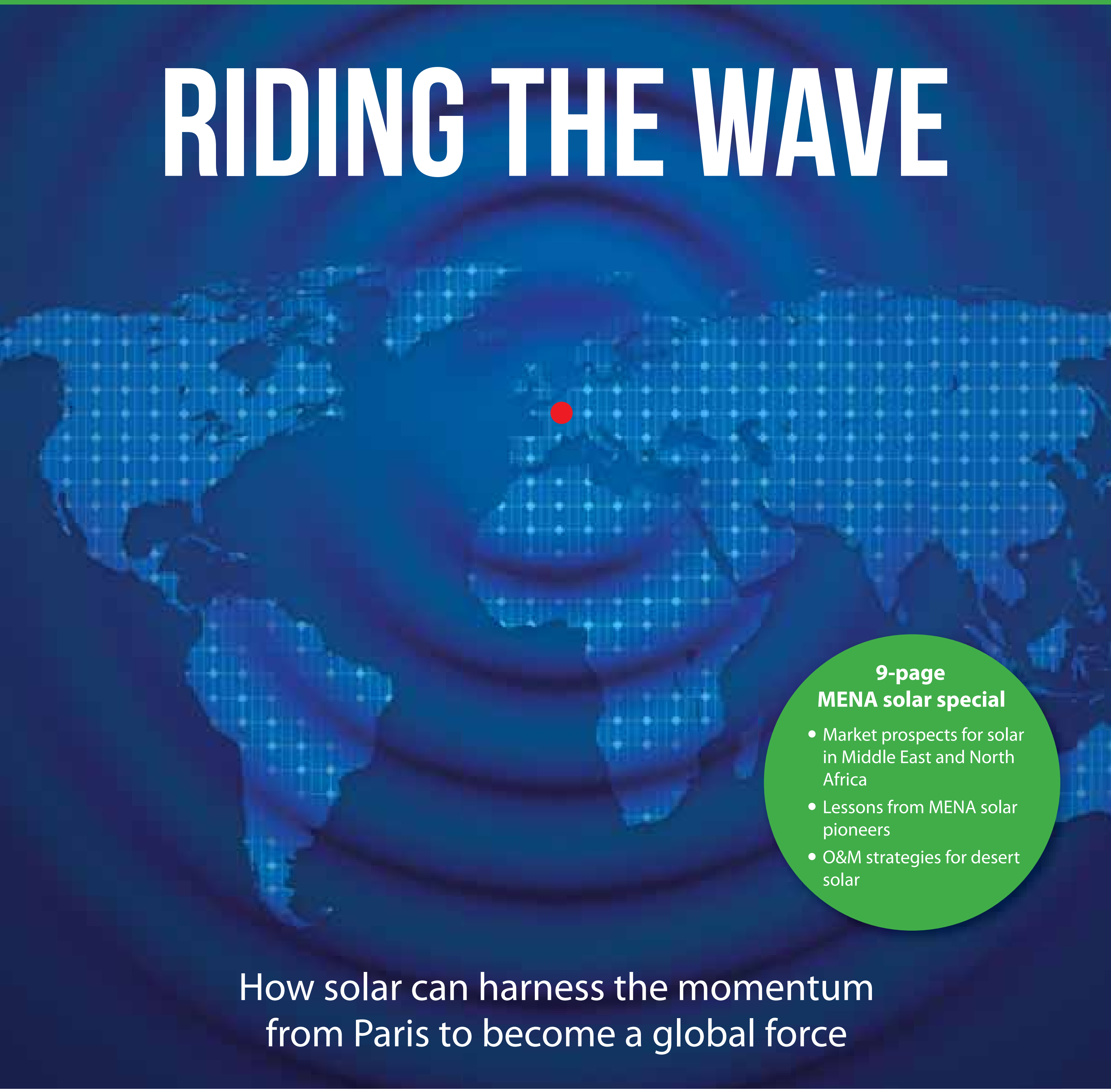
PV TECH POWER

Volume 06 | PV POWER PLANT TECHNOLOGY AND BUSINESS | February 2016

RIDING THE WAVE



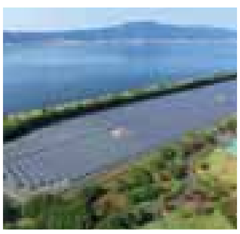
9-page MENA solar special

- Market prospects for solar in Middle East and North Africa
- Lessons from MENA solar pioneers
- O&M strategies for desert solar

How solar can harness the momentum from Paris to become a global force

MARKET WATCH

Japan looks for alternatives to mega solar



FINANCE

Opening up the finance markets for merchant solar

SYSTEM INTEGRATION

Reliability of large-scale PV power plants and inverters

STORAGE & GRIDS

Energy storage in 2016: where next?

PV TECH POWER

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3rd Floor, America House,
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Tel: +44 (0) 207 871 0122
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Publisher:
Chris Riley

Editorial
Head of content:
Ben Willis
Deputy head of content:
John Parnell
Senior news editor:
Mark Osborne
Reporters:
Andy Colthorpe, Tom Kenning, David Pratt, Liam Stoker

Design & production
Design and production manager:
Sarah-Jane Lee
Sub-editor:
Stephen D. Brierley
Production:
Daniel Brown
Infographics:
Leonard Dickinson

Advertising
Sales director:
David Evans
Account managers:
Matthew Bosnjak, Graham Davie, Colin Michael, Lili Zhu

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Introduction

The 2009 international climate change talks in Copenhagen saw great hopes for a new deal dashed as global power games prevailed over the general desire for progress. In hindsight, another reason for the talks failing was that even just those few years ago there was no viable alternative to the status quo. Most renewables at that time were costly and unproven at scale, giving those opposed to tackling climate change all the ammunition they needed for making their case.

Six years on and the world is a different place. Solar and wind, in particular, have made huge strides forward, to the extent that they are now cost competitive with fossil fuels in many parts of the world. In the run up to the Paris talks last December, when a deal was finally reached, the debate was not so much about how the world could pay the premium for transitioning to low-carbon energy as how the necessary investment should best be directed into energy sources that now make eminent sense.

In the context of the deal that emerged in Paris, that now is the big question. On paper at least, solar has a central role to play in delivering December's agreement. But neither the deal nor the advances made by solar in the past five years guarantee anything. Ranged against solar and its renewable-energy cousins are the not-insignificant forces of the global capital markets, which at the moment are built around the incumbent fossil fuel system.

In this issue of *PV Tech Power* we lead with a report (p.17) exploring the question of how solar can best capitalise on the momentum generated by the Paris deal. Analysis by Bloomberg New Energy Finance and Ceres has put the cost of the energy transition enshrined by the Paris deal at some US$12 trillion. That represents a huge opportunity for solar. But accessing that sort of finance will require a total change from the current set up, under which the big capital flows are still into oil, gas and coal. Our report looks at some of the key policy and regulatory changes needed to maximise solar's chance of becoming a central part of the energy transition.

Also in this issue, we turn our attention to Japan (p.21). Japan's status as the world's second biggest solar end market in 2015 is at odds with the fact that it offered one of the least ambitious emissions reduction pledges of developing nations in the Paris talks. Nevertheless, it's still a big market, with plenty more potential in the pipeline, and we explore how solar in Japan is evolving against the backdrop of shifting political and regulatory sands. We also look at the solutions being developed by installers to cope with the increasingly challenging nature of the sites available for solar development in Japan (p.53).

Coinciding with the Solar Middle East event in Dubai in early March, we also feature a series of articles exploring the development of solar in the Middle East and North Africa (from p.31). Better known for its petro-states, the MENA region is also rapidly cementing its place on the global solar map via some of the world's most exciting emerging markets. Our special report looks at the prospects for solar in the region and considers some of the challenges it faces, from regulatory hurdles through to operational logistics.

As always, *PV Tech Power* aims to bring together the latest thinking from the frontline of PV power plant development. We hope you find this issue a valuable resource.

Ben Willis
Head of content

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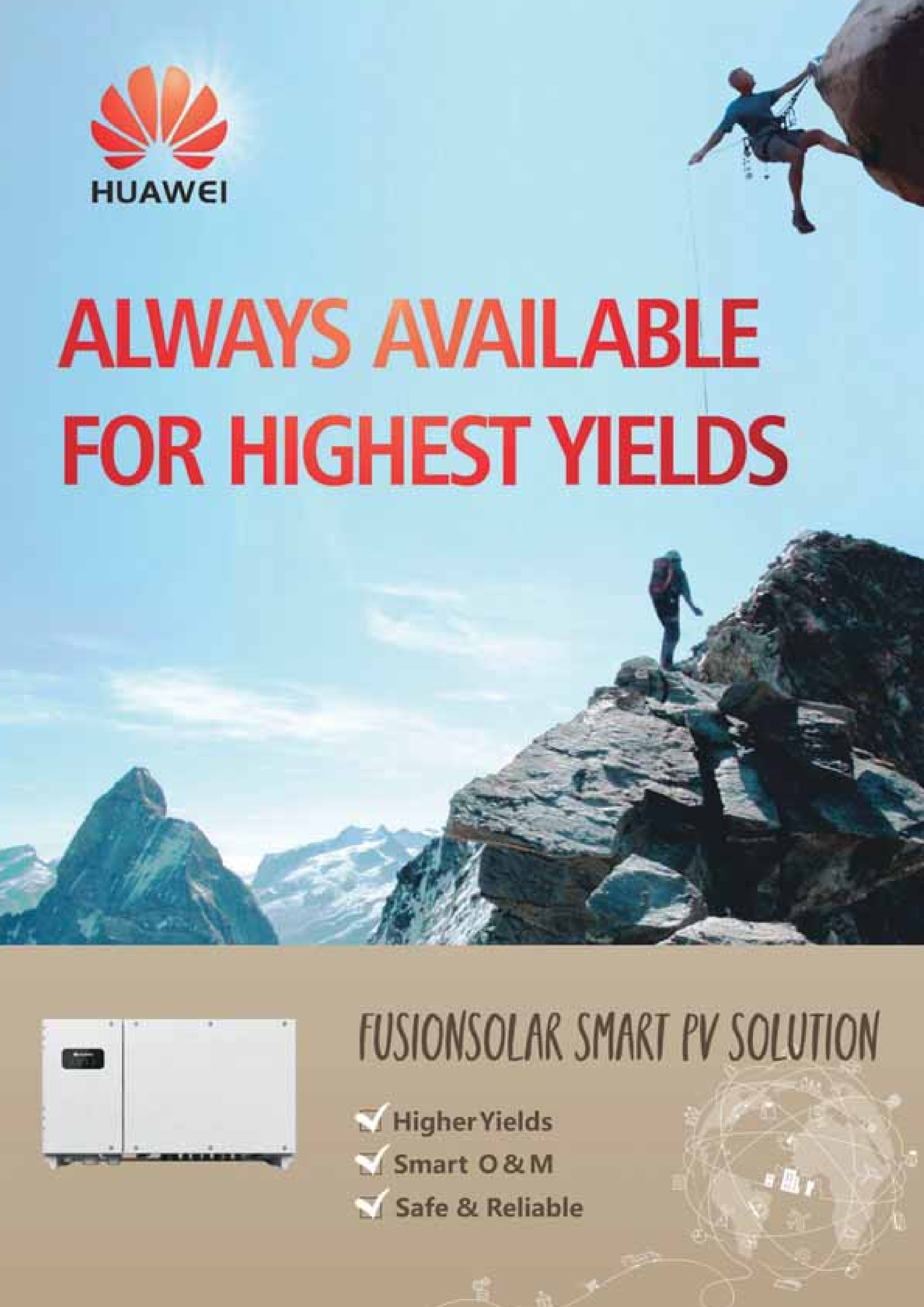
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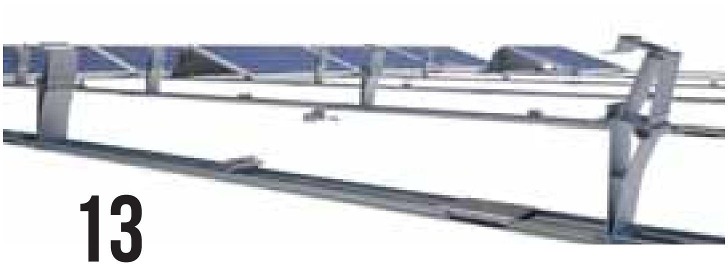
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EUROPE

UK install rush

UK rush to beat tariff change brings 4GW

The UK saw almost 4GW of solar installed in 2015 and a final-quarter rush ahead of planned cuts to key support regimes in early 2016. Figures gathered by Solar Intelligence, the market research arm of PV Tech Power's publisher Solar Media, reveal that 805MW of solar was connected to the grid under various deployment schemes in the final three months of 2015, taking final deployment figures for 2015 to 3.906GW. The figure beats 2014's total of 2.55GW by a significant margin. According to Finlay Colville, head of market research at Solar Media, the Q4 total was a record fourth-quarter figure and the third highest quarterly figure for the UK. Writing for PV Tech's UK-focused sister website, Solar Power Portal, Colville said the figures, particularly for residential, reflected the market's response to the pending cut to feed-in tariff rates, due to take effect officially in early February. For larger-scale projects, Colville said the significant proportion of ground-mount projects receiving the feed-in tariff gave an indication of how developers are responding to the imminent changes to the renewable obligation regime, the main support scheme for large-scale solar in recent years.

Credit: Krannich

The UK installed almost 4GW of solar capacity in 2015.

Deployment

France sees PV output rise 25% in 2015

The power output from PV systems in France grew by 25% last year to 7.4TWh, up from 5.9TWh, according to the latest figures from the French electricity transmission system operator Le réseau de l'intelligence électrique (RTE). The country now has a total of 6,191MW of PV deployed, having installed an additional 895MW in 2015. One third of this increase came from the commissioning of Europe's largest solar park, the 300MW Cestas solar park, developed by Neoen.

German FiT falls short of degression trigger while solar auction prices fall

German feed-in tariff rates remained unchanged for the first three months of 2015 after deployment fell 900MW short of the 2.4-2.6GW deployment trigger that would have seen rates degress by at least 0.5% per month. Meanwhile, the latest German solar auction launched at the end of last year saw prices tumble to €0.08/kWh (US$0.09/kWh). Bids totalling 562MW were submitted for just 200MW of available capacity, according to the country's Federal Network Agency. Prices in the previous auction in August 2015 yielded a contract price of €0.0849/kWh. Successful bidders have two years in which to build their projects.

Solar Power Europe calls 8GW of European connected PV in 2015

The UK installed 3.5GW of Europe's 8GW of PV capacity in 2015, according to SolarPower Europe. The trade group presented its first estimates in February ahead of the final figures being revealed in March. The numbers, based on actual grid-connected projects, are up 15% on the previous year with the UK market contributing a significant chunk. SolarPower Europe has also estimated global installed PV capacity of 50GW. "A figure of 3.5GW makes the UK market the biggest market in Europe again," he told PV Tech. "There is a huge pipeline that could be realised in 2016 as demonstrated by [Solar Intelligence's] Finlay Colville. So I've got a gut feeling that the UK could still be number one in 2016 depending on how many of those projects in the pipeline actually are realised."

Policy

UK and Germany at loggerheads on MIP extension

The UK and Germany appear to be increasingly at odds over the future of the solar price undertaking between the EU and China. As the UK government published fresh evidence of the costs the minimum important price (MIP) is adding on to solar installations, the German government weighed in, attacking UK proposals to suspend the MIP as "incomprehensible". The UK's Department of Energy and Climate Change yesterday published a letter from energy secretary Amber Rudd to a parliamentary committee in response to questions she had been asked during an earlier committee hearing. Rudd had been quizzed by the committee over her department's actions regarding the MIP but at the time did not have specific details. Her letter confirms that DECC has collaborated with "leading engineering consultants" to estimate the price differential caused by the policy.

Spanish court rules against solar industry over retrospective cuts

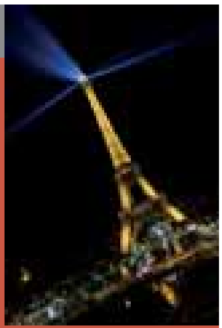
Spain's Court of Arbitration ruled against two companies who filed a lawsuit against the Kingdom of Spain over reforms to the PV sector made in 2010, according to a statement from the Spanish Ministry of Industry. The international lawsuit, based on Spain's commitment to the international Energy Charter Treaty, was filed over a decision made by the Spanish government to introduce retroactive cuts to feed-in tariffs (FiTs) for solar PV in 2010, and the harmful effects this could have on investors in the sector. One of the key pillars of the Energy Charter, which is a multilateral framework for energy cooperation that is unique under international law, is the protection of foreign investments.

Business and finance

World's largest IPP plots big pivot toward solar

French firm Engie, formerly GDF Suez, the largest independent power producer in the world, said it would announce its strategy for its transition away from fossil fuels by the end of February. The company, which has 115GW of electricity generation assets, has already increased its presence in the renewables sector, not least with the acquisition of French PV developer, SolaireDirect. It has also begun the process of backing away from conventional fuels. Speaking to PV Tech on the sidelines of the Solar Investment and Finance Conference in London, SolaireDirect CEO Thierry Lepercq said when it came to looking for competitive power for billpayers, solar was "unbeatable". "Moving a 150-year-old group to something totally different is going to take some time but there will be more announcements in late February with a number of details about the group's strategy, which

NEWS FROM COP21 IN PARIS



Credit: Flickr/UNclimatechange

Paris momentum to fuel green bonds, says Moody's

The December climate deal in Paris is to trigger a surge in the global green bond market, which is set to surpass US$50 billion this year, rating agency Moody's has said. Green bonds are financial instruments used to generate funding from the debt capital markets for projects with positive environmental or climate benefits. Following the global deal reached at the COP21 talks in Paris in December, Moody's said it expected bonds to attract greater attention because of the huge levels of capital investment that will be required to meet the targeted emissions cuts.

Solar shares surge as ink dries on UN climate deal

Shares in most major solar energy manufacturers and developers jumped on the first day of trading following the conclusion of the Paris climate talks. Residential US installer SolarCity jumped 12.28% while Trina Solar, the world's largest solar panel manufacturer, jumped 11.52%. Other risers were SunPower (8.17%), SunEdison (5.78%), First Solar (5.70%), Canadian Solar (5.03%), Yingli Green (1.45%) and Jinko Solar (3.61%) and Enphase (6.19%).

Global Solar Council launches at COP21

The Global Solar Council launched on the sidelines of the Paris talks, creating the broadest industry coalition to date. "The council is a consequence of a maturing industry," said Bruce Douglas, chief operating officer at SolarPower Europe and the inaugural chairman of the council. "It's maturing in terms of technology, business models and practices, and the companies involved in it. It's also a consequence of the globalisation of solar – as it's shifted from Europe and the US, and moved strongly into the Asian markets, we see a need for this coordination at a global level and communication of the benefits of solar – what we're delivering now and what we can deliver in the future."

will be renewable and solar driven. Even though, to be very frank, solar makes up just 1GW [of Engie's capacity] but the ambition is extremely big," he said.

UK firm in securitisation of small-scale Africa arrays

UK off-grid solar firm BBOXX and Dutch social investor Oikocredit closed the first ever securitisation of African off-grid solar arrays. The deal, closed at the tail end of 2015, is worth US$500,000 of BBOXX's recent US$15 million funding round but Oikocredit's renewable energy manager David ten Kroode said it paved the way for others to follow. "By demonstrating how securitisation can be used to finance home solar systems we pave the way for other lenders to scale up the much needed investments in this early stage growth sector. This deal also supports our mission of improving the lives of low income people by giving them access to clean energy," he said. Climate finance expert Sean Kidney has identified green securitisations in Europe as a target following the Paris climate talks.

AMERICAS

US deployment

US installed more solar power than gas in 2015

The US installed more solar power capacity in 2015 than new gas capacity, according to Bloomberg New Energy Finance (BNEF). The Sustainable Energy in America Factbook, claims that 6GW of natural gas power was connected compared to 7.3GW of solar and 8.5GW of wind. A record 11GW of coal power was retired and another 3GW of planned closures announced. 4.4GW of utility-scale solar was installed, up from 4.1GW in 2014. Small-scale solar totalled 2.9GW with 1.7GW of residential and 1.2GW of commercial-scale installs. The cost per Watt of utility-scale solar in the US was put at US$1.33 with the module accounting for US$0.60. Residential PV costs fell to US$1.84 with the module making up US$0.63.

US on course for record 15GW of PV in 2016 – IHS

US solar installations are expected to hit 15GW in 2016, a 60% year-on-year increase driven by the extension of the investment tax credit (ITC) at the end of last year, analyst firm IHS has predicted. The record deployment will be primarily due to strong demand for utility-scale PV. The west and south-west, traditionally the country's solar engine rooms, will account for 65% of demand this year. California, Nevada and Texas are all expected to install over a gigawatt this year. The US has a 50GW pipeline of commercial and utility PV projects planned for 2016 to 2019. Over half of the capacity planned over that period will be utility projects, which will be the main beneficiary of the ITC extension.

SunEdison

Hedge funds and investors continue pressure on SunEdison to change course

Troubled renewables firm SunEdison continued to come under pressure from hostile investors to change some of its business strategies, remove certain executives and force a sale of the business, as well as further class action law suits being filed against the company. US-based hedge fund Greenlight Capital, run by David Einhorn, continues to push for a seat on the board of directors of SunEdison so that it can push for changes to senior management as well as potentially drive a sale of parts of SunEdison, or the company as a whole. A number of planned acquisitions by SunEdison have collapsed and doubts have surfaced over other planned business joint ventures in wind and solar sectors going ahead due to the financial and legal challenges faced by the company.

Nevada

Nevada net metering fiasco leaves solar installers reeling

The Nevada Public Utility Commission's decision to amend rates for net metering left solar installers in the state in a precarious position with business having all but ground to a halt. The December decision has already prompted some high-profile players, including SolarCity and Sunrun, to cease operations in the state. Just days before Christmas, the Nevada Public Utilities Commission (PUC) approved a drastic new plan that would restrict net metering rates – pulling the rug out from both a number of residential PV companies within the state and thousands of customers that had already made the switch to solar. As a result of the new net metering plan, utility NV Energy would have to pay much less to solar consumers for the excess energy that their PV panels generate. Meanwhile, in a narrow 3-to-2 vote, the California Public Utilities Commission (CPUC) extended net metering for rooftop solar in California.

Mexico

New prospects for solar in Mexico as energy market reforms kick in

Mexico's liberalised electricity market traded openly for its first day as conditions continued to improve for solar developers. The first day of trading yielded average prices of 354.69 pesos per MWh (US$19.21/MWh). Prices in Texas in 2016 are averaging US$21.07/

ITC win

Approved ITC extension cements US leadership in 'new energy paradigm'

The solar investment tax credit (ITC) was extended beyond 2022 with the current 30% level remaining until 2019, putting the US at the forefront of a "new energy paradigm", according to the Solar Energy Industries Association (SEIA). As many as 220,000 new jobs could be created as a result. The ITC was due to close to projects that weren't operational by the end of 2016 triggering a spate of development activity. With the extension removing the need for a development rush, some speculated that there would be a new phase of oversupply, but this was dismissed by analyst firm GTM Research who said there would be greater supply stability after it forecast a strong global demand outlook. The extended tax credits will retain the 30% rate until 2019 before falling to 26% the following year and 22% in 2021 before remaining permanently at 10% thereafter. The new deadlines will only require projects to have commenced construction, not to have been grid-connected as is currently the case. This will apply at each step down in the rate of the ITC.

Congress passed a better than expected extension for the ITC.

Credit: Flickr/bclinesmith

MWh, according to the US Energy Information Administration (EIA). The liberalisation is part of sweeping changes to the country's energy market that have broken down monopolies and opened the door to greater competition. Despite its access to cheap natural gas, the government has set a target of generating 35% of its electricity from clean sources by 2025.

Chile

Chile introduces new Energy 2050 renewable-energy goals

Michelle Bachelet, president of Chile, signed off on a new energy strategy for the South American country, which sets a goal of generating 70% of national electricity generation from renewable sources by 2050. The new mission, titled "Energy 2050", was signed by President Bachelet and other top members of the Chilean government. The inception of Energy 2050 stands as the result of a partnership between President Bachelet and the Energy Agenda – launched in May 2014 in order to develop a shared vision for the future development of the renewable-energy market.

Brazil

Brazil moves one step closer to tax exemption on solar cells and modules

Representatives of Brazil's Chamber of Mines and Energy Committee approved legislation that includes new solar financing options and tax exemptions for solar cell and module imports, but the proposals must still pass through two more commissions to become law. The Brazilian legislation 8322/2014 would introduce an exemption from import taxes for monocrystalline and polycrystalline solar cells as well as PV modules. This would be beneficial in supporting the development of a local value chain with more attractive solar prices for the consumer. However, the exemption applies only for as long as there is no national production of these components within Brazil.

Brazil launches distributed generation programme emphasizing solar energy

Brazil's Ministry of Mines and Energy (MME) has launched a programme encouraging consumers to generate their own power from renewable energy sources, with a particular emphasis on solar. The distributed generation model is also promoted as a way to reduce the consumer's spending on electricity. The new programme, named the Distributed Generation Development Program for Energy (ProGD), could generate more than BRL100 billion (US$25.6 billion) in investments by 2030. It sets a reference price of BRL454/MWh (US$116) for power generated from solar PV systems. It also aims to simplify the mechanisms involved in selling electricity on the free market.

Argentina

Argentina plans 3GW of solar in Jujuy region

Argentina president Mauricio Macri announced plans to establish a solar plant of up to 3GW in Northern Argentina. The investment will be supported by the Federal government and will contribute towards the government's commitments at COP21 in Paris last year. The aim is for the region of Jujuy to have 8% of its power coming from renewables in 2017 and for this to climb to 70% over eight or nine years. The renewables promotion scheme, named 'plan Belgrano', will benefit 10 provinces of northern Argentina. Macri said: "Jujuy and Northern Argentina can be a place for the future generation of solar energy and is an example of what we can do for Argentina and the world."

MIDDLE EAST & AFRICA

Gulf progress

First Solar installs pilot project for Saudi agriculture firm

First Solar has installed a 684kW pilot PV system for a major agricultural firm in Saudi Arabia. The array will drive pumps currently powered by diesel to irrigate around 2.5 hectares of land. The agriculture company, Al Watania, owns the site in the Al Jouf region of the country. The farm covers a total of 31,921 hectares and uses 150 bore wells demonstrating the scale of the potential opportunity for PV in partnership with industrial partners in the Kingdom. The project was jointly funded by First Solar and Al Watania.

Abu Dhabi bank makes US$10bn renewables and clean development pledge

The National Bank of Abu Dhabi made a US$10 billion, 10-year pledge to finance renewable energy and other sustainable business activities. The bank said it would lend, invest and facilitate US$10 billion of financing in environmentally sustainable projects in the so-called West-East corridor, which stretches from Africa, through the Middle East to Asia.

Company wins

CSUN targets Middle East with UAE partnership

Nanjing-based PV manufacturer China Sunergy (CSUN) is to target

Market outlook

Middle East procurement plans for 2016 top 4GW

The Middle East will launch the procurement of more than 4GW of solar power in 2016, according to a report published by the Middle East Solar Industry Association (MESIA). With around 3GW added to the region's pipeline in 2015 and another 4GW expected this year, the market's arrival as a gigawatt-scale source of solar demand has been solidified. The 2016 MESIA Market Outlook anticipates the procurement to be led by 2GW in Algeria, 1,150MW by the UAE (800MW in Dubai, 350MW in Abu Dhabi) as well as a further 250MW in Egypt and 245MW in Morocco. Jordan (120MW), Kuwait (85MW) and even Saudi Arabia (170MW) will also contribute. Dr. Raed Bkayrat, director of research at MESIA and author of the report, told PV Tech that the track record of Dubai's 13MW project installed in 2013, coupled with the financing of a further 200MW second phase, has now opened the floodgates.

Credit: First Solar

Progress in Dubai and Jordan has paved the way for Middle East solar.

the Middle East and Africa after signing a joint venture with UAE's Z-One Holding. The two firms are collaborating to form a joint-venture, dubbed CSUN Solar MEA FZC, which will sell CSUN's full range of solar products and solutions. The JV is to be owned 60% by CSUN and 40% by Z-One Holding. The partnership will come as a boon for CSUN, which faced a difficult 2015 following de-listing challenges from NASDAQ and further losses

ABB wins 50MW order in Jordan

Power engineering manufacturer ABB won a 50MW supply deal in Jordan. The company will supply EPC Martifer Solar with central inverters and controllers for four projects near Ma'an and Mafraq. The plants include one 20MW project and three 10MW installs. ABB, which co-designed the plants to the grid operator NEPCO's standards, has also signed a service agreement with Martifer. The company will train Martifer's O&M staff on the "specialised O&M of its inverters". ABB will be providing 45 of its ULTRA central inverters.

Africa

African Development Bank targets universal energy access

A 20-fold increase in off-grid power connections is among the aims of a plan to achieve universal energy access in Africa by 2025. Launched at the World Economic Forum in Davos in January, the African Development Bank plan is being billed as a 'New Deal' on energy for Africa, in reference to former US president Roosevelt's plan to rebuild the US economy after the Great Depression of the 1930s. By 2025, the plan envisages 160GW of new grid-connected generation capacity and 75 million new off-grid power connections, a 20-fold increase in today's number, the ADB said. While no specific targets are given, the ADB envisages solar playing a key role in the delivery its overall figure, highlighting the 10TW of solar potential it says the continent offers.

Algeria solar installs hit 268MW in 2015

Algeria installed roughly 268MW of solar PV capacity in 2015, according to Algeria's state-owned renewable energy research institute CDER. SKTM, a subsidiary of state-owned utility Societe Nationale de l'Electricite et du Gaz (Sonelgaz), was mainly responsible for the strong progress in PV deployment last year, particularly in the highlands and southern regions. The target of the national renewable energy programme is to install 22GW of renewbales capacity by 2030 and for energy efficiency to save 9% of energy usage by the same date. At the time, Algerian energy minister Youcef Yousfi also announced that the government hopes to install 13.5GW of PV capacity by 2030. It plans to tender 2GW this year.

Djibouti in line for 300MW PV plant

Work was expected to begin on the first phase of what is expected to be a 300MW PV project in Djibouti. The tiny East African country is aiming to become 100% powered by renewable energy by 2020, and president Ismail Omar Guelleh held a ceremony to mark the first stage of the project in January. Swiss company Green Enesys is developing the €360 million project and is expecting to execute it in six 50MW phases. According to comments from the country's energy minister separately reported by Reuters, electricity from the plant will be sold to national utility Électricité de Djibouti under a power purchase agreement.

ASIA-PACIFIC

Australia

ARENA selects 22 projects to proceed in large-scale PV programme

The Australian Renewable Energy Agency (ARENA) has shortlisted 22 PV projects totalling around 766MW to move to the next phase of its competitive large-scale solar bidding process. All the shortlisted projects came in well below the threshold price of AU$135/MWh (US$93.4), fulfilling one of the aims of the programme in bringing large-scale PV costs down. Even though the shortlist was whittled down from 77 initial proposals, it still leaves the programme well oversubscribed, with AU$100 million available to fund up to 200MW of large-scale capacity. Meanwhile, Australia-based energy company Genex Power received development approval for its 150MW Kidston Solar PV project in Northern Queensland, which would be the largest solar plant in Australia once complete.

Japan

Japan set to OK auctions for solar as energy reform continues

Japan's renewable energy laws are likely to result in the introduction of an auction process for large-scale solar, after the Ministry of Economy, Trade and Industry (METI) put a plan for approval before the cabinet. The ministry is targeting the maximum introduction of renewable energy while "suppressing the burden" on the public purse, as the purchase price of power from facilities including solar is exceeding ¥1.8 trillion (US$8.7 billion). Around 90% of that sum is thought to be payable to solar power plant owners. The government will also create a new certification system, which is expected to take into account the feasibility of a project.

Taiwan

Taiwan doubles 2016 solar FiT capacity to 500MW

Taiwan's Ministry of Economic Affairs (MOEA) is increasing the

PV rankings takeover

China displaces Germany as solar capacity leader (PICTURE United PV)

China has officially overtaken Germany as the world's leader in installed solar capacity after Beijing confirmed that 15.13GW was added in 2015. The official figures now show that the country has 43.18GW of solar. The National Energy Administration (NEA) claims that 37.12GW is utility-scale and with around 6GW of distributed PV. The figure is a 43% in-crease on 2014's tally of 10.6GW and a huge 54% boost in total installed from 28.05GW at the end of 2014. Grid curtailment issues continue to plague some provinces with Gansu (31%) and Xinjiang (26%) particularly badly hit, according to the NEA statement. Germany has a 2.5GW annual cap on solar deployment that made China's ascension in the rankings inevitable.

Credit: United PV

After years at the top of the PV deployment rankings Germany has finally been surpassed by China, after Beijing confirmed that 15.13GW was installed in 2015.

amount of solar PV capacity available under its feed-in tariff (FiT) programme for 2016 from 270MW to 500MW. The ministry noted the trend of price changes in PV modules internationally last year, but the tariff adjustment will not follow the percentage of decline in international module costs and instead the FiT will be increased by 5.6% from the figure previously announced. The ministry will also increase its mark-up of the FiT in Northern Taiwan to 12.5%.

China

United PV in US$1.5 billion credit deal for PV power plants in China

China-based PV firm United Photovoltaics Group and major share-holder, China Merchants New Energy Group have secured RMB10 billion (US$1.53 billion) in financing from CITIC Financial Leasing Co. CITIC Leasing is providing lease arrangements and securitisation services to the companies for building and owning PV power plant projects over the next three years. The projects are expected to be built at multiple locations across China. Meanwhile United Photovoltaics Group has also transferred its deal with Hareon Solar to build 930MW of PV power plants to third parties in exchange for recouping its initial deposit and interest and expenses, while dropping its case in an arbitration court.

China's first solar securitisation launched

Shenzen Energy has launched the first solar securitised bonds in China with a CNY1 billion (US$152 million) tranche. BOC International, the Bank of China's investment banking arm, underwrote the bonds, which will have interest rates of 3.6-4.5%. The finance is backed against the future revenues of Shenzen Energy's solar projects. Securing finance against the income of existing projects and installations has fuelled the growth of US residential firm SolarCity in the last two years, which was the first to pool residential assets for finance.

Huawei signs 15GW deal with China Minsheng New Energy

Huawei will provide China Minsheng New Energy with 15GW of its smart PV systems over the next five years. The pair agreed the deal at the tail end of 2015 with Huawei agreeing to provide PV controllers, wireless broadband and PV management. China Minsheng has committed to investing RMB150-200 billion (US$23.0-30.7 billion) into solar during the next five years. China Minsheng plans to invest 30% in the building and operation in ground-mounted plants, 40% in distributed PV projects and 30% investment in developing PV technologies. The deal also includes the establishment of a joint innovation centre.

India surpasses 5GW solar deployments says energy ministry

India crossed the 5GW mark for installed solar capacity, according to the Ministry of New and Renewable Energy (MNRE). Cumulative installed capacity now stands at 5,130MW, with deployments of 1,385MW in the current financial year. The leading states for deployment are Rajasthan 1,264MW, Gujarat 1,024MW, Madhya Pradesh 679MW, Tamil Nadu 419MW, Maharashtra 379MW, and Andhra Pradesh 357MW. Bridge to India also released figures showing that India will install 4.8GW of utility-scale solar capacity in 2016, up 140% from 2GW in 2015. During this year, the southern states of Tamil Nadu, Andhra Pradesh, Telangana and Karnataka are expected to contribute nearly 80% of all new capacity additions.

