessment

Although the meteorological conditions are linked to the site they cannot be considered as a part of the given situation. The assessment of the meteorology, especially the solar resource, is rather one of the most important parts of the yield analysis.

Since several established global, regional and local independent meteorological data providers exist it is a matter of transparency to present monthly long-term average data by multiple sources. At least four data sources should be available anywhere; ideally the assessment would include five or more data sources.

Ground measurements provide one of the key sources of data for resource assessments

It is a common situation that long-term average data by different providers varies. One reason for deviation can be the averaging period. In order to represent latest trends and a judgment for future conditions the averaging period should include latest years. Nevertheless the report should mention that any prognosis is always based on past data. The averaging period needs to be 15 years or longer in order to represent typical long-term conditions. If shorter periods are used a corresponding low annual variability has to be proven for the considered site.

Data sources may also diverge due to different methods. The two major methods are site-interpolation of surrounding ground measurements and satellite-derived data based on cloud cover information as well as models and data of the atmosphere. The quality of interpolated ground measurements can be judged based on the distances and amount of nearby stations. But a profound evaluation is only possible if instrumentation, calibration and maintenance of the ground stations are also known.

Although satellite-derived data by different providers is usually based on the same satellite imagery the results may vary due to different atmospheric models and supplementary data (e.g. aerosol content) or aggregated or enhanced spatial resolution. Ideally, validations are available for the region under study. Regarding this situation a weighted average of multiple data sources is often the best solution if the individual weights are assessed based on the averaging period, spatial resolution and general confidence level.

Credit Kipp & Zonen

The use of just one data source is only acceptable if it is clearly proven as the best solution, which is possible if highly precise and nearby ground measurements are available. In this context it is welcome if measurement stations are installed in the course of the project development, especially in regions with low density of reliable public stations. Such data may also be used to calibrate long-term data sources that also cover the measurement period.

Regarding the cost-value ratio, yield analyses are usually based on the simulation of a typical meteorological year. Nevertheless the annual variability of the solar resource should be mentioned and analysed. Usually horizontal irradiation is used as input for the yield simulation. Although PV modules work with global irradiation the composition of direct and diffuse parts needs to be studied with regard to in-plane irradiation as well as all kinds of losses of irradiation (see below). Besides the solar irradiation, the meteorological data analysis should also include parameters with a secondary influence on PV production, such as temperature, wind and precipitation. The corresponding effects on the yield should be discussed (temperature, soiling and snow losses).

Data processing

The yield simulation should be done with software in at least hourly steps. Own programming is only an option if detailed documentation of the processes is available. Besides transparency, the use of commercial software has the advantage of quality control by a big group of users. In any case, all settings and models of the simulation tool need to be adjusted to the specific project and documented in the report.

As long as the user is not limited in the possibilities for representing the considered PV system in all details, the selected software product is not relevant or a quality factor. It is more important that the user is deeply familiar with the software and knows about all strengths and weaknesses. This is why averaging the results of simulations carried out with two or more different products does not necessarily increase the level of accuracy. Post-processing of the simulation results can be necessary for example to include further haircuts, but needs to be clearly described in the report.

The first task of the simulation software is the transformation of irradiation from horizontal to the plane of the modules. The monthly results should be listed in the report and the used physical model(s) and Albedo factors should be stated and justified. In an upstream process it might be necessary to synthesize a meteorological dataset in the time resolution of the simulation process on basis of the input data.

Determination of irradiation losses

Shading Analysis

Before the irradiation in module plane reaches the solar cells it is usually decreased in several steps. The first obstacle can be the horizon. All objects that are sufficiently big and distant that the whole PV array is shaded if the sun is located behind them can be treated as horizon elements. Besides computation with the help of digital elevation models, special equipment can be used on site to record the horizon line.

Other objects may only shade parts of the PV generator. Their shading impact can be determined with three-dimensional modeling. Also the self-shading of module rows including the terrain structure should be handled in a near shading analysis. The simulation needs to be set in such a way that not only shaded areas are identified but also the electrical mismatch due to interconnection of shaded and unshaded parts. The report should give a clear description of the shading situation and the methods used to identify the corresponding losses.

Soiling and snow losses

Directly at the surface of the PV modules irradiation may be reduced by soiling and snow cover. The corresponding losses are usually not calculated

Irradiation						
Step					Annual yield (kWh/m²)	Uncertainty (% (±))
Global horizontal irradiation					1,073	3.5
Irradiation in module plane					1,207	2.0
Electricity						
Step	Gross loss (%) *reference: PR 100 %*	Net loss (%) *reference: previous step*	PR (%)	Annual yield (MWh)	Annual yield (kWh/kWp)	Uncertainty (% (±))
Available solar energy	-	-	-	27,317,126	7,654	-
Nominal module efficiency	-	-	100.0	4,307,783	1,207	-
Horizon shading	0.5	0.5	99.5	4,286,244	1,201	0.5
Self and near shading	3.1	3.1	96.4	4,153,371	1,164	1.0
Soiling and snow losses	1.4	1.5	95.0	4,091,070	1,146	1.0
Reflection losses	2.7	2.8	92.3	3,976,520	1,114	1.0
Module quality (flash reports)	-0.8	-0.9	93.1	4,012,309	1,124	1.0
Initial degradation	0.9	1.0	92.2	3,972,186	1,113	1.0
Irradiation level losses	1.7	1.8	90.5	3,900,686	1,093	0.5
Temperature losses	2.2	2.4	88.4	3,807,070	1,067	1.0
Mismatch losses	0.3	0.3	88.1	3,795,649	1,064	0.2
DC wiring loss	0.4	0.4	87.8	3,780,466	1,059	0.1
Inverter losses	1.8	2.1	85.9	3,701,076	1,037	0.7
AC wiring losses (low voltage)	0.6	0.7	85.3	3,675,169	1,030	0.1
Medium voltage transformer losses	0.7	0.8	84.6	3,645,767	1,022	0.1
AC wiring losses (medium voltage)	0.2	0.2	84.5	3,638,476	1,019	0.1
Own consumption	0.3	0.3	84.2	3,627,560	1,016	0.1
Availability (system + grid)	1.3	1.5	82.9	3,573,147	1,001	1.0
Result			82.9	3,573,147	1,001	4.9

Source: SolPEG.

Figure 3: Example result table

by the simulation software and so need to be defined directly by the user (for example, on a monthly level). Although several studies on soiling and snow losses are available it is not trivial to find proper factors respecting all details of the location, planned installation and O&M concept; published findings usually refer to a specific system set-up and location or region. This is why comprehensible justification needs to be given in the report.

Reflection losses

Reflection at perpendicular incidence is already included in the nominal PV module efficiency. At higher incidence angles additional reflections occur that are usually described with an IAM (incidence angle modifier) function. In most cases module-specific data is not available and a standard behaviour needs to be assumed and described.

Module level losses

Module model

All PV module-related losses can only be simulated accurately if the underlying simulation model is adjusted in order to represent the real PV modules' behaviour in all irradiance and temperature conditions as per detailed technical specifications or laboratory tests.

As well as the level of irradiation, also the solar spectrum may influence the solar cell efficiency. Irradiation level losses can be determined quite precisely whereas spectral losses are subject to higher uncertainties also due to lack of meteorological datasets in spectral resolution. In central European conditions spectral losses may be neglected for crystalline silicon cells, as positive and negative effects usually equalise on an annual average.

Temperature losses

The difficulty in the temperature losses simulation is rather the solar cell temperature assessment than the efficiency response to it. Aside from the ambient temperature and solar irradiation level, the wind velocity and ventilation, depending on the installation, can play an important role. Typical simulation models demand wind conditions inside the PV field as input which is usually not well represented by meteorological wind data (referring to 10m height without obstacles). Consequently, the simulated cell temperature and corresponding losses need to be justified comprehensibly in the report.

Module quality and degradation

As well as the module losses due to changing meteorological conditions, constant losses due to module quality (deviation of the actual module power from the nominal value) and (initial) degradation may be applied and described. Typically the first year of production is simulated and a constant degradation factor is applied for the further life time. The applied degradation factors should be justified with respect to the module technology and site conditions.

Balance of system losses

Mismatch losses

Balance of system (BOS) losses include all losses that occur because the energy production of the single PV modules needs to be supplied to a user (grid and/or direct consumer). In this context also mismatch losses can be considered as BOS losses because the serial and parallel connection of modules is only applied to make the generated energy of each module serviceable. Mismatch occurs if interconnected modules provide different current-voltage-pairs due to different electrical properties or operation conditions.

As mentioned above, the mismatch of shaded and unshaded modules is typically included in the shading losses. Mismatch due to manufacturing tolerances is usually very small nowadays thanks to positive sorting in 5Wp steps. But in older systems, for example with module power tolerances of ±5 %, mismatch losses in the range of 1% and higher are possible. Other sources of mismatch could be interconnection of neighbouring tables with different terrain slopes and/or vertical stringing regarding different diffuse shading conditions of modules above each other. Mismatch losses are usually not directly simulated and need to be respected as constant losses. This is why detailed explanation should be given.

Wiring loss

The yield simulation needs to consider the dimensioning of all cables for the determination of the corresponding losses under operating conditions. DC and AC cabling (low and medium voltage) should be treated separately. On the AC side reactive power demand by the grid may increase cable losses.

Inverter losses

The simulation model of the inverter should majorly respect the temperature-, power- and voltage-depending behaviour of the conversion efficiency, MPP tracking range as well as maximal power and system voltage. In this context it should be judged if the module-inverter connections are planned or executed properly. Inverter power is often undersized on purpose or the grid capacity is limited. In addition reactive power may be demanded by the grid operator. The corresponding power limitation losses should be assessed carefully with respects to the time steps of the simulation. In case of only hourly simulation steps additional haircuts should be applied and justified.

Transformer losses

The operation losses of the medium-voltage (and possibly also high-voltage) transformers should be based on data sheet information about the no-load and on-load losses. Reactive power processing may increase transformer losses. Constant losses due to grid connection during the night may be excluded if explicitly stated.

Own consumption

The latter also accounts for all other night consumers (for example security systems or stand-by consumers). Usually night consumption is metered separately and possibly at another tariff than the production. In this case it is reasonable to exclude night consumption from the production estimate and to respect it in the economical calculation. Also the system's own day consumption (for example from ventilation, tracking system drives, auxiliary inverter supply etc.) may be taken into account externally and the yield report just provides a production statement. This especially makes sense in cases where these consumers are connected to a separate transformer via separate auxiliary wiring (and metered at another tariff) or if not all consumers can be identified at the current state of planning. Overall, the yield report just needs to state clearly if and how own consumption is considered.

Availability and failures

If made transparent, availability losses (grid and system) may also be excluded and respected in the external financial model. A reliable assessment of the availability demands a detailed evaluation of the O&M concept, the reliability history of the technical components as well as information about the electrical grid (for example using a historical System Average Interruption Duration Index (SAIDI)).

Results presentation

It is established practice that the results for the first operation year at typical meteorological conditions are broken down into single losses steps as described above. For each step an uncertainty should be estimated and combined to a total uncertainty of the final yield following the Gaussian error propagation. Results should be given as total production (e.g. MWh), specific production (e.g. kWh/kWp) and performance ratio (PR) if applicable for each sub-system. Figure 3 gives an example of a detailed results table.

The average long-term system production over its expected lifetime (usually 20 or 25 years) can be listed respecting an annual degradation factor. In this context it should be stated that the production in each year will likely be different due to the variability of the meteorological resource. This is especially essential if also monthly (or even hourly) results are provided since the variability on a monthly level is always higher than on an annual level even in quite stable climates. Monthly and/or hourly results are required in case of seasonal or intraday variations of the electricity selling prices or of the load that shall be supplied.

Revisiting the uncertainty, usually also yield figures for different probability-of-exceedance cases (e.g. P75, P90) are presented. This consideration is based on a Gaussian distribution of the expected yield in which the calculated result represents the median (P50) and the stated uncertainty the standard deviation of the distribution. These parameters allow calculating a yield for any other probability of occurrence. For example, P90 means the yield which will be exceeded in 90% of all cases.

Although the calculation of these figures is quite trivial there are often different concepts of what they should mean, i.e. which risks are covered with the assumed standard deviation. In order to avoid misunderstanding the report should clearly mention which risks are included in the stated uncertainty (e.g. uncertainty of long-term average solar resource, variability of solar resource, uncertainty of PR calculation, uncertainty of assumed degradation factors for long-term yields etc.).

General and additional content

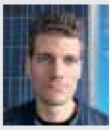
In addition to all the typical characteristics of a technical document (project-specific title and cover, list of contents, signatures, creation date, version number and history etc.) the report should contain a disclaimer with a "created in all conscience" statement and declarations of the intention, the client, the addresses, the validity and the copyright. A separate paragraph may provide recommended system optimisations. Finally, the study should have an appendix that contains the data sheets of the main components as well as the reports of the meteorological data sources and simulation software. Hourly and even sub-hourly results may be provided digitally in addition.

Outlook

In summary the yield assessment of a PV system is a complex and interdisciplinary task. It also needs experience to correctly interpret the results even if the documentation is thorough and transparent. In this context standardisation may help. This article as well as prior publications ([1, 2]) could act as a guideline. Any party interested to contribute to a normative process is invited to contact the author. ■

Author

André Schumann is a graduated environmental engineer and professional solar resource and PV yield assessor since 2004. Before co-founding and managing SolPEG (Solar Power Expert Group) in 2008 he worked in the global engineering department of SunTechnics (part of the Conergy Group).



References

[1] Schumann, A., "State of the Art Energy Yield Studies for Photovoltaic Systems", *Handbook of Renewable Energies,* to be published by Springer.

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Modelling PV systems to predict energy yield under fast-varying conditions

Yield forecasting | Rapid changes in weather can have a significant impact on the output of PV systems. Philip Pieters describes a new platform that has been developed to provide accurate short-term simulations of PV system yield in various conditions and using multiple technology combinations

Credit: imec

Fast-changing weather conditions, with varying illumination, wind, and shading have a profound effect on the energy yield of solar systems. Researchers from imec have created a new modelling platform taking these fast-varying conditions as parameters to make accurate short-term energy yield simulations.

The modelling platform is based on the characteristics and energy of individual cells and their specific configuration in a model or system. Using information about the cell type and module build-up, it may also be used to analyse energy losses in modules and systems. Due to its physics-based approach, the modelling platform can make 'what if' predictions, guiding the design of better-yielding modules and systems. To validate the model, the researchers also built an outdoor test set-up which monitors energy and environment parameters with an unprecedented resolution.

Researchers from imec have produced a new system for modelling rapidly changing weather conditions on PV system output

The need for an accurate cell-based prediction

In a maritime climate such that found in Western Europe, PV systems experience extremely variable conditions. Because of continuously changing temperatures and non-uniform, non-steady illumination, they produce considerably less energy than systems installed in a desert climate, even if the panels have the same maximum conversion efficiency (in watt-peak).

These maximum performances – still

Figure 1. Test site measuring illumination, temperature, wind, and energy output with one-second resolution

the cornerstone of solar cell research today – are measured in a test set-up under standard conditions. Such a set-up effectively shuts out all variations, be they short-term variations in illumination over whole modules, or variations in illumination between the cells within the module.

But exactly such variations are the hallmark of our maritime climates. They result in considerable energy losses compared to indoor test conditions. And these fast-varying conditions make it all but impossible to accurately predict output power at any precise time to balance the PV system with other energy sources on the grid.

The effective energy of an installed system can of course be deduced by averaging the yields of the system over a longer period. There are a number of prediction models that do just that – based on statistical analysis of databases of output power. Current state-of-the-art models reported in the literature predict an energy yield for the coming hour or even for 15 minutes. In stable conditions, these models have an average accuracy of 3 to 5%.

However, in fast-varying conditions, their energy predictions are widely off, inducing a prediction error of over 20% for the next 15 minutes, and even larger errors when we start looking at periods below 15 minutes. Also, these models cannot account for energy losses due to the assumptions underlying them (e.g. a uniform module temperature).

To get a real grip on the PV energy under varying conditions, the SmartPV researchers built a test-setup in Ghent, Belgium, which is now among the most accurate available, monitoring one-second variations [1].

On that set-up, they showed that even within 15-minute timeframes, conditions of illumination, wind speed and wind direction show large variations; variations that have an immediate and serious influence on the energy of a PV installation, and thus also on the grid balancing. So for a more fine-grained grid balancing, we'd need shorter predictions, even down to seconds. To cover these needs, the SmartPV project has created a comprehensive model suitable for very short-term energy calculations and energy loss analyses.

An optical, electrical and thermal model in one

Because existing models are based on averaging assumptions (both spatial and temporal) that do not hold in a maritime weather pattern, we built our model taking as input all relevant physical parameters that affect a system's energy. These include illumination conditions, the forced convection (wind velocity and direction), the operating temperature of the module, the thickness and transparency of the glass, the thickness of the solar cells and so on.

As the model is designed to account for intra-module losses, it needs to take into account the behaviour of each individual cell. Therefore, it consists of sub-models of the cells that are connected into a full PV system, with the possibility of varying the connection schemes. For a detailed description, see [2] and [3].

To account accurately for the major influences on the cell energy, the model of a cell is made up of an optical, thermal and electrical model, whereby the output of the optical model is one of the inputs for the thermal model, and the thermal model feeds into the electrical model.

The optical model uses either predicted or measured in-plane irradiance. To investigate the spectral effects on the energy yield, optical ray-tracing models were used. These take as input the characteristics of each layer in a cell (thickness, dimension, absorption...) as well as the electrical characteristics of the cell (doping concentration, sheet resistivity...) to simulate the generated heat in each layer in the PV module and photo-generated current in the solar cell.

In the thermal model, the operating temperatures in a cell are calculated using thermal RC-equivalent sub-circuits. A thermal sub-circuit incorporates the conduction, convection and radiation of heat, and takes into account the electrical operation state and the thermal state of the solar cell. It contains thermal resistors and capacitors, current sources equal to the heat generation, voltage sources equal to the ambient temperature and sky-temperature and components that take into account the radiation of heat and the electrical operation point.

When a module is only partly illuminated, heat will flow from the illuminated side of the module toward the part in the shadow. The conduction of heat within PV modules and systems can be modelled by connecting each RC-equivalent thermal network to the thermal network of the neighbouring solar cell. It was assumed that heat will flow only in lateral and longitudinal direction so that each node in the thermal network could be coupled with a resistor to the neighbouring node in the vertical or horizontal direction. The values of these coupling resistors were extracted from validated 3D thermal finite-element models (FEM) of PV modules built in COMSOL.