INDIA TENDER TIMELINE

22 DECEMBER: Vikram Solar, Tata Solar Power and Jakson won a combined 260MW of solar EPC contracts in Rajasthan.

4 JANUARY: SECI issues a request for selection (RfS) for 500MW of solar PV projects in the Ananthapuramu Solar Park in the Indian state of Andhra Pradesh.

6 JANUARY: The Solar Energy Corporation of India (SECI) awarded 42.75MW of rooftop solar capacity across India to multiple bidders.

7 JANUARY: Delhi-based private distribution company (Discom) BSES plans to procure 700MW of clean energy including solar power using a reverse auction process.

26 JANUARY: Adani Group and Azure Power are awarded 50MW of capacity in Uttar Pradesh.

27 JANUARY: NTPC invited online bidding for 750MW of solar capacity in Karnataka.

28 JANUARY: Uttarakhand invited expressions of interest for setting up 44MW of grid-connected rooftop solar PV and small-scale solar capacity.

2 FEBRUARY: MNRE approves scheme to set up 50MW of solar power capacity in areas that can be easily viewed by the public for demonstration purposes.

2 FEBRUARY: Indian state-owned utility National Thermal Power Corporation (NTPC) invited domestic bidding for the development of 250MW of solar PV at the Pavagada solar park in Karnataka.

8 FEBRUARY: Himachal Pradesh plans to establish 700MW of solar PV capacity under its revised Solar Power Policy 2016.

8 FEBRUARY: Karnataka Renewable Energy Development Limited (KREDL) has invited a request for proposal (RfP) for the allocation of a further 240MW of solar, after bidding shortfall in previous tender.

Product reviews

Pyranometer | EKO Instruments unveils a new generation of high-end ISO 9060 secondary standard pyranometers

Product Outline: The EKO MS-80 secondary standard pyranometer is claimed to represent a break with traditional pyranometer architecture, offering low offset behaviour and fast thermopile sensor response.

Problem: In order to assure well-founded decisions in designing and operating profitable solar power plants, solar irradiance should be continuously and accurately measured. Sensors for fulfilling these tasks must be able to withstand on-site environmental and atmospheric conditions, such as wind, rain, snow, soiling, spectral effects and re-calibration, as well as offer effective communication and compatibility.

Solution: The NEW MS-80 is a combination of EKO's isolated detector architecture and novel optical design. According to EKO Instruments, it pushes the limits of traditional pyranometer characteristics, offering immunity to offsets and a range of features including a ventilator, heater and different communication interfaces. Providing the lowest measurement uncertainties under all atmospheric conditions, the MS-80 is made for long-term unattended operation.

Applications: PV Power Plants & solar energy research

Platform: The MS-80M can be used whenever RS-485 Modbus RTU signal is required. The MS-80A converts the voltage output of solar radiation sensors into 4-20mA current.

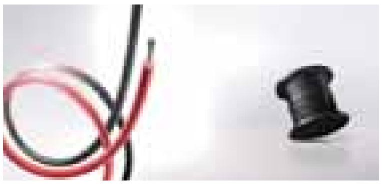
Availability: April 2016 onwards.

Cabling | IBC Solar's 'FlexiSun' VDE standard cable comes with ten year product warranty and meets new EN 50618 standard

Product Outline: IBC Solar's IBC FlexiSun solar cable is the first in the industry to meet the new standard, EN 50618. IBC SOLAR is also increasing the duration of the solar cable's warranty to up to ten years.

Problem: The new European EN 50618 standard regulates the features, requirements and use of cables and wires designed for PV systems. The aim is to make sure that PV cables conform to a consistent quality standard at a European level.

Solution: The IBC FlexiSun can be buried underground. This eliminates the costly



procedure of laying empty conduits to provide cable protection, especially when constructing large-scale open-space projects. Long cable life is ensured through its verified resistance to water, ammonia and abrasion. IBC FlexiSun is also a durable choice for roof-mounted systems – it can be used in all climate zones and can be laid at temperatures as low as -15 degrees Celsius thanks to its high temperature tolerance. Additionally there is available a new cable type coated with tinned copper mesh. This coating effectively protects the cable from being chewed by rodents.

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

Platform: With 30 years' life expectancy the solar cable is one of the most durable products available on the market. IBC FlexiSun

Availability: Already available.

Trackers | NX Fusion from NEXTracker offers pre-engineered bundled single axis system solution

Product Outline: NX Fusion is a product bundle of pre-engineered single-axis tracker and AC power system solutions that integrates a solar power plant's most critical mechanical and electrical components into a single tracker power block.

Problem: Solar installers require fast-track solutions to meet cost targets. NX Fusion is claimed to eliminate additional DC electrical design work and UPS backup systems, making installation quicker and easier.

Solution: NX Fusion includes NEXTracker's horizontal tracker, NX Horizon, DC wiring, advanced string inverters, UPS, piers, tracker monitoring and control system; and, optionally, PV modules. All of these components are said to be optimised to work in concert,

ensuring rapid installation, cost savings, scalability and maximum energy output for ground-mounted PV systems – eliminating the often complicated system design, permitting, and logistical challenges faced by today's solar developers. NX Horizon has fewer foundations and assembly points to help mitigate geotechnical risk and accelerate project construction schedules. With independent rows and high slope tolerance, NX Horizon minimises site preparation costs while enabling greater power density. NX Horizon's self-grounding and self-powered design provides valuable savings in labour and materials, while its wide rotational range enables PV systems to take full advantage of high irradiance environments, according to NEXTracker.

Applications: Utility-scale PV power plants using c-Si and thin-film modules.

Platform: NX Fusion also includes on-site weather stations that can guide the array to safe stowing positions within seconds of detecting increasing wind speeds. Quick fixes and diagnoses can now be conducted remotely via sophisticated monitoring systems in addition to locally or on-site, eliminating delays and loss of revenue for mission critical solar power plants.

Availability: Already available.

Mounting | Renusol's flat roof system provides aerodynamics for south-facing solar systems

Product Outline: Renusol is introducing a new ballasted flat-roof mounting system for mounting south-facing PV panels. The company says the system is price-efficient, quick to install and especially suited to buildings with lightweight roofs.

Problem: Renusol says it is increasingly emphasising simple mounting systems that can be installed quickly. A key aspect is the need for an innovative screw joint that works without a nut, meaning that fewer movements are needed. Since the rails are delivered pre-punched, there is also no need to take cumbersome measurements on site, which decreases installation errors.

Solution: All standard framed solar modules can be mounted with the new system, Renusol says. The FS10-S system mounts PV modules at a 10-degree angle, while the FS18-S mounts at an 18-degree angle. Short rails with lengths of 1.38m and 1.73m are used with the FS10-S and FS18-S, respectively. The remaining system components also offer easy handling and storage – an advantage for wholesale customers. The short rails are joined with connectors, making it possible to compensate for

unevenness in the roof. In addition, slots in the rail connectors compensate for temperature expansions, which could otherwise lead the PV system to shift on the roof.

Applications: The new mounting system is suited for commercial, industrial, agricultural and residential buildings with bitumen, concrete, foil and gravel roofs.

Platform: There is no need to penetrate the roof membrane in order to safely fix the system on the roof, according to Renusol. Instead, pavers or concrete slabs are placed in the channels of the wind deflectors. Renusol offers a 10-year product warranty.

Availability: Already available.

O&M | Gantner Instruments' monitoring solutions for utility-scale PV plants finds errors at string level

Product Outline: Gantner Instruments 'string.bloxx All-in-one' system recognises design and production errors with high resolution down to the PV module level.

Problem: In large PV systems monitoring and troubleshooting have become more complex. Operators are nterested in finding errors as quickly as possible. Accurate PV testing is rquired to maximise yield and deliver supportive functions to contribute to grid stability.

Solution: Design and production errors are recognised on the DC side for each PV string, regardless of inverter. The string.

bloxx provides current measurements typically 10 times more accurately and is not susceptible to temperature variance. In addition, string voltage (up to 1,000V) and DC power on every string can be continuously monitored ensuring maximum system productivity. Continuous measurement of both cabinet and panel temperatures, along with overvoltage monitoring and main switch control are claimed to improve system diagnostics.

This accurate measurement gives feedback about losses due to inverter malfunction, soiling, shading and module degradation.

Applications: PV power plants.

Platform: The reduction of interfaces in the system leads to reduced risk and faster plant installation time, according to Gartner. The intelligent data loggers are designed for the precise detection of analogue and digital measurement and state variables. They allow the acquisition, storage, reduction and transmission of data to higher level systems.

Availability: Currently available.

Inverter | SMA's Sunny Boy Storage system enables high-voltage batteries in residential market

Product Outline: SMA Solar has developed a new high-voltage battery-compatible inverter for private households. The Sunny Boy Storage ensures the cost-effective, easy and flexible integration of storage solutions into new or existing PV systems.

Problem: Residential PV coupled with storage means greater independence from utility companies. More and more people are doing this to reduce energy costs and contribute to environmental protection.

Solution: The new SMA Sunny Boy Storage battery inverter has been designed especially for high-voltage batteries like the Tesla 'Powerwall'. The AC-coupled system for high-voltage batteries operates in parallel with the PV system, making it possible to integrate battery storage systems into existing PV installations, while also flexibly enhancing the storage system. The reason

for this is that with an AC-coupled storage solution it is not necessary to touch the PV system. The system can be adapted to individual needs brought about by changes in living circumstances, such as the integration of an electric vehicle or changed energy demands, even after installation.

Applications: Residential high-voltage battery storage in parallel with PV systems.

Platform: The online portal Sunny Places gives users of the storage solution a transparent overview of their home, while an app enables them to view energy flows and access potential savings.

Availability: The first systems will be sold starting March 2016, first in Germany, and then in other important storage markets such as Italy, the UK, Australia and the US.

Product reviews

Inverter | SMA Solar's 30kW 'Sunny Tripower' inverter offers cost-optimised, decentralised solution

Product Outline: SMA Solar Technologies has expanded its commercial solutions portfolio with the addition of the new Sunny Tripower 30000TL-US. The 30kW, three-phase inverter is designed for decentralised PV plants.

Problem: PV installers require economical solutions for medium- and large-scale decentralised commercial PV plants that are able to meet the demanding interconnection requirements emerging in California, Hawaii and other key regional solar markets.

Solution: The Sunny Tripower TL-US delivers smart features including active power curtailment, adjustable power factor and

reactive power supply, frequency and voltage ride-through, and soft-start reconnection ramp controls. These features enable the Sunny Tripower TL-US to meet emerging interconnection requirements such as the recent revisions to California's Rule 21 and HECO's transient over-voltage and ride-through requirements. The inverter also offers a number of safety and reliability features, such as all-pole ground fault protection, reverse polarity indicator and granular dual MPPT DC monitoring.

Applications: Medium and large-scale decentralised commercial PV plants

Platform: The Sunny Tripower TL-US inverter line is also available in 12, 15, 20 and 24 kilowatt models. While the Sunny Tripower 30000TL-US is applicable for 1,000VDC systems, the rest of the inverter line are suitable for both 600VDC and 1,000VDC applications. SMA claims they offer peak efficiency of more than 98%.

Availability: January, 2016 onwards through SMA's North American distribution programme.

Balance of system | SnapNrack develops adaptable junction box and trunk cable clamping system

Product outline: SnapNrack has launched a new junction box and trunk cable clamp aimed at reducing solar installation times and installations costs.

Problem: PV system installation times still significantly contribute to the overall cost of a PV system. Simplified and lower-cost wire management solutions help to reduce system costs.

Solution: The SnapNrack UL-listed junction box is claimed to save installation time and cost while improving safety and reliability over the life of the system. Designed to be 6" x 5" x 3" and fully integrated with DIN rail mounts inside, it is large enough for wire management but small enough to be adaptable to any mounting configuration. A large temperature range of -40F to 185F will allow it to hold up in the most extreme environments, while its black colour will provide full UV protection to extend the life of the box and its contents, according to the company. The trunk cable clamp allows the

securing of up to two microinverter trunk cables along SnapNrack rail channels, transitioning in and out of channels, and routing across rails. The SnapNrack trunk cable clamp works with all known microinverter AC trunk cable diameters and is made up of fibre-reinforced resin developed for high UV exposure as well as to handle the extreme temperature range.

Application: Residential and commercial rooftop solar arrays.

Platform: SnapNrack's line of wire management solutions also includes the SnapNrack four-wire clamp, which provides the same benefits as the trunk cable clamp but for PV cables.

Availability: Already available.

Inverter | Tigo offers retrofit option for latest TS4 MLPE platform

Product Outline: Tigo has announced the availability of the TS4-R, which enables module manufacturers and installers to standardise on a single platform and utilise any of the module-level power electronics (MLPE) functions for retrofit or add-on universal base systems.

Problem: The introduction of TS4 platform gave installers a greater degree of control over what they want and need for any given project, according to Tigo. Whether an installer wants safety and monitoring to meet NEC 2014 rapid shutdown requirements or optimisation, or simply a traditional module that can be easily upgraded later in life, the TS4

platform can support them, the company says. However, retrofitting applications had not been catered for.

Solution: The TS4-R addresses the need for a retrofit solution that can be mounted on any existing installed PV system, connected into the PV module junction box abd offering improved energy harvesting, greater flexibility and increased control to the existing PV system. The offering for the retrofit project is composed of a two-piece solution: the TS4-R base, which is added on the solar module, and its covers, plug-and-play MLPE which can be swapped in and out. It supports any of the wide offering of the existing TS4 Platform functional covers. It can also be designed into a new system.

Applications: Any existing PV system requiring the benefits offered by the TS4 platform.

Platform: The TS4-R is available as a standalone unit or in three pre-assembled versions. It can be fitted with any of the five different covers: TS4-L Long String, TS4-O Optimization, TS4-S Safety, TS4-M Monitoring and TS4-D Diodes.

Availability: Already available.

Scaling up solar after Paris

Policy | December's international climate deal in Paris offers PV a platform to become one of the world's dominant energy sources. Now that the circus has left town, Ben Willis and John Parnell look at where the solar industry goes next to turn opportunity into reality

Credit: UN Photo/Mark Garten

Solar will be a key enabler of the Paris climate deal, but the road is likely to be a long one.

There can be little doubt that the Paris climate deal reached in December was a landmark moment. For 20 years the world had tried to reach an agreement on how best to collectively tackle climate change, but failed. This time around a deal looked more likely, but then only days before the COP21 negotiations got underway the appalling attack on Paris by Islamist extremists threatened to scupper the talks even before they had begun.

Nevertheless, against the odds, on 12 December 2015 world leaders defied history and the more immediate peril from terrorists to reach a deal. That deal leaves a lot still to resolve, and critics have been quick to condemn it for its lack of the necessary detail or teeth to drive forward the energy transition. But the very fact a deal has been reached is a huge statement of intent by the world finally to get to grips with arguably mankind's biggest existential threat.

"It's changed from 'if' to 'when'," says Sean kidney, chief executive of the Climate Bonds Initiative. "It's a clear message to the world that this transition is happening. Yes the detail is still a bit fudgy but when you get 187 nations putting forward climate change plans, that's pretty damn amazing."

For those working in the solar industry the Paris deal is of particular significance. Since the 2009 Copenhagen climate summit, when high hopes of a deal fizzled out, solar has been arguably the star performer among the clean energy technologies that will help wean the world off its fossil fuel habit. Indeed many ascribe the fact that a deal was reached in Paris at all to the progress that solar and wind power have made since Copenhagen. As governments around the world now retreat to their respective corners to work out how to deliver on the pledges made in Paris, solar is expected to be central to most countries' and regions' plans.

"It's now almost universally recognised that solar will be a principal contributor to addressing climate change," says John Smirnow, secretary-general of the newly formed Global Solar Council. "I don't think there's any doubt about that."

But while having an agreement is one thing, delivering it is another altogether. Some have likened the progress made by clean energy in the past five years to a juggernaut slowly gathering momentum. While that may be true, another equally apposite analogy would be that of the oil tanker, for which a change of direction is a protracted and tortuous business. Apply that to the current energy paradigm, and it's clear that even in the context of the incredible advances made by solar and its kin in the field of renewables, there is still a long way to go. Policy, regulation, the prevailing flow of investment into the energy sector … these are all still largely geared towards the incumbent fossil fuel-based energy system whose days must be numbered if the world is to achieve its aims. In other words, this is still a marathon for solar, not a sprint.

"Paris gives us a framework to move forward but the immediate impact on the solar industry is not going to be noticed for some time," says Michael Taylor, senior analyst at the International Renewable Energy Agency's Innovation and Technology Centre in Bonn, Germany. "Like all things, there is an element of inertia in moving from agreements to implementation. It will take some time for the coordination of additional policies to come through."

Nevertheless, the scale of the opportunity for solar is enormous. To paraphrase Sean Kidney, it's now a question of when rather than if the clean energy transition will happen. This article explores some of key building blocks that are now being put in place to ensure PV can make the most of the big opportunity it has post-Paris to become one of the world's main energy sources.

Finance

How the energy transition will be financed is the US$12 trillion question. That at least was the investment figure for keeping global warming under 2 degrees Celsius cited in a January report, "Mapping the Gap: The Road from Paris", by Bloomberg New Energy Finance and the sustainability body Ceres. That's some US$5 trillion more than under the 'business as usual' scenario outlined in the study. Within the report's

Credit: BNEF/Ceres, "Mapping the Gap: The Road from Paris", January 2017.

Figure 1. Limiting global warming to 2 degrees Celsius or under would require US$5.2 trillion of investment on top of 'business as usual' forecasts.

projections, solar would take a significant share of this investment, particularly in the 2030-35 period when it would attract US$1.6 trillion (Figure 1).

These are all massive, almost incomprehensible sums. Yet, the question of whether that money will be found is less one of whether it exists than whether it can be directed to the right place. The global financial markets could fund the energy transition several times over and still have plenty to spare. The issue is that at the moment the capital needed to deploy solar and other clean energy technologies at the sort of scale required is still flowing largely in the wrong direction – into fossil fuels.

"The money goes where the returns are," says Alex Perera, head of the renewable energy programme at the World Resources Institute in Washington. "It's not like you're trying to convince bankers to put money in different things; they don't really care what they're financing. It's all about the risk-return profile. So it's really about how you de-risk the good stuff and improve the returns of the good stuff, and then how do you add risk to the bad stuff."

With that in mind, one of the big efforts currently going on to turn around the oil tanker of the world financial markets is to highlight to the investment community just how risky their investments in coal, oil and gas are. At the forefront of that is London-based think-tank, the Carbon Tracker Initiative, which is building up a body of evidence to demonstrate this point.

Speaking at a recent solar finance event in London organised by *PV Tech Power* publisher Solar Media, the organisation's CEO Anthony Hobley said its latest analysis suggested that some US$2 trillion of planned fossil fuel projects "do not make financial or climate sense". The kind of projects Hobley referred to are the currently marginal ones in locations such as the Arctic or tar sands, where extraction is risky, costly and dirty.

"If those projects go ahead, there's a very high likelihood that US$2 trillion will be wasted," Hobley said. "It will create stranded assets in the energy sector. And if all the money is poured into those projects and wasted, the global economy still has to find that money again to fund the clean energy alternatives."

Hobley said the relevance of this work to the solar industry was to prevent money being spent by the fossil fuel industry that the renewable energy industry could spend more effectively: "Our work is to ensure the financial markets truly understand the risks, so fossil fuel pays the true cost of capital and you guys [the solar industry] are competing on a level playing field."

Hobley said that the trend of fossil fuel divestment was now picking up pace and reaching meaningful levels. The next part of that story would be the extent to which the solar and other renewable energy industries can offer investors an alternative place to put their money. Many mainstream institutional investors such as pension funds would find it very difficult to divest unless they had a clear choice of where to put their money, he said.

"What those who've committed to divest-invest need is the second part of that," Hobley said. "What do they do with the money they're divesting from fossil fuels but still want some exposure to energy? There's a huge opportunity for [the solar industry] to help them. Obviously some work needs to be done to create the right type of products and investment opportunities for them. But they're very eager to do that now because they've committed to it."

Creating those alternative investment opportunities will indeed be the big task for the solar industry now if it wants to soak up some of the capital being divested from fossil fuels. As such there will be no single answer to how it does this, but according to Kidney there are some tantalising signs of how the necessary volumes of capital may

DRIVING THE ENERGY TRANSITION

In the run-up to COP21, nations were required to set out their emissions reduction pledges in so-called intended nationally determined contributions (INDCs). These will be the starting point for policies countries now implement to meet the goal of the Paris agreement. We've selected some promising solar markets and summarised briefly any good omens for future solar deployment be it through an emissions pledge, renewable energy goal or a specific solar target.

INDIA 40% of installed electric power capacity to come from non-fossil fuel sources by 2030, along with a 33-35% reduction in the carbon intensity of its GDP from 2005 levels; a five-fold increase in renewable energy capacity to 175GW by 2022, including 100GW of solar.

EGYPT Will refocus energy subsidies from fossil fuels to renewables, replace "obsolete" generation assets. Praises renewables ability to help it meet its economic targets as well.

SAUDI ARABIA Will implement "ambitious programmes" to increase renewable energy's contribution to the energy mix"; scope to include PV, solar thermal, wind and geothermal energy, and waste to energy systems. A competitive procurement process for renewable energy is said to be under preparation.

Credit: Global Solar Council

The Global Solar Council is expected to give the industry some international lobbying clout.

start to flow into renewables, from green bond issues to high-level groups starting to look seriously at the question.

For example, Kidneys says, India's Securities Commission has just put out green bond regulations, citing the country's intended nationally determined contribution (INDC) – the pledge it made in Paris to curb emissions. "This is not an environment ministry or renewable energy ministry it's the securities regulator," Kidney says. "That's the sort of change we are seeing now."

Meanwhile, former New York mayor Michael Bloomberg has been appointed to chair an international task force to examine the financial exposure of the companies to the risk of climate change. "Central bankers, these are the grey men of the grey men and they have a group looking at sustainability issues and climate change headed by Bloomberg. That's kind of new!" Kidney says.

Policy and regulation

Globally, Kidney says he expects investment in solar and other renewables to grow significantly in the coming years. How that pans out regionally or at an individual country level, though, is another matter as "perverse policy situations" around the globe create a somewhat uneven regulatory landscape for investors and developers to navigate, Kidney adds.

As such this is another of the big-picture issues for industry and policy makers to address to ensure solar plays its full part in the energy transition. The main policy drivers for delivering the Paris vision will be the INDCs that countries committed themselves to ahead of the talks (see box). Aside from these, a number of solar-specific initiatives have also recently launched to address the policy and regulation questions.

The Terrawatt Initiative, for example, was launched on the fringes of the COP talks in December. Instigated by heavyweight French independent power producer, Engie, the venture describes itself as a private sector-led non-profit body aiming to mobilise investment in one terawatt of additional solar by 2030. Speaking to PV Tech Power, its secretary-general, Jean-Pascal Pham-Ba, explains how solar's shift to greater scale is currently being hampered by the patchwork of market rules in force around the world.

"The fact that each and every country has its own regulation, its own way to do things, makes solar development not scalable," he says. "You have to start from fresh each time, and each time you have to pay a lot for studies and advisory fees to have a sense of what's going on, whereas the resource is very well known and the technology is very well known; the regulatory framework is the hurdle, and it means developers can't industrialise the development process."

Pham-Ba says the Terrawatt Initiative's main aim is to work with stakeholders around the world – drawn from industry, finance, global bodies such as IRENA, utility companies and so on – to work out how to "streamline" the solar value chain globally.

This endeavour will focus on a number of priority areas, such as drawing together best practice from around the world on solar market regulation and contractual arrangements. "That's something we're going to work with IRENA on in the coming months, so we can offer a set of standardised master agreements, which will be considered as bankable by themselves, without having to spend hundreds of thousands of euros in legal fees each time you do a 10MW project," Pham-Ba explains.

Another aim will be to develop new business models that aggregate, package and de-risk the many small individual solar assets being built around the world and offer them to market at the sort of scale that would make them interesting to institutional investors. One idea is to create a new investment "label" for solar assets,

IRAN 4% reduction by 2030 compared to 2010 with GCCT, nuclear and renewables

TUNISIA Country will reduce carbon intensity by 41% by 2030.

MOROCCO 32% reduction by 2030, targeting 14% of its power from solar by 2020.

ALGERIA Emissions reduction of 7-22% by 2030 (7% by own means, 22% with finance and technology help). Algeria's INDC notes the country has one of the best solar resources in the world putting the annual figure at five billion GWh.

EUROPEAN UNION At least 40% reduction in emissions by 2030 with member states determining how they do so. There are no replacement country-level renewable energy targets to follow on from the 2020 goals, yet.

RUSSIA 25-30% reduction on 1990 by 2030; makes one reference to increasing the share of renewables.

TURKEY Up to 21% emissions reduction with solar to reach 10GW by 2030.

KENYA 30% emissions reduction 2030 compared to business as usual with geothermal, solar and wind energy listed as a focus for efforts.

says Pham-Ba.

"This would be very important to secure the safety and security of the market," he explains. "The last thing we want is that this sub-prime type stuff happens [with solar], which would be a catastrophe financially but also an environmental catastrophe, because there will be a bigger distrust after that of solar and the whole value chain, which means we won't be able to reach the transition."

IRENA's Michael Taylor says there's no "silver bullet" in terms of drawing up universal policy and regulation for a global solar market but agrees there is much that countries can learn from each other. "Countries still have to develop their own internal capacity and institutional arrangements," he says. "As we have seen in countries like South Africa, Brazil, Chile and Jordan once that has bedded in, there has been a rapid scaling up of deployment. There are lessons we think can be shared between countries that will help them enjoy a smooth acceleration."

Governance and lobbying

One area where the global solar industry is almost certainly going to need to raise its game in the coming years is in the area of lobbying. According to Hobley, although the fossil fuel appears to be in "structural decline", it is unlikely to go without a fight, making it a potentially dangerous opponent to a relatively new industry like solar.

"The fossil fuel industry still has a lot of money, it still has a lot of political connections and they know how to influence governments," he said. "And if you don't think they aren't going to lobby like hell to slow you down then I think there's a certain naïvety. So you need to ensure your trade associations are properly funded to compete with their trade associations, that your lobbyists are sat in the same dinners, in the same behind-closed-door conversations."

In building its capacity to take on the fossil fuel industry at its own well-practised game, two recent developments will likely further solar's cause. One is the International Solar Alliance, instigated by Indian prime minister Narendra Modi, the other the long-awaited Global Solar Council. Like the Terrawatt Initiative, both were launched on the sidelines of COP21 in December.

The Global Solar Council will bring together the world's solar industry under one umbrella, for the first time giving the industry representation at an international level. Its main purpose will be to function as a high-level lobbying organisation, working with governments, multilateral bodies such IRENA, the International Energy Agency and G7's Clean Energy Ministerial to represent solar's interests at the policy level.

According to its secretary-general John Smirnow, formerly of the US Solar Energy Industry Association, aside from lobbying, the organisation also sees itself as having a key role to play in building capacity among new or emerging solar markets.

"For countries that haven't yet fully engaged in solar, there's going to be a huge need for local capacity building, whether that's technical expertise or building relationships with local energy providers and local government," Smirnow says. "And that's going to be an important focus for the council: to utilise our network of technical expertise to help build solar capacity at the local level."

Already the council represents more than 50 national solar associations, Smirnow says, a number he hopes to grow this year. "As associations we want to help each other grow and share the knowledge, the technical expertise, the lessons learned from some of the more established associations with some of the new, younger associations and help grow associations that don't even exist today," he says.

The right direction of travel

In the context of the ambitions set out in Paris and the hopes many have for solar's part in delivering that vision, there is much work to be done, and the road will be a long one. As IRENA's Michael Taylor points out, there is no "easy fix" for accelerating new market opportunities for solar. "There are a lot of dominoes that need to be lined up before we can see that happen," he says.

But only a month or two after the Paris deal was reached, even though that deal itself lacked any significant teeth, there is plenty of evidence to be found of the catalytic effect many had predicted a positive agreement would have. Particularly encouraging is the extent to which there appears to be new momentum within the solar industry to operate collaboratively, something that has hitherto not been one of its strengths and put it a significant disadvantaged to the well-funded, well-connected fossil fuel business.

It is far too early to gauge the extent to which solar will capitalise on the momentum from Paris, but for now the signs are promising.

As Carbon Tracker's Anthony Hobley puts it: "The way I think about it is very simple: a huge flashing neon sign that says 'Direction of travel this way'. There's no question that we're in the middle of a technological transition and what the direction of travel is. The only question is will it be fast enough to stabilise the climate at 2 degrees?" ■

DRIVING THE ENERGY TRANSITION

NIGERIA Specific target of 13GW of PV by 2030.

SOUTH AFRICA Will peak emissions in 2020; lists solar as a key technology.

USA Pledge to reduce emissions 26-28% by 2025 compared to 2005 levels with "best efforts" to reduce by 28%; cites Clean Air Act and other existing policies.

CANADA 30% emissions reduction by 2030 compared to 2005, very little detail on how. New government could be more bullish on renewables.

BRAZIL 45% renewables by 2030 with 23% renewable minus hydro by 2030 through wind, solar and biomass.

MEXICO 30% emission reduction by 2020, 50% by 2050; will promote investment in solar for high irradiation areas and also will promote DG rooftop solar.

CHINA 100GW of solar by 2020 with current installed capacity listed as 28.5GW, not including 2015 deployment.

JAPAN Emission reductions of 26% by 2030 compared to 2013; 2030 target for 7% of electricity to come from solar.

REPUBLIC OF KOREA 37% GHG reduction from current policies.

INDONESIA 29% GHG reduction by 2030 and 23% renewable target for 2025.

Changing the mega trajectory

Credit: Kyocera

Market update | After Japan's solar market got off to a flying start, a combination of policy headwinds and grid constraints has made the going much tougher. But with new market segments opening up and an electricity market reform process about to get underway the prospects for the world's second largest PV market of 2015 still look strong, writes Andy Colthorpe

Large-scale PV projects are going ahead at pace in Japan and many are showing the quality of design, workmanship and ingenuity the country is famous for. Residential PV is becoming popular too and the business case for self-consumption from commercial rooftops has also grown.

Tokyo-based industry analysis firm RTS PV expects around 10GW of PV to have been installed in 2015. The long-awaited liberalisation of the electricity market finally begins in April of this year, intended to create competition in a space dominated by a group of regional monopoly utilities. Investment and research in energy storage, smart homes, energy management systems and other clean technologies like hydrogen is also well underway.

However, so far this year we have already seen new 'clean' coal power plants proposed and nuclear facilities coming back online, while the difficulty of obtaining grid connections is a problem that simply won't go away. Further ahead, more revision to the feed-in tariff is expected in the 2017 Japanese fiscal year, beginning April 2017. As things stand the government appears prepared to support 64GW of large-scale PV through to 2030 but not go much further and seems likely to tender out the remaining amount available through budget-capped auctions. And the promised land of a freely competitive electricity market is a work in progress in its earliest stages.

Mega-solar era seeing leaves of autumn

Utility-scale 'mega solar' power plants have been the main benefactor of the feed-in tariff (FiT), with around 10 times more ground-mount PV capacity deployed than residential to date. Introduced at ¥42 (US$0.36) per kWh in the first year of the scheme running, it's not hard to see why. While it accounts for much of the phenomenal success of Japan's industry (in some areas, daytime electricity demand is often covered by solar or close to it), this has led to a number of unintended consequences.

So-called mega-solar plants continue to dominate the Japanese solar market, for now.

In early 2015 RTS PV's Dr Hiroshi Matsukawa told *PV Tech Power* that solar had become embroiled in a so-called 'shakai-mondai' ('social problem'), fuelled mainly by the levying of the surcharge, the strain on the grid and – more questionably – by politicians and lobbying on behalf of heavy industry groups.

Once again, Matsukawa says PV is being drawn into 'shakai mondai' in the nation's media. Cost is still an issue. The surcharge levied by the government's Ministry of

Credit: Solar Frontier

Economy, Trade and Industry (METI) on consumers to pay for renewable schemes doubled last July to ¥1.58 per kWh, piling on political and media pressure. According to Matsukawa, an added element is that the success of mega solar appears to have come at the expense of other renewables, of which Japan still has relatively little. Official statistics show that of a total 25.16GW of renewable energy capacity registered for the FiT during the 2014 financial year, 21.93GW was solar over 10kW and above. Just 1.251GW of wind was registered, 0.463GW of bioenergy, 0.358GW of small hydro and 0.057GW of geothermal.

Build the dream

While there has been tremendous success in deploying over 20GW of mega solar in such a short time, cumulatively over 50GW of such projects FiT-accredited since 2012 have not been built. Many people without previous extensive experience with PV or even suitable land to build their projects registered and, by meeting the simple criterion of choosing government-approved equipment, got their FiT accreditation.

There was a cull of 270MW last year, but fears that speculators may be trading high FiT projects or waiting for equipment costs to fall remained. Developers now must obtain proof of a grid connection agreement with one of the regional power companies before the next incarnation of Japan's renewable energy laws are heard in 2017, or risk losing FiT registration altogether. RTS PV's Matsukawa says a rush to get projects in the ground could make it hard to call a prediction for the size of the market in 2016.

Even before agreeing a grid connection, finding open land in Japan is proving difficult. In many cases projects are being developed on steep hillsides, abandoned golf courses, former landfill sites and even bodies of water [see feature on p.53]. Securing land can be a complex issue in Japan for reasons other than just space too.

"You have to clear the land title issue with the landowners and [often] the land's been held for several generations. If you have to do a few kilometres of grid extension, you might have to clear the right of way," says Shawn Qu, CEO of Canadian Solar.

"The US and Canada are large countries and don't have that much history, as Japan does! In general it's easier to clear land titles in Canada and the USA. But still, Japanese projects are very good projects, they have very stable returns, and the interest rate in Japan is low."

Canadian Solar has 330MWp of grid connection agreements in place for FiT-accredited mega solar in Japan, and is working with a mixture of Japanese and overseas partners. As Japan awaits the 2017 laws, expected to bring about "fundamental" changes to the FiT, the last annual round of degressive cuts dropped it to ¥27 per kWh from July 2015, a sharper drop than in previous years by about 4-5% and dissuading some investment.

The prospects for self-consumed power from rooftop PV are looking more promising in Japan.

Qu says that while the JFY2015 FiT remained at an adequate level to spawn new projects, for Canadian Solar the curtailment rules attached to the last revision [see box] meant it was trickier to make the economics tick. The clauses on curtailment, Qu says, made projects and project financing difficult.

Changing market dynamics

There was shock at the suddenness of recent government measures to put the brakes on large-scale solar – the larger-than-expected FiT cuts and rules changes including curtailment measures. The retroactive nature of one of these new rules, which means a loss of the original FiT rate if changing equipment from that originally registered, will have caused some pain in the industry. However, it is accepted by the likes of RTS PV, the Japan Renewable Energy Foundation (JREF) and METI that suppression of the "bubble" once and for all was surely needed.

Hideki Gakumazawa, spokesman for Japanese vertically integrated CIS thin-film specialist Solar Frontier, says the company sees opportunity in the un-built mega-solar pipeline. The company could acquire some of the more promising un-built plants, applying economies of scale and obtaining relatively cheap financing. Others are investigating acquiring already-built plants that are not performing as had been intended due to poor or inexperienced design or construction.

As for the expected changes to Japan's renewable energy laws in the 2017 financial year, the biggest and most talked-about aspect appears to be a switch to a tender process for awarding the large-scale FiT.

Sources in Japan have previously said that the country's government has closely watched developments in other countries which have introduced "reverse auctions" for PV over the past couple of years, including Britain's controversial contracts for difference (CfD) scheme.

Nothing can be taken for granted in the policy landscape for renewable energy, and it is far too early to say what form the process will take; for instance, whether it will be capped by budget or deployment. The former seems likely given the economic imperative behind the auctions' introduction.

The Japan Photovoltaic Energy Association (JPEA), which defines itself as a loosely amalgamated group of industry players has previously said Japan could achieve 100GW of solar by 2030. However, in July last year the organisation, which has Panasonic Corporation chairman Shusuku Nagao as its chair, said that Japan will be on course for 64GW by 2030, in line with the government's long-term outlook for energy supply and demand. JPEA set that as its target, meaning there is a possibility the auctions could parcel out the remaining capacity from that figure over the period from the auctions' introductions until 2030.

Segments shift to rooftops

It has always been the Japanese solar industry's expectation that it would have to survive without subsidies before long. While the brakes might not have gone onto large-scale deployment as smoothly as they could have, it seems the PV market dynamic as a whole has indeed started shifting over to the residential and commercial segments.

Kyocera reported in recent financial results that despite a decline in Japan solar sales in the first six months of 2015, the third quarter had seen an uptick in sales to the commercial sector. Company spokeswoman Hina Morioka tells *PV Tech Power* that it sees the present market dynamic including a "shift to a market characterised by self-consumption".

Solar Frontier's Hideki Gakumazawa says the company's in-house analysts expect to see a market size of about 7GW to 8GW of PV in Japan in 2016. Within that the market's split is likely to be more even than in previous years, with around 1GW to 1.5GW of residential demand and the remaining 6GW to 6.5GW deployed split roughly evenly between mega solar and commercial.

The growing case for self-consumption PV solutions for businesses with rooftop installations of up to around 500kW helped Japan's overall market to have a softer landing at the end of the calendar year. JREF claimed socket parity for residential was reached at the end of 2014, while output obviously goes closer to matching demand in many cases for businesses. There are two tiers of electricity pricing too, with daytime electricity costing more than night. Hideki Gakumazawa says this means a market could open up for generator business models around rooftop leasing.

Electricity market deregulation

From the beginning of the 2016 financial year, an eclectic mix of 750 companies including mobile telecoms firms and petrol stations will start selling residential electricity, having registered to join Japan's deregulated electricity market. Package deals appear to be a popular marketing strategy, including electricity bundled with phone contracts, with natural gas or other utility supply deals. RTS PV's Matsukawa says it is positive that choice will be introduced and there is definitely excitement around the changes. JREF and Greenpeace Japan have hailed the fact that consumers will be able to choose greener options.

Matsukawa says it is too early to tell what effect the newly competitive market will exert on prices. Market liberalisation is only in its second year, with industrial power users given the option earlier, and the process will only be complete when the power companies' stewardship of both infrastructure and power delivery is unbundled, scheduled for 2020.

According to Matsukawa, the new system may turn out not to have a huge direct impact on solar, but Solar Frontier is optimistic it will "support the competitiveness and growth of solar and other clean, renewable energies", Gakumazawa says.

"The upcoming legal unbundling of power companies could help the growth of renewable energy. In deregulating the market, the government is essentially aiming to create a more efficient nationwide grid, increase price competition and enable the grid to handle changes to the energy mix. The significance for renewable energy is theoretically twofold. First, it means that the national grid could accommodate a much larger capacity of renewable energy. In turn, this could also reduce the risk of curtailment."

Curtailment rules hampered 2015 activity

To help resolve the mega-solar development bottleneck, rules were introduced last year allowing for more curtailment of PV power station output by utilities, with central inverters to be fitted with utility-controlled remote shutdown devices. The rules include the right to curtail PV station output to grid for up to 360 hours per year before having to compensate project owners. Previously, since 2012, if the output was curtailed for more than 30 days in a year – with any unbroken one hour period enough to count as a day – utilities had to compensate project owners. Worse than that, once a utility has reached the maximum capacity it says it can handle in an area, it can begin curtailing PV output without compensation.

Japan's solar irradiance varies greatly from its northern to southern islands. The island of Kyushu in the south, with a near-Mediterranean climate, saw PV plants sprout up quickly under the FiT and its local power company became the first of the utilities to call a halt to new grid connection applications in October 2014. Kyushu Electric Power (Kyuden) near the end of last December revealed it is at over 5GW of a permissible 8GW limit.

Then, near the end of January Shikoku Electric Power (Yonden), serving the fourth largest of Japan's main islands, announced that it had already arrived at the 2.7GW limit for connections, meaning any new facilities would be subject to curtailment rules.

While limiting PV generation to just 8GW before uncompensated curtailment occurs, Kyushu Electric Power has also applied to build 1.7GW of so-called 'cleaner' coal generation facilities already in 2016 and switched back on its Sendai nuclear plant last summer.

Dwindling ambitions?

The Japanese government set its sights very high in introducing the FiT in 2012 and now in a subsequent administration under the rule of prime minister Shinzo Abe appears contented to pull back from that initial trajectory, committing to a 22-24% renewable energy contribution to the national energy mix by 2030, with solar at about 7% within that framework.

Some have argued that this proportion of renewable energy will not be enough to allow Japan to meet its carbon targets, despite the fact that the country's INDC ahead of the COP21 talks were described as the "least ambitious" of any developed nation except for Russia by the World Resources Institute NGO. The reductions in greenhouse gases called for by 2030 are at 26% of 2013 levels. By comparison the EU's target is a 40% reduction from 1990 levels.

It remains to be seen if competition enabled by electricity market deregulation and a slowly rising but definite trend towards self-consumption PV can move the needle further. Ultimately, says Canadian Solar's Shawn Qu, Japan has "shown its technical ability and the policy success" in implementing large- and small-scale solar.

"Japan should also be proud of it because it's a leader in many clean energy technologies," Qu says. "For example, in combining PV with home energy management systems, Japan is leading. The world should be able to learn from what Japan has achieved." ■

Japan is expected to switch to an auction-based process for large-scale solar after 2017.

Emerging solar markets – the year ahead

Market forecasts | Last year saw a number of emerging solar markets begin to fulfill their potential, setting up some promising prospects for 2016. Josefin Berg, senior solar analyst at market research firm, IHS, discusses the emerging-market highlights of 2015 and what to expect in 2016. Tom Kenning reports

PV Tech Power: Will COP21 have any effect on emerging solar markets?

Josefin Berg: The initial indicators of the COP21 are very positive, but it is still too early to translate this into megawatts for solar. There are indications that there will be financing available to support PV in emerging markets, which is necessary. The formation of the India-spearheaded International Solar Alliance also put solar energy on the agenda.

The Middle East looks increasingly promising as an emerging solar region. To what extent did solar deployment become easier there over 2015?

Across the region there have been a lot of political challenges in terms of moving from initial policy all the way down to administration and handling the different solar programmes that have been announced. Financing has also been a hurdle with issues over reliability of off-taker contracts.

Jordan has advanced a fair amount with all the power purchase agreements (PPAs) being signed for its first tender round, but it lacked administration resources to be able to handle this tender. Nevertheless, there are signs of projects starting construction and the country is moving towards taking its place among the more active countries in the region.

For Egypt there is still a question mark over timing, because it has been more than one year since a feed-in tariff (FiT) was announced along with the pre-allocation of 2GW of PV. The country is still in the final negotiations for these projects and it is not yet clear whether it will mirror Jordan and take several years to obtain the final PPA or whether it will fast-track the PPAs to be signed in Q1 of 2016, which is what most stakeholders expect.

If the PPA is signed in the first quarter, it will change the whole picture for Egypt, which is already one of the most promising countries in the region. In contrast to Jordan, the United Arab Emirates (UAE) has overseen a far quicker process of awarding tenders and has a clearer trajectory going forward.

Has Morocco's progress been beyond expectations?

Over in North Africa, we expected solar to progress in Morocco but not this fast, with tenders being announced and a greater focus on PV coming through because the first concentrated solar power (CSP) projects are now being installed. We can expect some positive momentum in Morocco over the coming year.

In Algeria they have started construction of projects that were awarded two years ago to a couple of consortiums. They have a very ambitious solar plan so we would expect some more announcements this year.

To what is solar in Latin American starting to come of age?

This has been a very big year for Latin America, with Chile managing to install an estimated 1GW in 2015, which is a huge growth, and Honduras having a small boom of 500MW coming online or installed, but the region still remains fairly small compared to some of the other continents worldwide.

Honduras was a one-off situation, having awarded a FiT to 600MW of projects last year with a deadline to install these projects also within 2015, which drove the market. It is unclear whether there will be a new incentive. The government is likely to wait and see how this solar rush affects the economy and the power system before releasing new schemes.

Brazil has been a major focal point of 2015 after holding its solar auctions and the market is expected to take off in 2016; however, deployment, which is still almost non-existent so far in terms of megawatts, has been disappointing. It is starting to take off slowly, but it has been very challenging. Even projects that were awarded in the state of Pernambuco took a long time to sign the PPAs.

Meanwhile, the net metering system has also been hampered by the ICMS, the sales tax in Brazil, which has made the schemes more complicated. This tax being removed in several states is a positive signal.

Regional power prices have always been difficult to predict in Brazil. One year ago, prices were increasing until the government cut power prices and now they are rising again after the country faced power supply issues in the middle of the year when droughts interrupted key electricity supply from hydroelectric power stations. These power issues and rising prices should make installing solar systems more attractive in the year ahead, but there is an expectation that the government may now increase subsidies for the overall power sector, which would lower prices once again.

It was not until December 2015 that we saw more positive signals that Brazilian solar can take off. The country had taken longer than expected to start construction of projects, but work recently began on one of the larger projects, so we see some momentum from this. At the same time Brazil is in pretty heavy economic troubles at present and if that impacts the willingness of financial institutions to get involved, that could slow down the process.

Mexico is another market that has not been doing as well as initially expected. This has been due to the energy reform that has been taking place in the country throughout the year. This reform made it completely unclear what will happen with renewables and what power prices to expect and that has slowed down the market for the time being. Now the policy has become clearer, we can expect other renewable energy auctions in Mexico and more solar

Josefin Berg

After making headway in 2015, solar in the Philippines looks set to be one of the highlights of 2016.

Credit: San Carlos Solar

to deployed over the coming year.

Along with Mexico's cumbersome energy reform, there have also been some issues with import taxes, which have made some projects less economically viable.

Is PV in Sub-Saharan Africa still stagnant?

There have been scattered announcements from various countries, but the exact impact will still have to be seen and there is no clear direction apart from the more established South African market. Tenders were awarded in Zimbabwe to Chinese conglomerates. Ghana has been building up a great pipeline of PV projects and some may be starting construction now, but it is difficult to say how much will materialise. South Africa experienced a drop in installations over 2015, but this was down to its being caught in a lull between two large tender rounds.

Did the Philippines live up to expectations in 2015?

The Philippines has developed very quickly this year after clarifying its FiT scheme and putting in a deadline for installations by March 2016. Developers have come to build relatively large projects before that deadline and we've seen various plants get financing, start construction and be installed.

The next step will depend on the next FiT cuts and they have not yet announced what the new tariff will be and how it will function. While there are also opportunities for projects outside the FiT scheme using direct PPAs, right now everyone is building under the FiT scheme.

In the rest of Southeast Asia, Taiwan is coming out with more FiT announcements and looks good for the coming year, but there is no clear growth path for the other markets.

In Pakistan and Central Asia there have been a few big projects, but there is not an enormous pipeline building. These countries don't hold opportunities for everyone, but we are seeing interesting projects in the range of 5GW around Russia, Kazakhstan and Pakistan. It is not a boom but there is some activity here.

Which markets in Eastern Europe should be watched closely in 2016?

Poland finally approved the new legislation for renewables in 2015, but we are still looking into what exactly will come out of this. A lot of companies there have a pipeline ready and are prepared to participate in tenders.

How did your predictions for 2105 fare?

Worldwide in 2015, most markets took off in line with what we predicted. However the announcements in Morocco, which were very positive, were something we didn't completely expect. Mexico's stagnation with the energy reform and Brazil's lack of deployment have been the main disappointments, but Brazilian announcements have been very encouraging and now we just need to see how many megawatts get installed and when. Meanwhile Chile and the Philippines will continue to be strong emerging markets this year. ■

Flickers of solar progress in West Africa

Solar in West Africa may have been slow to kick off, but the last year has seen notable progress across the region. Mahama Kappiah, executive director of the Economic Community of West African States (ECOWAS) Centre for Renewable Energy and Energy Efficiency (ECREEE), tells Tom Kenning what potential solar has to revolutionise the energy sector in a region that suffers from severe power deficits

PV Tech Power: How has solar in West Africa progressed so far?

Mahama Kappiah: We would have expected to see more solar and quicker deployment up till now. Nevertheless it is really picking up. Initially there was scepticism from governments because the costs were high and the technologies that they deployed as pilot projects in earlier stages did not stand the test of time.

A lot has changed in the past five years. Now there is much more awareness and interest in climate issues in the region and that is pushing the PV drive now. Finally in 2013, after several years of difficulty, we managed to adopt a regional policy document on renewable energy. This was a landmark achievement and based on this document we have been working with all the member states to set targets for renewable energy technologies within their energy mix for 2020 and 2030. Positive change is coming in.

Furthermore, there are signs that the small pilot rooftop systems that were being played around with are becoming greater in scale.

We have seen large-scale solar projects coming up with a 5MW solar PV park in Santiago Island in Cape Verde, alongside a 2.2MW park and another 20MW park in Ghana, which has just come online. We also just helped Mali (20MW), Burkino Faso (20MW) and Sierra Leone (6MW) to prepare bidding documents for solar PV auctions. Ghana is also planning to auction another 20MW.

In the absence of stable grids for larger projects, what do you see as the best strategy to utilise solar in the ECOWAS region?

The other approach is distributed generation (DG) including solar home systems. The DG model does not disturb the grid in any way and it reduces system losses. Ghana for example is already planning to have rooftop systems up to 200MW [in total]. That is wonderful, but now customers are not being given any incentive, nor are suppliers being given motivations to enter the market and bring down prices that are attractive to the customers. Nothing is being done on the ground to support this programme. The government met and that was the end of it and you will not get 200MW in this way.

After the announcement, they should have put in place concrete measures to entice individuals to engage in rooftop solar. Instead companies are quoting very high prices for small installations. The government instead could provide a credit scheme to ensure consumers get a decent price. Within one year you could get the 200MW installed, but if they leave it to the market, anybody can charge anything.

Still, the DG model is suitable because most of the grid networks in these countries are composed of either one line that tends to stretch for roughly 1,000km, or they do not have a grid at all. Senegal, Mali, Côte D'Ivoire and Burkina Faso each have just one line, meanwhile Liberia, Sierra Leone, Guinea and Gambia have no grid. However, Ghana, Togo, Benin and Nigeria do to some extent have a grid.

What is ECREEE doing to promote renewables such as solar to industrial energy users?

We tried one project in Niger where a French company wanted to build a 20MW PV plant to supply an industrial area very far from the grid, but it failed because the private sector operator could not agree on the price. However, the same operator did eventually agree a price for a similar project in Benin. In the coming years, we will see large PV parks coming in to the interconnected network to support industrial areas, but so far we don't have any.

To what extent do you see potential for solar to be part of cross border energy trading in West Africa?

In July, ECOWAS proposed a 2GW solar corridor in the Sahara region from Senegal to Niger, which would involve seven or eight solar plants coming together. We are looking at how to develop this project further and get it implemented. If commissioned, it will become the largest solar park in this region. There are countries in the Sahara that have enormous amounts of irradiation, far more than their needs. When talking of a solar corridor the first countries to show interest are those in the Sahara. They see an opportunity to produce energy and ship it to the coast in the south.

> "We would have expected to see more solar and quicker deployment. Nevertheless it is really picking up. A lot has changed in the past five years"

As far as rural electrification is concerned, to what extent is pico solar a sustainable long-term solution?

Pico solar is particularly important because, as mentioned earlier, most of the countries in the region do not even have a grid. If you say people have to wait for a grid before getting electricity then they will have to wait another 30 years; pico solar is not a solution

Activity in West Africa's solar market is beginning to stir.

Credit: Wegmann, Wikimedia Commons

for the future, it is a solution for today.

We should start today building mini-grids and even solar home systems, depending on the settlement structures, to ensure that whilst we are providing grid-connected electricity for the urban communities we also provide something for the rural folks. If not, these are some of the things that will drive more people to come into the city and cause consistent urban migration. With pico solar, people are less likely to migrate to cities, because they will now have available in their rural communities what used to be exclusive to the city. There will be no need to go to the city and struggle to find a meaningful job. They can stay in their rural settlements and work on their farms to produce enough and still enjoy the comfort of their home.

So, in south Senegal we are building 40 mini-grids of 20kW each in 40 communities, which have never had electricity before, having secured funding from the European Union. The communities are very happy because even though we have not started installation this year they are very excited about having electricity.

What is the role of mini-grids and what can stimulate further deployment?

In some of these countries there is not a single transmission line so how are you going to connect communities? This makes the advantages of mini-grids more attractive and Mali and Senegal are making them more of a government policy. They can give installers a concession to deploy mini-grids if they identify a suitable community. The mini-grid prospects are, however, less strong in nations like Ghana where the grid reaches most locations apart from some lake-based communities.

Are solar parks, such as those seen in India, where the government purchases the land, applicable in West Africa?

It would be very good if West African countries adopt such a policy. The Cape Verde government provided land for the 2.5MW solar park despite being one of the smallest countries in the region.

Other countries are not doing the same, which is a problem because sometimes people have huge difficultly acquiring land. Furthermore, when you allow people to negotiate with local owners for land, some will take agricultural land for the solar PV park. Meanwhile, there are other areas where land is actually far more suitable, but landowners are not allowing it. Governments coming in could solve this problem.

What are prospects for solar and other renewables in West Africa for the next few years?

We expect to see a drastic growth, particularly in the solar PV sector. The present drop in crude oil prices poses a challenge because countries will be tempted to say that now fossil fuel power plants are going to be a lot cheaper to operate than renewables. However, the low oil price also presents an opportunity for renewable energy technologies to bring themselves down to cost-competitive prices so that they can still be in the market in the long run. That presents a very interesting scenario for now. ■

Mahama Kappiah will be among the speakers at the second Solar & Off-Grid Renewables conference in Accra, Ghana on 19-20 April. Hosted by PV Tech's publisher Solar Media, the event will explore the opportunities and challenges for solar and other renewables in the region. Further details are available at westafrica.solarenergyevents.com

How Indian rooftop solar will come out of the booming utility-scale shadow


Credit: Tata Power Solar

Rooftop solar | Although rooftop solar is expected to account for 40GW of India's 2022 target of 100GW, the sector has so far been slow to take off. Tom Kenning looks at some of the barriers to growth in this vital part of India's future energy mix

India's rooftop sector reached a significant landmark at the end of 2015 when Tata Power Solar installed one of the largest ever rooftop projects standing at 12MW capacity in the state of Punjab. It was a relative rarity in India; despite rooftop solar accounting for potentially 40GW of India's massive 2022 solar target of 100GW, so far action on the ground has been dominated by the booming utility-scale sector.

Indeed, many stakeholders have been left scratching their heads over what has so far been a muted lack of progress towards reaching the enormous 40GW earmarked for the rooftop sector. Even Ministry of New and Renewable Energy (MNRE) joint secretary Tarun Kapoor has admitted it has been a "slow start" and the industry has "not been very convinced" about rooftop in India so far. In short, rooftop PV in India has yet to ignite.

"Given that just a year back the cumulative number of installed solar rooftops was about 400MW, getting to 40GW is a huge path to walk," says Adarsh Das, co-founder and chief executive of Indian PV developer Sunsource Energy. "It is going to be a major challenge for the sector to get that kind of scale-up."

The Indian government has deliberately kept the price of power low, which makes residential solar unattractive in economic terms, says Das, but as these prices start rising over the next one to four years, residential rooftop solar will start to become more viable and suitably priced.

Rooftop cannot take off as quickly as the utility-scale market, which is booming, says Jasmeet Khurana, associate director consulting at analyst firm Bridge to India, however he forecasts an approximate 60-70% compound annual growth rate (CAGR) for the rooftop market. While there are multiple government incentives and policies in place, it will still take another six to 12 months for them to hit the market. For this reason, MNRE's target of jumping from 200MW rooftop in 2015/16 to 4.8GW in 2016/17 appears improbable.

Rooftop solar in India is still far from living up to its vast potential.

If the government pushes through with its plan to kick-start the market by deploying rooftop solar across most government buildings and railways, says Khurana, then that 4.8GW may be achievable. Yet Bridge to India still only forecasts roughly 500MW of rooftop to be installed next year, unless another major supportive policy initiative is announced.

While most companies have been focusing on the vast utility-scale capacities being tendered by state-owned entities such as National Thermal Power Corporation (NTPC) and Solar Energy Corporation of India (SECI), Khurana says: "Everybody understands that the market will shift from utility to rooftop – maybe not in next two to three years – but maybe after the government support for large-scale projects dries out.

"Strategically, I don't think any company can deny that the rooftop market will be important in the future. Some larger companies, which have been on the utility-scale side, are now beginning to explore the rooftop market. Consumers are also now starting to understand the dynamics of the rooftop solar system for their businesses or their homes, but for now, in relative terms, utility-scale is still the flavour of the town."

"There is a supply and demand issue on rooftops," says Bikesh Ogra, president of India-based EPC firm Sterling and Wilson's electrical and solar business. "The costs are dropping faster on utility-scale and the tariffs are reaching or even crossing grid parity, but if you talk about rooftop, it is very complex engineering. Each rooftop is a customised solution. You need to visit the roof to understand the limitations and the cost can vary significantly. A 20% swing is possible on a given rooftop cost."

Nevertheless, the company is still keeping its hand in in the rooftop sector, says Ogra, because it realises that in five years' time there will be an evacuation issue with larger PV projects and the distributed generation rooftop sector will become far more prominent.

Government rooftop PV incentives

Encouragement to domestic households for installation of solar panels:

- Generation-based incentives and viability gap funding for solar
- Accelerated depreciation, concessional custom duty, excise duty exemptions, income tax holiday for 10 years
- Concessional loans from IREDA
- Loans under 'priority sector lending' up to INR150 million for renewable energy projects with preferential interest rates
- Bank loans as part of home loan/home improvement loan for rooftop PV
- Subsidy for grid-connected rooftop solar, solar pumping systems, concentrated solar thermal and other off-grid solar applications.
- Subsidy of 30% of benchmark cost provided for general category states and 70% for special category states.

Financing and policy

The government still has a role to play in making rooftop solar as attractive as possible and it has set in place various incentives (see box, above). Ultimately, however, the sector has to be driven by the private consumer and rooftop owners, which means the uptake of rooftop will depend on its economic viability, says Khurana.

Foreign banks are also arranging the means to provide low cost financing through concessional loans to the sector, according to the MNRE. The World Bank, Asian Development Bank (ADB) and the BRICS New Development Bank are planning to provide US$500 million each.

The Indian government has re-introduced a 30% subsidy for rooftop solar projects.

"We are working with a public sector bank to create a rooftop debt fund," says Mohua Mukherjee, senior energy specialist at the World Bank. "We are essentially trying to make it very easy to do the third-party ownership model."

Mukherjee describes two third-party ownership models, including BOOM (build, own, operate, maintain) and BOOT (build, own, operate, transfer). The World Bank is also making money available for aggregators who own rooftop solar systems across the country. If the concessional loan scheme from the various banks works, says Khurana, it will probably become the most accessible subsidy route for end customers.

In another financial boon, the Indian Renewable Energy Development Agency (IREDA) has also launched a loan scheme for rooftop PV. Interest rates for loans under the scheme are ranging from 9.90% to 10.75% per annum, which is lower than rates for standard loans of around 12%. The minimum capacity of each system eligible for these loans is 20kW and a minimum of 1,000kW for aggregated capacity, with repayment periods of up to nine years.

Meanwhile, towards the end of last year Kapoor announced the return to the original rooftop subsidy level of 30%, up from the ineffectual 15% rate. This was followed by the news at the start of 2016, of an eight-fold, US$660 million increase in the subsidy budget, which could put to rest historical subsidy bottleneck issues

Credit: Tata Power Solar

that stemmed from a lack of funding (see box, below).

Indian challenges

Aside from financial and strategic incentives, for installers there are many challenges both unique to India and typical of any undeveloped rooftop market.

Sunsource's Adarsh Das says there are grid stability issues when using decentralised rooftop PV, which could become the biggest bottleneck; meanwhile clients are worried about higher efficiency solar technologies coming to market five years from now making them hesitant to invest now. There are also issues with the credit quality of the consumer. "For example in Uttar Pradesh it is very possible for someone to say – we are just not going to pay the bills," adds Das. "What do you do then?"

Furthermore, debt financing is difficult, as banks may not have the same faith in the client as the solar company does, Das says.

There are not many residential roofs in India where solar can be easily deployed, adds Reinhard Ling, managing director at Germany-based PV company IBC Solar, so a major part of the capacity will have to be on commercial and industrial buildings. This observation is backed up by MNRE's policy of excluding the private commercial and industrial sector from the rooftop subsidy scheme, because these sectors are expected to build up enough momentum on their own.

Vineet Mittal, vice chairman of India-based developer Welspun Renewables, also says that India has a unique problem with rooftops because they are often used as entertainment venues due to limited open space elsewhere. Contract enforcement is also challenging, alongside a lack of open access in certain states.

While net metering policies are in place for at least 16 states, full implementation of net metering schemes across the country is still patchy, but Mittal is confident that these policies will start to progress after the new Renewable Energy Act comes into law, expected to happen later this year.

State variations

At individual state level in India, there are large variances in the schemes for rooftop solar.

"Net metering is a little bit different in almost every state," claims Adarsh Das. "For example, in Delhi you have to get approval for net metering after you have built up the plant, but in Bangalore you have to get it before you build the plant. You have to be very mindful of each of these things."

However, the different policies between states will not adversely affect growth, says Khurana; it simply means that growth will not be homogenous across the country. Progress in each state will depend on how well the policies are planned and implemented, and whatever subsidy scheme is opted for, with some states powering ahead.

The state of Haryana was previously planning to make rooftop solar obligatory for buildings, but this plan did not take off due to poor planning and lack of time, says Khurana; however, this kind of policy will probably start having a role in two to three years. "If a state manages to successfully implement something like that, it can be a big game-changer for the future," he says.

State-led schemes and allocations are still likely to be the biggest driver of rooftops as long as subsidies are available. The state of Kerala had introduced a system where residential systems of 1kW were given a subsidy. This is likely to be taken up by several states, says Khurana. Historically, Tamil Nadu, Andhra Pradesh, Gujarat and Bihar all made movements towards this policy, but they were hindered by a lack of subsidy funding.

Madhya Pradesh, Punjab and Uttarakhand have also tried aggregating capacity allocation routes, in a similar vein to that of SECI.

MNRE says that states could improve the outlook for rooftop solar by making it mandatory in new buildings where possible, simplifying procedures for installation, preferably through a single-window clearance mechanism, and interacting with banks to ensure low-cost financing for the solar systems.

Distributed generation

A large part of the 40GW rooftop target is distributed generation PV says Rajnesh Trivedi, senior director, sustainable investment banking, YES Bank, but there are question marks over who will be the consumer in remote villages.

"The government has to encourage the private sector to put up rooftop and distributed generation projects and deliver power to places with no infrastructure, but again there are questions over the counterparty and subsidising," Trivedi says. "The individual size of the projects is so small that it is very difficult to get financing."

Furthermore, Ling says that the distributed generation aspect of the target is being neglected: "I don't see at all the decentralised approach in India. It's going in the opposite direction."

The vast number of individually installed small-scale systems required to reach the overall 40GW rooftop target and a palpable void in any comparable achievement anywhere else in the world have resulted in a level of doubt in the industry. However, the influx of foreign investment and players into what is now a cutthroat market at utility-scale level may yet spur a sudden thrust in the rooftop sector once the focus starts to swing. The fact some of the big utility-scale players are maintaining a small hand in the rooftop sector is also a telling indicator that many expect it to become a fruitful market in years to come. ■

Indian rooftop solar: quick facts

- Indian market potential for rooftop PV is 124GW. Technical potential is 352GW
- So far 2,080MW grid-connected solar PV plants sanctioned/ approved and 120MW commissioned
- Proposals of about 800MW have been received
- 16 states have come out with solar policies supporting grid-connected rooftop systems

The US$660 million rooftop budget increase

MNRE is trying to solve past issues from a lack of funding for subsidies through an eightfold increase of the rooftop subsidy budget from INR6 billion (US$90 million) to INR50 billion up to 2019/20, according to Bridge to India's Jasmeet Khurana.

Previously there were not enough funds so the subsidy became a bottleneck in the market, says Khurana. The government is trying to address that issue by reducing the scope of the subsidy by removing it from the commercial and industrial sector. The government also does not want to be seen as completely pro-business and not pushing for the residential sector and others to grow.

The government can then use the extra funds to kick-start rooftop solar in the institutional and government-building sectors.

Khurana says government buildings and public institutions such as hospitals, colleges and schools stand to benefit the most from the subsidies because they tend to have larger installations and pay higher tariffs. Whereas, even with the subsidy, the smaller-scale residential sector will see a slow uptake and will not gain as much as the government would hope, he adds.

POWER PVTECH

SPECIAL REPORT

Solar in the Middle East and North Africa

Perfect storm

The global forces driving solar on in MENA

Making it MENA

Lessons from the region's pioneer solar developers

Mopping up

Effective O&M strategies for desert PV power plants

Desert-proof

Solar hardware for desert environments

Perfect storm sets scene for solar in MENA

Market update | Falling fossil fuel subsidies, rising power demand and squeezed public coffers are bringing the most cost competitive power source to the fore in the Middle East, solar. John Parnell looks at the numerous routes to market emerging in the Middle East and the developments driving them on

Credit: Masdar

It's understandable that some in the solar industry became a little exasperated by the early days of solar power in the Middle East. There was lots of talk and huge solar targets were dangled in front of the industry. The ambition was there before the necessary regulations, resulting in what appeared to be an epic false start. Saudi Arabia announced it would invest US$109 billion into solar back in 2012. This was coupled with a 41GW deployment target by 2032.

"I understand why you might call them false starts but I would just say they were delays for a new market," says Dr Raed Bkayrat, research director at the Middle East Solar Industry Association (MESIA) pointing out that many in the region, including Saudi Arabia, are still undertaking the reforms necessary to build a sustainable solar industry.

Some countries in the Middle East are further along with that work than others. Successful tender rounds and the above-expectation performance of the earliest proof-of-concept projects have helped hasten along a string of additional tenders. The successful financing of the 200MW second phase of Dubai's solar park has shown that low-cost large-scale solar is bankable in the region.

With the main hurdles overcome, the next question is what shape will the next phase in the market's development take.

Bkayrat authored MESIA's recent 2016 Market Outlook, which puts anticipated tenders in the region from seven different countries in 2016 at 4GW. That's on top of the 2,972MW either under construction, with contracts awarded or with a PPA signed. There are numerous drivers behind this government-led procurement and it is Saudi Arabia that demonstrates these most succinctly.

According to Bkayrat, Saudi's peak load in summer is 58GW. The total installed capacity is 62GW. In winter, peak load is 27GW. Using solar to provide that peak power is eminently sensible. The use of trackers can deliver a flat peak or a delayed peak, to target the early hours of the afternoon when air-conditioning demand nudges the needle to its highest levels.

A combination of local and global phenomena have created good growth conditions for solar in the Middle East and North Africa.

Middle East solar procurement in 2016 (in MWs)	
Morocco	245
Algeria	2,000
UAE	1,150
Jordan	120
Egypt	250
Saudi Arabia	170
Kuwait	85

Source: MESIA Outlook 2016

When oil was US$100 a barrel, the further case made for solar was that it would free up oil and gas for export. So what do today's price levels do to the case for solar?

Scraping the bottom of the barrel

The price of oil has reached lows not seen for more than 10 years, dipping below the US$30 mark at one point. As the price of oil plummets, there is an assumption that this undermines the case for deploying solar power. In the eye of that particular storm, the Middle East, that logic is assumed to be even more potent.

For oil-producing nations encumbered with highly subsidised fuel at home and now with a major dent in their income, an unlikely opportunity presents itself. While the price of the raw material falls, the saving can be used to decrease the subsidy component. Reducing subsidies is not popular and creating unrest among its citizens was not an option the wake of the Arab spring.

In the last few months however, Kuwait, Saudi Arabia and the UAE have all brought the costs of fuels closer to market prices.

"Five years ago when oil was US$100 they were enjoying massive revenues and investing heavily in infrastructure; they were not too worried by the energy subsidies and they didn't pay too much attention to solar," says Bkayrat. "They started talking about solar five years ago but the motivation wasn't there because the cash was flowing in nicely. Most of the projects they were tendering were on an EPC basis and the government owned the asset, they weren't public-private partnerships or an IPP model. As cash started drying up, this brought to a halt the infrastructure projects tendered on an EPC basis and forced the government to revise their subsidies."

Bkayrat points out that with the EPC-only option off the table, and many countries facing double-digit growth in annual peak load, they need to turn to the private sector.

"The second point, which is another blessing in disguise of the drop in oil prices, is the fact that the low [energy] prices need to be revised and are being revised. The UAE has already revised the price of gasoline last year and this year all the subsidies for oil and gas and electricity rates in the UAE – deregulates them basically.

UAE energy minister Suhail al Mazrouei told the World Economic Forum in Davos this January that subsidies on electricity would be scrapped in an effort to reduce the country's dependence on the oil price. Egypt has also taken measures to reduce subsidies but the bigger development lies back in the Gulf.

"Saudi Arabia has started the process too, five years ago it would have been unheard of and now it's happening. It's the first step in a five-year reform," Bkayrat says. The reforms will increase the cost of natural gas by 67%. "Together, all those things are positive for the solar industry and even with oil at US$30, our cost of generation from solar is on a par with the average cost of generation in GCC countries," says Bkayrat. "Another industry's misery is a blessing to solar."

One immediate impact that rising liquid fuel costs have had is in the viability of off-grid commercial projects. In Saudi Arabia, Saudi Aramco has been an early mover and First Solar recently completed a demonstration project for a major agricultural firm in the kingdom.

"Diesel [in Saudi] has doubled in price from seven to 14 US cents per litre. That has shifted the cost of generation from four cents all the way to about seven to eight cents per kWh. That alone is creating a lot of attention," says Bkayrat. "Electricity will, I expect, float at nine cents for industrial applications and solar is in the range of six to seven cents. It is already making an economic case and we are seeing a lot more movement now in the commercial and industrial space [in KSA] because of these fuel and electricity price increases."

Jordan eyes next phase for solar

Jordan deserves the plaudits for getting its IPP programme up and running and the second 200MW phase drew bids ranging from 6.13 to 13.27 US cents per kWh.

The country increased its solar capacity target for 2020 from 600MW to 1GW but law firm Eversheds' head of clean energy and sustainability, Michelle T Davies, says there could be more cause for optimism outside of the government programmes.

"The real opportunity in Jordan, because its power prices are so high, is in the merchant project space that is net metering and wheeling projects," she says.

"Jordan's regulations preclude a split between asset ownership and the offtake so developers cannot own the projects and sell the power to an off-taker. Accordingly, high energy users will have to own the asset and contract the developer basically as an EPC. The developer cannot be the asset owner. Various structures are being developed to allow something more akin to a pure merchant project whilst remaining within the broader confines of the regulation,"" she says, although at the time of writing the requirement for the off-taker to own the asset remained.

Egypt finds many ways to skin a cat

While Dubai's IPP programme has grabbed the headlines of late, and Jordan deserves kudos for its work getting through two tender rounds, it is arguably Egypt that has the most potential for the solar industry in the more immediate future.

The country completed a tender for 2.3GW of solar capacity available under a feed-in tariff (2GW of large-scale and 300MW for projects under 500kW). It was hugely oversubscribed. Eversheds' Davies says progress on those developments has been positive.