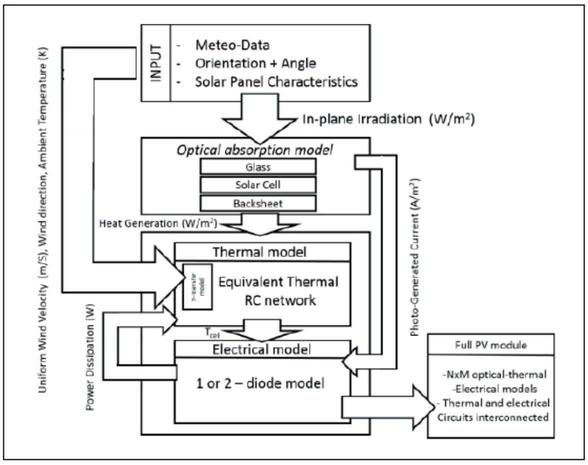


Figure 2. Schematic overview of the model, including optical, electrical and thermal sub-models

The thermal response of a cell is also influenced by the electrical operation point. Therefore to complete the thermal model, the power output of the electrical circuit of the solar cell was measured and deducted from the heat generation in the thermal network.

Last in the series of sub-models comes the electrical model. Again, we used one circuit to model the electrical response of one cell, this is one based on a one-diode model. The parameters of the circuit are extracted from steady-state or flash IV-measurements under standard conditions. To come at a model for a module, we again connected the individual electrical equivalent circuits by including resistors that are equivalent to the resistance of the interconnecting ribbons.

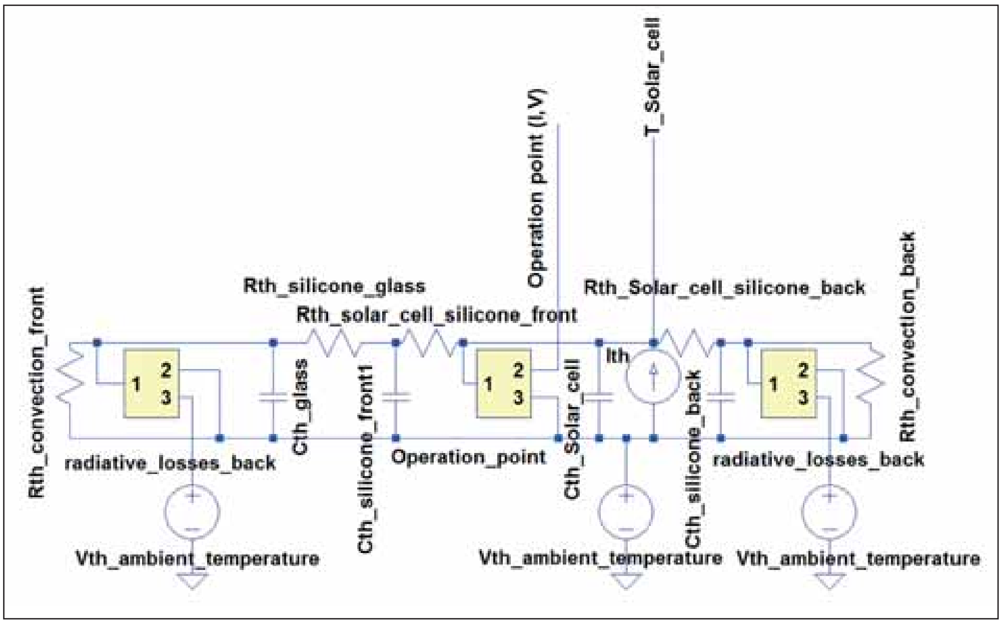


Figure 3. Thermal sub-circuit used to calculate the solar cell temperature

The full optical-thermal-electrical model as described above was ported into Verilog-AMS to reduce the computational effort and a 'perturb and observe' maximum-power-point tracker was incorporated.

Validation of energy evaluation

In parallel with drawing up the model, the advanced outdoor measurement station for PV modules and systems in Ghent was set up. The main goal of the set-up was to be able to measure the effects of fast-changing conditions on the thermal and electrical response of PV cells, modules and systems [2].

In the set-up, the irradiance, ambient temperature, wind speed and direction and module temperatures are measured and logged per second. At the same time, and also per second, we measure the power and energy yield of the novel modules and inverters under study. The DC values of the modules and inverters are obtained by custom-built, low-cost, galvanically-isolated signal conditioning boards.

On this set-up, we gradually refined and validated the model. The basis was a Phoenix Solar PHX-160 module, which we installed in Ghent and concurrently modelled in our optical-thermal-electrical model. The fine-grained meteorological data measured in Ghent were used as input for the model to obtain the same working circumstances in the model as in live outdoor use. For the final, refined model, the measured and simulated results are almost identical. Note for example that for the conditions shown in red and green, the module temperature is lower than the ambient temperature, which proves the importance of incorporating the radiative losses.

To test the usefulness of the model to predict energy yields, it was also validated against the energy yield of a residential PV system (managed by Oldenburg University, Germany) for a period of three months. In parallel, we also evaluated the yield with PVsyst, a software package specifically designed for PV system design and evaluation. Our optical-thermal electrical model predicted daily energy yields with an average error of 3.6% and a standard deviation of 2.8%, whereas for the same days ,PVsyst reports an average error of 5.5% and a standard deviation of 4.1%. Especially on days with fast-varying conditions, our model keeps on performing well, while the average error of PVsyst climbs to 9.5%.

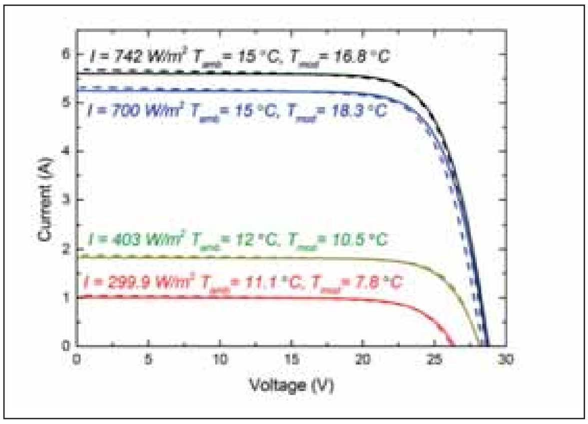


Figure 4. Measured and simulated IV curves of Phoenix Solar PHX-160 module during different conditions

What-if analysis of roadmap assumptions

Because an instance of the new model is built up using all the physical characteristics of cells and modules, it is fairly straightforward to build models that simulate the behaviour of new cells or alternative module configurations.

That way, for example, it is possible to study the effect of the thickness of the solar cell or its glass covering on the system's yield under various climate conditions. Thicker cells and glass covers, for example, will take longer to absorb temperature changes caused by factors such as a change of wind direction. In contrast, cells with a thinner body and covering will show a faster reaction. With our model, we can now quantify these differences for all possible glass/cell combinations. For a standard cell of 200µm, covered by a 3.2mm thick glass plate, the dominating time constant is around 16 minutes. This is mainly due to the response of the glass, which has a large thermal mass and thermal resistance for the convection and acts like a filter damping the response. If we now simulate the same cell with a glass covering of only 0.5 mm, the solar cell will really start to respond more quickly to the fast-varying illumination.

These RC time constants suggest that for PV systems with thinner cells and thinner glass covering (as suggested by the ITRPV roadmap), we'll need a higher-resolution yield prediction to be able to balance module and systems correctly with the grid. This will be especially true under fast-changing weather conditions and non-steady-state illuminations.

Modelling a better module for maritime climates and urban areas

Another area where we used the model is to look for ways to mitigate the intra-module losses caused by spatially varying conditions of illumination. A major cause of these losses is the current architecture of the panels, consisting of strings of solar cells that are connected in series. This topology functions well under ideal circumstances where all cells in the string receive an equal amount of sunlight. In maritime climates and urban areas, however, it is much more likely that at any time one or more of the cells will be shadowed, which will cause the yield of all cells in the string to drop.

To overcome the effect of shadows to some extent, standard solar modules are organised in three strings of 20 cells, each with a bypass diode connected in parallel. That way, the yield loss of a panel caused by a shadowed cell can be limited. But the loss of one third of a panel for one ineffective cell is still rather large. In the project, the researchers looked at a compromise between cost and fine-grained bypassing and modelled set-ups with 10 strings of six cells each. This already allows a more fine-grained approach, shutting down a panel in steps of only 10%.

A second improvement involved replacing the bypass diodes with smarter bypasses. These new components measure when the string yields less and activate a switch. The power that gets lost in such a switch is only a fraction of what is consumed by the conventional bypass diodes. Once switched to off, it periodically checks if the string's yield is back to normal so that it can be switched to active again. Next to modelling the effect, the researchers also fabricated a prototype for the smart bypass in the form of a small (10mm^2) power chip.

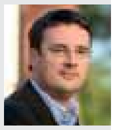
Last, the experts also looked into the possibility to configure the solar panels dynamically. In a static bypass system, parts of the panel are switched off that could still contribute some energy. In a more dynamic system, all cells which have comparable light conditions could be strung together dynamically in a circuit with a local DC-DC converter. The ideal dynamic system would be able to connect any cell with any other cell, making all cell configurations possible. But this level of complexity is too expensive to outweigh the extra yield. So the project investigated the optimal topologies, searching for those with the best result in fast-varying Belgian weather conditions.

The most complex topology that was examined uses 10 substrings of six cells, which are further subdivided into two strings of three cells. The chosen topologies were simulated and compared to more conventional panels in a number of shading scenarios. For some of these scenarios, especially when dark shadows are involved, the smart dynamic panel doubles the energy yield of conventional panels. In the case of fast-changing shading and clouding, when conventional panels stand to lose most, the smart panels show the greatest benefit.

Also for fast varying weather

The new model was developed in the frame of the SmartPV project, a project sponsored by the Flemish agency for innovation (VLAIO), aiming at developing smart techniques to improve the energy yield of PV modules. The results open the path to smarter panels and systems that guarantee a maximal efficiency despite varying conditions of light and shadow. The researchers were aided by a panel of industrial experts from the energy sector. They provided information on the evolution and demand in the market. And they critically evaluated at the project's results with a view to turning them into industrial products.

Author



Philip Pieters is business director at imec, Europe's premier centre for nanotech R&D. Philip received his PhD in electrical engineering from the KU Leuven (Belgium). He joined imec in 1994 doing pioneering R&D work for innovative heterogeneous integration and RF-SIP technologies. Today, he is business director for energy technologies, creating a bridge between imec's research and the markets.

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Typical climate stress and impact on module degradation and material failure in different areas of China

Module protection | DuPont Photovoltaic Solutions has conducted field studies of crystalline silicon modules for several years, with a resulting accumulation of abundant degradation and failure data. Experts from Dupont China, USA and Switzerland discuss and analyse the study results, with a particular focus on cases of solar module and component failure under the variable climate conditions in China

As a result of the increasing demand within the international community for clean energy alternatives, and because of China's continued efforts at air and environment pollution abatement, the PV industry expects rapid growth over the next five to ten years. Laboratory testing is an important way to understand the performance characteristics of PV components and materials; however, test equipment today does not accurately simulate complex outdoor weather conditions, and current testing standards have many deficiencies [1]. The most representative and significant data can only be gathered by measuring the actual performance of PV modules in outdoor settings, which requires that technical experts carry out field studies using professional equipment in different climates over an extended period of time. These real-world results will help researchers develop realistic and representative methods for conducting accelerated durability tests in the laboratory. The results of the DuPont study can serve as a reference for future solar module field studies, by establishing a more scientific accelerated-ageing test method, and help investors make decisions based on actual field experience in order to achieve more rigorous risk management.

DuPont's field studies

DuPont began a global outdoor field study project in 2011 to measure what the impact of different climate conditions, across a range of different regions, might be on component reliability and integrity. From 2011 to 2014 the study covered more than 60 global PV installations, which ranged in project size from 1kW to 20MW, representing 1.5 million PV modules and a total power output of over 200MW. Modules of all ages were examined, from brand-new installations to those with over 30 years' service. In addition, over 400 modules from 45 different manufacturers were subjected to both non-destructive and destructive testing in the laboratory.

The testing focused mainly on analysing the chemical and physical changes in the solar module materials that exhibited outdoor power station failure characteristics. As the solar industry shifts its focus from the 'design and build' stage to the operation and maintenance of systems, and the industry's PV module workmanship warranty period begins to extend from two years to ten years in some cases, visual defects are becoming key indicators, along with the evaluation of safety and power output, in determining the value of a PV system.

Identified visual defects

Particularly among the increasingly large PV assets in the secondary market, visual defects increase operating costs and raise the cost of ownership, thus reducing the value of the assets. The different types of visual defect seen on PV module components are shown in Table 1.

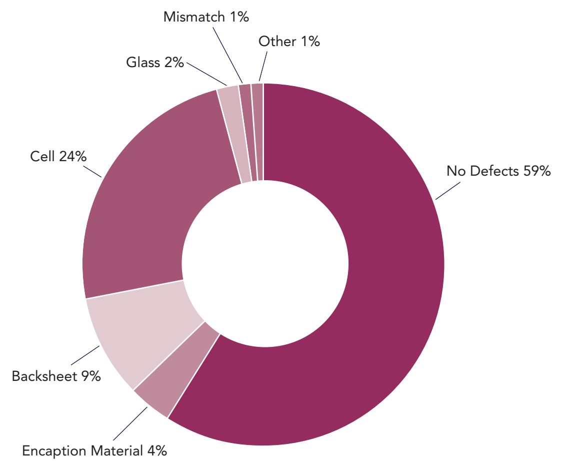

Figure 1. Subcomponent visual defect percentages [1]

Table 1. Description of the visual defects in each subcomponent category

Component	Visual defect
Superstrate	Broken, etched or hazed glass
Encapsulant	Discoloration, delamination
Cell/interconnection	Corrosion, hot spot (thermal non-uniformity), broken interconnection, snail trail, crack, burn mark
Backsheet	Cracking, yellowing, delamination, thickness reduction

All of the identified defects relate to one or more of the four major subcomponents of a PV module: superstrate, encapsulant, cell/interconnection and backsheet (Table 1). In many cases the interactive effects of the subcomponents are responsible for the visual defect. Of all the study components, 41% had visual defects (detailed failure classifications can be found in Fig. 1); 24% of the defects related to the cell, including hot spots (identified via thermal camera), visible corrosion, burn marks at interconnections, and cracks (identified by snail trails). Encapsulants accounted for 4% of defects. While this percentage is low, it represents an important cause of defects, because

Climate	Weather station	Annual irradiation [MJ/m^2]	25yrs UV on module rear side* [kWh/m^2]	Annual average temperature [°C]	Annual Ave. humidity [%]
Temperate	Beijing	4912	204	11.9	57
Arid	Dunhuang, Gansu	6560	273	10.8	41
	Urumqi, Xinjiang	5519	230	4.5	54.8
Highland	Lasha, Tibet (subtropical)	7598	317	4.5	55
Tropical	Sanya, Hainan	5944	247	24.3	83
Subtropical	Guangzhou, Guangdong	4234	176	20.4	74.7
Seashore	Dongtai, Jiangsu (subtropical)	5019	209	15.1	76.5

**Note: 1) 5% UV ratio in solar irradiation and 12% albedo from the ground surface is assumed; 2) 1kWh/m^2 = 3.6MJ/m^2.*

Table 2. Typical climate categories and associated climate data for China

of the resulting loss in transmission, as well as a shift in the transmission spectrum, which allows a shorter wavelength of light to penetrate the module.

The backsheet accounts for 9% of defects – this is the highest component failure rate other than that for cell defects. The backsheet impacts module insulation and durability. Backsheet yellowing and brittleness, resulting in loss of mechanical properties and insulation failure, are potential reasons for workmanship warranty compensation claims. Insufficient durability that leads to a reduction in cell performance and an increase in power degradation has a direct impact on return on investment.

China's variable climate

China has become the world's largest PV manufacturer and boasts the most installed PV applications in the world; this country has multiple climate types, including large areas of harsh environments, such as arid, tropical, desert and highland. Table 2 shows the typical climate categories for China, and the associated climate data for each region [2]. While China has mostly arid, temperate, subtropical and tropical climate regions, it is also known for areas of desert, highland and seashore. It is clear from Table 2 that the main climate data (UV irradiation, temperature and humidity) varies significantly among the different regions.

Understanding module operation characteristics and material failure incidences in various climate types can help improve quality and sustainable development in the PV industry. DuPont experts visited 12 provinces in China, inspected over 20 PV systems and power plants accounting for nearly 210MW, and conducted a thorough investigation of module ageing under various climate conditions. The results show that module degradation and ageing differ depending on the climate, with module EVA encapsulant and backsheet material also having significant impacts on module performance.

"Less-durable backsheet materials show degradation issues, even in temperate climates"

Temperate climate

The middle and northern regions of China have temperate climates. The climate in these areas can be characterised as mainly dry (55% annual average humidity), with significant temperature differences between day and night, as well as during winter and summer. The annual average temperature is lower than 15°C, while the annual UV irradiation is medium, with a 25-year accumulation of UV dosage measuring about 210kWh/m^2 on the rear side of the modules.

Backsheet discoloration is a widely observed defect that happens on less-durable backsheet materials in various climate regions. Outer layer or inner layer yellowing of the polyester backsheet, and inner layer yellowing of the single-sided PVDF (polyvinylidene fluoride) backsheet, have been extensively documented by numerous field studies in the European Union, Japan, North America and Asia-Pacific [3]. However, even in mild climates a number of cases of backsheet yellowing have been reported.

Fig. 2 shows four-year-old field modules installed in Ningxia province, comprising a single-sided PVDF backsheet (Fig. 2(a)) and a PVF (polyvinyl fluoride) backsheet (Fig. 2(b)); the modules were all installed at the solar farm at the same time.