"It was oversubscribed but there was concern that the currency liquidity challenges which caused issues for certain banks could have resulted in not all of the 2GW getting through but recent developments over the last few weeks seem to indicate otherwise. The first round of solar is looking good and a significant percentage of the projects have secured funding with many others in the process of doing so," she says. A host of development banks are involved and commercial banks are now looking at whether they can do the same, she adds.

While it is the largest, quantified source of solar demand in the country, the FiT programme is by no means the only one. There is also a build-own-operate (BOO) tender for 200MW of solar capacity in the West Nile region. Davies says these will be paid out in dollars, removing the currency risk that has complicated the issue the some would-be bidders.

Then there is scope for direct agreements with the government, such as the UAE's Masdar and Saudi's ACWA Power are doing through a joint venture. Merchant projects are also an option but those opportunities could be limited by the number of bankable off-takers and whatever the wholesale power price might do in the near-term.

"Finally there are the Suez Canal projects and these are the ones that many have their eye on," says Davies. "We could be looking at very, very large projects, particularly solar, to service the various developments around the Suez Canal Authority's ambitions, which are significant. Egypt is more diverse and allows for merchant off-take to happen, and it is quite possible, that as hopefully more blue chip offtakers invest in Egypt, this will be the next phase of focus."

How low can you go?

The opportunities are numerous and varied in the MENA region, encompassing feed-in tariffs, IPP, merchant and everything in between. With the help of some cheap finance, ACWA Power's Dubai project has set the bar for PV pricing in the region with its sub-6¢ solar project. So will this price have governments and off-takers around the region scrutinising the pricing of their solar power?

"Definitively," says Gus Schellekens, partner in consultancy EY's clean energy and sustainability practice in Bahrain. "In the UAE the benchmark will now be the Dubai project and only lower offers will be considered. For other countries other factors are still in place so prices will remain higher for some time but a downward trend will also be expected."

Schellekens also expects desalination and hybrid projects (already under tender in Saudi Arabia) to become more common. He also suggests that developers should consider approaching potential off-takers directly as the amenability to (slightly) smaller projects increases.

So with PV costs continuing to slide and both electricity and liquid fuel costs rising, the economics are stacking up nicely and further dramatic downward surges in the region may not be needed. Governments and industrial customers are paying attention. It may be a while before anyone announces ambitions on the scale of Saudi Arabia circa 2012, but it is projects not targets that count, and across the region, including Saudi Arabia, solar is stepping out of the shadows. ■

Making it in MENA

Strategy | The Middle East and North Africa region offers many exciting prospects for solar developers, but also presents challenges for new entrants. Ben Willis looks at what they could learn from the early movers in the region getting the first wave of projects off the ground

Credit: Masdar

The solar opportunities emerging in the Middle East and North Africa (MENA) region have put it squarely on the A-list of project-hungry developers. From a handful pioneer companies that took an early lead in countries such as Jordan, recent tenders have seen players from France to Japan enter the picture, drawn by the multiple government-backed programmes springing up across the region.

But the opportunities emerging in the MENA region are not without their challenges for new market entrants. While the complaints voiced by some of MENA's first movers – of opaque, labyrinthine contractual processes – have to some extent abated, the view of developers and IPPs approached by PV Tech Power is that despite the apparent pace of solar's emergence in the region, playing the long game is nonetheless an approach that pays dividends in this part of the world.

"The process of developing projects can be very lengthy – definitely lengthier than what we're used to in our home markets," says Adel Baba-Aissa, director of Renewable Energy Partner, a UK-based project developer currently working on the first independent power producer solar project in Algeria. "The main thing really is patience; you've got to realise this is a different market, so whatever you factor in for your home market, you've got to scrap that, throw it out of the window and rethink it completely."

Of course, much of that work is just part and parcel of the process that must inevitably play out as the officials and key personnel in countries coming to solar for the first time become familiar with its specific commercial intricacies. Here again the consensus is that patience is the watchword, and indeed it would seem to be in the interests of prospective developers to help move that process along by taking the lead in educating other parties on how project contracts should be put together.

The first PV projects are appearing in the Middle East and North Africa

Raymond Carlsen is CEO of Norway's Scatec Solar, which is currently building three projects in Jordan under the kingdom's first-round tender and currently moving forward with projects under Egypt's 2GW solar feed-in tariff. The company was also one of the early movers in South Africa, whose IPP procurement programme is regularly held up as the gold standard for such initiatives.

In all of these markets, Carlsen says, early negotiations have been protracted but necessary in order to produce satisfactory contracts. "There are a few challenges; we have seen this elsewhere: when a programme starts you need to adjust the regulatory regime to match the contractual requirements of an IPP. And doing that for the first time takes a bit of time," he explains.

Such requirements cover everything from land lease arrangements to payment terms for power purchase agreements. Carlsen says that on all of these, it is up to individual developers to help authorities understand their particular requirements and ensure watertight contracts. He cites the case of Egypt.

"We have been interfacing with the authorities for a long time providing information on how these programmes have been implemented in other countries," Carlsen says. "In Egypt's case, they have been able to absorb that and understand how this would impact the regulatory regime in their own country and where you need to make certain adjustments to make these projects bankable and make them fly."

Currency and tenders

One particular issue that has not yet been resolved, and which appears to be a source of some concern at the moment, is the question of foreign currency risk in the MENA region.

"Most MENA countries are linked to how well or badly the oil and gas markets are doing," explains Baba-Aissa. "This has seen a lot of volatility in the currencies, which means there are issues around liquidity as some of the PPAs are payable either partially or totally on foreign currency – i.e. US dollars. And since revenues in most of these countries are highly dependent on the sale of oil and gas, there is some risk that there may be a liquidity risk there."

Baba-Aissa stresses that the risk from this is not immediate, but is something developers should be aware of looking further ahead. "A lot of the oil and gas-rich countries are still sitting on massive reserves of dollars, so it's not something you need to worry about for probably the next 12-18 months, but if prices continue, it's definitely something to bear in mind," he says.

It's an issue that is certainly on the radar for Rafael Benjumea, CEO of Fotowatio Renewable Ventures, a Spanish firm that was recently acquired by the Saudi Arabian conglomerate, Abdul Latif Jameel. The company is involved in Jordan's 200MW second-round solar tender as well as working on projects in Dubai and Egypt, and in Egypt Benjumea says the currency question is a particular issue. "We are looking at it very deeply to understand how can we solve it and how can we get comfort with that as a long-term investment," he says.

Another matter that has emerged in some of the other programmes in which FRV is participating is that of the level of evidence required of financial backing at the bidding stage. In the case of the Dubai tenders, for example, bidders have been asked to have financial close on projects or committed finance from banks, something that Jordan, for example, does not ask for at that stage. Demanding such levels of finance-readiness is not always helpful in realising the best possible price for a project, Benjumea says.

"My preference is to be less committed when I am bidding," he says. "I am happy to give a letter of credit to support my bid and I am happy to commit my reputation, but I have learned that if I win a project my ability to negotiate with providers and banks is much bigger than if I am in the bidding process. Those kind of tenders, where they request everything is fully closed, are introducing some inflexibility that will have some impact on prices."

Such requirements are no doubt intended by authorities to act as safeguards against overzealous bidders getting carried away in the increasingly cutthroat tenders taking place in the MENA region. These have become a central feature of the MENA markets in the past couple of years and yielded some memorable headlines, the most notable being the sub-US$0.06 per kilowatt-hour winning bid from IPP ACWA Power for the 200MW second phase of Dubai's Mohammed bin Rashid Al Maktoum Solar Park, eventually expected to top 5GW.

While for solar in general the increasingly competitive pricing seen in some of the MENA tenders is a positive story the flip-side to that is that it makes market entry harder for smaller developers. According to Baba-Aissa, non-tender procurement processes are increasingly rare in the region, other than in Algeria where his company is active.

"We're definitely watching this trend very carefully," he says. "We're seeing a lot of countries outside of the MENA region, even in sub-Saharan Africa, going this way. There are still enough markets out there that are not tender-based that it's ok for now. But if more and more countries go down this route, it is going to exclude quite a big section of the market. This is a worrying trend the way we see it."

Nevertheless, for Benjumea the tender process in the Middle East has been an "efficient" way of quickly stimulating market activity, particularly in Egypt, where the demand for power is immediate and pressing. "You only have to see the result of the prices," he says.

Carlsen also highlights how the increasingly low pricing being achieved in some of the Middle East tenders signifies crucial advances in the way the solar industry is securing finance.

"People tend to look at the price per kilowatt hour without understanding what brings you to whatever level that is at," he says. "The ACWA project was pretty competitive. But if you dive below the clouds there and look at how they can do that, well it was because they had financing that had never been seen before."

That's a key point, as aside from the cost of equipment, the cost of capital is the other key determinant of a project's overall price. Carlsen believes that the prices being achieved in the Dubai tender indicate how much progress solar is making from an investor perspective: "We've seen the same in South Africa, we've seen the same elsewhere: financing is becoming more and more competitive, which is good for the industry as a whole."

And it seems likely that ACWA's bid in Dubai won't be the lowest we'll see. In maturity terms, the MENA solar markets are really only in their first stages of development. As they develop, one near-certainty is that whereas until now much of the expertise and money that has been coming into the region's emerging solar markets has been coming from overseas, more and more of that is going to be coming from local sources.

"There's so much money around in the Middle East I'd be surprised local investors aren't going to get in on the act," says Baba-Aissa. "It's natural that for the first tranche of projects for the first few years of when a market evolves from nothing that only the most sophisticated people in the market will take a look at that. But there is going to be this copycat effect as people get more comfortable with technology risk, get more comfortable with the markets and understand that governments really are behind this."

As things stand, the prospects for solar in the MENA region have never looked better. Government programmes appear to be having the desired effect in kick-starting market activity, opening up new prospects and making solar an increasingly competitive energy source for the region.

Seemingly the biggest barrier for would-be developers or IPPs wanting to access MENA's many opportunities at the moment is simply one of competition. But prospectors should not forget that the region's biggest solar-market-in-waiting, Saudi Arabia, has not yet even begun to get going. If the Saudi giant stirs and anything like the +40GW solar programme previously under discussion is put on the table, there will be plenty more opportunities there for the smart developer to take. ■

Solar programme highlights in the MENA region

United Arab Emirates:
- Dubai: Aiming to meet 25% of its power needs from solar by 2030, by which point rooftop PV will be mandatory; 5GW of utility PV planned under multi-phased Mohammed Bin Rashid Al Maktoum Solar Park
- Abu Dhabi: Tender for 350MW of solar planned in 2016

Egypt:
- Targeting 2.3GW of solar by 2017 – 2GW of centralised utility projects, 300MW decentralised

Jordan:
- Contracts for 200MW of PV awarded in round-two tender in 2015; a cancelled round-three tender of 400MW is not expected to restart until grid issues are resolved

Algeria:
- Around 268MW of PV projects completed in 2015; the country is targeting 13GW by 2030, with a feed-in tariff and draft PPA now in place
- One of the few MENA markets not following the tender route

Morocco:
- 20 IPP consortia have pre-qualified for the 170MW NOOR PV I project, with three separate projects expected to make up this capacity. Final winners expected to be chosen in early 2016
- Three projects totalling 75MW are being contracted under a separate 400MW programme by Moroccan utility ONEE, though on an EPC basis only

Source: Middle East Solar Industry Association

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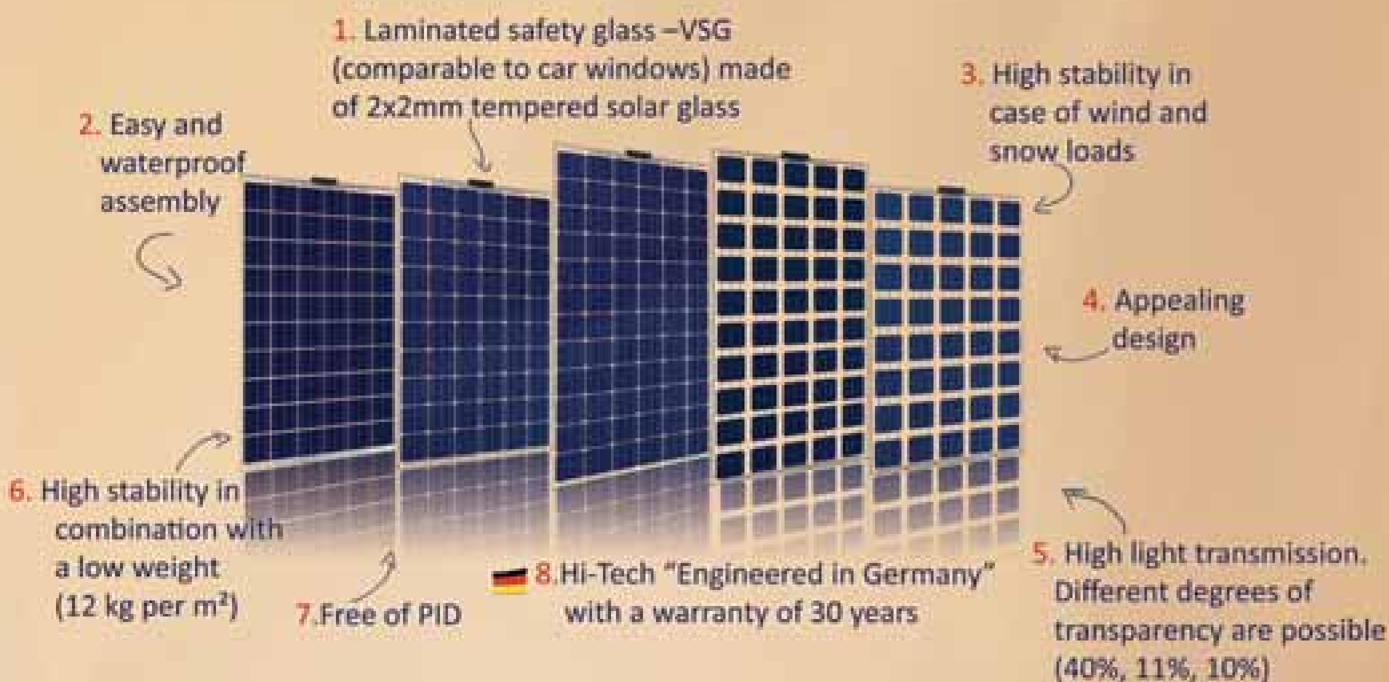

Almaden MENA FZE
Plot 4-001, PO Box: 341497
Dubai Silicon Oasis, Dubai, UAE

M: +971 55 364 8668
mfussi@czamd.com
www.almaden-mena.com

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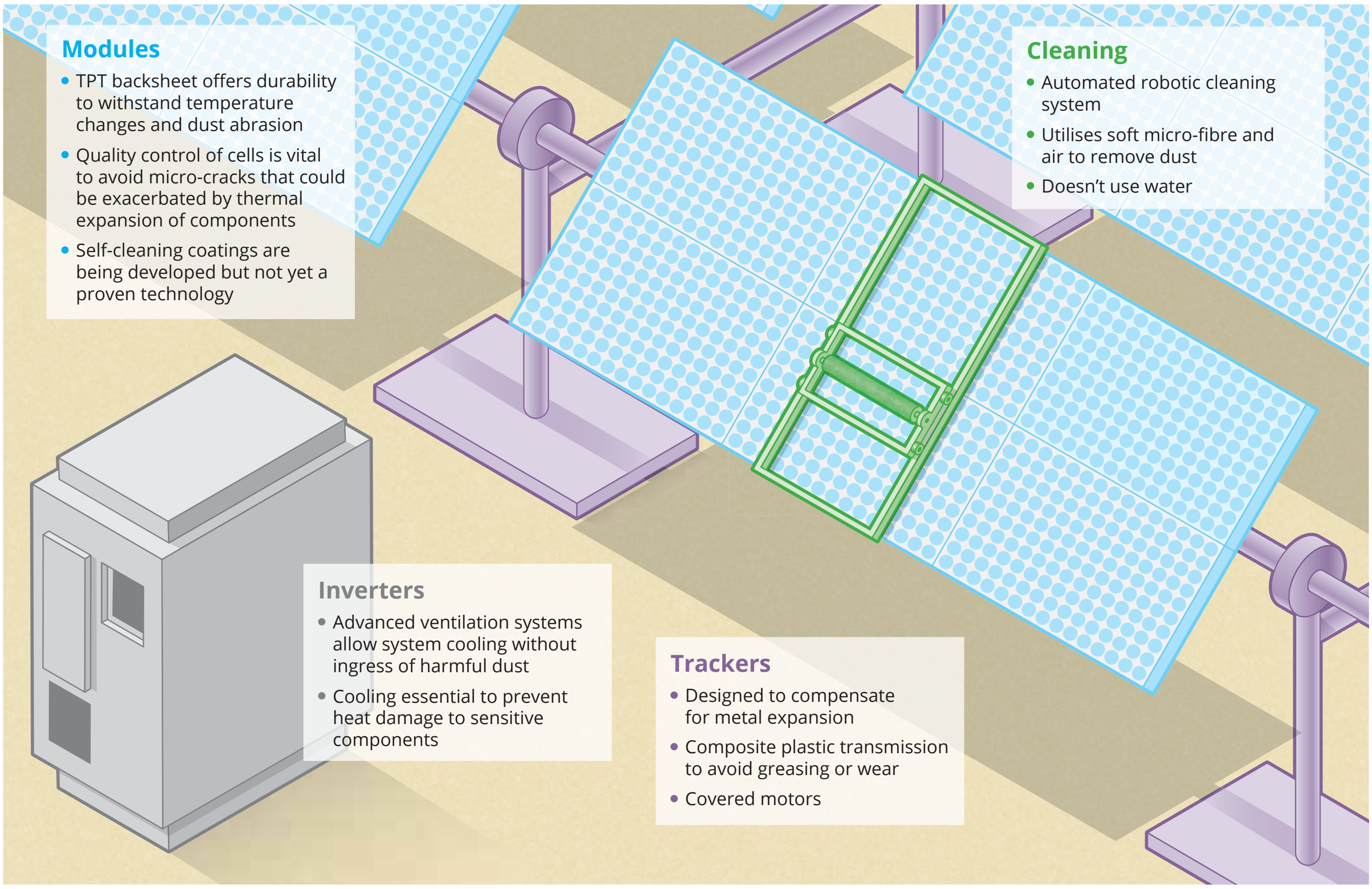
Desert-proof

Hardware | Much work has gone into adapting PV equipment to withstand the rigours of the desert, which range from dust to wide temperature fluctuations. John Parnell and Ben Willis look at how some the main elements of a PV power plant are being made desert-ready



Infographic: Leonard Dickinson

Key attributes of PV system components in desert conditions.

MODULES

Aside from the obvious impacts of dust and sand, PV modules deployed in the desert must be able to contend with large temperature fluctuations.

"In the desert the temperature can go up during the day to over 50C and in the night it can go below zero," says Nabih Cherradi, chief technology officer for Desert Technologies, a Saudi-based developer and module manufacturer. "So you can have a lot of problems just generated by the temperature regardless of sandstorms."

The potential problems caused by such a wide temperature gradient arise from the differing thermal expansion coefficients of the various module components – the glass, cell, ribbon and backsheet. These can inflict damage on cells or exacerbate any existing flaws in cells such as micro-cracks. For this reason, keeping tight control of the quality of cells going into modules to be used in desert areas is of paramount importance, says Cherradi.

Another factor for desert modules is the quality of material used for backsheets. High temperature again is a factor here, but so too are the effects of erosion from sand and dust. Cherradi's view is that only TPT backsheets, which sandwich polyethylene terephthalate (PET) between two layers of polyvinyl fluoride film (often known by its brand name, Tedlar), offer the kind of durability needed to withstand the temperature and abrasive forces found in the desert.

Then there is the issue of dust settling on module surfaces. A number of cleaning solutions have been developed for desert modules (see p.40). Research is also ongoing to develop 'self-cleaning' modules coated with special materials designed to prevent dust settling, but these are not yet proven technologies. Furthermore, says Cherradi, they don't address the issue of humidity, something that can be a big problem in the desert and causes dust to stick, Cherradi claims.

A number of companies produce modules said to withstand desert conditions, but Cherradi is sceptical about some of the claims being made. His main contention is over whether the necessary controls are in place to ensure the quality of the cells in the context of the issue around thermal expansion of components. "I would advise the people who don't have deep technical knowledge, the EPC people, to hire consultants to really check," he says.

Various other research efforts are also going on around the world to develop desert-specific modules. Notable among these is the 'AtaMo' project, which is creating a module designed for the conditions found in Chile's Atacama Desert (see p.55, *PV Tech Power*, Issue 5). As these are perhaps even more extreme than those found in the MENA region, researchers on this project have suggested adaptations of the AtaMo module could be made for the Middle East and other arid parts of the world.

INVERTERS

With more potential for failure during operation than modules, getting the right inverters for your project is crucial. As with other components, heat and dust are the two main enemies for inverters in desert conditions.

Most of the major inverter suppliers have developed technologies specifically designed to allow inverters to function in the desert.

German inverter specialist SMA Solar has developed its own OptiCool system, which, as the name suggests is designed to keep the inverter running in the oppressive heat of the desert. To do this without exposing sensitive power electronics to fine dust and sand, two ventilation circuits run in tandem – one for the less sensitive components using the outside air, and a second internal circuit for the rest, explains Khalid Al-Dam, programme manager at SMA Solar.

"We developed a type of sealing between the two cycles that stops the dust from passing from the outside to the inside ventilation cycle," says Al-Dam.

The sealing between the two cycles becomes vital in order to maintain the separation of the two cycles. "We have to control the airflow," explains Al-Dam. "SMA is a power electronics company though and designing sealing is not our main competence. So what we have done is look at the different sealing techniques and materials in the market and work with a number of partners to find how best to do this."

In order to prove the desert-readiness of its Sunny Central inverters SMA used crushed roof tiles in its lab testing to simulate the finest dust.

"We used this test procedure, based on a lot of projects in the US desert with the same temperatures and extreme climatic condition as the Gulf – temperatures of up to 50C and sandstorms impacting the equipment," says Al-Dam. "So the simulation takes into account the size of the sand and dust and the duration and direction that the sandstorms come from to make sure that we simulate the same conditions as in the desert as accurately as possible."

The inverters are designed to be used outside, walled off but with no roof covering and Al-Dam admits that one customer in the US took some convincing.

"We ran a nine-month test in Arizona, in the Sonora Desert, for two different outdoor systems. There were sandstorms and the test covered the entire summer period. We went back with the customer after nine months to open the unit to see how much dust was in to determine how often the system might need attention and they were surprised that there was almost nothing. So we have come to the conclusion that yes, we can install the unit outside and we can increase the amount of time between maintenance." Ultimately, Al-Dam says, the customer made a "huge order".

Ongoing support was also provided by placing a resident engineer in the O&M department of the customer to learn what they needed at that particular site.

"We appointed a resident engineer with the customer, in the O&M department, who worked together with them. They visited the different PV parks to see what the client needed. Working very closely with them customer gave us a lot of experience, and helped build their trust in the products."

TRACKERS

Trackers are an increasingly ubiquitous part of the modern utility-scale power plant, particularly in areas of high irradiation. With that in mind it is reasonable to assume we'll see plenty more trackers used in projects across the Middle East. With summer peak loads creating headaches, the production profile of a solar plant with tracking offers huge benefits by displacing the use of peaker plants and creating a flat peak over several hours.

But with dreaded 'moving parts' to contend with, how can tracker technology withstand the rigours of the region? Jean-Noel de Charentenay, VP of strategy and co-founder of tracker specialist Exosun explains the company's approach.

"The critical point is the piece that spreads the movement to the table. Our transmission is based on a composite plastic to avoid [the need for] any greasing or wear. That's why we don't need to seal this mechanism," he says.

The fact that trackers are used in areas with high irradiation, which in the absence of altitude tend to be very hot climates, means they are often designed from the outset to cope with harsh conditions, explains De Charentenay. "Everything is also designed from the outset to cope with the expansion of the metal that might occur as the temperature increases," he says.

"We use a protective cover on the motors to ensure they are never hotter than the ambient temperature and they can function up to 50-60C which is the highest temperature you will get in these regions," says De Chartentenay, "and because we use less motors per megawatt, we use higher quality motors that are completely sealed for their lifetime".

Generally, the move in the tracker business has been towards systems that are sealed and require little or no maintenance, an approach that is beneficial anywhere, but particularly in harsh, potentially remote desert sites.

"Simple is better and we try to do that in an elegant way," says Ron Corrio CEO of US tracker supplier, Array Technologies.

"We have eliminated any maintenance from the system; our v2 system had to be greased but now the gearing is in a sealed housing, sealed and lubed for life. Everything is made to survive 30 years without maintenance."

CLEANING

As dust settling on modules can drastically reduce their power, cleaning is a vital part of the operation of a PV power plant in the desert.

Various technologies are appearing on the market to automate this process. However, the jury is still out on which of these offer the best solution to keeping modules operating at an optimal power over their 20-25-year lifetime.

Recent research has suggested that some cleaning systems on the market used with certain types of module can cause damage to module surfaces, leading to a permanent loss of power. Another obvious consideration for cleaning systems in desert environments is that they must minimise or eliminate altogether the need for water use in the cleaning process.

"You have to be sensitive to the environment that these plants are going to operate in," says Scatec Solar CEO Raymond Carlesn. "And of course access to water, soiling on the panels, cleaning frequencies and things like that are going to be very key."

One company that claims to have come up with the answer to the module soiling issue is the Israel-based firm Ecoppia. Ecoppia's robotic cleaning system uses a combination of a soft micro-fibre and air to remove dust, without the need for water or abrasive brushes.

"You want something gentle that does no damage to the PV cells, that puts as little as possible load on the array tables and that can clean for as low a cost as possible, as frequently as possible and with as little need for water as possible. Those are the driving statements we used to build our solution," says company spokesman, Adam Taylor.

Tests of Ecoppia's robot with German lab PI Berlin showed encouraging results. "We did a simulated test for over 20 years, and in that test it was shown we did absolutely zero damage to the PV panels and kept them producing at peak capacity," Taylor claims.

The Ecoppia robot has also been designed to minimise damage to modules through loading. "If you see our robots in action, they're just lightly brushing the panels as they go past, so there's no load on the panels," Taylor adds.

So far, Ecoppia claims to be the leader in what is a relatively new sub-market for the solar industry, with 270MW of its robots set to be installed globally by the end of 2016. But with more and more solar being built in the desert that looks set to change. "There are companies that are keen to get into this space, I think you're going to see a lot of different designs tried," Taylor says.

Mopping up in the desert extremes of the Middle East

Credit: PI Berlin

O&M | The MENA region's conditions present some unique problems for PV power plant operators. As Tom Kenning discovers, getting the right O&M regimes in place is just as important as the technology

Temperatures oscillating from one extreme to another, high winds and copious amounts of sand and dust make the vast desert regions of the Middle East a unique challenge for operating and maintaining a solar plant. Despite recently emerging as a multi-gigawatt market, with more than 4GW of solar power to be procured in the region during 2016, according to recent analysis by the Middle East Solar Industry Association (MESIA), experience of operating a plant in these distinctive conditions is still fairly limited. Lack of access to water has been the main driver for new technologies in this O&M sector with various dry-cleaning and automated cleaning solutions becoming widespread, but there are disputes in the industry over whether these systems can cause more harm than good and what the most efficient method is for keeping PV power plants operating profitability over their planned lifetime.

There are several key causes of concern for a plant operator in desert regions, starting with whether the high temperatures can affect module efficiency. Secondly, while winds can alleviate problems of heat, they can also bring with them sand and dust, which blocks the PV modules. Thirdly, while the extremely limited rainfall in the region can help to clean modules in certain scenarios, high levels of humidity also serve to increase the adhesion of sand and dust on top of the module surfaces. All these factors mean that the seasons have a large say in the frequency of cleaning regimes and how necessary testing and modelling will be.

When it comes to cleaning modules, there are a variety of solutions available on the market, ranging from robots that clean the modules using water, to dry-cleaning systems that use air pressure or brushes.

Klaus Friedl, managing director of global solar developer Phoenix Solar Overseas, explains how Phoenix tested a solar array with oil company Saudi Aramco starting in 2010 for a period of three years and also signed an agreement to perform O&M services on a Turkish plant, to gain an understanding of best practices.

Phoenix purchased a cleaning machine for the Turkey project, which can be taken over the entire module row by hand or behind a unimog, which is an auto four-wheel drive truck, however relatively frequent rain means cleaning is required less regularly than in some desert conditions.

The company tends to stick to a rota of three dry cleans followed by one clean with water, both using brushes. This whole cycle can take place within three weeks or up to just two times per year depending on conditions.

Dust is just one of the O&M challenges in the desert

For a PV plant near to Dhahran, a city located in Saudi Arabia's Eastern Province, Friedl says that cleaning is required every three weeks, partly because it only rains two to three times per year. In the summer, humidity means that sand sticks to the modules. If no cleaning is performed in two months, the plant modules see an efficiency reduction of between 26-32% on average. By cleaning every three weeks there are output losses of just 2-5%.

However, cleaning is less frequent in December to February, when the weather is less hot and dusty, the air is cleaner and less humid, and there do not tend to be sandstorms.

"Dry cleaning is also possible in very dirty environments, if you clean every two to three weeks," says Friedl. "If you leave the dust longer on the modules, then it really sticks to the module surface and you cannot clean it dry anymore. Then you have to clean it with water."

The firm also uses software to calculate when the systems are performing at 2-5% less efficiency, which indicates that they needs cleaning. This is important as plant

operators may have to pay a penalty to the client if the plant is performing below its estimated output.

On the occasion of a dry sandstorm, cleaning with brushes can become obsolete and cleaning manually is often necessary. The modules being at a 20 degree inclination on average also means that cleaning needs to be done more thoroughly than with panels at a higher inclination.

"It's labour intensive but we need the labour only for a day or two depending on the site," adds Friedl.

There are some odd variances geographically. For example, while the Dhadhran plant is located near to the Gulf Coast, opposite Bahrain, where one would expect the benefits of less humidity and more wind coming from the sea, it still requires far more cleans than another Phoenix plant situated in central Saudi Arabia by the capital of Riyadh. The 5.2MW Riyadh plant did not require a single clean in 2013, and it managed to over perform by 6%. The following year, it required just two cleans. The wind climate is fairly similar in both Riyadh and Dhahdran, so in this case it was the humidity that made all the difference in the varying O&M requirements, says Friedl.

Besides dry and water-based cleaning methods, there are various chemical solutions available, however, Friedl says that they have not been working as well as expected. As a result Phoenix has continued with brushing methods, which always require approval from the module manufacturer first so that the guarantee or warranty is not lost should damage occur.

Trial and error

Sami Khoreibi, chief executive and founding partner of Middle East and North Africa based solar developer Enviromena, says that humidity and moisture levels dictate what time of day modules are cleaned on Environmena plants, however it is generally a regular schedule. For example, unexpected morning dew can mean delaying a clean to make sure the modules are dry before beginning.

"When it comes to O&M it is actually quite simple," says Khoreibi: "Keep the panels clean and ensure that they are cared for after something like a sandstorm, which is a relatively rare occurrence."

Khoreibi also insists that the net overall positive impacts of strong irradiation in the Middle East outweigh the negatives felt from the dust or challenging O&M conditions, especially when compared to having a solar plant in less dusty but cloudier climates.

Khoreibi says his firm learned many lessons by starting with a 10MW solar plant incorporated into Masdar City in Abu Dhabi, which was used as a test lab for methodologies on cleaning plants. The Masdar settlement has a strong emphasis on sustainability and minimising environmental impact so the team had to identify ways of keeping the plant clean with minimum water usage.

"We are using a dry brush method, but there are of course thousands of different forms of dry brushes that one can use to clean a system", says Khoreibi, "so we actually ended up trying 200 different brush head technologies."

Environmena attached wheels on either side of the chosen brushes, which then roll along the panel racks. It also worked alongside panel manufacturers Suntech and First Solar to make sure the modules were not being harmed by any micro-abrasion. As a result of the brushing, the plant's output has been able to overachieve in terms of its performance guarantees every year since beginning operation.

Environmena has considered automated technologies, but has not justified using them from a cost and technology perspective. Khoreibi says that performance issues caused by dust could become an even larger issue by using automated robots, so the company has stuck with manual cleaning so far.

German testing house PI Berlin last year developed a number of stress tests to assess the impact of cleaning systems in these desert locations and found that in some cases the cleaning methods can damage modules.

However, Juliane Berghold, head of module technology and research at PI Berlin, says that in most cases there is no visible or direct mechanical impact from cleaning technologies. The module glass can be scratched, but it is very rare to find a cracked cell.

"What is much more often the case is that the cleaning is resulting in a part removal of the functional layers like the anti-reflective coating," says Berghold, "and this has an impact because it reduces the efficiency of the module."

Nevertheless, removing these functional layers has a maximum impact of 3% on module efficiency, so output is not drastically affected. Furthermore, the chances of damage also rely heavily on the quality and mechanical stability of the modules themselves, the type of cleaning technology and the frequency of cleaning, says Berghold.


Credit: Phoenix Solar

Phoenix Solar's Kapsarc project revealed the imoprtance of humidity in the choice of module cleaning regimes.

Ultimately Friedl says that any negative impacts of poor cleaning technology is far less than the definite power output losses of leaving dust and sand on the modules. There is no alternative but to clean.

Heating up

When it comes to the effects of high temperatures, Khorebi says module degradation does increase in extreme heat, however this is well modelled and accounted for when forecasting the output of a plant. "Panel manufacturers have pretty set degradation formulas depending on additional heat per degrees Celsius," he says.

Furthermore, Khoreibi insists that higher yields coming in a climate of high heat and sunshine on a daily basis means the systems generally outperform plants from other parts of the world despite any higher rates of degradation.

Many O&M methods in the Middle East, such as monitoring plant performance, apply to other parts of the world, however plants in the desert may require testing for damage more regularly due to the temperatures, says Berghold.

The heat also means that O&M workers need to check cables and cable connections closely, says Friedl. For example, cable connectors and binders made of insufficiently protective material may have to be replaced after just one year due to exposure to the heat.

Most commentators say the difference in emerging technologies in the Middle East's O&M sector often comes down to the cleaning brushes being used, but the fact that cleaning technology is available without requiring water is a major boon for the sector. However, for some companies it will take improved technology and a stronger economic case to start adopting any automated solutions. ■

Opening up the finance markets for merchant solar

Future solar finance | As the economics of solar improve, merchant projects are already in place in Chile and various parts of the US. However, as lawyers from Chadbourne explain, financing them is not a straightforward business

Credit: First Solar

First Solar's Barilla project in Texas is one of the few merchant PV project operating in the US.

As a result of the risk inherent in merchant arrangements, few merchant utility-scale solar projects have been constructed, and only a handful of them have received debt financing. The dearth of merchant projects in the solar market may be contrasted to the relative prevalence of the merchant model in the wind sector; in the United States, around one fifth of wind power is sold by projects operating on a merchant or quasi-merchant basis, whereas almost all solar electricity is sold through PPAs. Merchant solar projects have been limited to projects in a limited number of locations with a confluence of favourable factors, including transmission constraints, fluid spot markets, high electricity prices and high insolation.

The north of Chile, where the electrical grid is not connected to the grid in the more populous centre and south of the country, which receives high levels of insolation (around 7kWh/m2/day), and where electricity prices were historically very high and expected to remain so, has seen the construction of the largest number of merchant solar projects. These have included the 70MW Salvador project, sponsored by Solventus, Etrion and Total and financed by the Overseas Private Investment Corporation (OPIC), the 51MW San Andres project, sponsored by SunEdison and financed by OPIC and the International Finance Corporation (IFC), the 73MW Crucero project, sponsored by SunEdison and financed by OPIC, the Interamerican Development Bank (IDB) and Corpbanca, and the 141MW Luz del Norte project, sponsored by First Solar and financed by OPIC and the IFC.