On the module shown in Fig. 2(a), which uses a single-sided PVDF backsheet (PVDF film/PET [polyethylene terephthalate]/E layer), the inner layer of the backsheet was significantly yellowed, and more than 50% of identical modules were observed to have the same issue. Although it is presumed by some that this yellowing is merely an appearance issue which does not

(a) (b) (c)

Figure 2. Four-year-old field modules with: (a) a single-sided PVDF backsheet (Ningxia); (b) a PVF backsheet (Ningxia); (c) a PET backsheet (Inner Mongolia)

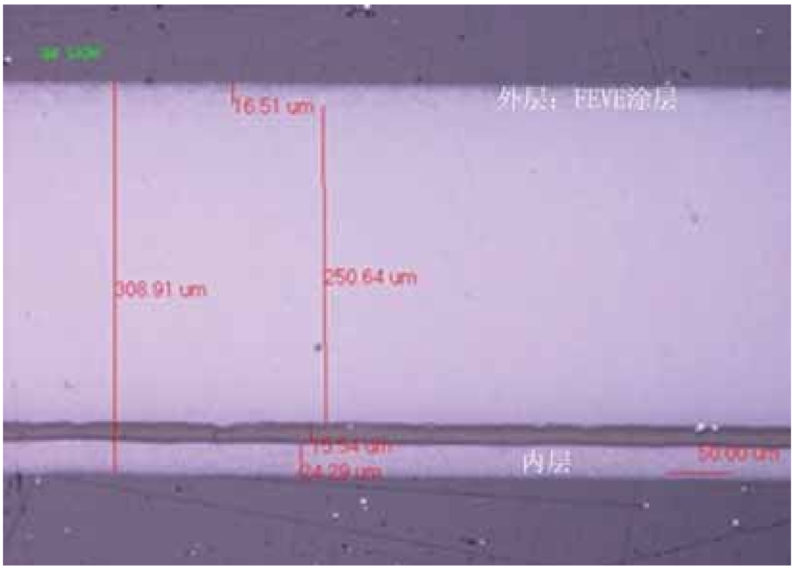

Figure 3. A field module that has been used for 18 months in Qinghai: the FEVE outer layer has been reduced to 16.5µm, while the nominal thickness is 20µm

affect power output, the results of the field *I*–*V* test show the average power degradation of three yellowing modules is ~11%; this is much higher than expected among four-year-old field modules.

Fig. 2(b) shows another type of module: this uses a Tedlar® PVF film-based backsheet and was installed at the Ningxia solar farm during the same four-year period. No abnormal changes were observed on either side of the backsheet, in clear contrast to the PVDF-based backsheet.

Fig. 2(c) is a photograph of a four-year-old solar farm in Inner Mongolia, which employed modules with a PET

> “Backsheet thickness reduction and sand coverage impact module performance in a desert climate”

backsheet (PET/PET/adhesive E layer). Yellowing of the outer layer of the PET backsheet in these solar modules was common, and b* (yellowness) values were as high as 8–10.

Arid climate

Qinghai, Gansu, Xinjiang and other western regions, including parts of Inner Mongolia, Shaanxi and Ningxia, have very arid climate with an annual average humidity of around 40%. The ground surfaces in these regions are predominantly desert sand. A 25-year accumulation of UV dosage on the rear side of modules can reach ~270kWh/m^2, while the annual number of windy days can be as many as 200 to 300 [4]. Despite these harsh conditions, these regions also happen to be the best choice for the development of large-scale solar farms, as they possess plenty of sunlight and inexpensive land, as well as being convenient for centralised management.

Sand coverage on the module glass surfaces is a widely acknowledged concern, impacting power output to such an extent that a routine clean-up is necessary. Additionally, prolonged sand wear will continually reduce the thickness of the backsheet outer layer and gradually degrade the original design features of the backsheet.

Fig. 3 shows a microscopic image of a FEVE (fluoroethylene vinyl ether) backsheet coating used in Qinghai province for 18 months. The outer layer of the FEVE-coated backsheet had 16.5µm thickness remaining, which is significantly lower than the nominal thickness of 20µm. If the erosion by sand of the FEVE coating continued at this rate, the core layer PET would soon be directly exposed to the harsh atmosphere. Clearly, sand wear-resistance and the thickness of the backsheet outer material are very important for PV modules used in China’s western regions, where sandstorms are a frequent occurrence.

Highland climate

Tibet has the highest solar radiation in China, receiving a large proportion of direct sunlight with little variation throughout the year. China’s longest duration of annual sunshine is also recorded in this region, with most parts receiving 3,100 to 3,400 hours of sunshine per year – an average of about nine hours a day. In Lhasa, for example, an annual solar irradiation of 7,600MJ/m^2 has been measured, which equates to more than 310kWh/m^2 of UV irradiation on the rear side of the module over 25 years.

Under such conditions, the durability requirements for the encapsulant and the backsheet are very high. Typical

> “UV irradiation ageing of the backsheet is significant in a highland climate”

module appearance issues in such regions primarily include encapsulant discoloration and backsheet yellowing, brittleness or peeling. Fig. 4 shows a nine-year-old field module in Tibet; the structure of the backsheet used in this module is white polyester/transparent polyester/adhesive E layer (from the air side to the inner side). As is obvious from the image, the outer layer of the backsheet is beginning to peel off. In the cell interspaces, where both the rear side and the inner side of the backsheet

Figure 4. Nine-year-old field module in Tibet with a polyester backsheet: the backsheet inner layer is yellowing and the outer layer is cracking and peeling off

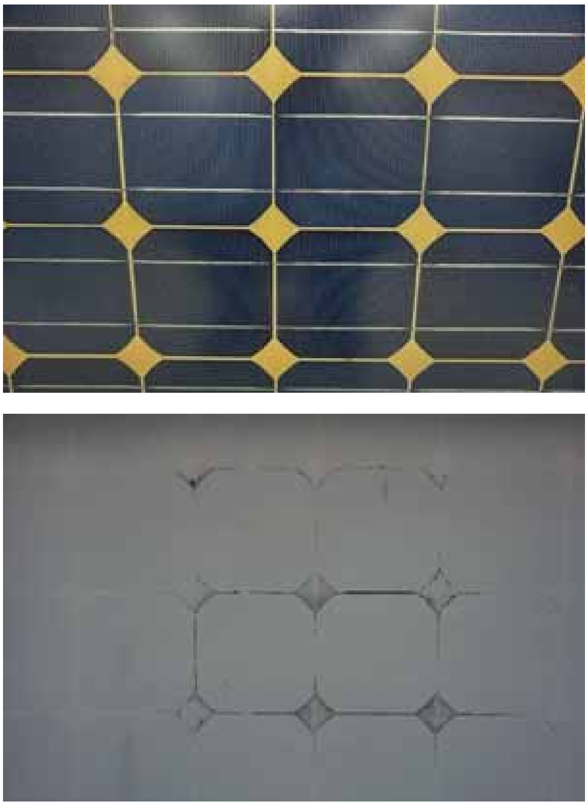

Figure 5. A fifteen-year-old (installed for 19 years) double-glass module in Hainan, showing cell corrosion and encapsulant yellowing

were subject to UV radiation, severe inner layer yellowing was observed and the white polyester outer layer was basically peeling off. The backsheet was completely brittle when it was taken from the module for mechanical performance tests.

However, certain backsheet materials can withstand the severe UV environment experienced in Tibet. The 'China's most beautiful old PV module' programme, which was led by the China Renewable Energy Society (CRES) PV special committee, has reported a number of success stories. One such story is a 17-year-old ground solar farm in Tibet with modules manufactured by a domestic company using DuPont™ Tedlar® PVF film-based TPT (Tedlar/polyester/Tedlar) backsheet. After 17 years of outdoor usage, solar cell grid lines show obvious discoloration; the Tedlar® PVF TPT backsheet, however, still looks good, with no appearance issues, and continues to provide insulation and barrier protection for the module. At the same time, the average power degradation of these modules was only 13.3% [5].

Tropical climate

Tropical climates feature high temperatures, high humidity and strong UV radiation. The main stresses on PV modules in these regions are thermal ageing, hydrolysis ageing and photo-ageing, all of which have significant impacts on the solar cell grid line, ribbon, EVA, silicone gel and backsheet.

Hainan is a typical tropical climate region in China: the annual average temperature is ~ 22–27°C with average rainfall measuring 1,639mm, which results in an annual average humidity of more than 80% (Table 2). PV modules used in Hainan commonly have solar cell grid line and ribbon corrosion and encapsulant browning issues.

Fig. 5 shows a 15-year-old double-glass module installed in Hainan. The power plant consists of many independent systems with four modules; these systems invariably exhibit corrosion issues with the cells, silver grid lines and ribbon. Although no current and power output could be measured using field *I–V* equipment, an inspection of the cell space area revealed that the encapsulant (EVA) was significantly yellowed, and that encapsulant delamination had occurred in some parts of the module. These particular double-glass modules use aluminium frames and sealant; nevertheless, this did not prevent moisture from causing degradation of the encapsulant and corrosion of the solar cells. This case highlights the fact that applications in tropical climates have stringent requirements for module electrical connections and encapsulant, and that the module encapsulation process and materials used are critical for module performance.

Seashore climate

As in subtropical regions, the humidity in seashore areas is very high (above 70% on average), especially when the solar farm is located in an intertidal zone or has ponding issues. Moisture and salt spray corrosion are therefore major environmental factors in seashore areas.

"Water vapour stresses the module encapsulation material and technology in seashore climates."

Fig. 6(a) is a typical photograph of a PV module used in the seashore area of Jiangsu province for four years. After long-term exposure, the aluminium frame and silicone seal have partially failed, resulting in water vapour seeping into the module. Fig. 6(b) and (c) show the bubbling and delamination of the PVDF backsheet, which occurred with a frequency of about 6.2%; no hot-spot

"Encapsulant browning and cell/ribbon corrosion are dominant failure issues in tropical climates"

Figure 6. Four-year-old field module in Jiangsu: (a) moisture ingress issue; (b–c) PVDF backsheet inner layer bubble/delamination issues

phenomenon was detected in this bubbling area. Field *I–V* test results show that the power degradation of the modules with a delaminated PVDF backsheet is ~11–14.7%, which is higher than the 6.5% average power degradation of the modules (with no delamination, in the same solar farm and of the same age).

Conclusion

Different climates present different environmental stresses for solar modules. As the key encapsulation material, the backsheet has a significant impact on module durability, performance and service lifetime; it is therefore essential to select a proven backsheet material in order to protect various module applications under any climate conditions.

"It is essential to select a proven backsheet material in order to protect various module applications under any climate conditions."

The results of this study indicate that Tedlar® PVF-based backsheets have been proved to provide reliable protection of modules for 25 (or even 30) years in various climate conditions around the world. Other backsheet materials can exhibit degradation or failure at a relatively early field age, which can result in higher module power degradation and can also pose a safety risk.

To a large extent, the long-term reliability and performance of PV systems depends on the materials used. The realisation of optimal system value, in terms of levelised cost of electricity (LCOE), is dependent upon modules operating reliably and as expected, thus providing a stable power output and a longer life. The benefit of using high-quality materials with proven long-term effectiveness at the beginning of a project are threefold: 1) module service life and power output performance can be ensured over the entire life cycle of the system; 2) the end-users' cost of electricity can be reduced; and 3) the expected project financial return can be achieved or even exceeded.

On the basis of the wide range of outdoor and laboratory performance studies conducted on solar materials, DuPont materials have the potential to become the industry standard, providing module manufacturers with materials technology that will best match power output and expected lifetime goals of solar installations. ■

Authors

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Going global when times are tough at home

Credit Conergy

EPCs | Europe's solar EPC companies are amongst the best respected in the world, but are seeing business opportunities on their home soil become scarcer. Sara ver Bruggen looks at some of the strategies being adopted by companies as they look to market their expertise further afield

To fill the void between falling solar PV demand in once-booming European markets, the region's engineering, procurement and construction (EPC) firms are having to think global.

The experience gathered over the years by these companies, not just in project construction and engineering, but through good relationships with suppliers of components as well as investors and financiers, can all provide compelling reasons for developers in new emerging markets to use European EPCs.

For a number of leading EPCs on the continent, international demand for their services is becoming an increasingly important part of their overall business.

Conergy, for example, mainly carries out EPC work on its own projects. The majority of the 1.3GW of solar capacity installed by Conergy is in Europe, including Germany, Spain and the UK. In comparison across Asia and the Middle East the company has supplied around 400MW of projects. However, in recent years, in Southeast Asia Conergy has emerged as a leading provider of third-party EPC services. In 2015, the pure EPC business in Asia accounted for 50% of Conergy's revenues.

In March 2016 the German company connected 201MW of solar PV capacity to the grid in the Philippines across eight solar projects, ranging from 13MW to 50MW in size. In total Conergy has completed a total of 274MW of solar capacity in the Philippines, more than half of the country's current 500MW feed-in tariff (FiT) quota for PV.

Conergy is also an early mover in Indonesia, which is only just beginning to develop its significant renewable energy resources, including solar and wind. Conergy was contracted by Buana Energy Surya Persada and Indo Solusi Utama in 2015 to build three 1MW ground-mounted solar PV plants in the East Nusa Tenggara province. Conergy is responsible for the engineering, planning, design as well as the component supply for the power plants, while construction and installation will be handled by Buana Energy Surya Persada and Indo Solusi Utama.

The Philippines has been provided rich pickings for Conergy in its bid to access new markets around the world

"We work with local partners for all our projects — on-the-ground crew who we use for many tasks, big or small," says Andrew de Pass, chief executive of Conergy.

The Indonesian government wants to develop over 140MW of solar capacity across the archipelago, which will consist of lots of small solar PV farms on each island, from 1-5MW in size, with companies such as Buana Energy seeking to diversify into renewables by developing projects.

"Southeast Asia has been a major growth market for us in the past few years and is shaping up to be a large market in 2016. The German history, a bankable balance sheet and innovative financing structures gives banks comfort to work with Conergy and finance our projects as well as the projects which Conergy is building for third parties," says de Pass.

Specifically in the Philippines, Conergy is now one of the only EPC providers that has high success rate in building projects on time and before regulatory deadlines, which are important metrics when entering new markets, he explains.

Reacting to change

When demand for solar PV is still contingent on changes to policy and incentives, EPCs have to be nimble. In the last few years Conergy has built hundreds of megawatts in the UK, mainly ground-mount solar farms. This has enabled the company to establish relationships with many of the banks lending to the renewables sector as well as other investors, including pension funds, hedge funds and closed end funds.

"The company still has some ground-mount projects in development and constructions, but due to the changes in regulations, we are transitioning our UK business from ground-mount to rooftop solar, which is an attractive market for us," says de Pass.

"Over the next two to five years the US and Southeast Asia will continue to be important markets for Conergy, but we expect to see additional business coming from Turkey, Middle East, North Africa and Latin America," says de Pass.

"We look at the policy incentives, the irradiation, the price per kilowatt, the cooperation of utilities and interest of renewable energy investors. There are several challenges we must face head-on in order to be successful."

But, gaining first-mover advantage requires companies to do their homework thoroughly, since early PV markets are still forming and evolving, as opposed to joining a market where projects have been completed and everyone knows the risks.

"Country risk is inherent in a developing economy. Additionally, attracting financing for market entrance in countries that are not seen as being politically stable is a challenge, as well as structuring sustainable power purchase agreements (PPAs) with off-takers and navigating grid issues," says de Pass.

Conergy views hybrid systems as a large opportunity especially in markets such as Australia. "We are developing a 13MW solar PV fringe-of-grid project in Australia with an additional 5.4MWh of storage, which has received a grant from the Australian government's Renewable Energy Agency (ARENA)," says de Pass. "Storage will be a very important part of the future of Conergy's business in future," he adds.

This type of experience of developing hybrid, or edge-of-grid projects, will also stand the company in good stead in Southeast Asia, where diesel gensets produce a lot of the electricity used in Indonesia and engineering hybrid systems that use solar PV, diesel and battery storage will help reduce diesel consumption across the islands.

Conergy provides operations and maintenance (O&M) services for all of the projects it builds. But, due to the disparity in size of O&M revenues compared to EPC and development revenues, it is not a large part of the overall business proportionately.

"However, we think that O&M can benefit from scale and therefore we are interested in expanding our O&M business by taking over third-party agreements in addition to continuing to offer O&M to our EPC customers," says de Pass.

Growth prospects in the mid-term for German EPC and developer Enerparc can be found in EPC-type services and O&M services, where chief operations officer (COO) Stefan Müller thinks it is conceivable to increase each of these by 200MW a year.

He says: "In the UK solar O&M oppor-

Credit Enerparc

tunities are really interesting for us. In Germany for example, banks and investors feel more comfortable with the developer being the one to carry out the O&M, which is usually for the lifetime of the plant. In the UK, where banks are more relaxed in their terms, we are seeing O&M contracts becoming available as more plants are changing hands and usually the new owners want to look for a new O&M contractor."

Due to the size of the UK solar PV market, potentially there are many megawatts of capacity that will be sold on to new owners annually for several years to come and this is providing Enerparc with new O&M opportunities. "We have the scale to do this sort of work, so it makes sense for us," says Müller.

Enerparc, founded in 2009 in Hamburg, Germany, has established itself internationally as a provider along the whole value chain of large-scale solar PV power plant development, construction and management, spanning technical planning to turnkey delivery – EPC – and O&M. Over the last five years Enerparc has connected more than 1.5GW to the grid, worldwide, and operates 950MW of its own PV power plants.

According to the Enerparc COO, acting as owner's engineer the company's business is about 100MW annually, and acting as general contractor, about 200MW a year; with more than 1GW of turnkey PV plant installations under its belt. Acting as technical consultant Enerparc's business is about 200MW a year with about half a gigawatt supplied as technical EPC partner to date. The company has about 1.1GW of O&M contracts.

As well as its German headquarters the company has offices in Bangalore, India and California, US, markets where the company is developing its global business. Both the US and India offer good growth prospects in the mid to long term as both are substantial in size and there are good incentives in place, mainly in the form of tax breaks.

A key part of Enerparc's business is raising finance to develop solar projects, since the company has built nearly a gigawatt of its own assets. All installations are funded by non-recourse project financing, organised by raising financing with local banks.

Being agile has allowed Enerparc to seek out projects in less popular emerging markets, such as Belarus

"For some players to remain near the top in the ranking, internationalisation has had to become a key part of their long-term strategy"

Seeking out new markets

Today about 50% of the company's business is from the German solar PV market, with 30% coming from other European states and the rest outside of Europe. The export side of the business will continue to grow, with Africa and Asia picking up the slack as demand in Europe reduces over the next two to five years," says Müller. The company is also busy in Egypt, central and eastern Europe and Jordan.

He says: "Because Enerparc is a private company we can be a little more entrepreneurial in terms of markets we decide to operate in. You won't find us in South Africa or Latin America, as these are the emerging markets that everyone is going after. After COP21, development banks in Africa are more compelled to finance renewable energy projects in developing countries, so there are interesting programmes in places like Madagascar and Zambia."

Currently the company is completing projects in Jordan and Belarus, the latter being a country where not many global solar developers and EPCs are active. "We are working with internal investors. The income from the projects, which include a 17MW solar farm, is from PPAs. We are doing the EPC work but we are also helping with financing. In Belarus it is quite challenging to convert local currency to US dollars, so we have a contract with investors where their payments from the plant are in US currency."

When entering emerging markets, the company always tries to employ at least one local as an employee and works with local partners and entities, including embassies, to have a clear understanding of all issues and potential challenges.

"In some markets, customs clearance is risky, so we have an arrangement with the local investor that we deliver outside of the border and they collect the goods and are the ones to get them cleared. In other markets, where grid connection is an issue, for example, we have found it is better that we have a local engineering consultant, dealing directly with the utility, while we won't be directly involved in those discussions between them."

Increasingly, as Enerparc seeks new markets to outside of Germany, the EPC side of the business plays an important role. In the US, for example, only companies incorporated in the country and paying tax are eligible for the production tax credit, which is a key incentive driving renewable energy projects in the US. In India, interest rates are high, so the cost of capital is expensive, which means going in as an EPC makes sense in some cases. In some developing markets it is simply too risky for Enerparc to invest its own capital in projects. "That's the other side of being a private company in this industry," says Müller.

Strategies for growth

According to solar project and database tracker Wiki-Solar founder Philip Wolfe, for many European EPCs, O&M work has become a bread and butter part of their business, particularly for those that do not have the financial resources to develop and operate their own projects or the resources to expand abroad into new markets. Providing O&M is an additional revenue stream, to offset falling demand for new solar projects in Europe.

It also makes sense for EPCs seeking to develop their businesses in other global or emerging markets to focus on regions, say Southeast Asia, as Conergy is doing, or Africa as Solarcentury is doing, or the US, where Phoenix Solar has been successful over the past five years. Internationalisation strategies, when a player strives to be in every market all at once, can backfire, as the demise of SunEdison has shown.

Back in April Wiki-Solar published it list of top 30 solar PV EPC contractors worldwide. Even though Europe no longer leads the world in terms of the rate of growth of its solar market, eclipsed by China and the US, European contractors' services are in demand throughout the world market for utility-scale solar projects. "For some of these players to remain near the top in this ranking, internationalisation has had to become a key part of their long-term strategy," says Wolfe.

As the global solar PV market continues to develop and evolve, it offers new opportunities for leading EPCs. Since it was set up in 1999 Phoenix Solar has acted as an EPC, often supporting its clients, which include independent power producers and project developers, with some development activities such as project finance and identifying long-term project owners. However, beginning in 2016 the company is using this know-how it has accumulated from its EPC activities over the years, to start its own project development activities in emerging solar PV markets.

Once projects are developed, Phoenix will hold onto them until long-term investors are more comfortable to invest in these markets and the company can sell on the projects for a good price. The company is also investigating other compatible areas to expand its services into, including hybrid plants and solar powered desalination plants in regions such as the Middle East where Phoenix is already active as an EPC.

While several EPCs are either starting to develop storage projects, such as Conergy, or are experimenting with and investigating energy storage, such as Enerparc, Belectric is aggressive by comparison, following the qualification of its energy storage system in Alt Daber to provide frequency regulations services in Germany. The company is working with various utilities to build more of its energy storage plants on the network.

For Europe's EPCs to remain leading players in the global solar market, it is dependent on expanding their businesses in terms of technologies they work with, such as energy storage, and growing their existing services, such as O&M in established solar markets. However, in many cases, expanding internationally is going to be critical to Europe's bigger EPCs' long-term future and success. ■

Tips for successful global solar EPCs

- Have a differentiated approach – every regional PV market is different with different dynamics so companies will need to adapt for each market they engage in
- Realise that local partnerships are key – good local partners have up to date knowledge of the market or region and good contacts within other important stakeholders
- Be flexible – identify if different local markets create the most value for your company either as a developer or an EPC
- Provide reliability, quality at competitive pricing – strive to continue same focus on quality components that established business and reputation in domestic markets but always focus on cost-saving initiatives
- Keep to time and budget – this will ensure projects make deadlines in terms of qualifying for tariffs and incentives and will help to ensure local developers will use your services for other projects
- Solve problems – good EPCs are valuable because they have built up knowledge and expertise of constructing and developing projects in different markets under different regulatory regimes, which can help developers and local investors in new markets that may often have less experience of solar
- Retain agility – be prepared to adapt to new markets and challenges, which could change rapidly due to developments in policy and incentives

Mounting concerns

Credit: PanelClaw

Codes and standards | A growing regulatory burden on PV mounting manufacturers in the US has prompted some of the leading players to set up a new trade body to represent their interests. Ben Willis reports on how the new body's members hope to turn back the rising tide of red tape

It would probably be fair to say that of all the components in a PV system, mounting – or racking – is the element that gets least public attention. Modules, as the engine room of an array, generally generate the most column inches, while in recent years increasing sophistication and competitiveness in the inverter space have ensured that segment has received plenty of interest. Mounting systems, meanwhile, frequently occupy the 'everything else' category that lumps them together with everything from cabling to switching under the catch-all title of 'balance of systems'.

For those involved in this vital part of the solar value chain there is clearly frustration at the lack of profile mounting manufacturers get, particularly given the nature of the product they produce.

"In some respects I think it's the most complex part of solar today," says Jeff Spies, senior director of policy at US racking manufacturer, QuickMount PV. "I'm not going to deny that making an inverter work properly with all the sophisticated micro-electronics isn't challenging, but [it's made in] a controlled factory environment like a module is. With a racking system we're at the mercy of an installer doing it the proper way. And because of the tremendous variations that exist in racking systems, we've got a challenge on our hands, no two ways about it."

And Spies' frustrations are about more than just pride. Adding to the basic complexity of a mounting system is the fact that as an essentially structural element it is subject to a swathe of building, fire and electrical codes that other components such as modules are not. In the US, these codes are enforced locally by thousands of different authorities, and it is not uncommon for local officials to interpret the rules in their own way. In some extreme cases, authorities have used the powers available to them to redraft some of the blanket codes to fit their own particular circumstances, creating an additional layer of red tape for mounting suppliers to navigate.

Tipping the balance

The combination of technological complexity, the increasingly onerous weight of bureaucracy involved in producing code-compliant products and the fact that those in the mounting sector often feel overlooked recently prompted racking manufacturers in the US to take matters into their own hands. Earlier this year, under the umbrella of the Solar Energy Industries Association, the main US solar trade body, a number of the country's leading mounting manufacturers joined forces to launch a new committee to represent their interests at a national level.

Mounting manufacturers rely on installers fitting their products properly and face a complex web of red tape.

The thinking behind the PV mounting system manufacturers committee (MSMC) is that as a segment of the industry that is being asked to take on more and more of the complexity and regulatory burden of PV system integration, manufacturers needed their own voice to ensure their interests are communicated to those involved in making the rules.

"We have a big responsibility within a PV system," says Mark Gies, vice president of reliability and compliance at PanelClaw. "It's been an ongoing discussion that I have had as well as all of our competitors – that we play an important role; we're the ones that are looked to, to make sure things don't fly off the roof. But yet we don't really have a unified voice. And when we individually talk to stakeholders, we don't have the gravitas that a Trina who's a major module manufacturer might have, or on the other side from a permitting perspective, the City of LA or these big cities that have a lot of power.

"As the industry changes, we decided that we needed a unified voice so that our collective expertise is tapped into. With a unified voice, people pay attention more; it's a louder voice as opposed to a lot of little voices."

Influencing codes

The main focal point for the committee will be to ensure that it is heard in the processes that go into the production of the various codes to which racking systems are subject. Spies is blunt in his view that all too often codes are developed by people who "don't know what the hell they're talking about". "This is a common theme in solar: that we're seeing code requirements put into place where there's only perception of a problem, but no real problem that's been proven," he says. "So they're finding solutions to problems that don't exist often."

The main code for mounting is UL2703, but others such as UL1703 for modules and UL1741 for inverters also have some cross-over into racking territory. Looking more closely, the main areas impacting racking systems and covered in the various codes are bonding and grounding, mechanical loading, fire classification – how flammable a system is – and others such as the new setback requirements governing the spaces that must be left for firefighters.

Again, Spies is critical of many of the codes that have been drawn up. "In my opinion many of them have not been developed with any input, or very minimal input, from the PV industry. The code-making community claims they've got input, when in fact they've got one or two individuals often whom don't have much engagement on that side of the business. So in my opinion we've seen a substantial increase in codes and standards which have had little or no input from the mounting and racking sector," he says.

According to Gies, the ongoing work to update UL2703 will be one of the first jobs for the committee to influence. His hope is that ideas agreed upon by the MSMC on how to evolve 2703 will have greater import by virtue of the fact that they've got the backing of a number of companies rather than just one. "We now have a group to bounce ideas around so it's not just a case of 'me' making up something that will help 'my' company," he says. "And then when we go to the people who vote on it, we can say this is not just me, 20 of us have agreed on this point. It puts more weight behind it."

LA story

Aside from collaborating with the relevant code bodies on drawing up and refining the overarching codes, there will also be instances where the new committee needs to work with individual jurisdictions. Indeed one of the first tasks the body has set itself is to work with officials at LA County on some additional requirements they have introduced on the safe bonding and grounding of mounting systems to reduce shock or fire hazard.

"The county feels the current codes they have in place aren't really addressing all the needs that they feel they have there," says Justin Baca, vice president of markets and research at SEIA. "And they wanted to either change or go above and beyond what was existing and develop a set of requirements they were going to apply specifically to LA County. And they've been working with the committee and members now to try to make sure that what they're asking for is in fact achievable."

> "We're the section of the industry that has to go through the meat-grinder to make sure the systems are certified and approved"

There will of course be a limit to the extent to which the committee will be able to work with authorities on a case-by-case basis. But with California accounting for some 50% of US residential installations, and LA one of the key markets in the state, it made sense for the committee to single this case out as one to tackle directly.

And Gies says it's highly likely that the committee will be working in this way again – targeting city or county authorities that are looking to introduce their own interpretations of codes. "We'd rather not see individual counties or cities take on their own rules, which make it harder for people to get projects permitted," he says. "Our position is – there is a committee on the standard trying to update the code, take your ideas up to code [level] then everyone will have to follow it. We'll be talking to other cities. Portland Oregon is another that has sort of created own rules – so that's in store to collaborate with these major public agencies."

Cutting soft costs

Ultimately, the committee's overriding objective is to avoid a situation where there is a patchwork of different rules in different parts of the US. And this goal isn't just about making life easier for hard-pressed mounting manufacturers, adds Gies. One of the perennial problems solar encounters in the US is that the so-called soft costs – all the costs that arise from the non-hardware elements of putting a system together – are frequently higher than in other parts of the world, and differ wildly from area to area within the country.

Gies believes that the very issue the committee has been set up in part to tackle is a key factor explaining the US soft cost conundrum. Therefore, if the committee is in some way successful in addressing the issue, the knock-on benefits for the whole US solar industry could be significant.

"There are multiple levels [of jurisdiction] – federal, state and the locality," he says. "And once you get to the level where you're actually talking to the people who are signing off on projects, everyone's subjective, they have their own interpretations, so it turns into this crazy mix of having to jump through different hoops: for one project, one thing is an issue, the next project something else completely different is an issue.

"People talk about soft costs as being a big thing to try to reduce; this is where it really hits home. We're spending a lot of resources in getting through the hurdles, getting things permitted and approved, you have to pay extra engineers, and everyone's interpreting it differently. There's a lot of opportunity to standardise - and what's happened with racking is that a lot of functionality aspects that are really tied in with code and regulation have come to us. We're the section of the industry that gets looked to, we're the ones that go through the meat-grinder to make sure the systems are certified and approved."

Spies agrees: "When we talk about the factors that increase the cost of solar, there's no doubt in my mind that racking is the number one factor today. It used to be module price declining was the most significant factor in the cost of solar; today it's the cost of the racking and the rules that you have to follow to get that racking system assembled and inspected. So that's part of the challenge – that we have the most complicated product sector in terms of how it should be done correctly." ■

Project briefing

DELIVERING WEST AFRICA'S FIRST UTILITY-SCALE PV PROJECT

Project name: Xiaocheng Technology Ghana Solar Farm Project
Location: Winneba, Ghana
Project capacity: 20MW
Site: 40.5ha

Ghana suffers a severe energy deficit with only around 70% of the population having access to electricity and regular power outages, so it was welcome news that East and West Africa's largest solar PV project was connected to the national grid in April. Historically, Ghana has relied on the huge 1.02GW Akosombo Dam to deliver cheap power, but as its supply has waned and electricity demand grown, the industry has had to diversify into thermal power. Continued demand and an understanding of the need to adopt clean energy means that solar could play a key role in the future of this fast-growing nation. The government has now introduced incentives to increase the renewable energy output to 10% by 2020.

PV Tech visited the new US$30 million solar project, built by China-based power firm BXC Ghana, a subsidiary of Beijing Fuxing Xiao-Cheng Electronic Technology, just after the plant's inauguration. Located near the historic fishing port town of Winneba, the 20MW project represents a significant step up from previous solar endeavours in the region, with the next biggest plants weighing in at 15MW for Masdar's project in Mauritania followed by Gigawatt Global's 8.5MW plant in Rwanda.

BXC Ghana, established in 2010 with a group of Chinese investors as a special purpose vehicle to execute energy generation projects in the West African country, also specialises in power management by training and employing Ghanaians to deploy prepayment metering systems and transmission systems for various types of electricity sources.

Policy

Last year, the Ghanaian government announced an investment of US$230 million to boost its renewable energy incentives through the Scaling-up Renewable Energy Programme (SREP).

"With the passage of Ghana's Renewable Energy Act, a framework was provided for interested investors to participate and enable renewable energy to play a significant role in the energy mix in Ghana," says Michael Yang, assistant managing director of BXC Ghana. "While working on trying to reduce distribution losses, the firm realised how big a challenge power shortages are for Ghana."

However, the government also brought in restrictions that limit solar plants to 20MW capacity unless they include battery energy storage systems, but batteries remain too expensive at present to implement, says Luan Ye site manager of BXC Ghana. Therefore, despite having enough land to build 60MW of solar on the project site, BXC had to stick with 20MW to comply with the new rules.

Credit: Tom Kenning

PPA

BXC approached the major utility Electricity Company of Ghana Limited (ECG), a government-owned electricity distributor, as a potential off-taker for the solar power produced. The two parties initially signed a memorandum of understanding to allow BXC begin the preparatory works, before they eventually signed a power purchase agreement (PPA).

The PPA signing was a significant step given that many industry commentators have questioned the financial credibility of most utilities in West Africa and cited the potential for delayed payments for independent power producers.

In any case BXC Ghana funded the whole project without any government financing, in contrast to most developers working in Ghana who have sought credit enhancements for major solar projects.

The installation marks a ten-fold increase on Ghana's previous flagship solar project, which stands at 2MW in Navrongo. Meanwhile, the optimism brought to the sector by the grid connection in April was complemented by the commissioning of a 30MW module manufacturing facility by Accra-based developer Strategic Power Solutions (SPS), a subsidiary of Strategic Security Systems International (3SIL). This facility saw an investment of US$50 million at a site in Kpone, a commercial hub just outside the country's capital.

Site

"A solar radiation map for Ghana indicates irradiation levels for different parts of Ghana," says Yang. "It is important to select a site that has adequate solar resources in order to justify the investment in the solar park."

BXC settled for a 40.5-hectare piece of land at Onyandze in the Gomoa East

By Tom Kenning

Credit: Tom Kenning

district of the Central region a short ride from Ghana's capital, Accra.

The land itself was very cheap and up for sale from a local landowner, but it will be used solely for the PV project and the ground beneath the modules will not be utilised for any other purpose. Meanwhile the company had already been working on a major transmission line, which can be seen running along the roadside as you approach the plant. This line took three years to build.

Ye says that 80% of the equipment used on the plant was shipped from China, but sometimes when necessary to deliver in a short time frame, machines were shipped via airline. Certain machines on site such as tractors did start having problems after three to five years of use, but there were few major challenges overall.

Modules

The modules used came from Chinese firm China-Electric and offer a 25-year lifetime.

The site uses:

- 80,960 modules
- 40 inverters
- 20 transformers
- 20 houses

The inverter specs are:

- Growatt PV grid-tied inverter
- Model CP 500 TL
- DC operating voltage range500-1000Vdc
- Operating temp range -25 to +55 degrees Celsius

The projects used fixed-tilt PV systems mounted at a pre-determined angle from which they will not move during the lifetime of the plant, says Yang. The limitations imposed on the system due to its static placement are offset by the PV panels being able to absorb "incident radiation" reflected from surrounding objects.

"In addition, the misalignment of the angle of the PV panels has been shown to only marginally affect the efficiency of energy collection," adds Yang.

He also lists various advantages including lower installation and maintenance costs that fixed-mount systems enjoy over tracker systems, which are more complex in terms of mechanics as they include moving parts.

Fixed-mount PV systems are an established technology with a proven track record of reliable functionality, says Yang. In addition, replacement parts can be sourced more economically and with greater ease than with alternatives. They are also robustly designed and able to withstand greater exposure to winds than tracking systems, he claims.

Construction

There were an adequate numbers of skilled technicians and artisans in Ghana which BXC utilised during the construction phase of the project, says Yang. Local contractors were engaged to do the civil works on the site. Ghanaian artisans were engaged and trained in fixing the panels. Local electrical contractors were also engaged to install the transformers and switchgears and also for the construction of 33kV overhead lines at the site. The construction of about nine kilometres of 33kV overhead lines to interconnect to the ECG substation at the Winneba roundabout was also done by a Ghanaian electrical contractor. The plant became fully operational within six to eight months of construction.

Ye says that nearby villages had negligible employment before BXC started implementing the project. The year-long construction phase created 100 jobs for both men and women, and 20 further full-time jobs have been created for staff run and maintain the plant over the next 25 years. Despite the project being based just a few kilometres away from Winneba, all electricity generated will go into the national grid run by ECG rather than being directed to any particular part of the population.

Transmission

The main transmission line for the project runs along the road from the Winneba junction to the plant. The 33kV overhead line was constructed to cover a distance of about 9 kilometres. Engineers from ECG and BXC collaborated in order to coordinate the interconnection of the facility to ensure safe delivery of power from the plant to ECG, says Yang.

The transmission project required the installation of around 2,000 transformers, adds Ye, and it took around three years to build, even after being in planning for roughly 10 years. BXC has been working on other projects to minimise distribution losses across Ghana and has worked on extension projects in the Central and Western regions. It also works on improving the network, removing overloads and performs audits of electricity flow at all voltage levels.

Credit: Tom Kenning

O&M

With the major solar project now up and running, BXC has a dedicated team who monitor the operation of the plant. General workers are engaged from the local community to do routine cleaning of the panels, says Yang.

Security guards are posted on towers at the periphery of the site. Ye, says there have been incidents of locals stealing the solar panels, with the latest occurrence resulting in the theft of 11 solar panels with a combined cost of US$2,000. As a result, the company has had to put up an electric fence around the perimeter instead of relying solely on the guard towers.