Another Latin American merchant project of note, the 30MW Aura Solar 1 project in Mexico, built by Gauss Energía and financed by the IFC, shares similar features. The project is located at the southern end of Baja California Sur, where insolation is on par with levels in northern Chile, the electrical grid is not connected to grids in the rest of the country and electricity prices have historically been relatively high.

In the United States, First Solar has constructed and is operating the 30MW Barilla project in Pecos County, Texas. The Barilla project was financed on balance sheet, and was conceived in part as a proof of concept for merchant solar in the Electric Reliability Council of Texas (ERCOT) market.

White Camp Energy also reportedly plans to develop a 135MW merchant project in Kent County, Texas. Although it does not receive the same amount of sunlight as the projects located in Northern Chile and Baja California Sur, West Texas, where these projects are located, benefits from relatively high insolation. Moreover, the ERCOT grid features a fluid spot market, is relatively easy for a merchant project to connect to and is not connected to grids in the rest of the country, resulting in the potential for high peak prices. In the ERCOT market, spot energy prices can reach such heights during hot days in the summer

that selling electricity into the grid for a few hours can bring in as much revenue as weeks of production during other times of the year.

Financing merchant solar projects

To date, it has been difficult for sponsors to find debt financing for merchant solar plants. Although development finance institutions and a handful of local banks were involved in the financings of utility-scale merchant solar projects in Latin America in recent years, there has yet to be a utility-scale merchant solar project in the United States financed with debt.

Given the greater degree of risk involved with selling on the spot market, lenders to such projects typically require more conservative terms in their financing agreements. Lenders may require sponsors to contribute more equity up front than they do for traditional solar projects. Where projects with long-term PPAs may have debt-to-equity ratios of 80:20 or 70:30, lenders to a merchant project may require ratios closer to 60:40 or 50:50.

Lenders also incorporate cash traps and cash sweeps into their financing agreements, using relatively conservative debt service coverage ratios. A typical cash trap or cash sweep may be based on both the project's historical debt service coverage ratio and its prospective or projected debt service coverage ratio. Prepayments resulting from cash sweeps are typically applied in inverse order of maturity, as the merchant risk to lenders is greater for later periods, for which forecasts of spot prices are less likely to be accurate.

Quasi-merchant arrangements

Developing a merchant project may be attractive to sponsors who are hoping to take advantage of the upside of the merchant market or are having a difficult time attaining long-term PPAs on sufficiently attractive terms, but exposing an entire project to merchant risk may not be palatable to risk-adverse investors or lenders. Sponsors may consider limiting, but not entirely removing, their merchant exposure by contracting for a portion of their revenues, either by obtaining PPAs for a portion of their output, entering into non-traditional PPAs or hedges or separately contracting for the sale of renewable energy certificates (RECs).

Several of the projects described above have entered into PPAs for some of their output. The Barilla project, for instance, has entered into PPAs for about half of the output of the plant currently in operation, although these agreements have a tenor of only a couple years, as opposed to the 10- to 20-year tenor of traditional PPAs.

Another method for mitigating the risk inherent in a merchant project is to enter into a "synthetic" or financial PPA, a contract with a hedge provider (which may

> "As development and construction costs for solar projects continue to decrease, it is likely that as in the wind market, quasi-merchant projects will become a more viable option that sponsors are willing to develop and lenders to finance"

be either a financial institution, a power marketer or a buyer of electricity, like a mine, factory, computer company or other large user of electricity) that provides a predictable price. While they have been used in some Chilean merchant solar projects, they have yet to catch on for solar projects in the United States, where wind projects are leading the way.

Synthetic PPAs are generally of a shorter term than traditional PPAs, so do not typically remove all merchant risk from a project. Their term is typically five to 10 years, as opposed to 10 to 20 years for a typical PPA. Synthetic PPAs are often structured as contracts for differences, under which the project sells its power into the wholesale market, and the hedging counterparty buys the power it needs on the wholesale market. The parties agree on a strike price; if the spot market sale price is greater than the strike price, the project pays the difference to the hedging counterparty, and if the spot market sale price is lower than the strike price, the hedging counterparty pays the difference to the project. There may be any number of variations on this arrangement – for instance, the strike price may be fixed or may adjust, and the timeframe over which it is calculated may vary.

While hedging arrangements mitigate merchant risk, they come with risks and complications of their own. For example, hedge providers may require a letter of credit or other credit support to secure the project's obligations, and they may demand a security interest in the project's assets, leading to tension between secured lenders and/or tax equity investors and the hedge provider. Synthetic PPAs also face regulatory uncertainty. The Commodity Futures Trading Commission (CFTC), has not yet indicated to what extent they will be subject to CFTC regulation under the Dodd-Frank Act. However, there is an exemption from regulation if one of the parties to the hedge is an "end user" – i.e., is not a "financial entity" – is using the hedge to mitigate commercial risk and notifies the CFTC regarding how it will meet its financial obligations regarding the swap.

A third method for obtaining some revenue certainty is for a project to unbundle the sale of RECs from the sale of electricity, selling RECs under a long-term contract while selling electricity on the spot market. There have been long-term REC offtake agreements in the US wind market, but this arrangement has also not yet gained a foothold in the solar power market.

Looking to the future of the merchant solar market

For solar projects, particularly in areas with a highly variable spot market resulting from constraints on transmission or variations in demand, selling on the wholesale market may be attractive, as the peak in electricity production during the day generally coincides with the hours of peak electricity use and prices. Moreover, solar power tends to be at the top of the dispatch stack, because it has no fuel costs. As development and construction costs for solar projects continue to decrease, it is likely that as in the wind market, quasi-merchant projects utilising the arrangements discussed above will become a more viable option that sponsors are willing to develop and construct and lenders are willing to finance. ■

Authors

Peter Fitzgerald is a partner in Chadbourne & Parke's Project Finance: Energy and Infrastructure practice. He has represented multilateral agencies, commercial bank lenders and project developers in connection with international project financings for over 30 years.

Brian Greene is an associate in the practice who focuses on energy and infrastructure projects, particularly in the United States and Latin America.

Law clerk Rachel Crouch also assisted with this article.

Reviving the stalled shift to solar self-consumption

Business models | Solar's widely heralded shift to self-consumption models has failed to happen to any meaningful degree. But as it remains PV's only viable future business model, it's time to get the project back on track, writes Gaëtan Masson


Credit: Sundog Energy

Welcome to the real world! The real world is what the PV sector faces in Europe for the time being: the end of a Golden Age when money was falling from the skies, profits skyrocketing and electricity consumers' discontent growing. If I wanted to shock a little bit, I could say that a large part of the global PV market still lives in a fantasy land: the Americans have extended the ITC, the Chinese and Japanese continue so far to love feed-in tariffs (even if mentalities are evolving) and many newly installed PV capacities outside of the old continent are still policy-driven, or to be more precise, financially supported.

How many gigawatts have been installed in the world in 2015 without any support scheme, with a market-based remuneration and outside of competitive tenders… granting a stable feed-in tariff for years? Well, the answer is not straightforward. Out of the estimated 51GW installed in 2015 (PV Market Alliance numbers from January 2016), we can hardly find many gigawatts where PV electricity is paid at market price or where self-consumption is the main driver of revenues. Let's face the truth: the policy-driven bubble is not over yet and it is time to prepare the transition smartly.

Self-consumption remains the only viable long-term business module for non-utility solar.

A failed transition?

From the 23GW installed in 2011, the level of installations in Europe has fallen to significantly less than 10GW in the last two years. And the number of markets in Europe where PV is still able to develop shrinks continuously. Only the UK, Germany, France, the Netherlands or Switzerland are still contributing significantly to the European PV market's development. Of course some dozens or hundreds of megawatts were installed in Belgium, Austria, Denmark, Sweden, Poland, Portugal or Italy in 2015, but far from the top numbers seen in the past. This can be easily explained by the continuous decline of financial support in some cases, but also the move to market-based incentives that confused investors. Retroactive measures have finally contributed to demotivate them, leading to a European PV market crippled and expecting much from new business models, ad hoc regulations and the end of anti-dumping tariffs.

But the major reason for the dramatic decline of European PV markets is the decline in policy support. In almost all European countries, politicians still willing to openly support PV as a future energy source are not the majority, and by far. At best, they agree that PV will be the source of energy of the 'future' without committing to any major regulation that could re-ignite the market. A significant gain in PV competitiveness or the end of the minimum import price (MIP) for Chinese modules would have little or no impact on most markets in the short term, simply because regulators left no space for PV development outside of the constrained corridors. Sometimes no space at all. What is not present is simply the political willingness to let PV eat up the share of conventional electricity sources.

A part of the responsibility lies in the hands of the PV industry: it claimed too often and too loud that grid parity was the Holy Grail of the industry and that, once reached, it would unleash the market without incentives and financial support. This pushed policymakers to believe it and, with the support of conventional utilities, to decide to step up the transition to a post-FiT era. The result was a rapid move in the direction of self-consumption policies and tenders for utility-scale plants.

After some years, the result is clear: the transition from a feed-in-tariff-driven market to a competitive PV market has failed in Europe, at least for the time being. Self-consumption schemes are in the best case incomplete and in the worst case inadequate or unfair. Regulations have been introduced in most European countries aimed at slowing or destroying the PV market, and those that could have offered a fair frame to define adequate self-consumption rules are either too weak or too much oriented towards integration into the electricity markets. And when regulations were acceptable, such as in Italy or Germany, they were either retroactive measures or ill-fated anti-self-consumption regulations that contributed to damaging the investors' appetite for PV. In almost all cases, the consequence was a market crash that the temporary boom in the UK cannot contradict any longer.

Self-consumption

This having been written, self-consumption remains the way to go: the only business model for PV in the future outside of utility-scale plants selling their electricity is and will remain self-consumption – PV as a way to decentralise electricity production and to reduce electricity bills.

But first, we should all start to use the same vocabulary. 'Self-consumption' is the generic term to qualify any kind of situation where a PV installation produces electricity first for local consumption (in the building or nearby or even elsewhere) and injects the excess PV electricity into the grid. All other systems are variants where the treatment of the self-consumed electricity and the excess PV electricity differ. In other words, any self-consumption scheme can be qualified by defining the conditions of remuneration of the self-consumed electricity and the value given to the exported PV electricity.

One main criterion in a self-consumption scheme is the ratio of self-consumed electricity to the total PV production; in other words an economic ratio that under normal regulatory conditions has to be maximised – retail electricity being more expensive than the wholesale market price. The prosumers will try usually to maximise this ratio. But in most cases, unless the PV system is really small compared to the annual electricity production, this ratio will be significantly lower than 100%: everyone knows that reaching high shares of self-consumption with a PV production close to the annual consumption of a building is a complex technology challenge. Battery storage offers options to increase the self-consumption ratio but at a high cost, DSM through HVAC offers cheaper options, but unfortunately PV will have to face the truth: unless systems are strongly downsized, the excess electricity has to be valued.

Net-metering and net-billing

In order to value this excess electricity, net-metering has been popular for at least two reasons: it is easy to put it in place (with power meters turning backwards for instance) and doesn't require important regulatory changes. Actually net-metering is the most simple self-consumption system: it simply values the excess electricity at the retail price. But it was as difficult to tune as it was simple to implement, which explains why several countries have taken the decision to amend it, adding taxes or grid costs rather than switching to a pure self-consumption system.

> "The only business model for PV in the future outside of utility-scale plants selling their electricity is and will remain self-consumption"

On the road towards the pure self-consumption system, the net-billing concept starts to emerge. Net billing attributes different values to electricity depending on its direction, which allows the valuation of PV electricity injected into the grid below the retail prices. In that sense, net billing is almost as simple as net metering but much easier to tune.

The value of PV electricity

Since net metering is a temporary scheme, the main debate becomes, especially in the USA, how to value this excess PV electricity. At market price? Below (to take transaction and management costs into account)? Or above (to include some additional services to the grid, to the system, to society)? In Europe, this is the direction that has been taken by European institutions: valuing PV on the electricity market, an interesting idea if the electricity markets conceived for dispatchable conventional sources were able to value correctly variable renewables. Germany and the UK offer a premium above the market price, fixed or variable, but the idea is there: the excess PV electricity should be valued on the wholesale electricity market. Spain was more radical: excess PV electricity below 100kW receives zero. And all other countries where PV is allowed are proposing a value for PV electricity between these two boundary values: the retail price (net metering) and this Spanish extreme.

The right to self-consume

In the last two years several countries have set up policies aimed at restricting the right to self-consume PV electricity and to reduce electricity bills. Such policies have taken various forms: in some cases, variable grid tariffs have been transformed into fixed ones that have to be paid, even in case the real consumption of electricity falls to zero. In other cases, it is a specific tax on self-consumed electricity that is applicable (Austria, Spain), or it is a part of the contribution for renewable energies that has to be partially paid by prosumers (Germany).

In all cases, these policies impact the profitability of self-consumption-based business models by reducing the part of the electricity bill that can be compensated. In most European countries, the part of energy in the electricity bill represents between one-third and half of the bill: in that respect the right to self-consume can be significantly reduced and the profitability of PV installations become really difficult to achieve, even with high self-consumption ratios.

This shows immediately the complexity of any self-consumption regulation: whereas a feed-in tariff requires simply the definition of a price for every kilowatt-hour produced, self-consumption requires the right to self-consume electricity, the right to compensate grid costs and levies, but also the need for a regulation on the excess electricity, either a feed-in tariff or a way to trade electricity on the electricity markets, directly (which is complex for small installations) or through an aggregator (which requires also ad hoc regulations). This is also the reason why so many different schemes have been implemented in Europe.

Common sense for regulators

Some simple ideas should guide regulators in establishing efficient and fair self-consumption policies:

- **First** the right to self-consume should be granted and without any self-consumption tax. The electricity that is self-consumed has, contrary to what

Spanish law says, exactly the same effect as energy efficiency.

- **Second,** taxes and levies should be compensated without any limit. It makes no sense to promote the development of renewable energy and then to brake it to save the revenues of the authorities.
- **Third,** variable grid costs shouldn't be paid until the penetration of PV reaches a significant percentage of the electricity demand. The grid costs unpaid by prosumers can be easily mutualised in the overall grid costs with a very limited impact on the electricity bill of all consumers. Three percent of self-consumed electricity (which is close to the German number) increases the electricity bill of all consumers by 1%, less than annual inflation. And without taking into account the positive effects of PV on the cost of the distribution grid. In a nutshell there is no urgency to modify the ratio between fixed and variable grid costs. This can be done in a few years, for new installations, when PV costs will have further decreased.
- **Fourth,** existing systems should be protected from regulatory changes. A grandfathering clause is absolutely necessary in all European countries, at least until the end of the grant period for ongoing feed-in tariffs.
- **Fifth,** it seems obvious that for the time being electricity markets are unable to bring a reasonable return for PV electricity. With prices around four eurocents per kilowatt hour, this doesn't represent the real value of PV electricity. In that respect, ensuring a low feed-in tariff for self-consuming PV installations, in order to value PV at the right price, can be a much simpler option than forcing small installations to pass through an aggregator to get a reduced market price.

Reviving the self-consumption project

Europe has clearly missed the opportunity to frame its PV transition. The efforts from European institutions have been insufficient to counter the anti-self-consumption policies of some countries and the obvious mistakes of others. Now, consistency is needed at all levels to ensure that the right policies will be put in place and that the barriers to self-consumption will be lifted.

There is hope coming from the European Commission but the final decisions will have to be taken by national administrations that need to pave the way for a sustainable development of PV through self-consumption in Europe. Under these conditions, the European PV market will have a significant chance to experience a re-birth and play a major role in the PV market that continues to grow swiftly on a global scale. ■

Author

Gaëtan Masson is founder director of the Becquerel Institute, a Brussels-based research and consultancy organisation specialising in renewable energy, particularly PV. He previously led the business intelligence of arm of trade body EPIA, now SolarPower Europe. He is the operating agent of Task 1 of the International Energy Agency Photovoltaic Power System Programme (IEA PVPS), vice-chairman of the European PV technology platform and participates on the scientific committee of EU-PVSEC and Intersolar Europe conferences.

Financing trends in the solar industry

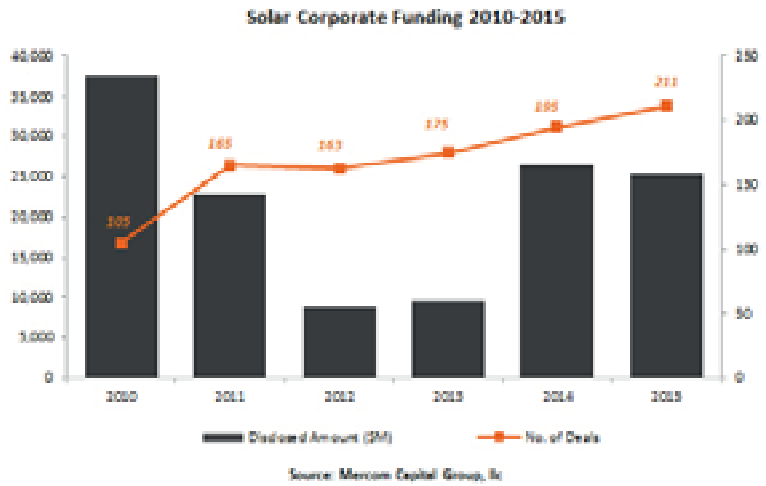
Finance in 2016 | It was a turbulent year for solar finance in 2015 with big successes, more innovation and a few nasty surprises too. Mercom Capital's Raj Prabhu takes a forensic look at solar finance in the last 12 months and the clues offered for the year ahead

Corporate finance in solar has evolved quite a bit over the last seven to eight years since the great recession. The first wave of funding into solar was mostly venture capital (VC) and private equity going into promising technologies, such as thin-film, CSP and CPV, and especially crystalline silicon. It's hard to believe, but this was a time when polysilicon costs were about US$300-400/tonne and crystalline silicon module costs were about US$4/W. Venture capitalists poured a lot of money into developing a replacement for the 'expensive' crystalline silicon technology based modules. Chinese companies, armed with strong support from the government, flooded the market with cheap crystalline modules which killed off most of the VC-funded technology companies. Chinese government-owned banks provided credit of more than US$30 billion to Chinese manufacturers in 2010 alone. With the capital markets affected by the recession, public market financing was scarce and debt was expensive and hard to obtain, not to mention the financial markets were new to solar and not yet comfortable with investing.

Post recession, as venture capital funding dried up, the capital markets began to thaw and we started seeing solar companies beginning to access public and debt markets for financing through initial public offerings.

Total corporate funding, including venture capital, public market financing and debt, amounted to US$25 billion in 2015 compared to US$26 billion in 2014, though the number of transactions went up from 195 to 211.

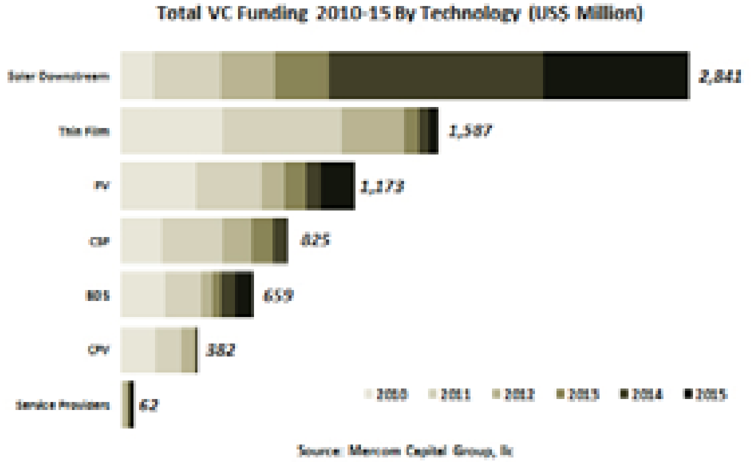
Venture capital funding into solar crossed US$1 billion in 2015 compared to US$1.3 billion in 2014. Solar downstream companies, especially third-party finance firms focused on residential and commercial lease, loan and PPAs, received most of the VC funding. Some of the important deals in this space were the US$300 million raised by Sunnova Energy, followed by the US$80 million raised by Sunlight Financial and the US$50 million raised by Sungevity. We expect this trend to continue and possibly accelerate as the Investment Tax Credit (ITC) extension in the US has cleared the way for these firms to grow exponentially over the next five years. Innovative solar technology companies meanwhile continue to receive smaller rounds of funding. Funding for manufacturing-focused companies has become rare with a few exceptions, like Solexel and Oxford Photovoltaics.



We are also seeing more money going towards off-grid markets in Africa, India and South Asia. Some notable deals included Off-Grid Electric, a Tanzania-based company providing solar energy in Africa using a prepaid model, with US$25 million raised, M-KOPA Solar, an asset financing company that sells solar home systems to off-grid households on a mobile money payment plan in Kenya, Tanzania and Uganda, with US$19 million, and BBOXX, a company that designs, manufactures, distributes and finances plug & play solar systems, raised close to US$10 million among others. Mercom's Q4 and Annual 2015 Solar Funding and M&A Report tracked more than US$100 million in VC funding going towards rooftop, distributed, financing and product companies in these markets.

Financial innovation in the solar industry

There have been several innovations on the financial side to bring the cost of capital down including no-money-down lease, loan, securitisation and yieldco structures. Yieldcos tend to lower the cost of capital and help recycle capital by separating long-term cashflow from riskier assets in the project pipeline. As a result, the market had been willing to assign higher multiples of earnings for distributed cashflow. This enabled companies to access the low cost capital required to fund rapid growth. Yieldcos can usually generate an annual dividend yield of 4-10% or more, with attractive dividend growth potential over the long-term. Typically, the same projects in a yieldco tend to be valued more than if they remained with the parent project

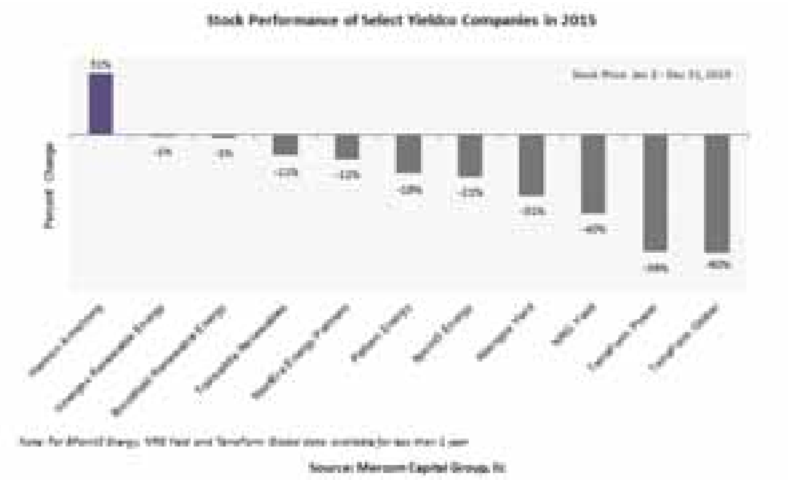


development company.

Publicly-traded solar companies, especially yieldcos experienced a lot of turbulence in 2015. The year began with yieldcos taking off and they were extremely popular with investors in the first half of the year, but were hit hard in the third and fourth quarter with most stocks declining significantly. Yieldcos were supposed to be relatively safe bets with a predictable growing dividend yield. Newly minted yieldco stocks jumped in the first half of the year and companies that were expected to behave and operate like traditional, dull utilities suddenly began to operate like high-growth tech companies. SunEdison's acquisition of Vivint Solar, a rooftop solar company, went a step too far for the markets, which began to question its pace of acquisitions, the strategic fit of the Vivint acquisition and the company's over-leveraged situation. Rather than operating like a traditional yieldco, which is supposed to have a low-risk profile with predictable and growing cash flows (most of which is distributed to investors as dividends), Terraform, SunEdison's yieldco and the poster child for solar yieldcos, began operating like a high-growth company in the eyes of the market which in turn has made investors skeptical of all solar yieldcos. While a course correction could happen quickly, this has been the major story playing out over the last six months. In the short-term, we may see slower fundraising and project acquisition activity from yieldcos.

The overall stock market decline further slowed public market financing activity in Q4, but 2015 was still the best year we have seen with almost US$6 billion raised in 2015 compared to the US$5.2 billion in 2014. This included seven initial public offerings (IPOs) bringing in US$1.8 billion in 2015. The largest IPOs were the US$675 million raised by TerraForm Global Yieldco (SunEdison's global yieldco) and the US$420 million raised by 8point3 Energy Partners, a yieldco formed by First Solar and SunPower. Other IPOs included Sunrun's raise of US$250 million, Xinte Energy's raise of US$166 million and CHORUS Clean Energy's raise of US$133.5 million. The remaining two IPOs were the US$126 million raised by SolarEdge Technologies and the US$4.2 million raised by Grenergy Renovables.

Securitisation deals are another growing trend that can help lower financing costs. Solar lease companies like SolarCity are using securitisation deals to aggregate rooftop asset pools and transform future



cashflows into securities. Interest rates paid to investors typically tend to be lower than tax equity financing, which is in the 8-10% range.

Securitisation deals are slowly making inroads into the solar sector. SolarCity executed the first securitisation deal two years ago. The industry has so far seen only eight of these deals totaling US$849 million, including five deals from SolarCity. In 2015, there was one deal each from Sunrun, AES and BBOXX. BBOXX was the first to execute a Distributed Energy Asset Renewables (DEAR) securitisation deal for distributed solar projects.

We also continue to see money going into solar funds and it was a record year for dollars raised in residential and commercial solar project funds by solar lease companies. There were 23 funds announced for a combined total of US$5.5 billion in 2015, a 36% increase over the previous year. Of the US$5.5 billion, US$4.3 billion went towards the lease/PPA model and US$1.2 billion went to loan products. Since 2009, US$17 billion has gone into residential/commercial solar funds to support lease/PPA/loan financing for residential and commercial installations led by SolarCity, Sunrun, Sunpower, Vivint Solar, Sungevity, Clean Power Finance and SunEdison.

With the ITC extension, we expect third-party financing companies to continue to raise residential and commercial lease/loan funds in record numbers.

Solar mergers and acquisitions

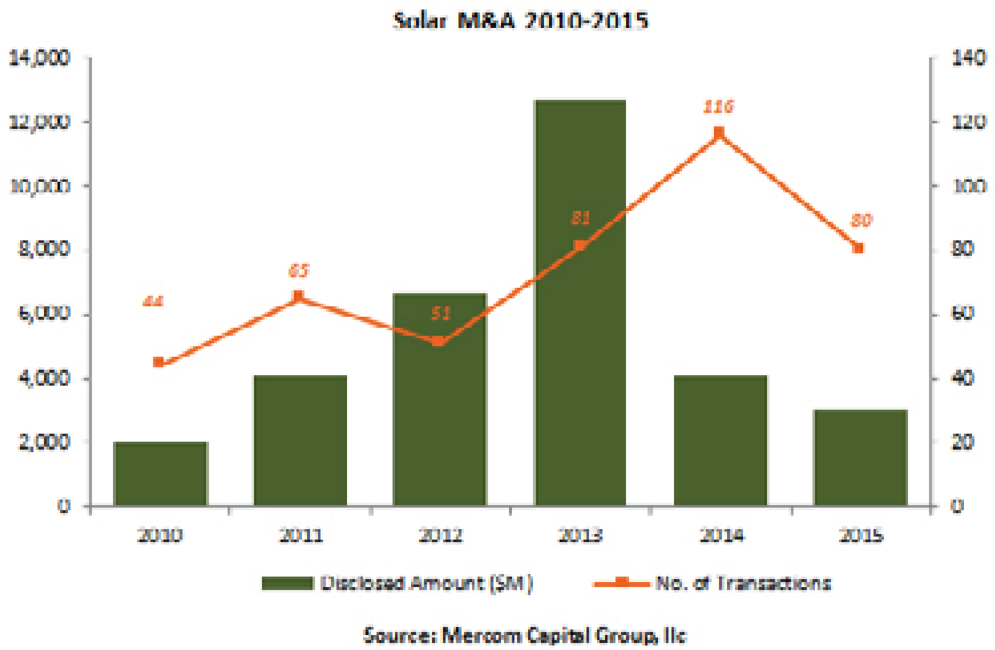
While there were fewer solar corporate M&A transactions in 2015, with 80 compared to the 116 in 2014, solar project M&A activity, on the other hand, soared to a record 204 transactions in 2015 compared to 163 in 2014.

Most of the corporate M&A activity was in the solar downstream space with companies purchasing solar developers for their pipelines. Solar downstream companies logged the greatest number of acquisitions with 49, followed by solar manufacturers with 13, and BoS companies with nine transactions. Of the 80 corporate M&A transactions in 2015, 21 were in the United States and 15 were in China. Companies that made mulitiple acquisitions in 2015 included SPI Solar, which acquired four companies, Global EcoPower which acquired three companies and SunEdison which acquired two.

The largest project M&A transaction was the US$1 billion acquisition of an 80% stake in Gestamp Asetym Solar from Gestamp Renewables by KKR, an investment firm.

Solar project acquisition activity surged in 2015 with a record 204 transactions (82 disclosed) compared to 163 transactions (61 disclosed) in 2014. Spurred by yieldcos, 2015 has been by far the best year for solar project acquisitions. More than 12.7GW of solar projects were acquired in 2015, a record for the sector. Project developers were the most active acquirers with 74 transactions, acquiring close to 3.9GW, followed by investment firms with 42 transactions for 2GW of solar projects. Yieldcos acquired 41 projects for 2.3GW.

As we look beyond 2015, we expect VC funding to continue to go towards downstream companies. We expect to see more securitisation deals and strong tax equity fundraising by residential and commercial solar funds with the extension of the ITC. We also anticipate the next three to five years to be strong for project acquisition activity especially if yieldcos recover. ■



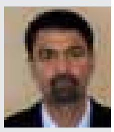
Active Project Acquirers in 2015

Project Developers	Yieldcos	Investment Funds	Utility/IPP	Manufacturers	Others
3,866.8 MW	2,271.6 MW	1,956.8 MW	1,902.4 MW	1,892.3 MW	843.4 MW

Source: Mercom Capital Group, llc

Author

Raj Prabhu is CEO and Co-Founder of Mercom Capital Group, llc, a clean energy communications and consulting firm with offices in the United States and India.



Moving mountains

System design | Land constraints, hilly terrain and adverse weather conditions are among the many practical complications facing solar developers in Japan. David Pratt looks at some of the technical solutions being devised in response to Japan's challenges

Credit: Clenergy

Extensive earthworks and specially adapted mounting systems allow solar developers to cope with Japan's hilly terrain.

Solar PV deployment in Japan is continuing to impress, with 11GW connected in 2015, according to figures released in January by GTM Research. The upcoming deregulation of the country's energy sector, coupled with the government's pledge in December's climate talks in Paris that around 30% of its renewable energy will come from solar by 2030, suggests this growth is set to continue. Factor in the 80GW backlog under the feed-in tariff and there's a lot of business to be had.

However, all the activity scheduled for the future depends on developers overcoming a problem that has plagued the market almost from day one – the issue of land availability.

Over 70% of Japan is mountainous, with the remaining flat land used predominantly for urban development or agriculture. For large-scale solar projects, this presents a significant challenge for developers, who are looking further afield to find new locations and coming up against a range of challenges in the process.

Mounting systems specialist Clenergy has been operating in Japan for almost four years and, according to Charles Ando, vice president for the Asia-Pacific region, the shortage of flat land has led to challenges that come up repeatedly.

"There aren't many easy sites left now in Japan, only those that are difficult. We have installed over 2,000 projects in Japan and most have had difficulties. Over 90% have had different terrain, ground conditions, snow loads, wind loads, earthquake; you name it," he says.

Climbing to new heights

With flat land at a premium, Clenergy and other firms like it are turning to Japan's hills for an answer. While these sites are difficult to build on, they do offer lower land costs, allowing developers to take a more proactive approach to construction.

An obvious use for this extra cash is grading the land to a level base or one with a specified slope, a tactic being used by Pacifico Energy on a number of projects. The company's largest development to date is being built on Kyushu and according to Nate Franklin, the firm's country manager in Japan, the 96MW project has involved over five million cubic meters of earthwork.

This method is used widely across the country to ease construction on hilly or mountainous sites, with civil engineering work being carried out on a unique scale.

"One thing that I've learned over the last three or four years in Japan is that no other markets are grading this much or doing this much civil work for solar projects. I've seen some projects in Europe on hilly sites but no projects in the world are similar to what's being done in Japan as far as the civil challenges," Franklin explains.

While it may be difficult to avoid civil works on some level, there are ways to get efficient results.

> "We haven't seen a flat, easy to develop site for about two years, at any price"

"When we first started, a lot of the EPCs were designing projects on a tiered system. You see it sometimes with agriculture where there are a lot of flat tiers that step down a sloped site. That's really inefficient for solar; the module racks are like building blocks so if you have a lot of breaks in it you have a lot of inefficiencies," Franklin explains.

"We have a continuous grade on as much of our sites as possible so that there's not a break in the rows. That's just one trick that can really increase your capacity," he adds.

Over time, companies have been able to develop systems allowing them to build on 35% slopes, opening up new possibilities for solar deployment. For example, Clenergy offers a combination of

Credit: Clenergy

Tilting panels and snow-blowing equipment are two of the solutions to heavy snowfall.

specialised mounting and racking systems for sloping areas, all of which can be altered at the firm's manufacturing facilities to suit the requirements of each location.

This ability to adapt is key, according to Charles Ando, who says: "You need to be very flexible to change to different solutions."

Carrying a heavy load

This flexibility is also needed to tackle the heavy snowfall common in Japan, particularly in Hokkaido where Clenergy has completed a number of projects.

The most widely used method for solving the issue is to tilt the panels to ensure the snow falls unaided. Laying panels at 30 degrees is generally accepted as the most effective way to do this, however with land at a premium this limits how many modules can be installed on any one site.

While it is difficult to overcome this, stopping the snow from affecting power generation remains key, with a number of techniques being implemented to tackle the problem. Pacifico Energy is testing new machines to blow the snow from the panels into the gap underneath the row in front, while Clenergy ensures that as many of its sites as possible are located near a reservoir or waterway to allow snow to be removed quickly.

A different angle of approach

While the use of hillside developments is expected to grow as new innovations emerge, there are a number of other alternatives to deal with Japan's land constraints.

Serving as an abiding legacy of the boom years, the country's obsession with golf led to the construction of many courses across the country. A large number of these have now fallen into disuse, with large-scale developers taking advantage. Three of Pacifico Energy's four sites currently under construction are on former golf course sites and, as Nate Franklin explains, the nature of these courses suits solar down to the ground.

"Japan just overbuilt golf courses during the boom, which was a great combination when solar came. They make sense because at least the fairways are somewhat flat and so there's already been some earthwork done and trenches that have been put in that you can utilise," Frankin says.

"When you're talking big projects of 20MW and above, I think anything that was flat and usable got done at the very beginning. We haven't seen a flat, easy-to-develop site for about two years, at any price. Golf courses are about as good as it gets."

While the location of some courses can present difficulties in reaching transmission lines for interconnection, they remain a popular choice for solar developers. However, many are now looking to avoid the issue of land scarcity altogether by looking to Japan's waters.

Riding the waves

Floating PV systems are considered by many to be an ideal solution to Japan's lack of available land, with the country's agricultural traditions coming into play. While re-zoning of farmland is difficult to achieve, the nation's historic use of irrigation ponds has left a number of water bodies available for solar installations.

Harold Meurisse, international sales manager for Ciel et Terre, the French firm that specialises in floating PV, claims increasing success is down to the suitability of floating systems in the Japanese market.