Ye says it is a challenge to educate locals that there is higher demand for energy in Ghana than the country's capacity can provide. In this way, the solar project does not just benefit BXC, but also aids the whole community.

Nevertheless, when solar panel snatchers are not prowling the site, it is usually stray animals including snakes, rabbits and giant snails that invade the premises, according to daily reports from the local Ghanaian workers.

As the plant is so close to the sea, many of the panels are heavily covered in salt in some places, which is proving very difficult to clean off when trying to keep the panels functioning with the highest efficiency. The salt can be seen collecting in the corners of each of the lowest panels. This is providing a unique challenge in the maintenance of the plant. The team does use automated mechanisms to clean the panels, but the build-up of salt remains evident.

Despite the landmark achievement that may give hope to solar developers across the West African region, delegates at the Solar and Off-grid West Africa conference in April widely reported disappointment in the progress of utility-scale solar in Ghana over the past 12 months due to a lack of clarity surrounding the 20MW cap on individual projects. Nevertheless news of a major project being able to successfully sign a PPA with ECG, particularly one located in the Southern region of Ghana, which tends to have lower irradiation that the northern regions, must come as some comfort to large-scale PV enthusiasts.

Another positive can be drawn from the recent announcement by Wisdom Ahiataku-Togobo, director of renewables and alternative energy at the Ministry of Power Ghana, that Ghana will soon update its feed-in tariff (FiT) programme for solar to include the possibility of having contracts last for 20 years.

At the time, he said: "Any moment from today, a new set of feed-in tariffs will come out and I believe this FiT is going to take into consideration most of your worries."

He added that many developers had raised concerns and asked for a 20-year period for the FiTs instead of the previous 10 years and this is being accounted for in the next update. Meanwhile, another tender for solar capacity in Ghana is forthcoming. ■

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Cyber-attack

Plant security | As the amount of solar on the grid grows, so too does the risk from cyber-attackers. Nicholas Manka looks at the security considerations of large-scale solar fleets and assesses how the solar industry is likely to have to adapt to increasingly tight regulation

Solar and other renewable generation infrastructure has resided at the periphery of reliability and security awareness for some time, but no blackout attribution or attack has yet occurred to push regulators and utility management into codifying many answers to the specifics of solar operations. However, with the explosive growth of solar installations, it is only a matter of time before a regulator or malefactor notices that there several cities worth of load being handled by generation capacity sitting out in the sun, in many cases managed outside the control-centre environment historically responsible for electric transmission and large generation systems.

Cyber-security has historically been an afterthought in every industry, and the power industry has not been an exception. Despite decades of available academic and engineering knowledge, the computers that run everything from household thermostats to protection relays have had relatively little analysis by security experts outside fits and starts. The commonly imagined exception to vulnerabilities in special-purposes or proprietary industrial systems ("security by obscurity") persists only until someone looks, and someone is now looking.

Operating a solar site via an iPad from the shores of a lake while enjoying the breeze sounds like a winning proposition, but the assumptions built into making that happen raise a number of security and integrity questions that traditionally have not been accepted for critical infrastructure.

A very brief regulatory history

As a result of wide-scale inaction in the power sector at large, regulatory bodies in several nations have established standards or task forces – the North American Electric Reliability Corporation (NERC) founded in 2006, and the 2005 European Programme for Critical Infrastructure Protection (EPCIP).

In North America, NERC's Critical Infrastructure Protection (CIP) standards were originally targeted at transmission and very large generation entities that compromised what is referred to as the Bulk Electric System (BES) – in simplistic terms, the AC Transmission lines operating at 100kV or more. However subsequent revisions have expanded the applicability of a subset of the security requirements to almost all NERC-registered facilities – in particular, solar and renewable sites rated at 75 MVA (i.e. 75MW operating at unity powerfactor) on a single connection to the BES on transmission tie lines (≥ 100kV) will be required to meet a set of security requirements being phased in from April 2017 through September 2018.

A less brief regulatory overview of North America

In the interest of clarity and brevity, this section focuses primarily on the NERC CIP standards in effect in North America, primarily in the United States but also parts of Canada and Mexico. Some security standards focus on best practice and implementation guidance; NERC's CIP standards, by comparison, instead require compliance programmes to be created by subject entities, while staying light on technical implementation. This leaves the programme open to numerous methods of compliance, but also creates an intimidating blank page as a place to start.

Readers hoping for a quick summary of how NERC CIP will affect solar generation may be relieved to learn that while NERC has set a 75 MVAAC of variable generation as a minimum for registration and compliance with the reliability standards, the CIP requirements at that MVA rating are what NERC has deemed to have a "low impact" on the greater BES. The weight of CIP resides at the "medium" and "high impact" designations, which are intended for much larger operations that any single renewable power generation facility is likely to reach in the foreseeable future – in order for a generation facility to qualify as CIP Medium Impact, it must be rated at 1,500 MVAAC tied into the transmission interconnection.

For a Low Impact facility, the Generator Owner (GO) and Generator Operator (GOP) are required, at a minimum, to develop and implement a cyber-security policy or policies that protect the critical control networks and address:

1. Physical access controls
2. Electronic access controls for networked sites
3. An incident response plan (including E-ISAC)
4. A cyber-security awareness programme (training).

GOPs and their control operations, however, are more likely to fall into CIP Medium Impact as the 1,500 MVAAC threshold is applied to the amount of control capability the GOP has within a single Interconnection (i.e. Western, Eastern, Texas, Quebec). As centralised operations and maintenance capabilities may rapidly acquire or be tasked with the responsibility for multiple sites, this threshold can be quickly approached and crossed without any warning until a Regional Entity notices.

So what is the end result? To rephrase the goals of the NERC CIP (and a dash of the operational standards):

1. There should be some means of knowing who is entering and leaving a BES facility, and who is operating its computerised controls, and there needs to be an affirmative granting of access (i.e. no default passwords)
2. Basic access controls, integrity measures and logging should be enabled on computers and protection relays
3. Computerised systems should be backed up and there should be a plan to rebuild or replace them if they are damaged or compromised
4. There should be a plan, at least a high level plan, of what to do, or who to call, in the event bad things happen
5. Important equipment should be tested and calibrated every few years
6. All that should be written down so a single individual leaving doesn't take critical knowledge along with him or herself
7. People should be trained on their expected responsibilities, and the plans for events.

Stripped of the strange motley of legal and engineering language that haunts the NERC regulatory standards, those sorts of measures are good practices for any company.

Changes and challenges

Many renewable O&M providers do not have control centres in the sense in which the term is normally used. A cloud service can dispatch dozens of sites from a web interface with no defined building or operator anywhere.

Manufacturers of the working parts of a PV farm also have come up with dozens of independent and frequently web-based management and control schemes due to a lack of overarching standards and normal business logic.

The cost-effective solution to that scenario is usually an internet link, possibly redundant, that provides access to plant networks from the internet and often serves multiple stakeholders' needs with differing cloud services, HMIs and remote access methods in parallel.

Some solar integrators and operators have wisely taken proactive stances and invested in secure control system architectures, but there has yet to be a pressing and obvious external driver to do so—in other words no blackout or attack has occurred yet to force regulators and utility management to make security a priority. Additionally, the engineering, procurement and construction contractors (EPCs) often have little reason to deliver strong security controls because 1) their contractors do not say so and 2) their business is based on using their prior experience and replicating the prior installation at least cost.

Risks

Nothing at a generation site, with control automation that operates expensive equipment with long replacement lead times or which may be used in life-safety procedures, should be accessible directly via the internet.

No matter how many geniuses may be employed, there is an asymmetry of costs for defensive measures versus threats exists. There are millions and millions of clever people in the world, and criminal and state organisations have discovered they can be paid for highly useful information about how to break security measures. This professionalisation was a key factor in the Ukrainian power grid attack of 2015, in which one set of intruders with no particular interest in the specific utility networks appears to have sold their illicit access into multiple EMS control centres to another party that had a very specific motivation to use that access to malicious ends.

Professionalisation does not slow down unless the money goes away, and as of 2016 there is more money than ever on both sides of security research. It does not take a business prodigy to realise he or she can trade serious vulnerabilities to people with money instead of responsibly publicising it for a tiny bit of internet fame and perhaps a footnote mention in an academic paper.

To pick two examples of many, consider how much effort companies like Microsoft and Juniper devote to security. And yet in 2015 and 2016, both have had major security issues that potentially could have affected millions of people and companies. Microsoft personnel fixed both operating system bugs and implementation errors with some of their cloud services, but these had existed for extended periods (in some cases, years). Juniper Networks, a major security appliance vendor, also discovered in late 2015 that a backdoor had been placed in the login code for their firewalls and another in one of their cryptographic libraries. It is tempting to criticise these organisations for having such a problems, but more important to remember is that the issues were found because they have proactive security teams and are under the scrutiny of thousands of unaffiliated researchers.

Now consider how much effort the many different companies making specialised plant control systems are devoting to security. These are serious risks that threaten even the largest organisations, with robust security programmes and dedicated computer security professionals on staff.

Mitigating risks and automation integrity

Security, harkening back to its dictionary meaning, is not merely protection from harm, but also includes the notion of integrity, which is tightly tied with reliability in the case of operational technologies. A relay that can be assured to have the accurate and engineering-approved settings is a relay that is less likely to mis-operate. A SCADA system can likewise be better trusted if it has accurate and up-to-date displays and telemetry.

Minimising the attack surface

Implementations of open standard Virtual Private Networks (VPNs) exist and should be employed. Cost-effective internet WAN links can still be deployed, and then the internet can stop at a modern firewall that only allows predefined remote hosts to connect and build VPN tunnels. In these VPN tunnels, business and operational connectivity can exist with the measure of safety that a widely deployed VPN technology is under wide scrutiny, and offset some of the asymmetry of effort.

If there is a single effort applied to protecting critical infrastructure, it should be reiterated that nothing at a solar generation facility should be openly on the internet.

Electronic intrusions

A reoccurring fact of major compromises is that even organisations that have security event logging often do not have staff monitoring it. The scalability of effort for log analysis makes it such that a relatively small investment in log aggregation to a cloud service or centralised repository, that is combed by both people and automated logic, can serve hundreds of sites. Logs and event records that are not analysed and responded to are useless, as is a guard tower with no guard. Almost every device can be configured to log at least some sort of access and security events, either via SCADA protocols or common standard protocols such as syslog or SNMP, and these should be employed.

The same conceptual methodology for telemetry recording that is being used to translate transformer temperature readings into actionable preventive maintenance can be applied to the communications infrastructure at a generation site as well as the security and integrity of computers and electronics.

Secured network segmentation

In the language of regulatory standards, two terms that will be making the rounds at North American utilities in the coming year are Low Impact External Routable Connectivity (LERC) and Low Impact Electronic Access Point (LEAP). In terms anyone outside the sphere of NERC might recognise, firewalls and access control should exist between computerised assets that have different administrative responsibilities. Renewable generation has a twist on that issue in that it is fairly common to have multiple independent organisations with entirely reasonable and valid desires to have computers at a site with access to plant operational systems.

Historically these have all been placed on a small number of local area network (LAN) segments, sometimes as few as one, with shared passwords or unchanged vendor default passwords, because that was expeditious and pragmatic.

"Technologies, methodologies, advisors and training programmes already exist that can be leveraged to help secure renewable generation. Planning for security ahead of time as a normal cost of doing business is a good idea today, and preparation for when it becomes mandatory"

When trying to assert and maintain system integrity, however, it presents a set of challenges that multiple authorised groups will have access to a network, and measures should be taken to segregate those systems so that access to a historian or fault recorder doesn't also implicitly grant access to a SCADA master and transmission breaker relay.

The concept of a LEAP is simple: place an access control device between networks to deny such access, and then only allow what is actually needed. When applied to public networks, this minimises the attack surface. When applied to private networks, this helps prevents accidents, confusion and blame games by establishing clear responsibilities.

Planning ahead

"The only alternative to risk management is crisis management—and crisis management is much more expensive, time consuming and embarrassing." –James Lam, the first chief risk officer of the United States

A final effort with high reward is basic planning. Even the most high-level plans and responsibility assignments at least force an organisation to consider security events (under NERC standards like CIP) or general operational issues (EOP, PRC).

It is important to remember that no one is going this alone. While some competitive advantage may exist in being more secure or not suffering operational failures, in practice most power industry organisations are willing, and even relieved, to collaborate and share their knowledge and experience. This was borne out of self-preservation: security is a hard problem, and compliance is an expensive problem.

An important element shared by both CIP and EPCIP is the creation of a data sharing programme. For NERC, it is E-ISAC, the Electric Information Sharing and Analysis Center. For EPCIP it is the Critical Infrastructure Warning Information Network (CIWIN). E-ISAC in particular is intended primarily for representatives of electric utilities and has been restricted from vendors and consultants, although that position is under reconsideration.

The near future

Solar power generation is experiencing amazing growth, which is good for both the industry and humanity at large. One consequence of that growth is that minor integrity and security concerns will become more important because either a malefactor will do something awful, or a regulatory body will be worried enough about that eventuality that it will create obligations for renewable generation to address that risk before it results in a blackout when 20 GVA of solar is tripped off during a hot summer afternoon. In particular, NERC's CIP Low Impact requirements have been expanded slightly in the most recent revision, and that is expected to continue as the standard evolves, and the larger control operations (in control rooms or not) of solar generation in the United States will be coming under NERC's CIP Medium Impact in the summer of 2016.

What comes out of the first few audits of those control operations will have significant impact on what is expected of other solar generation ownership and operations in the years ahead.

Technologies, methodologies, advisors and training programmes already exist that can be leveraged to help secure renewable generation. Planning for security ahead of time as a normal cost of doing business is a good idea today, and preparation for when it becomes mandatory. ■

Author

Nicholas Manka is a SCADA and security expert for US-based consultancy GridSME. He advises electric utilities and power automation vendors on security, regulatory compliance, and SCADA modernisation in the United States and Canada. His background is in SCADA and EMS for transmission and distribution, and he is currently assisting CIP version 5 and 6 transitions, as well as building compliance and operations programmes for renewable generation.

O versus M: the case for separating operations and maintenance

O&M | Usually lumped together as a single activity, PV operations and maintenance activities in fact encompass two distinct sets of disciplines. Matt Murphy considers the arguments for separating the two sides of this vital aspect of solar power plant business

Credit: Borrego Solar

Operations and maintenance (O&M) is the oft-neglected part of solar installations, which many owners end up realising is the lynchpin to a successful return on investment. The importance of O&M first became apparent when incentives began to change from lump-sum payments based on kilowatts (kW) installed to kilowatt hours (kWh) produced. Therefore, O&M is becoming the most critical component in sustaining investment in and adoption of solar PV. Turning kW into the most kWh possible is the key to the promising future of our industry.

While it's now clear to solar asset owners that O&M is a critical component to realising expected return on their investment, it's not always clear what service, operations or maintenance, deserves more attention and investment. I am increasingly being asked by owners and financiers whether these two services are so distinctly different that they should be decoupled to the benefit of the industry. To properly frame the question we need to define what O&M is exactly.

Operations: SCADA/DAS monitoring, KPI reporting, data analysis, dispatch services, remote troubleshooting, maintenance scheduling, utility interaction, inventory management and oversight of maintenance contractors.

Maintenance: All preventive maintenance services, including but not limited to visual inspections, mechanical maintenance, OEM maintenance, electrical testing, thermography, DAS maintenance and medium voltage maintenance, as well as all reactive, corrective and performance services. Performance services are defined as module washing, vegetation maintenance and snow removal.

As you can see, O&M encompasses two distinct services, leading some plant owners to consider decoupling them and turning to different providers for each service. It makes sense to consider it. The provision of operations services needs a different skill set than that needed for maintenance. Owners are thinking that perhaps hiring two providers more skilled at one will yield a better return on investment.

On the other end, they're questioning if one firm for both O&M would be able to excel at all the specific and important tasks.

Investors and plant owners are beginning to question why PV operations and maintenance services are not decoupled

Accountability also comes up as a concern with hiring one provider for all O&M tasks. Owners are concerned with whether they will have to spend a considerable amount of time making sure the provider has done their job and done it well. Their concern centres on a core fear all owners have and are trying to avoid with O&M: that their system is not performing optimally and they don't catch it until there's already been a considerable loss of kWh revenue.

These are all valid questions and good reasons why plant owners are strongly considering separating the O from the M. After all, owners are trusting providers with the optimisation of the production of kWh. In the case of most solar PV plants today, even minor and temporary underperformance can far outweigh the annual costs of O&M services. Any question that can lead to better and more economical performance of power plants for owners is one worth asking.

The truth, which is perhaps not well socialised outside of the O&M community, is that parsing out some services has been going on for the last decade and will continue to go on whether owners become involved or not. O&M providers have always maintained contracts and sub-contracted out portions of the services in the scope of work. Traditionally, the sub-contracted

"In the case of most solar PV plants today, even minor and temporary underperformance can far outweigh the annual costs of O&M services. Any question that can lead to better and more economical performance of power plants for owners is one worth asking"

Credit: Borrego Solar

work has been mostly maintenance or reactive services but it is also becoming more common for the contracted O&M provider to only perform the on-site services and sub-contract the operations services to another provider.

This happens mostly with utility-scale plants where there isn't even a handful of facilities with the necessary Medium Risk NERC-CIP credentials that provide PV operations services. So if an O&M provider is performing utility-scale services, they are typically sourcing the operations services to one out of a few companies such as First Solar and EDF Renewables.

At Borrego Solar our strategy for separating O&M services has changed drastically over the last five years. Previously, we only provided operations services and hired sub-contractors for all preventive maintenance, reactive service and performance service. Over the last few years we have built up an extremely strong solar electrician staff that has changed those practices. While we still perform operations services, we now perform all of the preventive maintenance and nearly all of the reactive service in house. We still, however, sub-contract a minor portion of our on-site services and all of our performance services. There are instances where we sub-contract some operations services—mainly for large utility plants that require the NERC-SIP standards mentioned above.

Thus, we are effectively separating the O and the M on any occasion where it makes sense to improve the product to the customer. Today we even perform work with other O&M providers that others might think of as our competitors but we think of as partners. In these relationships, our partner holds the O&M contract and primarily performs the operations services and hires us to provide the on-site maintenance services.