"Land in Japan is lacking, especially for 20-25 years for the purpose of energy. If you use unused dead spaces, you solve this equation. Being on water also removes the issue of earthquake codes which bring a lot of problems as they require foundation or civil engineering works," he says.

Solar on water also offers higher levels of generation thanks to the cooling effect of the water, while the installations avoid the high costs of land and even reduce surface evaporation and algae growth.

Despite these benefits, floating solutions present their own issues. As it embarks on a 13.7MW floating installation (see case study, next page), Kyocera tells *PV Tech Power* that the systems often present unique challenges. These include making the solar panel and wiring materials waterproof; engineering the system to comply with relevant environmental regulations; and ensuring the system does not corrode over time. Special permits are also typically required which can vary from region to region.

The area often requiring the most attention is anchoring, as this determines how the floatation devices are secured against the wind and other factors. As Meurisse explains, Ciel et Terre has gone to great lengths to ensure this aspect of its systems has been addressed during development.

"We have conducted lab tests and determined the exact maximum loads that would be applied on the platform and their diffusions. From there we computed an anchoring tool that determines precisely the number of anchoring points needed and each tonnage," he says.

> "No other markets are grading this much or doing this much civil work for solar projects"

Cemil Seber, director of product marketing and development at REC Group, claims nothing about floating solar makes the technology "uninvestible" and that its use will grow assuming further developments are made.

"I think that the most important thing is to see how this market develops considering the advantages that solar PV offers on water because of the space issue. The jury is still out on how large the market is going to be. The interest in this is reasonably high, but having said that we need to think about salt water solutions," he says.

Before floating systems can be rolled out on the open sea, issues around salt water degradation will need to be solved, as will

Ciel et Terre Floating solar systems are one solution to the shortage of land in Japan.

Credit: Ciel et Terre

Floating solar goes large

Kyocera has begun construction on what could be the world's largest floating solar installation. The 13.7MW plant is being built at the Yamakura Dam on the Chiba prefecture and is expected to be completed by March 2018. The plant will incorporate around 51,000 Kyocera modules installed over a fresh water surface area of 180,000 square metres. Floating structures are expected to be supplied by Ciel et Terre, which Kyocera says it has chosen in the past due to the firm's floating platforms being 100% recyclable and made of high-density polyethylene that can withstand ultraviolet rays and corrosion.

Speaking to *PV Tech Power* about the project, Kazuhiro Nakamura of Kyocera's Corporate Solar Energy Group, says: "The installation area is very broad because of its large scale. As ground conditions at the bottom of the reservoir are uneven, the project requires know-how on the anchoring method and the number of anchors. "For this plant, we proposed anchoring the floating platforms to the bottom of the reservoir rather than to the dam body because the latter method entailed multiple concerns."

Kyocera began working on floating installations due to land constraints for new large-scale PV development in Japan. Its latest project could showcase the scale at which floating solar can be delivered, with even larger projects expected to follow. A Ciel & Terre representative recently told *PV Tech Power* that the company is developing a 100MWp floating project in South America, but was unable to give further details.

Credit: Kyocera

Kyocera Kyocera's 13.7MW floating PV array is expected to become the largest in Japan and the world

security. Closed lakes or reservoirs provide an element of control in terms of both O&M services and general security of an installation; this cannot be said of open water.

Despite these questions, Seber expects to see saltwater solutions by 2017, with work already underway to improve the durability of solar panels. This development could also address a consequence of the growing success of floating PV: eventually Japan's inland water bodies could become as rare as its flat land.

With the Japanese solar market set to benefit from April's deregulation process, as well as the possible introduction of an auction process for large-scale solar projects in 2017, the availability of sites for solar development is likely to only get more critical. The importance of alternatives like mountainous development and the growing trend for use of reclaimed land and floating systems will only increase as a result, and could set Japan up to grow even more solar deployment. ■

Shortcomings and developments in PV forecasting

Forecasting | Accurate forecasting is becoming increasingly important as PV penetration grows. Jan Remund of Meteotest looks at some of the recent developments in forecasting science and the work going on to improve this vital aspect of solar's interaction with the grid

Credit: Jon Simon, Feature Photo Service for IBM

Recent years have seen the fast development of solar forecasting. Today, large scientific communities as well as many private companies are working on enhancing solar forecasts. Meanwhile, the scientific communities dealing with solar resources and with numerical weather prediction (NWP) modelling, for so long separated, have now met and are working together.

The improvements are strongly driven by end users, which are mainly PV producers or grid operators in need of accurate solar forecasts. According to the 2015 International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) report, 'Trends in Photovoltaic Applications', 13 countries had reached the milestone of 2% of yearly PV penetration in relation to electricity demand in 2014. Two percent seems to be a low value on an annual level (Italy reached 8% in 2014). However with 2% of the yearly energy share, instant PV penetration can rise up to 20% in certain moments. Experience in Europe has shown that above this level accurate solar forecasts are of great importance to run the transmission grid stably and safely. Local solar forecasts – mostly for big PV installations – are also common nowadays. The need to provide forecasts for those installations is mostly based on grid or market regulations and therefore depends on countries' specific legislation.

Improved forecasting is vital to help solar penetration carry on growing.

A short history of solar forecast validation

Today's state-of-the-art solar forecast is based on a mixture of nowcasting models and NWP, adapted to local measurements – based on model output statistics (MOS) or Kalman filters.

Looking back only seven years, predictions have come a long way: in 2009, the results of a first international benchmark were presented [1]. Mostly direct model output (DMO), the raw and unchanged results of different weather models, was compared. The first simple statistical bias corrections had been proposed, but the application of MOS was not common. Uncertainty levels were in the range of 42-50% of relative root mean square error (rmse) for a day-ahead forecast including hourly values, referenced to average radiation and analysed for sites in Germany. The lengthy definition of the validation in the study (measure, forecast horizon, time resolution, reference, region) shows also one major issue of benchmarks in those first years: the results heavily depend on these definitions and make comparisons difficult.

In the IEA PVPS report, 'Photovoltaic and Solar Forecasting: State of the Art' [2], an overview of existing models and validations was given. In this report, different nowcasting methods based on sky cameras and satellites were introduced (Figure 1). All methods show their optimum performance in different forecast horizons as well as in different temporal and spatial resolutions.

Nowcasting based on sky cameras can be produced in half- or one-minute temporal resolution for up to 10-15 minutes ahead with a spatial resolution of tenths or hundreds of meters. Nowcasting based on satellites is available with temporal resolutions of five to 15 minutes and for forecast horizons from 15 minutes to four hours ahead. Spatial resolutions are in the range of two to 10km. NWP output is optimal for forecast horizons of three to 120 hours ahead with a temporal resolution of one hour and a spatial resolution of 10-50km.

For both nowcasting methods – sky cameras and satellites – images are analysed to obtain the current cloud position. Cloud motion vectors are calculated based on multiple images or retrieved from NWP to be able to compute forecasts of cloud movement. Those forecasted layers are used together with clear sky forecasts to produce global and direct radiation predictions.

Nowcasting – defined as forecasts up to six hours ahead – implies the ability to forecast cloud positions accurately, which isn't possible with NWP due to the chaotic behaviour of the atmosphere. This is the

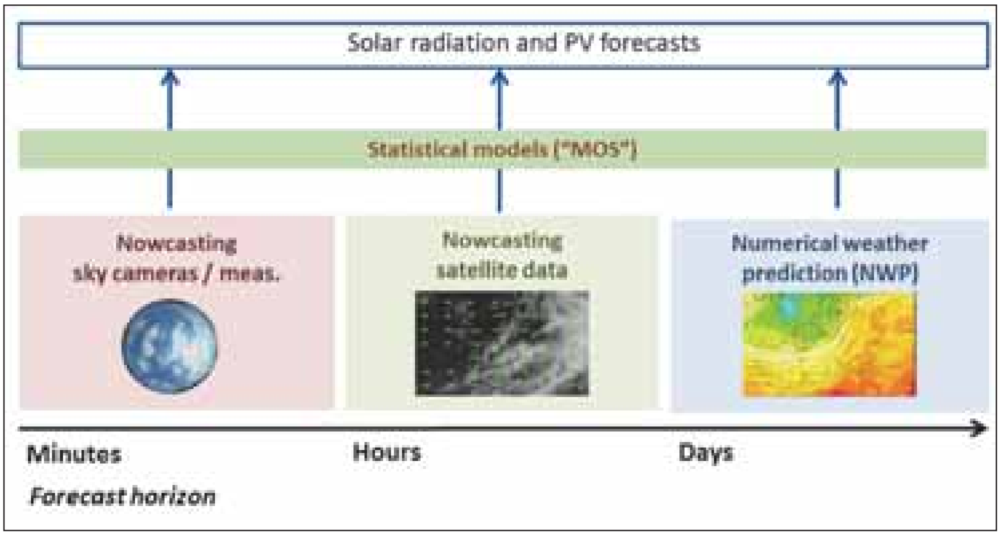


Figure 1: Three different forecast methods and their forecast horizons. Statistical models include model output statistics (MOS) like multiple linear regressions, neural networks or Kalman filter.

biggest advantage of nowcasting methods with satellites and sky cameras. However cloud formations are not stable over a long time. At least after four to six hours the cloud forms have generally changed, dissipated or new clouds have formed. All current validations show that for longer timescales NWP delivers more accurate results than nowcasting methods. Since 2012 many scientific groups have been working on forecasts with the help of sky cameras. However uncertainty levels are still high, forecast horizons short (10 minutes) and commercial applications still rare.

In the PVPS report of 2013 the validations for day-ahead forecasts showed relative rmse levels of 18-64%. The main differences are not based on the forecasting technique – but on the local climate. For sunny climates the forecast accuracy is much higher than for cloudy climates as the biggest source of uncertainty comes from the positioning and optical density of the clouds.

Also in 2013, the second benchmark of IEA Solar Heating and Cooling programme Task 46 was published [3]. This paper included four different benchmarks in the USA, Canada, Central Europe and Spain. Again, mostly DMO data was compared. The relative rmse was between 32% (USA, global models) and 52% (Central Europe, regional models). The uncertainty levels had only marginally lowered since the first benchmark in 2009.

The weather research and forecasting model (WRF) of the US National Center for Atmospheric Research (NCAR) and the integrated forecast system (IFS) of the European Center for Medium Range Weather Forecast (ECMWF) were applied to all areas. In all of them IFS showed the lowest uncertainties – together with Canada's weather model, GEMS (for Canadian sites). It could be shown that averaging of models lowers uncertainty. The global forecast system (GFS) of the US National Weather Service produced higher levels of uncertainties than IFS. WRF – together with other regional models – showed clearly higher uncertainty. Overall the IFS model was the state of the art in those days. In contradiction to the experience from other meteorological parameters – that using nested models with higher spatial resolution enhance the quality of predictions – this wasn't the case for global radiation. Further, below we will see one of the reasons for this behaviour.

In 2016 a new benchmark paper will be published within the framework of IEA SHC Task 46 [4]. This paper will include the latest results of the benchmarks for Central Europe and includes nowcasting methods based on satellite images and output of NWP – or a mixture of both. The benchmark was done for 18 sites in Germany for the period of March 2013 to February 2014 (Figure 2) and additionally for Switzerland, Austria and Denmark, which are not covered here.

Results of $ECMWF_{IFS}$, the COSMO model of the German weather service the Deutscher Wetterndiest, ($DWD_{COSMO,EU}$) and the HIRLAM (high-resolution limited area model) of the Danish Meteorological Institute ($DMI_{HIRLAM,SKA}$) are based on direct model output. IFS has a temporal resolution of three hours, the two others one hour. Meteotest's $MT_{GFS\text{-}MOS}$ is a MOS based on GFS including ongoing hourly updates of meteorological stations provided by. UOL_{Combi} is a combination of DWD and ECMWF model provided by the University of Oldenburg. Both are based on hourly data.

The GFS-MOS with online updates results in the lowest uncertainties for short periods (relative rmse of 30%). The combination of COSMO and IFS is best for the time range of 12 to 38 hours. Regional models of DMI and DWD show somewhat higher uncertainties. The 24-hour forecast shows uncertainties of 40-48% relative rmse. These results show that the general level of forecast uncertainty could be lowered by 10% – from 40 to 30% relative rmse – between 2009 and 2016. Regional models still can't beat the global models, but the differences are getting smaller (especially for mountain areas). Multi-model combinations and MOS are delivering nowadays the best results.

Regional aggregation results in clearly lower uncertainties as the errors, because of inaccurate positioning of clouds, are smoothed out. For the comparison of benchmarks of regional aggregation it is important to keep the referencing value in mind. In this text average radiation is used. Using installed capacity would result in clearly lower values (about 50%). The rank of the models for regional aggregation is the same. However the differences between the multi-model combination and MOS to the DMO results are bigger than for single site forecasts. Best forecast models (GFS–MOS, multi-model approaches) reach 11% for three-hour forecasts and 16% for 24-hour forecasts.

Nowcasting forecasts based on satellite images and cloud motion vector (CMV)

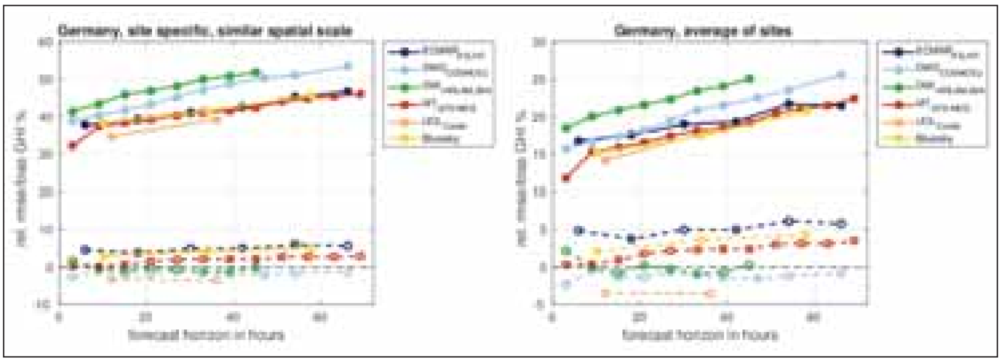


Figure 2: Relative rmse and bias in dependence of forecast horizon for site specific (left) and regional aggregation (right).

EKO Instruments unveils a new generation of high-end ISO 9060 secondary standard pyranometers

In order to assure well-founded decisions in designing and operating profitable solar power plants, solar irradiance should be continuously and accurately measured. As of today, there are a myriad of solar sensors available in the market. Choosing the best pyranometer requires expert understanding of sensor properties and knowledge of the on-site environmental and atmospheric conditions: wind, rain, snow, soiling, spectral effects, re-calibration, not to mention communication and compatibility.

If you believed that 'high-end' solar sensors are only meant for research purposes, the EKO MS-80 secondary standard pyranometer will prove you wrong. This new-generation sensor broke with the traditional pyranometer architecture. The innovative design enabled a breakthrough in unprecedented low offset behaviour and fast thermopile sensor response.

Reducing measurement uncertainty

- ISO 9060 Secondary Standard
- Immunity to zero offsets
- Fast analogue response time
- Low temperature dependency
- ISO17025 accredited calibration

Minimised maintenance and optimised ease of use

- Five-year warranty and re-calibration period
- No need for desiccant inspection or change
- Optional built-in 4-20mA or MODBUS 485 RTU
- Optional ventilator / heater (MV-01)

MS-80 on test in Cedar City (Utah)

MS-80 with MV-01 ventilation/heating unit

The NEW MS-80 is a unique combination of EKO's isolated detector architecture and novel optical design. It pushes the limits of traditional pyranometer characteristics to become a new reference in its class. The compact sensor with single dome is immune to offsets and easily integrates all value-added features such as a ventilator, heater and different communication interfaces. Providing the lowest measurement uncertainties under all atmospheric conditions, the MS-80 is made for long-term unattended operation. It comes with a five-year warranty and has a five-year recommended re-calibration interval. Moreover, there's no longer any need to inspect or change the desiccant.

The MS-80M can be used whenever RS-485 Modbus® RTU signal is required. The MS-80A converts the voltage output of solar radiation sensors into 4-20mA current.

MV-01 ventilation/heating unit

The MV-01 is a low power consumption ventilation/ heating unit. It can extend the sensor maintenance interval period and ensure the availability of solar irradiance data when deployed in cold-climate regions or desert environments.

Availability: April 2016 onwards

result in lower uncertainties for the first two to three hours (Figure 3) compared to NWP. The forecast for 15 minutes shows the uncertainty of the estimation of solar radiation based on satellite data (15-20% depending on region). After three hours the uncertainty level of NWP is reached (30%).

Aside from the already well-understood comparison based on relative rmse (or mean absolute error) a new measure based on the variability index is being introduced. Rmse does not show the whole picture. Smoothing of models lowers the rmse as even small errors in the timing of peaks and valleys results in a double penalty. Figure 3 shows an example of this effect. The smoothed model (blue line) results in a lower rmse value than the original unsmoothed model (red) as the forecasted peak and minimum is slightly delayed in contradiction to the human eye.

Therefore another measure based on variability is introduced to calculate the ability of the models to forecast the correct variability (Figure 4).

The rank of variability and rmse measures are inversed. The best models concerning rmse ($MT_{GFS-MOS}$, $ECMWF_{IFS,HR}$) are the worst in variability forecasts and vice versa. Regional models and especially nowcasting methods are showing the best results.

Experience of the variability measure has to be gained yet. However we can advise today the user to weight the measures, depending on the usefulness and adequacy for their application. For example, rmse is a good measure for forecasts of PV production for electricity markets because in many cases the correct timing of the production is important and producers get financial penalties for deviations. In other cases, like forecasts of the probability of ramps, the smoothed models are not useful and the variability index measure is more adequate.

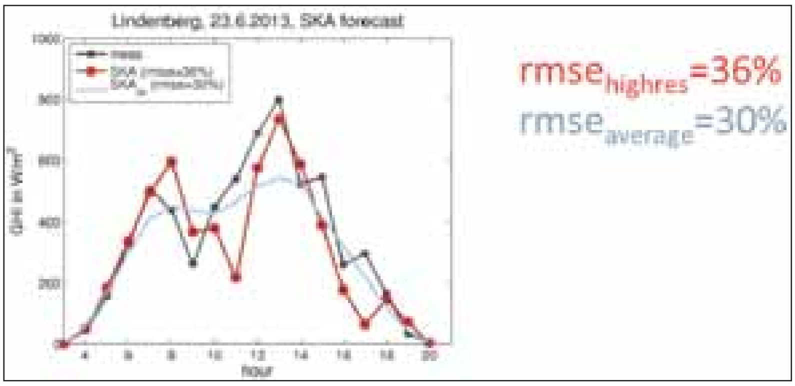


Figure 3: Comparison of a smoothed and unsmoothed regional weather model (Hirlam-SKA) and the resulting rmse values for an example day in Lindenberg (Germany).

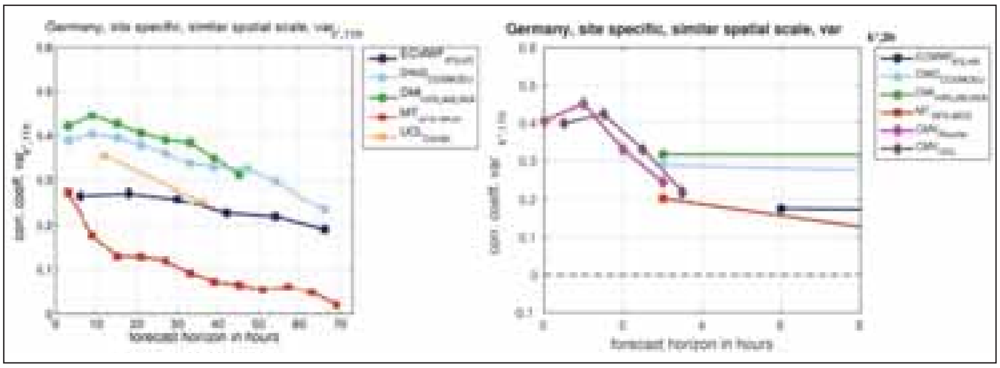


Figure 4: Correlation coefficient of the variability forecast in Germany. NWP models (left) and nowcasting and NWP models (right).

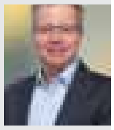
Outlook

As shown the forecasts have seen a rapid development in the last years resulting in clearly better products. In the next years this development will go on as the importance of accurate forecasts will grow with growing penetration levels, and many groups and companies are working on improving the models. Here are some of the most important issues in progress:

- Enhanced forecast models: e.g. a special WRF version for solar is being introduced. The improvements include parametrisation of aerosol data, improved aerosol-clouds interactions and shallow convection schemes. The updated model will be accessible for all WRF users;
- Updated aerosol data. Aerosols are the biggest source of uncertainty especially for direct normal irradiance and for sunny periods and climates. The change from using climate averages of aerosols to ongoing forecasts (e.g. ECMWF MACC) is a first step. Additionally MACC and other satellite-based sources also have to be enhanced in the future to eliminate especially high bias in certain (dry) regions like western USA;
- Optimised combination of NWP with nowcasting methods;
- The use of probabilistic predictions and variability forecasting (up to now not yet very common for solar energy);
- Enhanced forecasts of sky cameras, which allow forecasting of the next 15 minutes in very high temporal resolution (30 seconds to one minute);
- New forecast schemes based on ground measurements: forecasts based on networks of ground data – e.g. the fleet of PV installations – is another newly proposed way for nowcasting solar. This "big data" approach will evolve in future.

However we have to keep in mind that miracles won't be possible and uncertainty will never reach zero due to the chaotic nature of the atmosphere.

Author



Jan Remund is head of the solar energy and climatology business units at meteorology firm, Meteotest, based in Switzerland. He is also a member of the IEA PVPS Task 14 group, which is looking at issues around the high penetration of PV systems in electricity grids, and the IEA SHC Task 46, focused on solar resource assessment and forecasting.

References

[1] Lorenz, Elke, Jan Remund, Stefan C Müller, Wolfgang Traunmüller, Gerald Steinmaurer, David Pozo, J.A. Ruiz-Arias, V L Fanego, Lourdes Ramirez, and Martin Gaston Romeo. 2009, "Benchmarking of Different Approaches to Forecast Solar Irradiance", Proceedings of the 24th European Photovoltaic Solar Energy Conference.

[2] Pelland, Sophie, Jan Remund, Jan Kleissl, Takashi Oozeki, and Karel De Brabandere. 2013, "Photovoltaic and Solar Forecasting: State of the Art", IEA PVPS, http://iea-pvps.org/index.php?id=278

[3] Perez, Richard, Elke Lorenz, Sophie Pelland, Mark Beauharnois, Glenn Van Knowe, Karl Hemker, Detlev Heinemann, et al. 2013, "Comparison of Numerical Weather Prediction Solar Irradiance Forecasts in the US, Canada and Europe", Solar Energy 94 (August): 305–26. http://dx.doi.org/10.1016/j.solener.2013.05.005

[4] Lorenz, Elke, Jan Kühnert, Detlev Heinemann, Kristian Pagh Nielsen, Jan Remund, and Stefan C. Müller. 2016, "Comparison of Irradiance Forecasts Based on Numerical Weather Prediction", 31st PVSEC 2015, 14-18 September, Hamburg, Germany.

Impact of installation handling on cell cracks and power loss of PV modules

Testing | PV modules are subjected to various loads during installation handling. Research teams from the Institute for Solar Energy Research Hamelin (ISFH) and Hanwha Q CELLS attended the installations of PV modules in order to develop various test sequences for quantifying the effects of handling loads on the modules. As a result of these observations, lab tests have been designed to evaluate the impact of module-handling loads on cell cracking in the modules. Some rules for module handling are subsequently proposed

In previous publications, transportation has been discussed as a source of solar cell cracking in PV modules [1]; this cell cracking may reduce the reliability of the modules [2,3]. However, the correlation between cell cracking and power loss trends after the cracking damage is still not clear. Very often a direct impact on module power is below the detection limit for absolute power measurements (<2.5%) [2]. It is only after some additional load, such as thermo-cycling or further mechanical loads, that the cell cracking causes a relevant power loss. Kasewieter [4] found that the most significant mechanism for a permanent power loss is the electrical isolation of the aluminium metallization of the cell rear side. The aluminium rear metallization forms bridges over the crack, with no change in resistance taking place during the first load. After further mechanical loads, however, these bridges break and randomly reconnect, causing isolated cell parts to appear and disappear.

Olschok [5] has already shown that a handling failure – such as dropping the entire PV module from the carrying height, dropping a cordless screwdriver on the module, or stepping on the module – may cause cell cracks. Some very severe handling failures and corresponding tests have already been described in one proposal for a transportation standard [1], but these are not included in the corresponding IEC standard (IEC 62759: Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units).

In this paper some typical situations that seem to be the most challenging for the mechanical integrity of solar cells in a PV module are identified. Simple tests are subsequently created for simulating the handling of solar modules and for analysing the cell cracks. The goal of these tests is to answer the following questions:

1. How does a specific handling step affect cell cracking in a PV module?
2. Does the ambient temperature during installation influence cell cracking in a PV module?

The test results will lead to recommendations for PV module handling. In this paper the focus is on modules containing 60 cells, with a cell size of 15.6cm × 15.6cm, embedded in ethylene vinyl acetate (EVA), a glass cover and a backsheet foil.

Field observation

To answer question 1, three PV module installations were attended, and test procedures were extracted from the observed handling. During these installations, the ambient temperatures were between –5°C and +25°C. The handling tests are therefore conducted at –5°C and +25°C in order to address question 2. Table 1 documents all the handling steps during the installation that are suspected to cause cell cracks.

Test set-up

In Table 1 the handling steps 1 to 6 are accidental and therefore excluded from the test set-up. Olschock et al. [5] have already

Handling step	Observed handling loads
1	Overturning from vertical onto the glass side
2	Overturning of a pallet (vertical transport)
3	Inadequate pallet for modules (horizontal transport)
4	Horizontal dropping from the carrying height
5	Vertical dropping from the carrying height
6	Scratching of a module's backsheet by the corner of another module during destacking
7	Pulling the module rear side over a ladder
8	Stepping on the module frame
9	Crossing a generator area
10	Dropping a tool on the module
11	Fall of one side of the module caused by sticking of the stacking corners
12	Non-gentle laying-down of a module on the module substructure during de-stacking
13	Overhead handling (module backsheet lying on top of a helmet)

Table 1. Critical handling loads observed by Olschock et al. [5] and used in this paper: 1–6 are accidental handling; 7–10 are prohibited, but sometimes occur; 11–13 are normal handling.

Test number	Test description	Temperature [°C]	Number of modules
1	Loading on the frame corner, with increasing weight	–5 / +25	2
2	Loading on the long edge of the frame, with increasing weight	–5 / +25	2
3	Loading on the module centre, with increasing weight	–5 / +25	2
4	Dropping a skittle ball on the module centre/corner above the centre of the cells, with increasing drop height	–5 / +25	2
5	Dropping a module over its short edge, with increasing drop height, sunny-side down	–5 / +25	2
6	Dropping a module over its short edge, with increasing drop height, sunny-side up	–5 / +25	

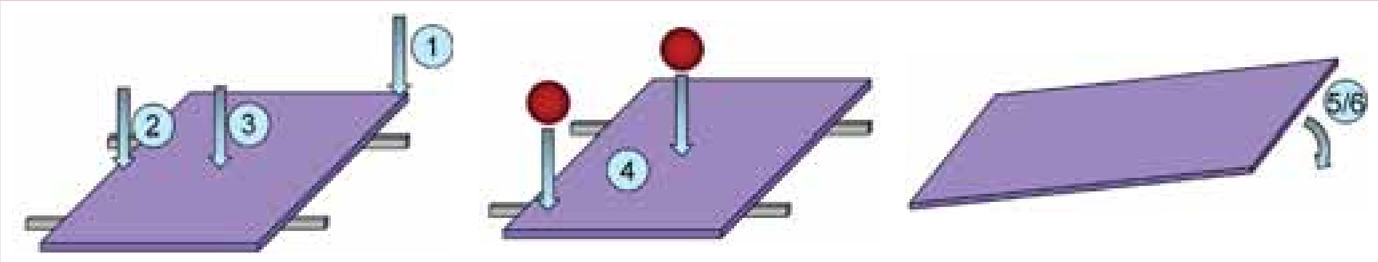


Table 2. Overview of the installation handling tests.

shown that overhead handling (i.e. module backsheet lying on a helmet) is not harmful to PV modules [5]; this type of handling is therefore also excluded from the tests. All the other observed handling types form the basis of the following test set-up. A shortlist of the tests inspired by the observations in the field is shown in Table 2.

Tests 1–3 are derived from stepping on a mounted PV module. The dropping of a cordless screwdriver on a PV module is simulated by Test 4. The tipping test in Test 5 is created to simulate the situation of destacking a module from a module stack; during destacking, the next module in the stack may be lifted up because of the sticking of the module stacking corners, and subsequently fall back onto the stack after a certain height. Test 6 simulates the non-gentle laying-down of a module onto a pallet or a mounting substructure.

Each test is conducted at –5°C and +25°C in order to examine the temperature sensitivity of the modules; for each temperature a new module is used. Before and after each test step, electroluminescence (EL) images are taken and the module power is measured. The output power of the PV module is measured by a flasher with a reproducibility of ±0.3% in module power for repeated measurements at standard test conditions.

Cell cracks are counted by using the differential EL method, which reveals even small cell cracks in multicrystalline solar cells. The EL image of the PV modules is recorded in the initial state and after any test procedure.

For each test a new module is used, apart from Test 6, for which the corresponding module of Test 5 is reused, since it is virtually undamaged after Test 5. In total, 20 modules (10 per type) are used for all tests.

"Cell cracks are counted by using the differential EL method, which reveals even small cell cracks in multicrystalline solar cells"

Tests 1–3

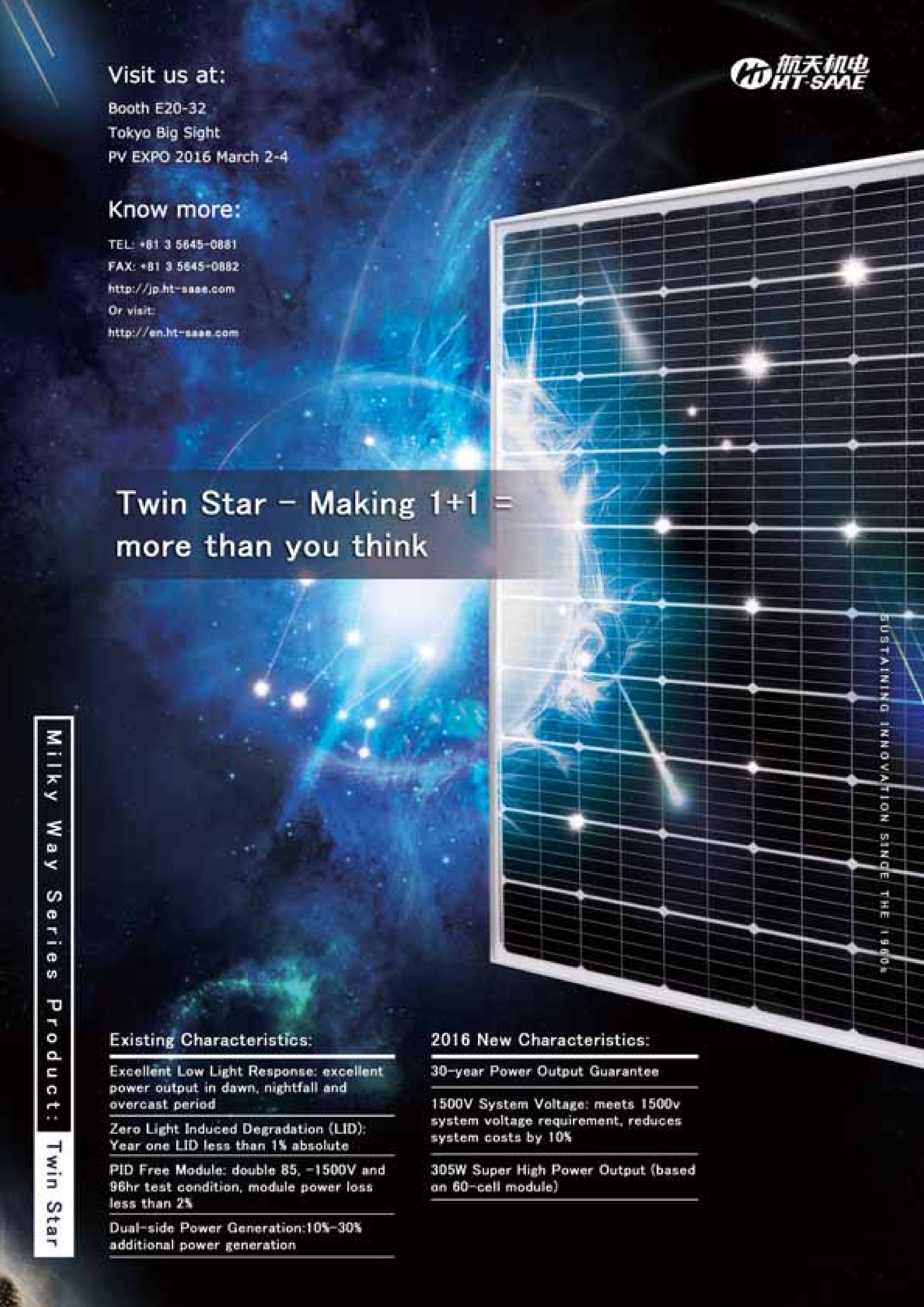
For Tests 1–3 the modules are mounted on a two-rail mounting system using four clamps, as suggested by the module manufacturer; the rail system is fixed on a rigid substructure. A laser distance sensor measures the deformation of the module surface, as shown in Fig. 1. The desired weight for the load tests is adjusted by adding weights to a rucksack carried by a person. From one test to the next, the weight of the load is increased: 25kg, 35kg, and then from 50 to 120kg in steps of 10kg. The person steps on the module slowly (1 sec) with one foot, remains for 5 sec, and then removes the foot again slowly (1 sec) (see Fig. 1). The module is loaded at the module corner for Test 1, at the centre of the module long edge for Test 2, and at the module centre for Test 3. For Tests 1 and 3, the module clamps are adjusted for the maximum distance between the clamps and the neighbouring module corners; for Tests 2 and 4, the clamps are adjusted for minimum distance between the clamps and the neighbouring module corners. These configurations result in a maximum deflection of the module in Tests 1 to 3.

Test 4

An internet survey of 2,687 cordless screwdrivers was performed; of these, 1,369 (50%) had a weight in the range 1–2kg (September 2014). A 'C-Jugend' (German youth athletic group C) skittle ball with a diameter of 130±0.2mm and a weight of 1.515kg was therefore chosen for the tool drop test (Test 4). The surface hardness of the skittle ball was 75±5 on the Shore D scale at 20°C [6]; the weight and the hardness corresponded to typical values for cordless screwdrivers.

The 20°C tempered ball is fixed by a pneumatic suction cap on a beam above the centre of a cell at each drop position, as shown in Fig. 2. The centre (o) and corner (x) fall positions on the PV module are indicated in Fig. 3. The distances between the drop positions are maximized in order to reduce any interaction of the drop tests. For each position, the fall test is repeated

Figure 1. The top, middle and bottom pictures show the loading set-up for Tests 1, 2 and 3 respectively. The local bending of the module is measured by a laser distance measurement close to the loading point (black box in the images).



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1500V System Voltage: meets 1500v system voltage requirement, reduces system costs by 10%
305W Super High Power Output (based on 60-cell module)

Figure 2. Set-up for Test 4 – tool drop test.

with increasing drop height, from 5cm to 20cm in steps of 5cm and from 30cm to 90cm in steps of 10cm, until the impacted solar cell breaks. Cell cracks below the point of impact are classified as primary cell cracks, and cell cracks elsewhere are secondary cell cracks. When the directly hit cell is broken, the next test is started at a 5cm drop distance in a new position, until all the marked positions of Fig. 3 have been tested. For Test 4, the clamps of the module are placed as close to the module corner as permitted by the manufacturer. These configurations allow the evaluation of the effect of the most rigid mechanical support at the corner position and the least support at the centre position.

Test 5

Test 5 simulates the drop of a PV module onto a module stack during destacking. Because most modules are stacked with their sunny-side down, the modules are dropped back onto a second module, both sunny-side down, as illustrated in Fig. 4. The short side of the module is dropped in order to test the case of the maximal drop energy. This side is jacked up with a stick, which is then pulled away at the start of the test. To adjust the exact drop height, several sticks of the following lengths were prepared: 5cm to 20cm in steps of 5cm, and 30cm to 50cm in steps of 10cm. The opposite side of the module is taped so that it cannot slide horizontally; this avoids an irreproducible jump-out of the module stack.

Figure 4. Set-up for Test 5.

Figure 5. Set-up for Test 6.

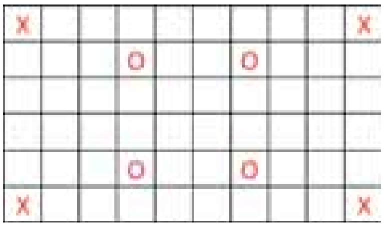

Figure 3. Pattern of the positions chosen for the drop test. The square grid indicates the cells in the module (x = corner drop locations; o = centre drop locations).

Test 6

Test 6 simulates a non-gentle laying-down or the dropping of a module onto the substructure of a PV system, or the laying-down of a module onto a pallet. This test is executed in the same way as Test 5, except that a rigid pallet is used as the bottom surface (rather than another module), as shown in Fig. 5. The chosen pallet and the module frame must not be deformed by the module drop. Furthermore, the pallet must have a partly open surface; this allows the air between the module and the pallet to escape, thus avoiding an airbag effect.

Results

Tests 1–3

Figs. 6 and 7 show the results of Tests 1–3 for module types I and II. The effective weight m_{eff}, which affects the module bending in the direction of the normal of the module glass plate surface, is calculated for a rooftop with an angle α of 45°. This effective weight is indicated on the top axis in Figs. 6 and 7 as the orientation for the loading effect on rooftop installations.

The bowing of the module caused by stepping on the module centre and on the module edge is similar for both module types. The bowing of the module corners by stepping on the corners, however, differs by 10mm. The much higher bending of the module corners for the type II module than for the type I module is due, at least in part, to the greater distance (+6.1cm) allowed from the mounting point to the neighbouring module corner.

Stepping on the module corners and edges does not result in cell cracks for either module type under 25°C test conditions. Stepping on the module centre, however, does cause cell cracks for both module types. For module type I, cell cracks occur at 90kg and above, and for module type II, from 50kg. In the case of both module types, the total number of cracked cells initiated by Tests 1–3 at –5°C is at least double the number of cell cracks at +25°C.

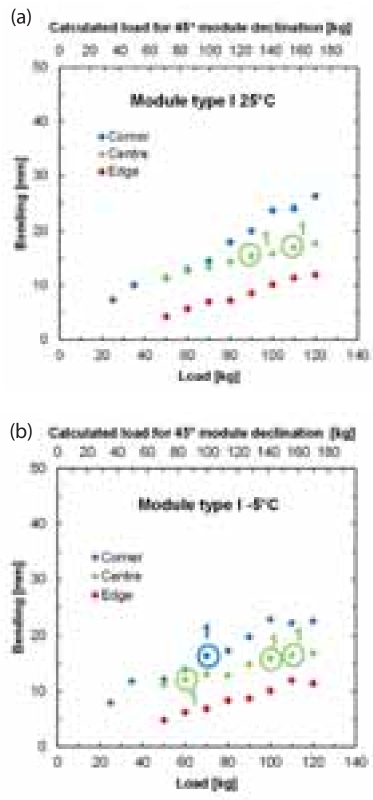

Figure 6. Results for Tests 1–3. Measured bending of a type I PV module close to the load position as a function of the applied load weight and temperature (a) +25°C; (b) –5°C. The circles show the loading steps that result in a cell crack; the number next to the circles indicates the number of cells cracked during this step.

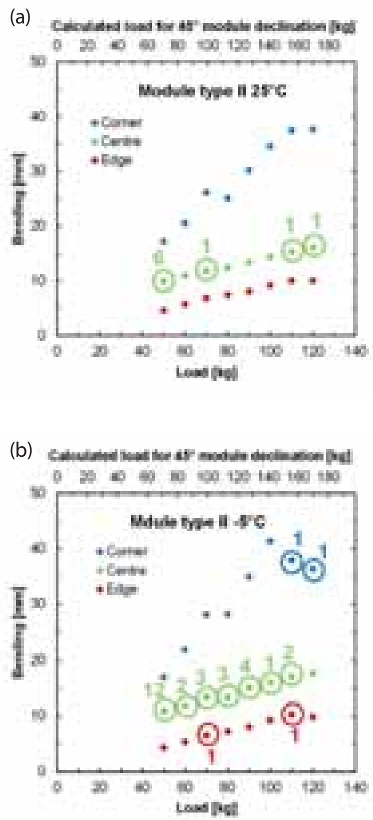

Figure 7. Results for Tests 1–3. Measured bending of a type II PV module near the load position as a function of the applied load weight and temperature: (a) +25°C; (b) –5°C. The circles show the loading steps that result in a cell crack; the number next to the circles indicates the number of cells cracked during this step.

Test 4

Fig. 8 shows the results of the drop test (Test 4) for both module types. The effective height, which affects the impact energy of the ball in the direction of the normal of the

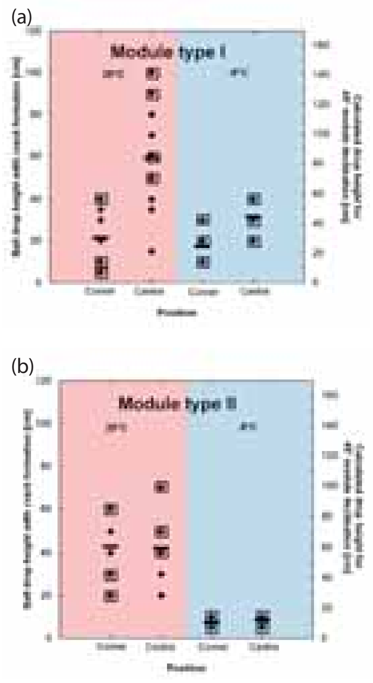

Figure 8. Dependency of cell crack occurrence on the impact position and on the temperature for (a) type I and (b) type II modules. The symbols inside squares indicate a crack of the cell direct below the point of impact of the ball. The other symbols represent secondary cell cracks of surrounding cells. The bars show the mean ball drop height for each test.

module glass plate surface, is calculated for a rooftop with an angle of 45 degrees. This effective height is indicated on the right axis in Fig. 8 as the orientation for the corresponding impact on a rooftop installation.

It was found that no safe dropping distance exists in the drop test; in some cases, even a drop height of 5cm resulted in a cell crack. Below a 15cm drop height, the resulting cell cracks were predominantly sustained by the directly hit cell. Of the 16 cells cracked by a direct hit, 14 demonstrated a star-shaped crack pattern.

Fig. 8 shows that the greater the ball drop height, the greater the chance of secondary cell breakage. None of the secondary cracks exhibit a star-shaped crack pattern. Secondary cell cracks are found up to two-thirds of the module length away from the direct hit location. Modules of both types are more sensitive to ball drops at –5°C than at +25°C: all directly hit cells survive at most a drop height of 30cm at –5°C , wheras some cells may survive even up to a drop height of 90cm at 25°C.

Tests 5 and 6

Fig. 9 shows the cumulative number of cells cracked in Tests 5 and 6 for both module types. The results in Fig. 9(a) and (b)

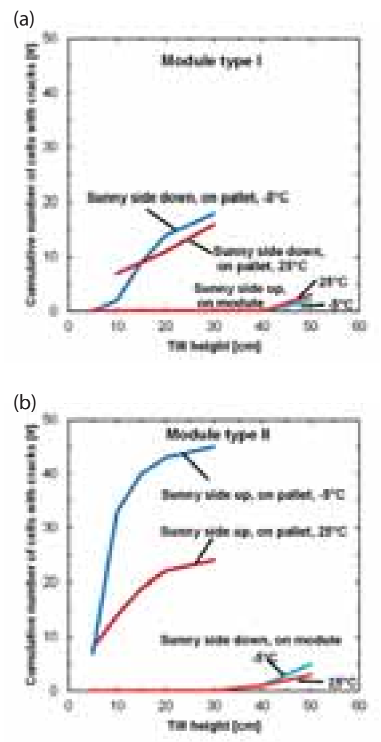

Figure 9. Cumulative cell breakage as a function of the tipping height of the short edge of (a) module type I and (b) module type II. The results for Test 5 (sunny-side down) and Test 6 (sunny-side up) at +25°C and –5°C are shown.

demonstrate that tipping a module with the sunny-side down onto a module stack does not lead to cell cracks for a tipping height of up to 30cm. Even a tipping height of up to 50cm only leads to a maximum of six broken cells.

In contrast, the tipping of modules with the sunny-side up onto a pallet results in numerous cell cracks. For a module type I cell and at 25°C, cracking starts at a dropping height of 10cm, with seven cell cracks reported, while module type II shows seven cell cracks already at a drop height of 5cm. Although module type I exhibits a similar number of cell cracks at 25°C and –5°C, the number doubles in the case of module type II at the colder test temperature.

Impact on module power

		ΔP [%]				
Test		1	2	3	5	6
Module I	25°C	–0.2	–0.2	–0.4	0.0	–1.2
	–5°C	–0.2	–0.2	–1.7	–0.2	–0.4
Module II	25°C	0.1	0.0	0.1	0.0	–1.2
	–5°C	–0.3	0.0	–1.0	–0.3	–0.8

Table 3. Relative power loss of the tested PV modules. Relative values below IΔPI= 0.3% are below the reproducibility of the test system, and are indicated by a darker background.

Table 3 shows the module power changes after Tests 1–3, 5 and 6, relative to the initial power; the power loss in all cases is less than 2%. For Test 4, a module power comparison makes no sense, because the number of ball drops is different for all modules since the drops are continued until the cell below the drop position breaks, whereas other cells in the module may break at intermediate test steps.

Discussion

Cell cracks typically cause only a small immediate power loss [3]. In the tests carried out, all the modules lost less than 2% of their initial power (Table 3), which indicates that the handling-induced cell cracks are not immediately relevant when considering the total power of a PV installation. The defects might get worse, however, during the service life of the PV system.

Despite the significantly greater bending of the module corner during the loading in Tests 1 and 2, many fewer cell cracks occur than when the module centre is loaded in Test 3. As a result of the down-bending of the corners, the cells are compressed in the laminate. However, solar cells are much more resistant to compression than to tension loading, which occurs when the edge and centre are loaded.

The load situations in Tests 2 and 3 result in both compression and tension of the

> "The most critical handling failure is the dropping of a sunny-side up module, even for short distances of a few centimetres"

solar cells in the module. However, the total bending by stepping on the module edge (Test 3) is the lowest of all three test scenarios, and therefore the number of broken cells is also low. Stepping on the module centre means that the cells in the module centre are strained in tension; as a consequence, and because of the relatively high bowing that occurs, a greater number of cells are cracked.

The loads at –5°C lead to cell cracks at lower loads than at +25°C, because the EVA lamination material is one order of magnitude stiffer at –5°C than at the higher temperature [7].

The impact tests on the centre cells lead to many secondary cell cracks in the modules. During a hit in the module centre, the cells crack because the glass bends over a long distance and consequently stretches the cells. The bending of the glass can crack cells far away from the point of impact, because the strike causes a wave to pass along the entire glass plate. This effect carries the impact energy away from the point of impact, which may explain the high number of secondary cell cracks found in the case of drop tests in the middle of the module. The glass may locally deform if a support structure is close; this is true for corner cells, which break mostly with a star crack.

The type II module demonstrates cell cracks at lower ball drop heights in the module centre than the type I module. The type II module demonstrates similar mean crack heights in the centre and in the corner, whereas the mean drop height for type I is much higher for the centre compared to the corner. It is thought that the mounting is the reason for this effect, because for module type I the mounting points are 6.1cm closer to the corners than for module type II. The closer the drop point is to a rigid fix point, the higher is the cell crack impact of the drop, because the glass cannot bend down as a whole and must deform locally.

It is considered that the relatively low cell-breakage rate of the modules tipping with the sunny-side down compared with the sunny-side up case is due to the bending of the module's front glass after the touch-down. The sunny-side down module bends and so the cells are in compression, which is much less harmful to the cells than tension. Furthermore, in Test 5 the module directly under the tipping module prevents the air below the dropping module from escaping; an airbag effect might therefore reduce the touchdown speed of the tipping module.

In contrast, in Test 6 the sunny-side up tipping module bends after the touchdown and thus the cells are in tension, which increases the cracking – for example, from zero cracks for the sunny-side down test for a 10cm tipping height, to 2–33 cell cracks for the sunny-side up test. Moreover, an open pallet is chosen as the touchdown surface in Test 6; this allows the air under the tipping module to escape through the slits in the pallet, and so the module can reach a higher speed shortly before touchdown. The situation in Test 6 is similar to a typical module-mounting substructure.

Summary and conclusion

From earlier work [5] it is known that the handling of a vertical module is not critical with regard to cell breakage; for example, a module might have dropped vertically from a raised height of 20cm with no breakage of cells (although the frame may show some scratches and dents). For this reason, PV modules in the field, or especially calibration modules in the lab, should always be handled and stored vertically. For horizontal test equipment using modules sunny-side up, one should have specially supported modules that prevent bending of the laminate.

The dropping of modules with the sunny-side down onto a module stack is quite safe for a single-side drop distance of up to 30cm. However, if modules are dropped on stony ground, the glass plate may crack, and this handling failure should therefore be avoided.

The installation instructions from the module manufacturer with regard to not stepping on PV modules must be taken seriously; even stepping on the frame might crack cells in the module. To help avoid stepping on the PV modules during installation, service and repair, there are currently many solutions on the market; for example, special commercially available crossbars, which are placed on the module frame, may be used to step on a module.

Heavy tools, such as a cordless screwdriver, should be secured at the wrist with a tool lanyard during any work undertaken on PV modules, because no safe drop height exists for this situation. The most critical handling failure is the dropping of a sunny-side up module, even for short distances of a few centimetres, which must therefore always be avoided. This caution should be taken seriously, especially during the placement of the modules on the roof/substructure. If possible, the module should be laid down directly onto the roof/substructure without any dropping distance. In the authors' opinion, this step is more important than most other typical transport and handling issues, because it is a frequent and typical step during a module installation. The handling of cold PV modules, especially in temperatures below freezing, should be avoided if possible. Furthermore, a 5cm drop test could be performed (even on a building site) using EL imaging equipment to check the crack sensitivity of a PV module. A well-processed module should not show new cell cracks after a 5cm drop of one edge with the sunny-side up.

The effects of handling failures on module power are initially very low: even the worst handling test demonstrates a power loss of less than 1.7%. However, any solar cell cracks that are initiated might increase the degradation rate of carelessly handled modules compared with carefully handled ones. Installers should be fully conversant with module-handling rules in order to ensure a long service life for the PV system. ■

Acknowledgements

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References

[1] Reil, F. et al. 2010, "The effect of transportation impacts and dynamic load tests on the mechanical and electrical behaviour of crystalline PV modules", Proc. 25th EU PVSEC, Valencia, Spain, pp. 4125–4128.

[2] Köntges, M. et al. 2011, "The risk of power loss in crystalline silicon based photovoltaic modules due to micro-cracks", Sol. Energy Mater. Sol. Cells, Vol. 95, pp. 1131–1137.

[3] Schulze, K. et al. 2013, "Investigation of ageing effects for monocrystalline PV modules with more than 15 years of operation by electroluminescent and power measurements", 28th Symp. Photovoltaische Solarenergie, Bad Staffelstein, Germany.

[4] Kasewieter, J., Haase, F. & Köntges, M. 2016, "Model of cracked solar cell metallization leading to permanent module power loss", IEEE J. Photovolt., Vol. 6, No. 1, pp. 28–33.

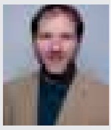
[5] Olschok, C., Schmid, M., Haas, R. & Becker, G. 2013, "Inappropriate exposure to PV modules: Description and effects of handling defaults", Proc. 28th EU PVSEC, Paris, France, pp. 3138–3141.

[6] Technische Vorschriften Ninepin des DKB – Classic 2012 (Skittles Technical Regulations, in German).

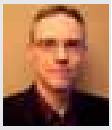
[7] Mickiewicz, R. et al. 2011, "Effect of encapsulation modulus on the response of PV modules to mechanical stress", Proc. 26th EU PVSEC, Hamburg, Germany, pp. 3157–3161.

Authors

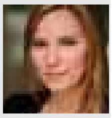
Marc Köntges received his Ph.D. in physics from the University of Oldenburg, Germany, in 2002 for his research in thin-film solar cells. He is head of the module technologies group at ISFH, where he currently works on the development of characterization and production methods for PV modules.



Michael Siebert received his B.Sc. in mechatronics from the University of Applied Sciences Ostwestfalen-Lippe in 2009. He is a member of the module technologies group at ISFH and is currently working on the design and testing of new measurement methods for PV modules.



Nicole Bessing received her B. Eng. in packaging technology from Leipzig University of Applied Sciences in 2012. She is a packaging engineer for solar cells and modules at Hanwha Q CELLS GmbH.



Romy Illing received her engineering degree, with a specialization in packaging, from Leipzig University of Applied Sciences in 2008. She is the manager of global packaging in the quality assurance department at Hanwha Q CELLS.

Frank Wegert graduated from the University of Rostock, Germany, as a mechanical engineer in 1990. He is a senior staff engineer at Hanwha Q CELLS and currently works on the planning, erection and optimization of cell and module lines.

Reliability of large-scale PV plants and PV inverters

Inverter reliability | The renewable energy market is currently booming, with large numbers of PV systems being installed throughout the world. However, a primary objective of any PV power system is to ensure that the system operates continuously and reliably. As Vicente Salas from the Universidad Carlos III de Madrid (UC3M) explains, this aspect takes on special relevance in the case of utility-scale PV projects

Figure 1. Inverter reliability is a vital aspect of ensuring the expected performance of a PV power plant.

Reliability is a key risk in any project, including PV plants, but the risk is more significant in the case of large-scale PV plants, where the cost of the project is high. In those projects, where the typical design target lifetime is around 25–30 years, there is a discrepancy between the lifetime of the PV inverters (5–10 years) and of the PV modules (20–25 years). In addition, while inverter interconnection, performance and safety standards exist, there are no well-established reliability standards. A reliability evaluation (simulation and test) must be carried out in order to observe failures of PV inverters and to better understand their failure modes and lifetime characteristics. From this it will be possible to guarantee the lifetime of the inverter. Clearly, PV inverter reliability has an impact on life cycle cost, and is therefore an important aspect to address.

For large-scale PV plants, financing is very important and complex, and involves many different parties, including developers, landowners, utilities, grid operators, government agencies and financing institutions. PV projects are a financial investment, which means they are all about returns. Additional operations and maintenance related to PV inverters, however, can erode returns.

As shown in Fig. 2, many tasks – both technical and non-technical – are involved in the financing process of any PV plant; the plant viability is linked not just to the technical tasks but to all the tasks as a whole. The objectives of any utility-scale PV project include:

- Establishing a trade-off between risk management and crisis management.
- Implementing a long-life power plant, with high energy yield and availability.
- Operating correctly and safely, in compliance with the relevant requirements.
- Keeping costs low and achieving a high return on investment.

Nevertheless, a profitable, reliable PV project is only possible if its components are reliable.

It is clear that a PV power system consists of many vulnerable components whose life cycle reliability is highly sensitive to temperature, power losses and ambient environments. This can lead to high electrical stress, as well as to temperatures in PV modules as high as those in power electronics converters; this may shorten the operational life cycles and consequently result in lower system reliability compared with conventional generation sources. Damage, defects and failures of the equipment and elements therefore affect PV plant production during the exploitation phase (Fig. 2).

The non-functioning of some element of the plant is a sensitive issue from the financial point of view. The PV inverter is always a critical component in the PV system, and for many years the inverter was one of the components most responsible for failures. Fortunately, PV inverters have improved, thanks above all to the advances made in power electronics, and today these products are more reliable. To increase availability and secure maximum return on investment, a PV system requires high PV inverter reliability in order to reduce downtime and ensure regular power generation.

PV module technology has also continued to improve: the robustness of modules is evidenced by the standard 20- to 25-year warranties that accompany most PV modules today. Thus, it is reasonable to expect that the PV system inverters

Just one stop can cover your whole system

Sangri project, Tibet, 10MW

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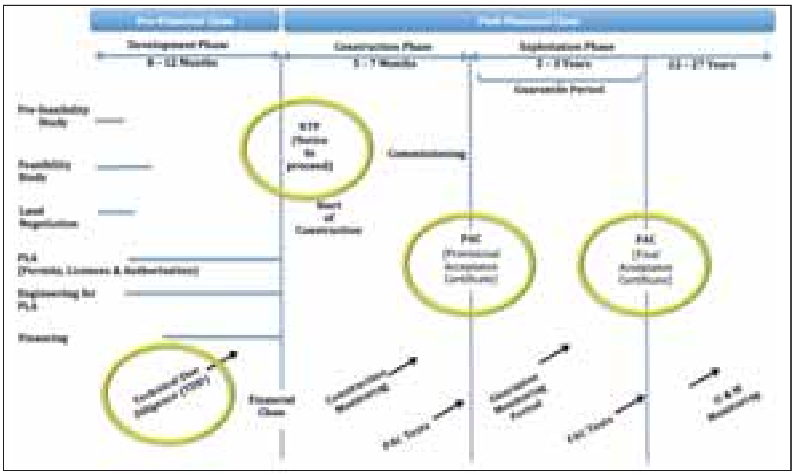


Figure 2. Stages of a typical utility-scale PV plant.

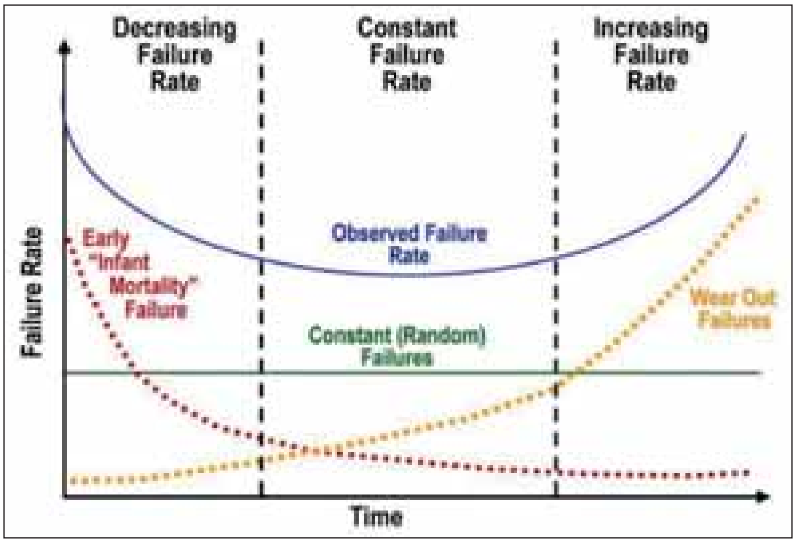


Figure 3. The bathtub curve, describing the correlation between failure rate and time.

have a comparable service life. However, although inverters have made progress over the same period of time, it has only been modest: manufacturers today offer inverter warranties of only 10–15 years, which means that replacement is necessary long before any other components of the PV system.

Failures in PV inverters

Three types of inverter failure can be distinguished: unplanned failure (where the equipment has failed in normal operation and was not expected to fail), planned failure and repeat failure. The most critical, and the most difficult to predict, is the unplanned failure, which can happen at any time. Different factors can cause such failure:

- Latent internal causes that existed in the product from the beginning (predispositions).
- External stressors, such as heat and humidity of the installation environment (external causes).
- Degradation with time.

These unanticipated interruptions will result in a significant amount of economic losses, and are a potential risk (financial risk). The bathtub curve, shown in Fig. 3, expresses the correlation between failure rate and time.

In addition, from the point of view of time, failures can be classified (according to the time of occurrence) into three regions:

- Early failures (initial or 'infant mortality' failures)
- Intrinsic failures (random failures)
- Wear-out failures

Early failures are failures that occur relatively soon after the beginning of operation; the main causes of these initial failures are manufacturing or material defects. The failure rate in this phase decreases over time.

Intrinsic failures are failures that occur at a fairly constant rate after the initial-failure period, until wear-out failures start to occur. The majority of electronic components fail at a constant failure rate during this random-failure stage.

Wear-out failures are failures that are caused by wear and fatigue, and occur because of the physical limits of the materials. The failure rate in this phase increases over time.

In order to achieve a highly reliable system, it is important to reduce the initial failure rate, provide a low rate of intrinsic failures, and ensure that wear-out failures begin to occur only after the system's useful lifetime ends.

Product life cycle

Product defects and failures can be anticipated by managing the product life cycle (PLC). All manufactured products have a limited lifetime, and during this lifetime they will pass through four PLC stages: introduction, growth, maturity and decline. In each of these stages manufacturers face a different set of challenges. PLC management is the application of different strategies to help meet these challenges and ensure that, whatever stage of the cycle a product may be going through, the manufacturer can maximise sales and profits for their product.

Historically, the quality and reliability of products has been approached in different ways. For many years manufacturers paid little attention to historical failures; they assumed that quality and reliability groups were responsible for quality and reliability. Moreover, manufacturers assumed that the product design did not significantly affect quality and reliability, and that quality and reliability failures were not caused by manufacturing and suppliers. However, that approach has now changed, and a revised reliability concept is already beginning to be applied. As mentioned earlier, PV inverter reliability affects life cycle cost, and therefore needs to be dealt with [1].

Reliability management process

The reliability of a PV inverter depends on the reliability of each of its components (for example, semiconductor and soldering failures lead to inverter failure), which is illustrated in Fig. 4. Unfortunately,

> "PV inverter reliability affects life cycle cost, and therefore needs to be dealt with"

in general a PV inverter has no parallel redundancy built into it, which means that a failure in any one of its components will lead to an outage of the entire inverter. It must also be taken into consideration that a PV inverter may handle a high level of power flow and operate under high-temperature conditions, which degrades the inverter reliability and increases the risk of age-related component failures [2].

In a reliability management process, the PV inverters should be designed to last the entire life cycle (up to 30 years) of the product; this process should begin with an initial checklist of requirements, and finish with an evaluation of operation in the field. As shown Fig. 5, the reliability management process must <AQ4>take place in parallel with other company processes, such as product definition, development, manufacturing and customer service (field deployment).

The reliability management process utilises individual sub-processes from other processes, but at the same time adds or superimposes unique and challenging elements (e.g. stringent qualification and test procedures for materials, products and processes, as well as advanced methods and tools for failure analysis).

Reliability approach

The reliability approach involves a physics-based multi-level analysis and identification of the failure points. The ultimate goal is a system operational lifetime with a low failure rate, and the only way to achieve this is to utilise a combination of:

- Reliability-oriented design rules.
- Selection of top-tier suppliers and acceptance testing of their components.
- Manufacturing in well-controlled environments.
- Accelerated lifetime testing of the system (and its components) up to the wear-out point in order to determine when the product will fail, at what rate and which failure mechanisms are at fault.

Reliability prediction methodologies

The newest reliability prediction methodology, the so-called *physics-of-failure (PoF)*, emphasises the root cause of failure, failure analysis, and failure mechanisms as the basis of an analysis of parameter characteristics. The procedure involves a focused examination of failure point locations which takes into account the fabrication technology, process, materials and circuit layout obtained from the manufacturer. This methodology is capable of providing recommendations, using intuitive analysis, for increasing the reliability of components.

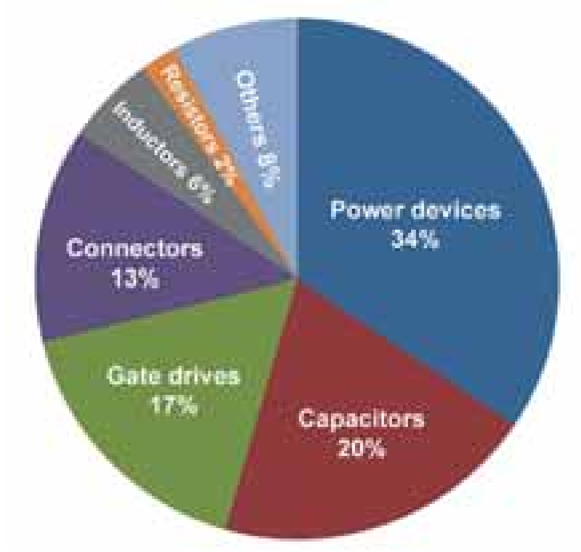


Figure 4. Failure percentages of the most fragile components of electronic power systems. (Taken from an industry survey [2].)

Design for reliability

Reliability should be designed-in from the very beginning of the design phase; this process is referred to as *design for reliability (DFR)*. The DFR process therefore starts from topology selection, circuit design, and component selection and application, and uses a highly accelerated testing method to discover design flaws in the early development stages. The major DFR aspects that should be borne in mind during a PV inverter design include topology selection and design, and thermal design and management [3].

Thermal management

Thermal management is an essential part of the reliability of any electronic system [4] and is even more critical in the case of a PV inverter, which may be required to endure both extremely hot and extremely cold ambient temperatures and daily temperature variations of 30°C or more. Thermal management in commercial PV-powered inverters is accomplished by means of a fully integrated mechanical design that is simple and reliable and which delivers exactly the cooling that is required to each part of the system. Forced convection cooling is used because it provides superior cooling performance at a lower cost, and with less mechanical complexity, than other types of cooling (e.g. liquid cooling).

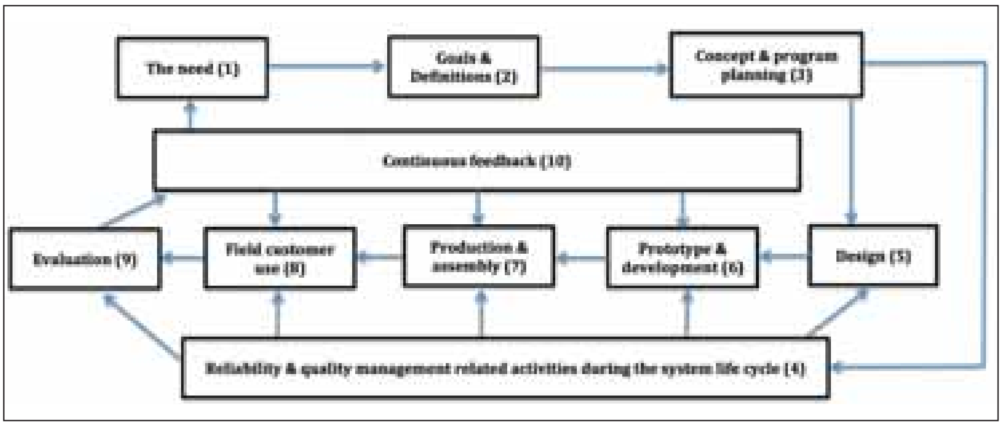


Figure 5. Reliability management process.

Reliability evaluation

A reliability analysis during the design and development of such complex equipment as a PV inverter is important in order to detect and eliminate reliability weaknesses as early as possible and to perform comparative studies. Different reliability evaluation techniques exist for PV systems: they can be classified as either theoretical (simulation tools) or practical (experimental tests). The simulation tool category includes the Markov process method, Monte Carlo simulation, state enumeration method, reliability block diagram and fault tree analysis.

As regards reliability tests, those must be carried out at each stage of development and mass production. When a product is developed, a reliability test will be performed to check the design, material and process; then, during mass production, a reliability test will be performed as a quality-assurance inspection or a failure-rate test for predicting the reliability of the product. The purpose and type of reliability test therefore greatly depends on the device manufacturing stage.

There is a distinction between quality and reliability control. Traditional *quality control* assures that the product will work after assembly and as designed, whereas *reliability* provides the probability that an item will perform its intended function for a designated period of time without failure under specified conditions. In other words, reliability looks at how long the product will work as designed, which is a very different objective from that of traditional quality control. Therefore, certain tools and models can be applicable to reliability but not necessarily to quality, and vice versa.

The reliability test generally has associated time and cost implications. Testing under normal operating conditions requires a very long time, especially for products with long expected lifetimes. The results are only useful for an operating environment which is similar to that in which the tests were conducted; they may not be suitable for predicting the reliability of units operating in significantly different conditions. Alternative methods therefore need to be investigated for 'predicting' the reliability metrics using data and test conditions other than normal operating conditions. The main objective of these methods is to induce failures or degradation of the components, units and systems in a much shorter time, and to use the failure data and degradation observations for these accelerated conditions in order to estimate the reliability in normal operating conditions.

Careful reliability testing of systems, products, and components during the first stage of the product's life cycle (design stage) is crucial for achieving the desired reliability in subsequent stages. During this early stage, the elimination of design weaknesses inherent to intermediate prototypes of complex systems is conducted via the 'test, analyse, fix and test' (TAFT) process. This process is generally referred to as *reliability growth* [5].

Types of accelerated test

Each type of test that has been designated an accelerated test provides different information about the product and its failure mechanisms [6]. Generally, accelerated tests can be divided into three types: qualitative tests, environmental stress screening (ESS) and burn-in, and quantitative accelerated life tests.

Qualitative tests

Qualitative tests yield failure information (or failure modes) only, and have been referred to by many names, including elephant tests, torture tests, highly accelerated life testing (HALT), and shake and bake tests. In the qualitative category, the typical tools are:

- Failure modes
- Effects and criticality analysis (FMEA/FMECA)
- Reliability-centred maintenance (RCM)
- Failure reporting, analysis and corrective action systems (FRACAS)
- Root cause analysis (RCA)

Qualitative tests are performed on small samples, with the specimens being subjected to a single severe level of stress, to a number of stresses, or to a time-varying stress (i.e. stress cycling, cold to hot, etc.). If the specimen survives, it passes the test; otherwise, appropriate actions will be taken to improve the product's design in order to eliminate the cause(s) of failure.

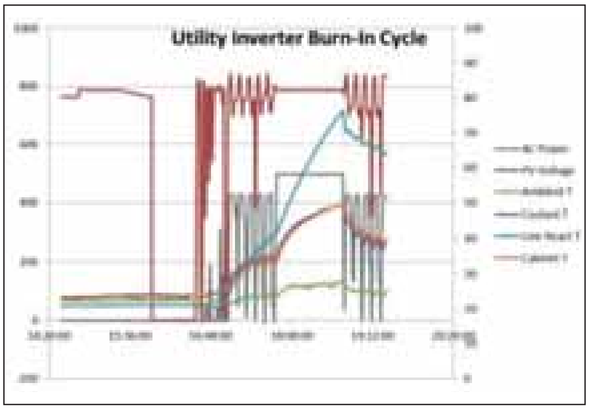


Figure 6. Example of a utility inverter burn-in cycle [7].

ESS and burn-in

The second type of accelerated test is ESS and burn-in testing. *ESS* is a process involving the application of environmental stimuli to products on an accelerated basis; the stimuli can include thermal cycling, random vibrations and electrical stresses. The goal of the test is to expose, identify and eliminate latent defects which cannot be detected by visual inspection or electrical testing, but which will cause failures in the field. ESS is performed on the entire population and does not involve sampling.