I recommend owners contract one provider and trust that provider to make decisions about when it provides the most benefit to the owner to sub-contract for specific services for these main reasons:

Some services, such as day-to-day plant maintenance have always been sub-contracted

Kilowatt-hours trump kilowatts

Put simply, preventing the loss of potential kWhs is the number-one job of an O&M provider. In cases of critical failures, an O&M provider needs to be able to act as quickly as possible to correct the problem. If there are separate providers for operations and maintenance, there will likely be a lag in communication that can increase kWh loss. Owners will also have a much more difficult time enforcing response time guarantees if they're based on the actions of two entities responding to one problem. It's a lot harder to say a maintainer didn't respond to a notification from an operator on time than it is to pin your O&M provider to the time-stamped receipt of an alarm from a monitoring platform.

With one O&M provider, there is a clearer path to success and an easier time enforcing agreements. KWh production suffers when time is wasted waiting for notifications or with delayed site-response times.

One responsible party

Tying directly to the last point, PV power plant owners will have a much easier time managing their plants and enforcing their agreements if they have one party that is responsible for performing all O&M services. This point becomes exponentially more important if there are performance or availability guarantees involved. An owner should feel most comfortable with their assets when they have a good contract in place and they have one provider to blame and one party to seek restitution from if that agreement is violated.

In my experience argument and finger pointing always result when there is a dispute over services and the owner has separate contracts for operations and maintenance. Ideally, a good operator and a good maintainer can work together fluidly and at a benefit to the customer. However, in reality the relationships are most often complicated. Owners should think strongly about the amount of free time they have and the value of that time before hiring separate O&M providers. Managing multiple contractors to perform these services will always increase administration time for the owner.

Cost

Given the lack of available data, I polled some of my customers and industry partners when writing this article to ask about what they are seeing for cost trends in the industry when O&M services are separately contracted by plant owners. In every case it was reported that overall costs run between US$1/kW and US$5/kW more when the two services are split. I've said throughout this article that kWh revenue always trumps service cost, but that is a considerable increase in price. The price increase is attributed to providers wanting to either have full control and full responsibility or no control and no responsibility. This puts providers into a grey area of responsibility and increases time spent managing communication between the two parties.

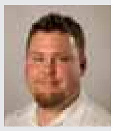
The case for separating O from M

Could there be a benefit in certain occasions separating O&M services at the owner level? Yes, I believe in certain cases there could be. Have I experienced it to date? No. I have, however, experienced many very successful relationships where portions of the operations and portions of the maintenance services are separated and sub-contracted at the provider level. As stated earlier in the article, the whole industry is operating this way and has been for a long time. The popular discussions today aren't about separating O&M, but about separating O&M at the owner level.

For owners that are interested in proceeding down the path of separating their O&M services I have two pieces of advice. First, make sure to budget in more time to deal with the operation of your assets, especially at the onset of the agreements with your O&M contractors. Second, build some kind of performance-incentive mechanism into your contracts that encourages (read: forces) your providers to learn to cooperate and operate in tandem. There's nothing like a financial incentive to get separate companies to cooperate.

Whatever you decide… here's to more kWh per kW!

Author



Matt Murphy is the director of O&M for Borrego Solar. He manages a national O&M team and is responsible for the highest level of escalation within the department. On a daily basis he ensures that each region is performing optimally. He also serves as the department's data and communications technical expert.

SEAWARD

Maintaining diversity in your solar PV installation business

Working in the solar photovoltaic market has never been easy. Cowboys continually knock consumer confidence, governments can't seem to make their minds up and global module supply has been inconsistent.

Experts are forecasting the cumulative worldwide total for PV to reach 321GW by the end of 2016. When we, as an industry, sell these systems we promise the operators they will last for 25 years, so let's get out there and make sure they do!

As an experienced PV professional your barrier to entry into the secondary operations and maintenance market is paper thin. You have the leads on hand, you have a wealth of transferable skills and the equipment/software needed is more user friendly and cost effective than ever before.

Now is the time to readdress your customer list and offer them what we could potentially call a PV Health Check:

- a full physical inspection of the PV array including roof fixings, cabling, module integrity and inverter functionality
- a full electrical inspection of the PV array including an open circuit voltage test, short circuit current test, insulation resistance test and I-V curve trace
- an energy efficiency survey of the property and its occupant's energy use.

Using the above information we can then produce a report for the client detailing how efficient their array really is and what we would suggest to improve its performance. This leads us into up-selling opportunities such as module cleaning, voltage optimisation, monitoring systems or perhaps energy efficiency technologies such as LED lights or heat storage batteries

These PV Health Checks could come in Bronze, Silver and Gold packages with the level of detail of the inspections and reports varying accordingly. By giving the client options we are giving them control and that is what this is all about.

As an industry we can no longer rely on a subsidy to drive growth, so let's empower PV operators of all sizes to properly manage their investment and their energy use.

At Seaward we manufacture an advanced range of PV diagnostic equipment that encompasses all the necessary tests in a compact, hand held kit.

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The Seaward Solar range of electrical solar PV test equipment enables Photovoltaic installers to meet all testing and certification requirements of IEC 62446 safely and efficiently.

With over 75 years' experience at the cutting edge of electrical safety testing, our expertise and innovations have produced a number of world firsts.

The market-defining range of solar PV test equipment makes meeting IEC 62446 and other PV test and documentation requirements faster, safer and easier. From solar site survey to commissioning tests, PV system maintenance and PV system certification, Seaward Solar has it covered.

Specialised test equipment for solar PV installations has been long-anticipated within the industry so we responded by creating a range of solar PV test equipment specifically designed to meet the needs of solar installers.

Seaward Solar PV test equipment and software is designed to enable installers to:

- test and commission PV systems correctly and comprehensively
- identify faults within existing PV systems quickly and easily
- ensure maximum electrical output from PV systems
- document and record electrical test and environmental readings such as irradiance for total traceability.

Navigating the maze of energy storage costs

Storage | The anticipated growth in stationary energy storage will be dependent on a significant decrease in costs, but the many different storage applications and technologies make comparisons of costs a complex undertaking. Florian Mayr and Hannes Beushausen of Apricum – The Cleantech Advisory describe what to consider to determine the costs of energy storage in a meaningful way

Credit Younicos???

The future market for stationary energy storage systems (ESS) is one of the most heavily discussed topics in the power industry today. Significant growth is expected in particular for stationary battery systems, which accounted for only 2GWh globally in 2015 but are expected to grow to 33GWh by the end of the decade.

One of the key drivers – and prerequisites – of this growth is a significant cost decrease and the resulting competitiveness of energy storage systems compared to traditional, non-storage solutions. At the same time, an increasing number of ESS technologies has become available for commercial application in a variety of use cases, each with a different cost of energy storage that needs to be compared in detail, to be meaningful.

But what does "cost of energy storage" really mean?

While there is general consensus to use levelised cost of energy (LCOE) for comparing different energy generation technologies, such as solar parks, wind farms and coal plants, there is no universally applied metric for calculating the cost of energy storage.

As a result, the assessment of costs for different energy storage solutions can become a tough exercise for all stakeholders: storage system manufacturers have a hard time explaining cost advantages over their competition, investors struggle with making an educated decision for financing and end users do not know which energy storage solution is most economical in the targeted application.

In this article, we will examine what to consider for calculating meaningful, comparable ESS costs.

Let's start with two simple but important rules:

Meaningful cost assessment is key for all stakeholders, such as ESS manufacturers, investors and end users

1. Cost comparison for same use cases only

In contrast to technologies for generation, which have a single use case (i.e., the generation of electricity), energy storage technologies can serve a variety of use cases, including both in-front-of-the-meter (e.g., supply of reserve power, black start support, dispatchable PV) and behind-the-meter applications (e.g., increase of self-consumption). Each use case requires different operating parameters, which affect the costs, and each storage technology optimises along these parameters differently according to its relative strengths and weaknesses.

Therefore, cost comparisons of energy storage only make sense for a common and clearly defined use case. Furthermore, only energy storage systems that were designed to serve the technical requirements of a specific use case should be compared: a storage technology with higher costs than an alternative technology is not necessarily "worse" or "less advanced", it is probably just meant for a different application.

2. Choose the right basis

The cost of energy storage is typically based either on the provided energy (i.e., kWh, MWh) or on the power capacity (kW, MW). The appropriate basis to choose depends on the value that energy storage is adding in the specific use case, i.e., in many cases, the costs that are avoided through application of energy storage.

Consider the two following examples:

- In an island grid, an ESS could be used to shift PV generated electricity to the evening to meet peak demand instead of using electricity generated with a diesel genset. An investor would therefore want to compare the cost of adding energy storage with the cost

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of diesel-based generation, which is denominated in US$/kWh. Therefore calculating the cost of storage on an energy basis is the right starting point.

- The peak demand behind a power transmission line exceeds the available capacity. To remove the bottleneck, the grid operator could install a battery storage system to serve the excess demand or extend the grid infrastructure. The cost of a transmission line is typically based on its power capacity denominated in US$/MW. Therefore a comparison with the cost of storage based on an energy basis is not applicable but should instead be done on a power basis.

With this clarified, we will focus on calculating the cost of ESS on an energy basis as follows.

Know your cost influencers

The key to comparing apples with apples is to make sure that individual cost figures are calculated at the same level of detail and are based on comparable assumptions. The prerequisite for this is a deep understanding of the different factors influencing the costs of an ESS, i.e., upfront costs, O&M costs, charging costs, useable energy over lifetime, residual value and financing costs.

Upfront costs: Already at this basic level, a close look is required when comparing different energy storage solutions. Are all necessary investments for the complete and connected system included in the initial quote? Very often, for example, costs for the necessary inverters, safety engineering or for shipping and installation are not covered. To assess these costs correctly, specific characteristics of the individual energy solutions have to be considered, such as the impact of gravimetric and volumetric energy densities on transportation and space requirements.

Operation & maintenance costs: Like all infrastructure assets, energy storage requires periodic minor and major servicing. Depending on the components that need to be replaced, and how frequently, this can cause significant additional technology-specific costs. For example, a redox-flow battery features mechanical parts such as pumps that can require maintenance not needed for other battery technologies.

Charging costs: The cost of charging the ESS needs to be taken into consideration, but is often left out. Losses during a complete charge-discharge cycle (i.e., reduced roundtrip efficiencies) mean that more energy has to be purchased at a certain price for charging the system than can be sold when discharging – often constituting a significant cost factor depending on the charging electricity price.

Also, the energy consumption of the system differs considerably from technology to technology and depends on local conditions such as ambient temperatures, which should be included in the costs. For example, Li-ion chemistries can require energy intensive air-conditioning to maintain favourable operating temperatures.

For behind-the-meter applications, particular caution should be exercised in determining the efficiency. For example, the load of households is often dominated by times with low loads. This translates to low discharge power for a residential storage system, which in turn results in significant energy losses compared to nominal power usage. As a result, the actual efficiency of home storage systems is often significantly lower than the rated (maximum) efficiency of the systems published in the data sheets.

Useable energy over the lifetime: The cost of an ESS intended for energy-based applications should be put in relation to the energy output of the ESS expected over its lifetime. For batteries, the lifetime often refers to the projected cycle lifetime (e.g., 5,000 cycles), which is the number of complete charge-discharge cycles a battery is expected to perform before its nominal capacity falls below 70–80% of its initial rated capacity as a result of continuous degradation.

Different storage types claim different cycle lifetimes. It is important to understand that a very high number of projected cycles is not necessarily an advantage, depending on a) the ESS' calendar life and b) the number of cycles required per year.

The calendar life is simply the elapsed time before a storage solution becomes unuseable, whether it is in active use or inactive. For batteries it mainly depends on the chemistry and manufacturing specifics of the ESS (e.g., life period of the electrolyte, quality of sealing rings and welded joints) as well as on the voltages applied and the battery temperatures – as a rule of thumb, calendar life drops by 50% for each 10°C increase above 20°C.

The number of cycles required per year depends on the nature of the individual use case. It is determined by the required number of full cycles per day and the number of operating days per year. For example, a replacement of peaker plants through energy storage in the USA typically requires one full cycle per day for 300 days of the year, leading to 300 cycles per year. In contrast, frequency regulation demands up to five cycles per day for 350 days per year, so requiring 1,750 cycles annually.

It is also important to note that the same use case can lead to a different number of required yearly cycles depending on the geography. In sunny California, it is fair to assume that a residential storage system with the purpose of increasing the self-consumption of rooftop PV reaches 300 complete charge-discharge cycles annually. In Germany, however, the same use case would instead require 200 to 250 cycles per year. This is mainly due to the more significant variations between summer and winter: the German winter has little sunshine and does not allow the battery to fully charge during the daytime, while the extended daylight in summer leads to residential storage not fully discharging during the night. Hence, the number of full-cycle equivalents over the year is much lower than in California.

If an ESS in question has a calendar life of 20 years and the targeted use case requires only 300 cycles per year, a cycle lifetime of 300x20 (6,000) cycles would be sufficient – anything beyond does not add extra value and should not be included in the cost calculation. If the remunerations to be received are limited to a period shorter than the ESS' calendar life, for example in the case of a power purchase agreement, the relevant number of cycles is reduced even further.

Finally, the useable energy of batteries greatly depends on the depth of discharge or DOD. For most chemistries, the lower the DOD applied, the higher the number of cycles and the roundtrip efficiency (see above) – but obviously the lower the amount of energy that can be discharged in each cycle as well. Consequently, cost figures should not only include the (relevant) number of cycles and roundtrip efficiency, but also the corresponding DOD.

$$\text{NPV of cost} = \text{NPV of remuneration}$$

With NPV = net present value

$$\sum_{n=0}^{N} \frac{\text{cost}(n)}{(1+r)^n} = \sum_{n=1}^{N} \frac{\text{remuneration}(n)}{(1+r)^n}$$

With cost(*n*)/remuneration*(n)* = cost/remuneration in year *n*, *r* = discount rate, and *N* = lifetime in years

$$\sum_{n=0}^{N} \frac{\text{cost}(n)}{(1+r)^n} = \sum_{n=1}^{N} \frac{E_{\text{out}}(n) * LCOS}{(1+r)^n}$$

With $E_{out}(n)$ = electricity discharged in year *n* and *LCOS* = price for each kWh

$$\sum_{n=0}^{N} \frac{\text{cost}(n)}{(1+r)^n} = LCOS * \sum_{n=1}^{N} \frac{E_{\text{out}}(n)}{(1+r)^n}$$

LCOS is constant over time, i.e., levelised

$$LCOS = \frac{\sum_{n=0}^{N} \frac{\text{cost}(n)}{(1+r)^n}}{\sum_{n=1}^{N} \frac{E_{\text{out}}(n)}{(1+r)^n}}$$

Figure 1. Formula showing the calculation for levelised cost of stored energy

Residual value: Even after an ESS has reached the end of its lifetime, it bears a certain residual value based on the achievable sales price for the individual components including inverters, switchgear and transformers. Obviously, the shorter the period of time an ESS has been used, the higher the residual value. In extreme cases, the residual value can be negative if costly dismantling and recycling has to be paid at end of life.

Financing costs: The time value of money dictates that time has an impact on the value of cash flows. In other words, future cash flows have a lower present value than cash flows generated or paid today. Therefore a discount factor reflecting the financing costs, typically the weighted average cost of capital (WACC), needs to be applied to all outflowing (i.e., O&M and charging cost) and inflowing cash (i.e., the remuneration for the useable energy and residual value).

Levelised cost of stored energy

In order to reflect all of the cost influencers explained above in a simple metric, it makes sense to assume a constant – or levelised – price per kWh over the applicable lifetime of the ESS. The resulting cost metric is called levelized cost of stored energy (LCOS). In other words, the LCOS is the constant and thus levelised price per kWh at which the net present value of the ESS project is zero.

Although a bit counterintuitive, it is important to "discount" also the useable energy (electricity discharged), as can be seen in the derivation of the LCOS formula in Figure 1.

The LCOS formula can be structured along the individual components of CAPEX, O&M, residual value and charging costs, as shown in Figure 2.

By applying LCOS, the significant impact of including or leaving out any of the described cost influencers becomes obvious, as illustrated in the following examples.

Example 1: Dispatchable PV in island grid

For the use case of dispatchable PV, i.e., shifting PV generated electricity to the evening to meet peak demand, a Li-ion battery would end up with an LCOS of US$0.35/kWh given the conditions assumed in our example (see graph, Example 1, on following page). When compared to non-storage solutions such as expensive diesel-based generation in island grids, Li-ion is already economically viable for this use case.

Example 2: Residential storage

Germany is the world's largest market for residential battery storage systems with ~30,000 systems installed today, predominantly for the purpose of increasing PV self-consumption.

Interestingly, for potential customers who are purely financially motivated, i.e., who want to reduce the total procurement cost of electricity, installing rooftop PV plus residential storage is often not feasible yet without subsidies, as seen in the graph below: the costs for storing a kWh simply exceed the savings from self-generated PV power (reflected in charging costs) compared to the electricity price from the grid. Key drivers for the rather elevated cost of residential storage include not only the initial investment, but also the low numbers of cycles used in Germany and the decreased effective efficiency, as described earlier.

However, a PV system combined with energy storage can still offer a lower average energy procurement cost than pure grid supply over a year, as not every self-generated kWh needs to be stored – although in this case the PV system is "subsidising" the storage unit (see graph Example 2 on following page).

Hence, if the reason for increased self-consumption is not purely return driven, but is also motivated by, for example, the wish to be more independent from the utilities, residential storage is a viable solution to achieve this objective. The majority of the residential installations in Germany are in fact based on rather non-financial rationales. Also, if the current incentive programme for solar plus storage from the German government is factored in, the economics can further improve.

Impact of meaningful cost calculations on attractiveness of energy storage

We have seen that the consideration of all relevant costs still allows for an economical application of energy storage in specific use cases, depending on the available alternatives with which the ESS is competing.

Many more attractive opportunities for energy storage are available if applications related to power capacity are considered alongside the energy-based use cases covered in this article. A prominent example is the provision of ancillary services to the grid, which is successfully done through ESS in many markets

$$LCOS = \frac{CAPEX}{\#cycles * DOD * C_{\text{rated}} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} + \frac{O\&M * \sum_{n=1}^{N} \frac{1}{(1+r)^n}}{\#cycles * DOD * C_{\text{rated}} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} - \frac{\frac{V_{\text{residual}}}{(1+r)^{N+1}}}{\#cycles * DOD * C_{\text{rated}} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} + \frac{P_{\text{elec-in}}}{\eta(DOD)}$$

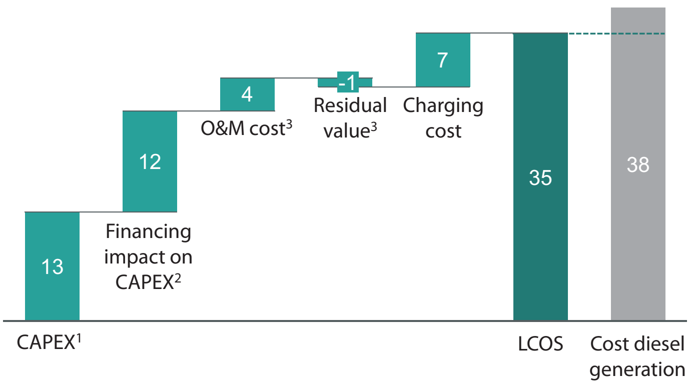
With:

$\#cycles$ = full charging/discharging cycles per year
DOD = depth of discharge
C_{rated} = rated capacity
DEG = annual degradation rate of capacity[1]
N = project lifetime in years
r = discount rate (e.g., weighted average cost of capital)
$O\&M$ = O&M cost (assumed to be constant)
$V_{residual}$ = residual value (after project lifetime)
$P_{elec\text{-}in}$ = charging electricity tariff (assumed to be constant)
$\eta(DOD)$ = round-trip efficiency at *DOD* (assumed to be constant)

1) Assuming linear degradation

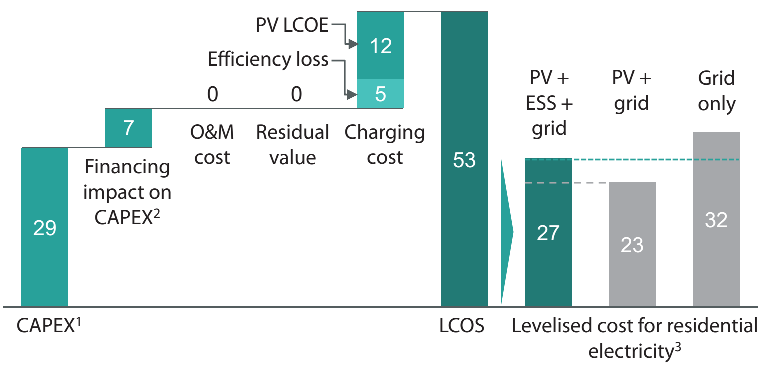
Figure 2. LCOS reflecting individual components of CAPEX, O&M, residual value and charging costs

Example 1: Cost components and LCOS for a utility-scale stationary battery storage system for dispatchable PV in island grid [US$¢/kWh]



1) Divided by undiscounted total energy; 2) Impact of discounting total energy; 3) Discounted and divided by discounted total energy
Source: Apricum analysis, Assumptions:
Technology: Lithium-ion battery technology with CAPEX of 500 US$/kWh, based on 6 MWh/MW with 300 US$/kW and 450 US$/kWh
Use case: dispatchable PV with 350 cycles per year at 80% DOD
Lifetime and degradation: project lifetime 15 years; battery lifetime of 6,000 cycles
O&M: constant annual O&M cost of 10 US$/kWh p.a. (2% of initial CAPEX)
Charging: constant charging cost of 0.06 US$/kWh with 92% ESS efficiency
Discount rate: 10% (assuming 50% of debt at 8% and 50% equity at 12%)
Residual value: assumed to be 20% of initial CAPEX
Diesel generation: LCOE calculation over 20 years with fuel cost 1 US$/l (incl. transport) with 2% yearly increase (variable cost 0.36 US$/kWh)

Example 2: Cost components and LCOS for a residential storage system to increase PV self-consumption in Germany [US$¢/kWh]



1) Divided by undiscounted total energy; 2) Impact of discounting total energy; 3) Over 20 years
Source: Apricum analysis, Assumptions:
Technology: Lithium-ion battery system with CAPEX of 1,000 US$ per usable kWh
Use case: increase PV self-consumption with 250 cycles per year at 100% DOD
Lifetime and degradation: system lifetime 15 years; battery lifetime of 5,500 cycles
O&M: battery system is assumed to be maintenance free (no O&M cost)
Charging: constant charging cost with PV LCOE of 0.12 US$/kWh with 70% battery efficiency
Discount rate: 3% (assuming 100% equity)
Residual value: residual value neglected
Levelised power procurement cost:
Grid only: 2015 average household electricity price of 0.32 US$/kWh; no price increase
PV + grid: 36% of self-consumption; excess power sold at feed-in tariff of 0.14 US$/kWh; 10 kW_p PV system size; yield of 900 kWh/kW_p; lifetime 20 years; 0.5% annual degradation
PV + ESS + grid: 5 kWh ESS system size; all other assumptions as stated above

around the world.

It has to be stressed that our analysis was limited to single use cases only. In reality, most energy storage systems installed today are meant to address various applications simultaneously to generate additional revenue streams and create cost synergies – so-called benefit stacks. For example, residential storage systems do not only allow for more self-consumption of rooftop PV power, but could also provide back-up power and, if aggregated, could provide ancillary services. Grid-scale energy storage systems can offer a combination of black start capacity, peak shaving and demand charge reduction, among others.

Last but not least, the overall trend of decreasing costs of energy storage will continue to enhance the competitiveness of energy storage solutions significantly: the costs for the balance-of-system alone are expected to decline by up to 40% by 2020, according to GTM Research.

Implications for energy storage stakeholders

It is most important to be aware of the various factors influencing ESS costs and how to apply them correctly depending on the individual use cases. In consideration of certain limitations as described above, LCOS can be an easily calculable, sufficiently detailed metric that enables a meaningful comparison of different storage technologies, as well as between storage and non-storage solutions, in energy-based applications.

Cost metrics like LCOS should be applied with caution, though. Even if the underlying assumptions of a cost comparison are clearly communicated (e.g., which ESS technology is applied, value of benefit stacking considered), the results might still "stick" – and are quoted as a reference for the general viability of ESS in completely different, non-applicable situations. As perception often creates reality, energy storage may be ruled out before a detailed assessment related to the specific use case is done.

Nevertheless, standardisation of the methods for calculating storage costs is definitely needed to increase transparency and therefore help to set the right level of expectations regarding the feasibility of energy storage solutions today. This will allow the market to weed out business cases where ESS is not feasible presently and focus on the already considerable – and consistently growing – number of economically viable projects. As a result, the energy storage industry as a whole will benefit from further increased confidence in ESS as a viable alternative to non-storage solutions.

Authors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Will solar burn out on its own success?

Credit: San Diego Gas & Electric

Grid penetration | Although solar is enjoying runaway success in many of parts of the US, with increased penetration levels comes the risk of value deflation. Amit Ronen and Josh Harmon examine the phenomenon and possible solutions, including greater deployment of storage

The outlook for solar has never been better. Projects in global pipelines now exceed 200GW, and the US Solar Energy Industries Association predicts that cumulative solar capacity in the United States will quadruple to 100GW by 2021, thanks in part to the recent multi-year extension of the 30% investment tax credit (ITC). Global annual PV installations have increased from just 16.6 GW as recently as 2010 to nearly 60 GW in 2015. Even cloudy and historically fossil-fuel-dependent Great Britain reached a milestone in April when solar power generated more electricity over 24 hours than the island's coal-fired plants.

Rock-bottom natural gas prices in the United States aren't knocking solar off its game either. New solar and wind installs accounted for over 68% of new US capacity in 2015 and will likely be even higher this year. Unsubsidised PV is already undercutting fossil fuels in markets as diverse as Chile and India.

Grid can integrate renewables

Operators around the world are also successfully integrating more and more renewables, providing real-world rebuttals to long-held concerns over the ability of today's grid to handle higher levels of intermittent clean energy. Germany's pioneering *Energiewende* saw the market share of solar and wind reach 26% in 2013 while simultaneously decreasing outages. California did the same despite more than tripling PV installs from 2006 to 2013. And in January Hawaii's Kaua'i Island Utility Cooperative met an eye-opening 62% of its average daily electricity needs with solar. Just a few years ago, such high penetration levels of a variable supply source were thought unmanageable.

Solar value deflation

However, while technically the grid can handle more two-way intermittent power than previously thought, economically too much solar power when it's not needed can significantly reduce its value. That's because every additional non-dispatchable solar system in the same area generates more electrons at the same time, at a negligible marginal cost, regardless of whether the market demands it or not. The result is that after a certain threshold, each new solar system installed will reduce not only the value of its own generation but also cannibalise the market clearing price for all its neighbouring systems.

The increased penetration of solar on the US grid could make it a victim of its own success

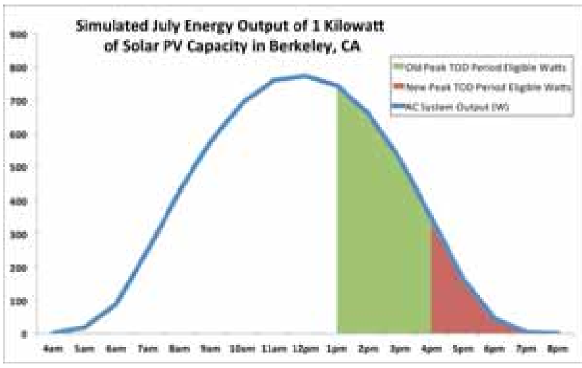
We could soon be reaching the point where too much solar at certain times and places will consistently depress the value of all the solar generated for that particular market. In other words, as solar penetration rates increase solar's levelised cost of energy will start to matter less than its locational marginal price (LMP).

Peak solar production periods in some high penetration regions have already begun putting downward pressure on corresponding wholesale electricity prices. Negative electricity prices, often linked to renewables oversupplying local markets and increasingly common in places like Germany and Texas, are a leading indicator of this phenomenon. According to a Bloomberg analysis, over the past year Southern California has experienced about a dozen of instances of LMP going negative when more power was generated than was needed to meet local demand. And on March 27th, some Golden State solar farms had to shut down because the sunny weather combined with low electricity usage meant supply exceeded demand. The production tax credit, which rewards every extra wind-generated kilowatt hour, has further exacerbated oversupply periods in some cases.

In 2012, Andrew Mills and Ryan Wiser of the Lawrence Berkeley National Laboratory (LBNL) started looking into this phenomenon and found that as PV penetration increased its marginal economic value began to decrease. In their model, based on the expected California grid in 2030, PV's value was determined by what costs were avoided for capital investment, fuel, and operations and maintenance. Their analysis projects that solar devaluation may begin at levels as low as 2.5%, and that PV in California's electricity market would be worth 38% less at 10% penetration when compared to a base case with no PV. As solar penetration grows to 30%, the marginal value of PV energy decreases by 72%, nearly 3% is curtailed, and wholesale electricity prices drop to zero 10% of the time. The Massachusetts Institute of Technology's 2015 Future of Solar report also found that rising solar PV penetration rates would require increasingly higher levels of economic and security-related curtailments.

California solar prices already impacted

These projections are already starting to play out in California where solar now accounts for around 10% of the Golden State's energy. The biggest utility in the United States, California's Pacific Gas and Electric (PG&E), has begun adjusting both its PPA time-of-delivery (TOD) periods and factors for its Renewable Portfolio Standard and solar procurement programmes. New TOD periods shift the peak demand period from 1-7pm to 4-9pm to discourage midday generation. The summer monthly period with the highest compensation rates was shortened from four to three months by moving June to the least compensated spring period.



PG&E's shift in peak period means significantly less of the output of typical solar array in Berkeley, California, is now included

These changes could make many new solar projects uneconomic. According to estimates by California solar market expert Tam Hunt, the weighted average for PG&E's midday TOD adjustment between March and June 2016 is 72% less than a base PPA price for non-residential systems under 3MW, averaging out to a 42% reduction over the course of a year for this group. Though the percentages vary for larger systems, the trends are the same. Clearly, if PG&E is only paying an average of 58% of its former rate during sunny hours, that is a major problem for new installs.

Further highlighting the significance of LMP, while PG&E is effectively telling solar generators it doesn't need any more of their midday generation, neighbouring Southern California Edison is paying a 24% premium for power produced between 2pm and 5pm. With California now legally bound to get half of their electricity from renewable resources by 2030, these dynamics will only become more important.

> "As PV continues to increase its market share, the gradual decline in its real value to the grid may erode political support for net metering and other supportive policies, a future the solar industry should both acknowledge and prepare for"

Overproduction not yet a widespread issue

With solar only accounting for about 1% of the current US electricity mix, overproduction has by and large not impacted market-clearing prices and is not yet a concern for today's solar generators. Despite operating in volatile wholesale markets, most utility-scale projects receive guaranteed prices based on long-term power purchase agreements. And owners of rooftop solar are typically reimbursed based on net metering policies that pay retail rates for the excess electricity fed back to the grid.

However, 27 states took legislative or regulatory action over net metering policies in 2015, demonstrating that continued retail rate compensation cannot be taken for granted, even at today's relatively low penetration rates. And, as recent proposals in Nevada have shown, even rooftop system owners with long-term fixed price contracts have cause for concern. As PV continues to increase its market share, the gradual decline in its real value to the grid may erode political support for net metering and other supportive policies, a future the solar industry should both acknowledge and prepare for.

Many mitigation strategies available

One notable solution advocated by Varun Sivaram of the Council on Foreign Relations and Shayle Kann of GTM Research is to strive to make the cost of solar installs decrease faster than their declining marginal value. Sivaram and Kann calculate that solar needs to drop to 25 cents per watt by 2050 to outpace the value deflation effect. While a worthy long-term goal, which if achieved would likely make solar significantly cheaper than any other energy source, there is a wide range of more immediate technical and policy tools that can be more strategically tailored to meet location-specific energy profiles and demand curves.

These mitigation strategies basically boil down to shifting demand to better match solar's generation profile or shifting supply to better match what the market would naturally demand. However, it should be noted that at low levels some of these measures can actually harm PV's value if not thoughtfully implemented.

Shifting demand

More accurate price signals that correspond to the actual supply of electricity available on the grid could shift flexible consumption to better match supply and smooth demand curves. As Figure XXX shows, LBNL estimates that at 10% solar penetration real-time pricing (RTP) is the most effective way to improve PV's value of the three mitigation strategies tested. However, real-time pricing programmes are technically

and politically challenging to implement, particularly at the residential level, despite the fact that they have proven effective at lowering costs and improving grid efficiency. Time-of-use (TOU) pricing may be a more practical alternative. Although TOU pricing cannot dynamically adjust to real-world supply and demand imbalances, it can be designed to use price signals to get demand to meet solar's average production patterns.

Another decades-old strategy that can be utilised to tackle the unique challenge of solar value deflation is demand-side management (DSM), which is undergoing a resurgence as grid operators seek new tools to meet and balance more intermittent and distributed supply sources. While DSM has historically paid ratepayers to reduce peak power demand by decreasing or curtailing HVAC and lighting loads when needed, many of the same techniques can tackle solar value deflation by shifting demand to better align with solar generation patterns. The strategy even received a major boost from a recent US Supreme Court decision that effectively ruled that regional and national interests trump those of states when it comes to using demand-side management to smooth electricity consumption levels.

Shifting supply

In the long term, particularly at higher solar use rates, strategies that are able to shift or balance clean electrons will likely prove the most effective ways to combat solar value deflation.

One relatively limited strategy is to encourage pairing of solar and wind investments because, even though both are intermittent sources, they generally produce the most electricity at different times of the day. LBNL found that a 10% wind penetration rate would boost the value of solar at the same penetration. Unfortunately, at higher PV rates the two sources are more likely to simultaneously supply power and thus drive down market-clearing prices, outweighing their complementary generation schedules.

California has also sought to use financial incentives to encourage more westward facing solar installs, which can produce more desirable late-afternoon power, although at the cost of lower overall generation than south-facing panels.

A broader and more effective way to offset intermittent energy sources is to expand the pool of available suppliers in a balancing area. Geographically dispersed

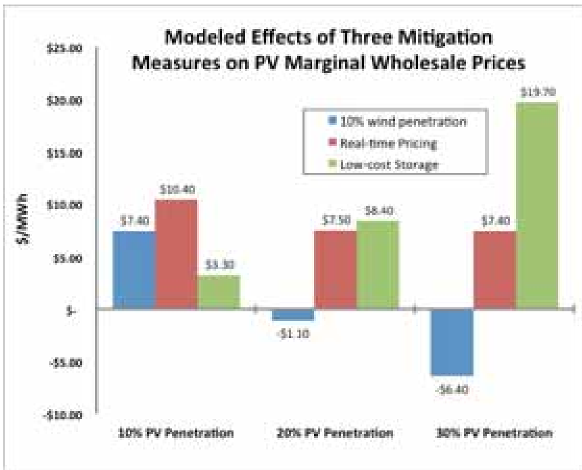


Figure 2. The impact of various mitigation measures on PV wholesale pricing under different penetration scenarios. Source: Lawrence Berkeley National Laboratory

renewable supplies are less likely to produce at the same time or be subject to the same cloud and rain patterns and can improve grid flexibility by merging more baseload and backup options. However, this is far from an easy solution. New long distance transmission lines, if needed, cost billions to build and often encounter political resistance regarding their proposed routes. In California, many stakeholders are concerned about plans to link their state's insular grid to outside sources that are more carbon intensive and may not share the Golden State's aggressive environmental goals.

Role of storage

Pairing affordable, flexible and reliable storage is arguably the most promising way to buttress and maximise solar's value. Storage comes in many forms, including on-site batteries, smart water heaters utilising thermal storage, and repurposing electric vehicles to also provide grid services. In LBNL's model, adding low-cost storage maintained and actually enhanced the value of solar energy at higher penetration rates. At 30% penetration low-cost storage increased the marginal value of nearby PV by 80%, nearly triple the value of real-time pricing, the second-best mitigation measure analysed.

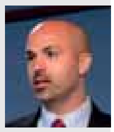
The question is whether storage costs are decreasing at a rate fast enough to accommodate solar's growth. The answer is complex since accurately determining the cost of battery storage depends on normalising utilisation rates and cycle lives, as well as accounting for the cost of control equipment. The economic benefits are equally challenging to ascertain since storage has a variety of uses of differing value that include frequency regulation and a host of other ancillary services that are not typically aggregated. What is clear is that lithium-ion batteries, which made up 96% of grid-connected storage last year, are on a steep cost reduction curve with a trajectory similar to the dramatic decline in solar panel prices starting around 2008. The scale and price decline of this kind of storage is seven to 10 years behind that of solar.

The US Congress may have unwittingly bolstered storage when it extended the 30% ITC last December. According to GTM Research, between now and 2020 the ITC extension will result in an additional 500MW of energy storage being paired with renewable energy, a boost of 33%. If the Internal Revenue Service or Congress allows solar storage projects to unambiguously claim the ITC then that number could rise significantly. Policies like California's 1.3GW 2020 storage mandate could also theoretically help mitigate some of PV's loss in value. However, even if oversupply mitigation were its sole purpose, 1.3GW of capacity would only be able to store 5% of the state's PV-generated electricity under optimistic assumptions. This would have little potential to mitigate the impact of local overgeneration.

Given the lack of real-time pricing, the tangle of cross-subsidies, and mandates like renewable portfolio standards that will increase solar capacity no matter what, thoughtful public policy will be integral to making sure that these mitigation measures are implemented well. Getting solar electrons to where and when they are needed will help ensure that the technology's future economic value to the grid is at least maintained, if not increased, and has important implications for key issues such as project siting, grid stability, regulatory ratemaking, and the structure of long-term PPA contracts.

We need to acknowledge that solar's future is tied intrinsically to that of storage and other mitigation measures, otherwise its success could be its own undoing. ■

Authors


Amit Ronen is the director of the GW Solar Institute at George Washington University. In this capacity he identifies, creates and shares pragmatic solutions to the public policy barriers preventing the adoption and scale of solar energy. He is also a principal at Enflection LLC, an advisory firm providing strategic guidance and solutions on distributed and advanced energy technologies, businesses and policies.


Josh Harmon is a recent graduate of the George Washington University. He focused his master's degree on international energy dynamics, power sector governance, and climate change and is currently seeking opportunities in the field.

Postcards from the energy transition

Storage policy | Through its Energiewende process, Germany has become a world leader in pioneering new ways for renewable energy to replace conventional forms of generation on the grid. Andy Colthorpe reports on how the country is once again taking the lead in storage and other technologies that will take its energy transition to the next level

Credit Younicos

The inauguration of a Younicos battery park was attended by Germany's minister Sigmar Gabriel (second from right) but it remains to be seen if deploying storage is a priority for the German government

Germany's energy transition ('Energiewende') represented the biggest expression of popular sentiment and political will at national level in favour of renewable energy in the world for over 30 years since the beginning of the 1980s.

Including the feed-in tariff-accelerated burst from 2010-2013 when around 25GW of PV was installed, Germany seemed to have struck a perfect marriage between idealism and industry. But capacity increases have slowed and not for the first time, Energiewende stands at a crossroads. Even as the country reached an impressive 40GW, China last year reached 43GW, and auctions, currently introduced on a trial basis for PV, look set to cap renewables for both cost and capacity across the board.

However, while market volumes of large-scale PV are limited to a gigawatt or two annually, Germany's pioneer status in global clean energy could still be regained. At the heart of the Energiewende is the question of how solar and wind can provide base-load energy for one of the world's most industrialised nations. Germany's energy transition now focuses on how to integrate renewables from both market and technical perspectives.

This is clearly an emotionally and economically charged national and local debate, with broad stakeholders from utilities and the incumbent energy industry, to transmission system operators, renewables generators and consumers, still unsure of what to expect in 2017's forthcoming revision of the EEG, the legislation underpinning the Energiewende. Where energy storage fits into this discussion is raising some interesting talking points.

Not until 70%

Think tank Agora Energiewende last year produced a report claiming Germany does not need large amounts of energy storage until renewables penetration reaches more than 70% on the grid.

"We're fine with the storage we have, we have a couple of gigawatts in pumped hydro storage and we also have reserve capacity in gas, coal-fired power plants and so on," Christoph Podewils, a spokesman for the group, says.

"After that we have to talk about storage, but probably long-term storage, like power-to-gas, or power-to-liquids, probably not that much about short-term storage like solar PV storage with lithium-ion batteries and so on. We need something where we can store electrical power in summer and use it during winter."

Agora Energiewende argues that in summer, the country still has enough power generation running to cover the main evening peak in demand and that in winter, lithium-ion based storage systems may lack the duration to store enough power to meet that peak while PV systems may not generate enough anyway. Podewils points out that Germany has overcapacity on its power plants with over 100GW of dispatchable power plants and a winter peak at about 85GW.

Podewils admits that from an environmental perspective, writing off low-carbon battery technologies to keep existing generators is "not nice", especially when Agora concedes that coal phase-out is absolutely necessary to meet international climate commitments. Nonetheless, Podewils says that from a system perspective, the need for storage to keep the lights on is "not really urgent at the moment". Agora predicts that just 40GW of storage would be needed to support 150GW of PV in Germany.

In a hierarchy of network flexibility and balancing resources including demand-side management, regional transmission grid interconnection and "more flexible" fossil fuels, storage is still considered by Agora to be one of the more expensive options – if one focuses on the cost of long-duration solar load shifting.

'Supergrid', storage or both?

Similarly, Dirk Biermann, chief officer for systems and markets at German transmission operator, 50Hertz, has said that he does not see "urgent need" for increased flexibility resources. Demand-side management and controlling the power from renewables are methods 50Hertz increasingly advocates as future flexibility options, according to Biermann's words at recent public appearances.

Perhaps more tellingly, 50Hertz and other grid operators appear to be keenest on the idea of grid expansion ('netzausbau') over long distances. PV from the south of Germany could be sent through cables to the north and wind energy sent the other way.

While a 'super grid' from Norddeutschland to southern Bavaria and the EU's continental Electricity Highways 2050 ideas sound enticing and are – on paper at least – feasible, the world cannot afford to wait for such grand schemes to come to pass, Germany's energy storage trade association BVES, argues.

"Everybody is talking about 'Oh, we wouldn't need any storage if we would have enough grid', but the grid-building that everybody's talking about…it's not that it wouldn't work, but it hasn't started. People don't want overhead lines in their village. It also is very expensive," BVES policy expert Miriam Hegner says.

Hegner says rather than focusing on "grid or storage", it should be "grid and storage", adding that re-dispatch of power cost Germany €1 billion last year, with the cost only expected to rise. The point Hegner and others including inverter maker SMA's vice president for storage and hybrid technologies Volker Wachenfeld make to PV Tech Power is that battery storage is happening anyway, due to falling costs and the appetite of consumers and businesses alike to self-consume PV power.

The network could take advantage of residential PV storage, in particular in aggregation. SMA is developing virtual power plant capabilities for its inverters for the first time this year. In a way, SMA is playing catch-up on a concept already used in 30 or so trials around Germany.

Credit Andy Colthorpe

Sonnen's trading platform SonnenCommunity is an early commercialised example of aggregated behind-the meter-storage

Broadly speaking, there are two business models for aggregated behind-the-meter-storage at residential level: using these distributed energy resources (DERs) to displace gas plants for frequency regulation, known as virtual power plants. Alternatively peer-to-peer (P2P) energy trading, perhaps best exemplified by SonnenCommunity and MVV Energie's Strombank trial, relies on communities using intelligent storage systems to trade their surplus PV energy and has attracted huge international attention.

Virtual power plants and aggregation strategies hold promise

The virtual power plant and the promise of behind-the-meter aggregation is one of the Energiewende's unsung achievements, Erin Grossi, chief economist of US accreditation services provider UL, says.

Grossi investigated the energy transition "more from a technical, less from a policy perspective" and found the Energiewende had spawned investment in cutting-edge technologies that could truly help DERs form the base load.

"What we came to find was that the digital disruption angle of the integration of these technology tools, sensors and what they call virtual power plants to better control these distributed resources and make them responsible at grid scale in the same way fossils have been, was really the answer of how they're making this [Energiwende] work."

Grossi says engineers she met all seemed confident that solar and wind as base-load energy is feasible. Digital technologies such as aggregating systems will come to define the parameters of the energy network as much as the generation mix fed into it.

However, the technology and business models need to be adopted at scale, which so far has been lacking. Early reports from SonnenCommunity sound good, with customers trading their surplus energy using the grid as a kind of 'virtual battery'. But Germany's market for residential electricity storage still stands at an estimated 30,000 units sold, just a handful of megawatt-hours, so there is still some way to go before it looks like a formidable set of assets. Nonetheless, when one considers that the spread of PV was underestimated hugely and that 50Hertz last year accepted 49% renewables penetration on to its north and east Germany grids, the network, government and industry need to be prepared for when it does.

Enabling revenue stream stacking

Younicos spokesman Philip Hiersemenzsel says that current legislation does not enable energy storage systems to provide multiple services in front of and behind the meter, so-called 'benefits stacking', combining several revenue streams. Younicos specialises in large-scale storage and has provided projects such as renewables integration at megawatt scale, to ancillary services provision from batteries.

"The marketplace is still not well

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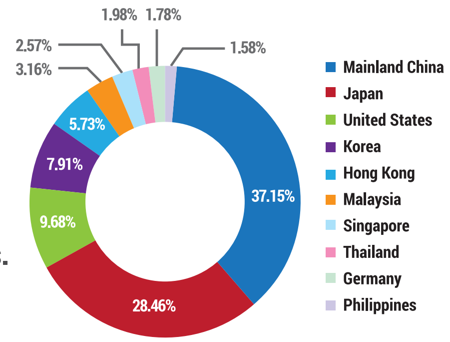

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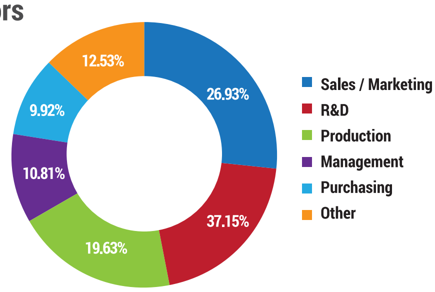

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Progress report

We asked our commentators to give their quick assessment on how the three major segmentations of the on-grid energy storage market look in Germany at present and going forward.

Residential

Residential (and small-scale commercial) energy storage is supported with a modest rebate scheme for purchases, KfW 275, which is a mechanism to incentivise PV-plus-storage owners to peak-shave. The scheme was expected to end this year but has been extended to December 2018. While uptake has been gradual, industry sources say there is growing interest in energy independence at home.

Meanwhile, new business models and means of financing home systems are coming into play. Sonnen's SonnenCommunity offers electricity at rates lower than utility prices, as well as the emotional pull of being a part of a social scheme to share green energy. Another new business model is being offered by Beegy Energy, a joint venture from firms including German utility MVV Energie and Irish heat pump maker Glen Dimplex. Again offering both low prices and simplicity, Beegy offers residential customers a form of PPA to receive both electricity and heat. Finance expert Gerard Reid of Alexa Capital says that both Sonnen and Beegy's business models are innovative and will compete for ever-greater market shares.

Meanwhile, BSW Solar and other groups are working on community solar-plus-storage business models, for instance for low income or multiply family dwellings such as apartment blocks.

Commercial

While it has received the least media attention, the likes of Younicos and SMA spy great potential for energy storage for commercial and industrial customers in Germany. Ultimately, the C&I segment will only go for environmentally friendly options if they can be justified through their business case and Volker Wachenfeld says that for some, solar-plus-storage is a "no brainer".

Commercial PV systems already pay for themselves in Germany, he says, while Philip Hiersemenzel of Younicos agrees there is also a growing business case for C&I storage.

"We see a segment for C&I where it's about using demand charges and having higher power quality, ways you can just also increase the efficiency of industrial processes through batteries," he says. "We definitely see that as a marketplace that's going to expand very quickly, just brought about by the continuously disruptive price of batteries."

UL's Erin Grossi says commercial organisations all over the world are starting to weigh up their options as more than just a corporate social responsibility exercise, even with the current rock bottom oil prices.

"We're looking at all kinds of models to try to show how, because of the new opportunity that we have with combining digital products with basic energy infrastructure, we have a market opportunity here that's extraordinary. The opportunity is greater than the immediate advantage of a low cost energy source."

Utility-scale

A couple of years ago utility-scale storage looked to be the next darling of the German clean-tech industries. However, there has been a lengthy delay in translating this to deployments due to technical and regulatory barriers. Younicos completed Germany's first 'commercial battery park', a 5MW/5MWh lithium-ion system in West Meklenberg, in the north in 2014. The system helps to balance the grid and integrate renewable energy into the local network.

"After almost two years in operation, it has exceeded expectations, revenue was higher than we had expected," Younicos' Hiersemenzel says. "This is despite the fact that the regulator forced us to fight with one hand bound behind our back. They increased the technical requirements in what we think was a ridiculous way. They're not applying a level playing field."

Hiersemenzel says factors like the efficiency and response times of coal generators decreasing after several round trips were not taken into account, while hypothetical questions were asked of the storage system that are, in his opinion, never likely to come into play.

"We integrated it into the grid, we integrated it into the European energy exchange and got a pre-qualifier for primary frequency control, so we delivered all this groundwork. We would've hoped for a more wholehearted embrace both by the German regulators as well as by the German transmission companies like the TSOs, who have everything to gain from this."

defined," Hiersemenzel says. "The easiest way to look at it is that [batteries] will always relieve the grid, but they also save all sorts of other costs and they have positive externalities that are not fully captured by the people that buy and operate them. It would make sense to update the rules so that the people who invest in these assets get to recover the rewards."

One example Hiersemenzel cites is that the regulator, the Bundesnetzagentur "continues to believe that storage is a consumer of electricity". Freeing up storage from regulatory constraints, and reconsidering market design would be a relatively low-cost way of supporting the technology.

Another nuance often missed by many is that far from considering energy storage to be the mythical 'silver bullet' to cure all energy network ills, it's a question of finding where on the network storage can be cost effective and applying it where it unquestionably makes sense. For example, Hiersemenzel says, since utility-scale batteries are most likely to be deployed for frequency services, which require short bursts of energy being deliver to balance the grid, the argument over the need for long-duration storage misses the point.

"Eventually we'll have other kinds of storage but now it's about integrating renewables and that will require increased flexibility overall. But we're still not talking about storing hours, let alone weeks or months of electricity.

"A lot of politicians don't understand that. If we're going to transform the power grid from a centralised, top-down system, to a decentralised system, flexibility through batteries is going to be a huge part of the equation."

Rallying the incumbents

Germany's 'big four' utilities have by all accounts taken their time to participate in the transition, facing criticism for not taking it seriously enough to begin with. However, E.On in particular has over the past year struck up partnerships with residential solar storage maker Solarwatt and is developing large-scale storage systems in territories including North America. RWE meanwhile has interests that include an investment in UK power-to-gas firm ITM Power.

Jörg Mayer of German solar trade group BSW Solar says that in utility-scale PV, E.On and RWE have not been as proactive or adventurous as Italy's Enel, for example. Nonetheless, he says, if they were to focus more on solar and storage in Germany, they and other major German companies such as engineering giant Siemens, could quickly find themselves in a strong position.

"They have an opportunity [to be significant agents] because they have big customer bases and they are a trustworthy partner," Mayer says.

It seems that whether those utilities finally establish their place in Energiewende for real and big engineering firms start to return, the transformation is going to happen anyway. Agora Energiewende's Christoph Podewils says polls find public approval for clean energy at 94% and while it is unquestionable that it took a tremendous effort on the part of the German people to bear the burden of making Energiewende a reality, PV is cheaper than ever. With the introduction of auctions looming and FiTs for residential solar almost gone, it remains to be seen if Germany will accept energy storage as a low-carbon option at the heart of the next step in its economic, industrial and environmental transformation. ■

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ITC extension 'highly unlikely, but not impossible' to be dismantled by Trump

The most important part of the passing of the colossal US$1.1 trillion spending bill in December for solar was the five-year extension of the investment tax credit (ITC). Danielle Ola's looks at the legislative repercussions of a situation where the ITC extension is repealed

The five-year investment tax credit (ITC) extension was a strong victory for solar, but is not completely safe from being dismantled by a future US president, according to Amit Ronen, director of the George Washington University Solar Institute. Ronen was involved with some of the 'behind-the-scenes' push for the recent ITC extension and authored the 2008 eight-year ITC extension when he worked for Senator Cantwell.

The extension of the ITC scheme was arguably the most important part of the passing of the colossal US$1.1 trillion spending bill in December for the US solar industry .

Solar, wind and bioenergy as a result can now enjoy federal backing until 2021. It was originally expected to be cut off at the end of this year, which most likely would have resulted in a mad rush for developers to finish products within the year to secure financing, casting doubt on the completion of projects that were not 'fully backed'. The extension should relieve some of that pressure.

The extension was hailed as a massive win for American renewable energy industries, with GTM Research originally predicting that the extension would foster US$40 billion in incremental investment in solar between 2016 and 2020. The firm also said that the extension would be most beneficial to the utility solar sector, increasing utility-scale deployments 73% through 2020.

Other key outcomes of a prolonged ITC include the fact that wind and solar are given time to achieve parity (or better) with conventional generation without subsidy. Furthermore, it also means that big multinationals pursuing PPAs for large off-site wind and solar transactions will continue to see competitive prices. The extension also alleviates the initial fear that was felt in the industry when the first cycle of credits came to an end: as the ITC now gradually declines over a period of years, the industry can plan accordingly, avoiding boom-and-bust cycles.

'Not bulletproof'

Whilst clearly a great measure for the solar industry, it is not bulletproof. Although it would be unusual, it is not impossible that the credits could be repealed from the bill. Ronen spoke to *PV Tech Power's* sister website, PV Tech on the likelihood of this happening.

"The president has no authority to do it on their own. It would take an Act of Congress because it is part of the tax code," he said. "In theory a president could push and use the leverage that they have to try and enact that policy but technically only an Act of Congress could do that.

"It is highly unlikely, but if you were to speculate you could say Congress could change any law they want. It's not impossible."

The legislative process to remove the extension from the omnibus bill is, perhaps surprisingly, relatively simple. The provision could be removed, leaving the rest of the bill unscathed.

"In theory there is no connection – you could take out any part of that omnibus bill and just narrow in on the provision; it's not all tied together," said Ronen. "If you're passing a new law that would say, we don't want the extension anymore, you could in theory do that. But there is no political pressure to do that, other than the people that had already previously opposed the insertion of the extension in the original…but there's no hypothetical situation where that would be an Act of Congress.

"It's very unlikely to happen unless you have a Republican House and Senate and Donald Trump is president than I guess they might do that.

"But even if it was a completely Republican control, they would be unlikely to do that because solar is by far the most popular energy source in the US, even among Republicans and Independents, it polls at [more than] 80%. It would be unlikely that they would use any political capital to try and force that through, relative to a lot of other priorities they have.

"The only real way is if there is fundamental tax reform then you could see perhaps a change in all the so-called expenditures that are part of the tax code. Then there might be an effort to try and streamline or get rid of a lot of those. But that's been talked about for years, and I don't see much progress in terms of consensus happening on the hill towards that end."

As things presently stand, the ITC will be extended until December 31, 2019 in its current form. After that, projects that start construction in 2020 and 2021 will receive 26% and 22%, respectively. All projects must be completed by 2024 to obtain these elevated ITC rates. For residential solar, a similar tax credit phase-out applies until the end of 2021, after which the scheme terminates.

This is an edited version of an article that first appeared on www.pv-tech.org

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Although highly unlikely, it would not be impossible for a US president, with the approval of Congress, to undo the ITC extension

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