Burn-in (Fig. 6) is a test performed for the purpose of screening or eliminating marginal devices, and can be regarded as a special case of ESS. Marginal devices are those with inherent defects, or defects resulting from manufacturing aberrations, that cause time- and stress-dependent failures. As with ESS, burn-in is performed on the entire population. Readers interested in learning more about the subject of ESS and burn-in are referred to Kececioglu and Sun [8,9].

Quantitative test

In the quantitative test category, the typical tools are:

- Life data analysis (a.k.a. *distribution analysis* or *Weibull analysis*)
- Reliability growth analysis
- Accelerated testing (a.k.a. *life-stress analysis*)
- System modelling using reliability block diagrams (RBDs)
- Simulation
- Fault tree analysis (FTA)
- Design of experiments (DOE)
- Standards-based reliability predictions (e.g. MIL-217)

Standards

Design qualification test protocols – such as IEC 61215 and IEC 61730 – have been key to mitigating 'infant mortality' in PV modules, but improvements to these standards are ongoing. They are necessary for ensuring the overall reliability and durability of products going into the field.

The recently published standard IEC TS 62941:2016, Ed. 1.0 ("Terrestrial photovoltaic (PV) modules – Guideline for increased confidence in PV module design qualification and type approval") is a collection of best practices from across the industry. It refers to the basic requirements of ISO 9001, and focuses on PV-specific manufacturing processes and procedures to ensure quality and consistency, and the key metrics and capabilities required for PV. Modules produced in accordance with this standard will be more likely to perform as warranted (25+ years).

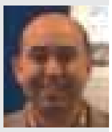
A dedicated reliability standard for PV inverters, however, does not yet exist; the standards that do exist – such as ANSI/UL 1741 and IEC 62109 Part 1 and 2 – focus primarily on the safety of PV inverters. Although Ed. 1 of IEC 62093 discusses inverter qualification, it includes all the balance of system (BOS) components. In a new edition of this standard, a well-accepted design qualification standard is being developed specifically for PV inverters that will significantly improve the reliability and performance of these devices. ■

References

[1] Margolis, R. 2006, "A review of PV inverter technology cost and performance projections", National Renewable Energy Laboratory, NREL/SR-620-38771.
[2] Yang, S. et al. 2011, "An industry-based survey of reliability in power electronic converters", *IEEE Trans. Ind. Appl.*, Vol. 47, pp. 1441–1451.
[3] Sintamarean, C. et al. 2015, "Reliability oriented design tool for the new generation of grid connected PV-inverters", *IEEE Trans. Power Electron.*, Vol. 30, No. 5, pp. 2635–2644.
[4] Catelani, M., Ciani, L. & and Simoni, E. 2012, "Thermal analysis of critical components in photovoltaic inverter", *Proc. IEEE I2MTC*, Graz, Austria.
[5] Elsayed, E.A. 2012, "Overview of reliability testing", *IEEE Trans. Rel.*, Vol. 61, No. 2, pp. 282–291.
[6] Weller, S.D. et al. 2015, "The role of accelerated testing in reliability prediction", *Proc. 11th Europ. Wave Tidal Energy Conf.*, Nantes, France.
[7] Vidano, R. 2015, "Accelerated reliability testing for commercial and utility PV inverters", NREL PV Inverter Workshop, Golden, Colorado, USA.
[8] Kececioglu, D. & Sun, F.-B. 1995, *Environmental Stress Screening: Its Quantification, Optimization and Management.* Englewood Cliffs, NJ: Prentice Hall.
[9] Kececioglu, D. & Sun, F.-B. 1997, *Burn-in Testing: Its Quantification and Optimization*. Englewood Cliffs, NJ: Prentice Hall.

Author

Vicente Salas is an associate professor at the Universidad Carlos III de Madrid (UC3M), and the CEO of the UC3M PV Lab. He has several years' experience in the fields of PV plant qualification and monitoring, laboratory PV inverter and module investigation, and performance measurement.



Project briefing

MEGA-SCALE PLANTS STILL POSSIBLE DESPITE JAPAN'S LAND RESTRICTIONS

Project name: SoftBank Tomatoh Abira Solar Park
Location: Hokkaido, Japan
Project capacity: 111MW
Size: 166ha

Settled on Japan's second largest and northernmost island, the newly activated 111MW SoftBank Tomatoh Abira Solar Park marks an impressive achievement in solar PV development given the huge restrictions of land availability across Japan. The project was developed by SB Energy Corp, which is a 50:50 joint venture between Japanese telecoms-provider-turned-solar-developer, SoftBank, and one of the largest corporate groups on the planet, Mitsuio.

Completion of the mammoth plant near the town of Abira, located in Yūfutsu district, Iburi Subprefecture, on the island of Hokkaido, comes several months after SoftBank announced its intentions to enter the Indian solar energy market via an investment of US$20 billion in renewable energy. This move prompted a huge influx of further foreign investments into the subcontinent and set the tone for what is now a booming Indian solar market. Last December SBG Cleantech, SoftBank's joint venture with Taiwan-based manufacturing services provider Foxconn Technology Group and Indian business conglomerate Bharti Enterprises, scooped all 350MW capacity in an auction in the Indian state of Andhra Pradesh, at a tariff that was then matching the record lowest ever in India.

Nevertheless, with its headquarters in Tokyo, SoftBank's influence on its domestic market has stayed strong. Constructed across 166 hectares of land roughly 10km from the Pacific Ocean, the SoftBank Tomatoh Abira Solar Park is expected to generate enough energy to power around 30,000 homes, according to the companies involved. The project, which was first announced in March 2013, was officially activated in December 2015.

Hokkaido, at the northern end of Japan, is located relatively close to Russia, with coastlines on the Sea of Japan, Sea of Okhotsk and the Pacific. The centre of the island features several mountains and volcanic plateaus, however with cool summers and icy winters the island has a lower irradiation than most other regions of Japan. Nevertheless, the island is much less densely populated than other major regions of the country so many solar developers have chosen it for utility-scale projects. The main shortcoming of this is the separation of Hokkaido from Honshu, the main island containing Tokyo, Kyoto and other metropolitan areas, which generally see greater demand for electricity.

This has not stopped Hokkaido from becoming a key centre for solar in Japan with the Ministry of Energy, Trade and Industry (METI) allocating a significant number of large-scale projects to the island. Between 2014 and 2015, projects of more than 10MW capacity were completed there by Sparks Asset Management (21.7MW), Orix (21MW), Watami ecology (15MW) and JAPEX and Sumitomo Trading (13MW). All electricity produced from these projects will be sold to regional investor-owned utility Hokkaido Electric Power Company (HEPCO) for 20 years under the feed-in tariff (FiT) programme.

However, back in spring 2013, HEPCO announced that applications for large-scale solar plants had surged to such an extent since the introduction of the Japanese FiT programme in July 2012 that the pipeline of renewables capacity was greater than its grid could handle. At the time, utilities in other Japanese regions, including Chugoku and Kyushu also reported having less than 1GW grid capacity available for new solar and wind projects.

In response METI worked on installing large-scale batteries to help integrate renewable systems, including potentially the world's largest flow battery on Hokkaido. Last December, HEPCO announced that this record 60MWh redox flow battery-based energy storage system with a rated output of 15MW had been switched on.

The redox flow battery storage system is situated at Minamihayakita substation on Hokkaido, not far from the Abira solar park, and was built and installed by HEPCO's partner on the project, Sumitomo Electric Industries (SEI), an arm of one of Japan's biggest trading companies, Sumitomo Corporatiom. Masanori Kinugasa, general manager, corporate strategy department, at SoftBank, says that SB Energy has not had any discussion with the battery developers.

However, the storage system is due to be tested over the next three years and is therefore likely to play a role in integrating any intermittent renewable sources of energy on the island.

Design

SoftBank's Kinugasa says that the first time SB Energy came to the Abira solar project site, bush standing above human height had filled the entire location, so it was not possible to assess the condition of the land underneath. This meant the team could not plan a layout with detailed calculations straight away. As a result the firm had to abandon its regular practices for planning solar projects. Eventually the company decided to install units containing 42 panels each across two main arrays. The units were three panels in height and 14 panels wide. This plan gave SB Energy the best chance of maximising its construction performance, says Kinugasa.

During the development stages, the joint venture did not face any trouble between stakeholders in relation to constructing the plant or any environmental concerns.

"SB Energy had made good relations with the governor, land owner and local inhabitants before starting construction," says Kinugasa.

In order to measure the irradiance levels of the site itself, the firm used a Japanese solar irradiation database called NEDO, which provides an METPV-11 score. This is a measurement of solar irradiation during the year. The database, provided by the Japan Weather Association, can also measure precipitation, temperature, and the most effective tilt angles for solar installations.

Structure

SB Energy used pile type arrays for the Abira project, but, given the difficult ground conditions, it had to use special equipment to adjust the height of the arrays in an attempt to decrease the time spent installing the project.

A plant at this scale requires far more

By Tom Kenning

Credit: Softbank

workers all doing their jobs simultaneously, so there are many risks.

"To keep all their performance at high level and give stability," says Kinugasa, "[the] project manager needs to standardise their operation and make an effort to minimise the opportunities in which they encounter irregular tasks."

The developers considered using tracker arrays at the planning stage, but then judged that the disadvantages of higher construction costs alongside not being able to install as many panels as fixed-tilt arrays outweighed the performance advantages offered by trackers. As a result, SB Energy opted for fixed-tilt structures.

Explaining the choice of modules for the project, Kinugasa says: "At the time we planned this project, feed-in tariff policy had just started and we thought the aim of the policy was to support growing domestic industry concerned with renewable energies. So we focused on domestic manufacturers and asked them to [provide] an estimate [price], and we adopted the best offer from Toshiba."

There are now no barriers to choosing solar panels, adds Kinugasa, and developers are not limited to Japan for options because the "premium term" determined by government in 2012 to drive renewables support has finished. Kinugasa says the Japanese market is now in a "competition term" where developers will look to source solar equipment from overseas.

SoftBank began investing in solar when Japan's FiT was introduced in July 2012, ensuring a set price for power producers at both commercial and domestic level and causing the industry to boom over the last three years, despite steady cuts to the FiTs scheme.

The company, which was one of a number of companies operating in non-solar sectors that moved into the PV industry, started by investing in a 39.5MW facility in Tottori prefecture followed by launching a programme to install PV arrays atop 1,000 residential rooftops in Japan in 2013.

SoftBank's projects are based on the FiT policy, says Kinugasa, and to ensure the best levelised cost of electricity (LCOE) for the Abira solar park, it had to work closely with suppliers to make the most effective procurements.

In terms of logistics, the delivery of heavy equipment meant that developers had to reinforce roads between common roads and the project site. They also had to build several bridges to cross some small rivers to assist in accessing the site.

Japanese conglomerate Toshiba Corp provided engineering, procurement and construction (EPC) services as well as the PV panels. Toshiba Mitsubishi-Electric Industrial Systems Corp (TMEIC) supplied power conditioning subsystems. Meanwhile, Toshiba Plant Systems & Services Corp built the mounts.

To obtain connection to the grid, SB Energy had to exchange some information about generating and connecting conditions with HEPCO. The utility then pulled in an interconnection cable from the nearest grid to the grid point inside the solar park.

SB Energy's challenges in terms of planning the project with the entire site covered in bush echoed that of another 46.5MW PV plant on Hokkaido developed by Japanese financial services group Orix Corporation and its joint venture partner Sharp. This recently switched on plant had to be nestled in amongst a forest with around a quarter of the project site covered with trees and the need to take into account various environmental considerations, which is another indicator of the restrictions of land availability in Japan.

The installation of the 111MW SoftBank Tomatoh Abira Solar Park marks the continuation of Japan as one of the world's strongest PV markets, with analyst firm GTM Research pegging Japanese PV installations at 11GW for 2015, despite feeling the negative impact of FiT cuts. Japan's transition to large auction-based projects, away from the high FiTs for rooftop, will also pull back the market by at least 3GW in the coming years, says Mohit Anand senior analyst at GTM Research.

The Japanese market this year awaits the liberalisation of the electricity retail sector, which will allow private businesses to enter the retail electricity market for the first time. This market has been dominated by Japan's 10 regional utilities up until now in the various prefectures of the country. They are responsible for operating the regional electrical grids to which solar installations have to be interconnected.

METI has been posting the names and details of companies set to enter the market from 1 April 2016, with familiar names including SoftBank and conglomerate Itochu among those expected to join in with what several industry observers feel could benefit both consumers and the solar industry. In the meantime, Mitsui and SoftBank continue to collaborate on a number of other utility PV projects in Japan. ■

To read more about how PV developers are coping with land constraints in Japan, turn to p.53.

How O&M contractors can deal with issues in newly and recently built PV plants

O&M strategies | With either newly built PV plants or plants in operation for a couple of years, an O&M contractor may face a series of issues related to the plant's design and construction, the quality of the equipment and parts, and warranty claims. Vicente Parra and Gorka Oña highlight some of these issues and recommend how O&M contractors can address them

Expenditure related to PV facility construction and operation has fallen dramatically in the last eight years. Specifically, the reduction in capital expenditure (CAPEX) accounts for approximately 85% of this fall, and the operating expenditure (OPEX) has dropped by more than 50%. (It is also important to note that the costs for projects in countries where the solar industry is currently under development – such as India, Thailand and Central America – are 15 to 20% higher than in European countries that have a proven track record in PV development. However, these additional costs can be mainly attributed to the lack of efficient logistic networks and the shortage of qualified personnel.)

Given this reduction in operating expenses, O&M contractors have adapted to the new framework. Thus O&M budgets have been adjusted to allow the PV industry to compete with other sources of energy. In order to maintain the quality of the service, it is common to find global companies providing O&M services in numerous locations. On the other hand, small local companies are finding it difficult to compete in such a globalised market.

These economic variables have an impact on the O&M contractor's responsibility to operate and maintain PV plants. PV technology has significantly progressed and the result is high-quality equipment at a lower price. However, when an O&M contractor takes responsibility for a PV plant, it is essential that its business model be completely conscious of the design, the installation, the equipment utilised and the warranties in force. This aspect has even more importance in markets where regular incentive deadlines or financing structures are forcing developers to build plants quickly. In addition, O&M contractors need to structure more efficient strategies in order to comply with the contractual requirements at the current fees, while ensuring a high standard of performance.

Credit: Martifer Solar

One of the more recurrent schemes in the PV industry is the provision of O&M services by the EPC contractor during the period when there are some warranties in force related to the EPC contract. In many of these cases, however, the EPC contractor takes the risk of the O&M contract and subcontracts services to a third party; hence, it is likely that the risk is transferred to such an O&M subcontractor. After the EPC contract's warranty period expires, it is not uncommon that, upon the financing entities' consent, the owner of the plant looks for more economic alternatives and renegotiates the terms, or even appoints another O&M services provider.

O&M contractors can face numerous issues from a plant's design and construction, requiring the correct due diligence procedures.

Design and construction

A good way to prevent design-related issues being passed on to the O&M contractor is to ensure that a satisfactory commissioning system has been completed prior to the PV plant's provisional acceptance, which is the time when the facility is handed over to the operator. If the O&M contractor finds that this has not been done or that some part of the report is missing, Enertis recommends that verification tests always be performed.

Another aspect that the O&M contractor could possibly encounter is that the as-built drawings have not been updated. Not having the drawings that reflect the actual construction of the PV plant can greatly hinder the plant's preventive and corrective maintenance. Enertis therefore highly recommends that the contractor always obtain a good set of as-built drawings.

Regarding construction- and installation-related issues, as part of the routine work carried out by Enertis different construction defects have been noted. These include bad wiring (causing ground faults), under- or over-torqued wiring connections, and MC4 connectors that melt because of a bad part or simply

"It is essential that an O&M contractor's business model be completely conscious of the design, the installation, the equipment utilised and the warranties in force"

Credit: Enertis

Figure 1. Snail trail visual defect.

bad connections to inverters that have been wired incorrectly – the issues can be vast.

Quality of equipment and parts

At the PV module level, a non-negligible number of defects can still be encountered through standard technical audits on site, even during the early stages of the device's operation (within the common two-year EPC warranty period). These defects can occur by their very nature as a result of the inherent malfunctioning of the module, because of either manufacturing issues or poor quality of materials; alternatively, they can manifest during the installation phase as a consequence of improper practices implemented by installers throughout construction and commissioning rush periods. Among the first type of defect, it is worth highlighting issues such as the well-known discolouring of a module's polymer, or the presence of defective junction boxes with activated diodes, which entails episodes of major underperformance.

Special attention should be paid to the harmful potential-induced degradation (PID) phenomenon, a severe polarisation effect related to the solar cell architecture; the bill of materials used to produce the panel generally influences the PID-resistance behaviour. PID is strongly linked to the ambient conditions at the PV site, which are mainly high temperatures and high relative humidity rates. Indeed, besides the level of the effect within a PV plant, the high power loss per module makes PID the most important module degradation phenomenon leading to major underperformance in a PV plant.

In relation to issues associated with the mounting phase, anodisation damage to the aluminium frames of the panels, improper racking and torn backsheets can be systematically observed when conducting dedicated visual inspections on site. The so-called *snail trails* phenomenon (Fig. 1) is typically a result of internal cracking issues within the solar cells composing the panel. This cracking phenomenon, if it extends all over the PV plant or occurs in well-defined places, can be linked to inappropriate handling during transportation and installation of the modules. In this regard, quality control activities carried out beforehand at the module manufacturing location will help determine and trace the origin of such undesirable occurrences.

In many cases, these faults lead to performance losses that should be considered by O&M contractors at all times during the project's lifespan. For example, in the case of snail trails, this visual defect in itself does not imply any power loss; it could, however, be a sign of intrinsic breakage issues, which can lead to inactive regions within the cells, as observed by electroluminescence (EL) analysis. A proper and systematic visual inspection during the first year of operation can help detect this type of problem and will allow the O&M operator to prepare a mitigation plan. In fact, although this kind of defect does not typically fall under the O&M contract's warranty and liability, it can undeniably affect the correct operation of the PV plant.

Credit: Enertis

Figure 2. Enertis' PV Mobile Lab.

Identification of problems in the field

The most suitable ways of identifying PV module failures and underperformance in the field are still the classic methods, such as conducting visual assessments, determining the maximum power, analysing IR thermographs and inspecting modules by EL imaging. All of the equipment used for these tests must meet calibration requirements in order to authenticate the test results and meet industry standards; this ensures that the test measurements are accurate for all types of PV module. Mobile tester solutions equipped with high-quality solar simulators, such as Enertis' PV Mobile Lab, are very practical assets in this respect (Fig. 2).

Apart from the PV modules, it is important to consider other tests, such as *I–V* curve tracing at the module string level, IR thermography inspection of combiner boxes and inverter connections, and the assessment of the structure and PV module assembly (foundations, galvanised coating and corrosion, screw torques and bolt tightening, structure tilt, and module connection). Other aspects worth taking into account are the fence, the inverter houses, the spare parts warehouse and the drainage system. Furthermore, an O&M contractor should also verify the correct operation and performance of the monitoring system and check the weather station's equipment (design and equipment calibration). Finally, because vandalism acts may cause downtime and require additional labour costs to be borne by the O&M contractor, the security system is an important part of a PV facility.

Due diligence

O&M contractors should undertake a complete due diligence process that allows them to identify the previously mentioned issues. This analysis should be carried out in accordance with the O&M contract's framework. From the perspective of this paper, it is important to define within this contract a comprehensive preventive maintenance plan (tasks and frequency), the corrective actions (labour included but parts replacement borne by the client constitutes the more common scheme), and the overall liabilities and warranties.

As part of the due diligence process, it would be prudent to run verification tests and check to see if there are issues at the PV plant, especially if the O&M contractor finds that the commissioning has not been done or that there is some part of it missing. In this regard, a practical testing package for a 10MW plant in the UK includes a full thermography of the panels and connections, *I–V* curve tracing in a sample of strings, and the performance of accurate *I–V* flash and EL testing. A representative sample for the control of degradation of the panels or the identification of issues (using an accredited mobile tester at the site, for instance) can be around 5 to 10% of an average O&M annual cost; this could equate to just a 2% decrease in production. Thus, from an O&M perspective, having these kinds of annual verification would help to keep the PV plant operating at a reliable level, while the owner of the facility can maintain control over revenue risks.

"An increasing interest from owners in having information about O&M activities requires an organised and automated structure to the strategies employed"

Plant location

It is also essential to understand where the PV plant is located in order to mitigate potential issues created by soiling factors or environmental conditions. For instance, Enertis served as an advisor for a utility-scale PV plant that presented severe drainage system problems, which led to flooding on site. This situation, combined with corrosive soils, caused issues with the racking foundations and early signs of corrosion in the racking structures. Mitigation measures were defined by all parties, and the O&M contractor provided labour, which was included in the corrective maintenance scope of the work.

The location of the PV plant is also a key aspect when dealing with the availability of spare parts or with the access to qualified technicians. Enertis' experiences in Europe and the USA indicate that the spare parts warehouse is often located outside of the PV plant's boundary, and parts are stored there for other plants managed by the same operator. However, in other regions, such as the desert areas in South America, warehouses are built on site in order to avoid downtimes caused by the lack of parts.

Warranty claims

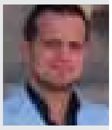
O&M contractors are typically in charge of warranty claims. In these cases, it is necessary to analyse the supply agreement and the warranty conditions. In order to foresee potential problems, it is recommended that a reliable quality control be verified for the purchased equipment – the PV modules being the most important aspect. Enertis strongly recommends that a full quality assurance process be implemented during the selection and manufacturing of equipment (around 0.1 to 0.5% of the total PV module supply cost, depending on the size of the supply), since this will prevent potential production pitfalls and will facilitate the plant's operation.

Conclusion

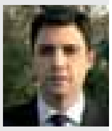
With all this information, the O&M contractor will be able to gain a detailed understanding of the PV plant and assess the labour and tasks needed to ensure that the system is safe and can operate at maximum capacity. As an additional way of optimising the operation of a PV plant, centralised control centres are being utilised by companies for monitoring large portfolios. From this kind of centre, the O&M contractor can alert the on-site team and perform corrective actions in the most efficient way possible. Enertis has detected that there is an increasing interest from owners in having information about O&M activities, which requires an organised and automated structure to the strategies employed in order to comply with such a demand. Finally, it is also typical to find O&M contracts with relatively low fixed fees, compensated by a bonus scheme linked to PV plant performance. ■

Authors

Dr Vicente Parra is the head of quality and testing services at Enertis. With nearly 10 years' experience in the PV industry, he has extensive knowledge of performance and quality issues related to solar PV devices.

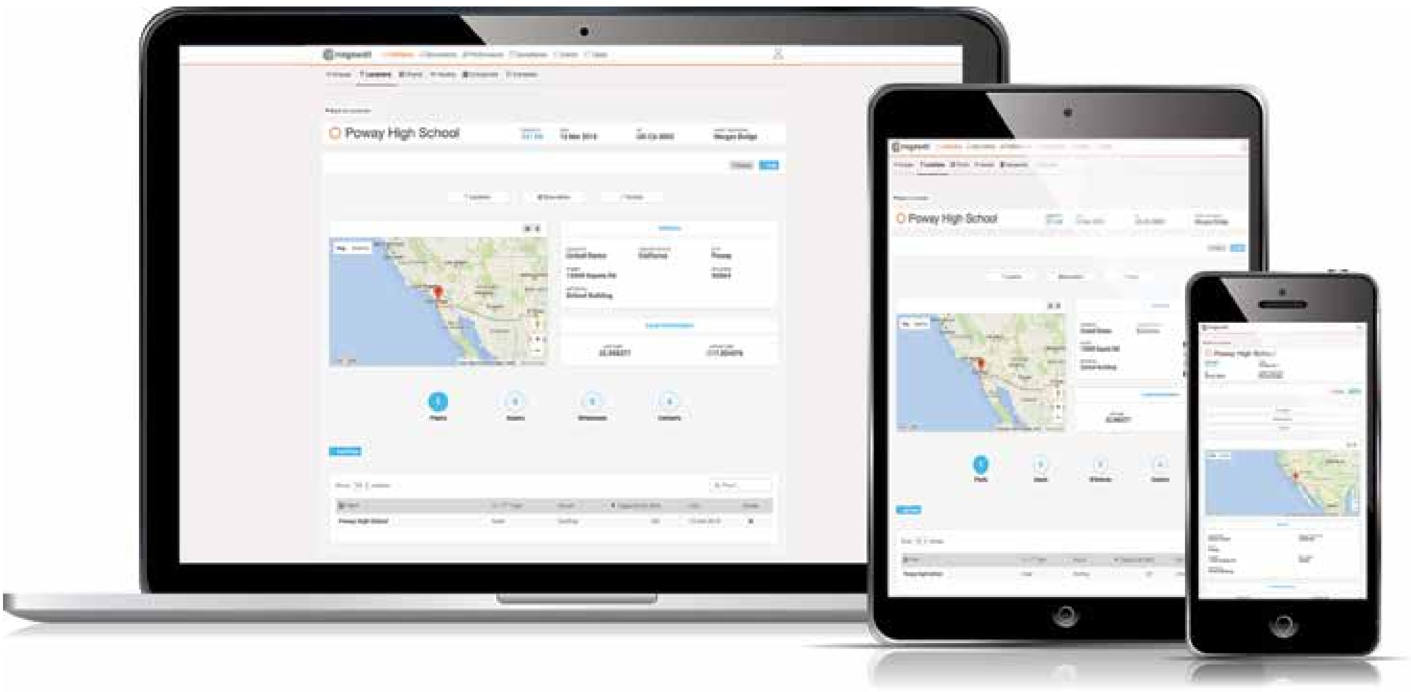


Gorka Oña is the UK manager and a senior consultant at Enertis. He specialises in solar PV and has experience in assisting lenders, investment funds and developers through every stage of a project's life cycle.



Proactive monitoring in effective PV asset management

Monitoring | Datasets from multiple sources allow PV power plants to be monitored more closely than ever before, but how best to use this data is another ball game. Edmée Kelsey and Gwendalyn Bender look at how data should best be stored, managed and mined for effective solar asset management



Credit: 3megawatt

There is an ever-increasing amount of data available for PV plants and the data source that immediately jumps to everybody's mind is the PV monitoring system. Monitoring systems display data captured from the many measuring devices on a solar plant. These systems not only produce masses of performance data, but also a vast array of fault detections and other alarms.

However, this is not the only data source that is relevant for operators to manage and analyse their plants. Increasingly the industry is looking at parallel datasets that can either validate monitoring datasets or replace missing or erroneous data.

Data sources

One key input is independent weather data, which validates measurements from pyranometers, or provides an alternate information source when a weather station is not available at a plant. While considered "ground truth" and the best source of site conditions, pyranometer accuracy is highly dependent on the type of equipment and how well it is maintained. Additionally, unfavourable weather conditions, such as heavy snow or hail, can impact measurement equipment performance.

For these reasons, having an independent data feed helps validate or substitute on-site irradiance measurements. If you have many remotely operated sites, these data feeds also provide a consistent source of information across a fleet of projects that you may have acquired or that use varying measurement equipment. This gives you an "apples to apples" baseline across your portfolio to evaluate weather-adjusted performance.

Weather data can come from a variety of sources and with varying quality and price tags. The industry standard would be a satellite-derived solar irradiance dataset. However, just as important as data quality is availability. Does your vendor offer data coverage across your entire existing and potential project network? Can they guarantee data will be available on a reliable basis 365 days a year? If you are making operational decisions based on this information, you will want to make sure it is consistent across your sites, again for apples-to-apples comparisons, and that it is always available when you need it. To make sure the information is best leveraged, you'll also want to consider ease of integration with your existing performance monitoring platform.

PV system monitoring produces large volumes of data that must be stored and used effectively for optimal management of assets.

Another critical dataset for many asset management activities would be utility data for the plant. Depending on the country and the utility, this data can be hard to obtain and this is why in certain markets third-party providers are offering these datasets in an 'easily digestible format' for a fee.

Detailed field information is an often overlooked operational input. Field technicians on the ground are usually the personnel closest to actual operations and frequently have very interesting observations. Their insights could allow operators to safeguard or improve the long-term performance of the plant long before monitoring systems signal a problem.

Keeping data

But with so many different data inputs into performance, what kind of data should you collect? How granular should it be? What are the key time intervals? Finally, how long should you hold on to all of this information?

The safe bet is to keep everything. That will not get you fired and perhaps one day in the future there will be some new ingenious analytic tool with a magic formula that optimises your plant by 100%. No one wants to be the fool who threw data away that is needed later on down the road.

But although data storage is cheap, it is expensive if you are storing unusable rubbish you don't know what to do with. In order to make a more informed decision about which data to collect and keep, it might be more practical to look at some of the main use cases for performance data that we know of today:

Performance analytics: The most cited use case for plant data is analytics for performance enhancement. If you can separate production impacts from weather and production impacts from equipment, you can reconcile recent performance and identify and fix performance issues. You can also avoid wasting time chasing down equipment problems that don't exist. To complete this analysis, at minimum you need access to concurrent power meter information and weather inputs.

Performance reforecasting: An increasingly important use case for plant data is the evaluation of a plant by a potential buyer or for bank refinancing. Investors and financial institutions may send in a technical advisor to assess the health of the plant. Bringing in a technical advisor report is no longer only a check mark on due diligence lists; it directly affects transaction value or refinancing conditions.

Financial forecasting: Cuts or changes in feed-in tariffs in some countries have created a need for owners and operators to perform detailed liquidity analyses and assess if they will be able to meet debt service during low irradiation months. For this use case, it is more relevant to look at the actual historical performance of the plant, rather than at the theoretical P50 forecast data.

Meeting regulatory requirements: Regulators require storage of specific datasets to prove compliance with national and federal energy regulations. Operators will want to track revenue loss and potential compensation for lost output events, such as curtailment instructions by the energy buyer or transmission operator. These lost output events will need to be documented in detail and stored for a considerable period.

Plant enhancements: Solar assets may at some stage be repowered as part of a micro-grid or have storage added to them. In these cases, detailed historical performance data will be critical for making sound engineering and financial decisions.

Using data

After deciding which use cases are relevant and therefore what data to collect, the next step is to ensure that the data is actually useable. Analytics will be relatively useless if the underlying data is missing or incorrect. To ensure that the data is of sufficient quality, here are a few best practices for operators to follow:

Validate data: Data quality will be significantly improved if operators have a data validation process in place. Data validation processes could be comparisons of two similar datasets, such as inverter data against utility meter data, with automated algorithms or manual validations. The most important thing is that this process can be audited. For example, if some data are altered, approximated, or backfilled the organisation should have a record of who made the change, when the change was made, why it was made and what data source was used.

Fill data gaps: If data is missing, incomplete or corrupted the asset manager should attempt to create an alternate dataset as a proxy and be sure to flag it as such.

Keep consistent records: Detailed record keeping for alarms, alerts and events are important. This does not only include events tracked by the monitoring system, but also a detailed log of external events such as grid outages, curtailments and any other external events that have direct or indirect impact on the performance of the plant

Maintain field records: Record keeping for field observations and interventions is critical, but often harder than it sounds. Many owners are struggling with incomplete records because they switched O&M service providers, or their O&M provider has gone out of business. These records may have been lost or simply never kept in a professional manner.

Integrate data into one platform: A great best practice is to "free" the respective datasets from their silos. Often monitoring data lives in one or more monitoring platforms while weather data resides in weather portals. Meanwhile events and work orders live in CMMS systems, spreadsheets or email correspondence, and the utility data lives on a utility portal, a spreadsheet or even just a piece of paper. In order to do be able to do any meaningful analytics or data validation, the data needs to be easily accessible and comparable. This will involve standardising, normalising and storing the datasets in a centralised data warehouse.

Future benefits

Tracking all of these project data points and following these best practices may seem like a lot of effort at first sight, but future benefits are considerable.

So let's be practical. The requirements at every site are going to vary in terms of the information you need to gather and keep for making different decisions. Knowing this, it is best to begin with the end in mind. What are the most important decisions you need to make now or foresee needing to make in the future? After a close evaluation of top priorities, you can determine the performance monitoring information and platform that will best address your core obstacles and concerns. ■

Authors

Edmée Kelsey is founder and CEO of 3megawatt, a provider of solar asset management software. She was the former CFO of Main Street Power, where she closed project financing for over 100 distributed solar PV projects and was responsible for the asset management of those solar assets. She was also formerly a VP at the investment bank JP Morgan and managing director of a clean energy corporate finance advisory firm.

Gwendalyn Bender is energy assessment product manager at Vaisala, a global leader in environmental and industrial measurement. In a similar role at 3TIER (acquired by Vaisala in 2013), she has served the global solar community since 2009 and played an integral role in the development of solar assessment techniques and datasets, which have largely been adopted as industry standard best practices for solar development, operations, and asset management.

Five lessons from the storage frontline

RES' Jake project; one of the pioneers

Credit: RES

Grid storage | Deploying battery storage at grid level is relatively uncharted territory, but a number of pioneers projects are now in the ground. Patrick Leslie and colleagues at RES, which built some of the first wave of storage projects, teases out the key technology, finance and regulatory lessons the industry can learn from these early experiences

Renewable Energy Systems (RES) started developing battery energy storage projects over six years ago. In early 2014 RES commissioned its first project in Ohio, a 4MW lithium-ion battery for frequency regulation in the PJM interconnection area of the North-Eastern United States. In total, RES has now completed six projects for a total of 73.4MW/30.8MWh and has six further projects in construction phase. Inevitably, there have been valuable lessons learned along the way. Heeding these lessons will be important for developers, utilities and asset owners as the storage industry grow further.

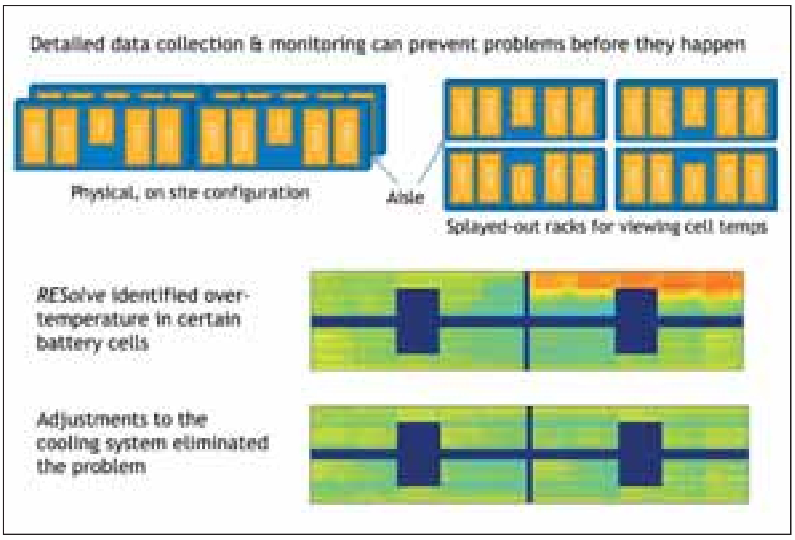
1 - Controls and monitoring are essential to ensure safety and maximise value for owners

Lithium-ion is currently the battery of choice for grid-scale energy storage, and individual projects are scaling up to the tens and soon hundreds of megawatts. These battery cells have certainly proven themselves in laptops, cell phones, and electric vehicles, but for large-scale grid energy storage, the battery system architecture is quite different. Large grid batteries typically have long battery strings, sometimes with as many as 300 cells each. The performance of the system often hinges on the weakest link, which introduces new challenges and some risks. With grid energy storage projects that contain thousands of cells, the controls and data acquisition systems are critical.

Failure to properly monitor and manage these long strings can result in poor performance, premature degradation, and potentially what Tesla's Elon Musk would call "RUD" (rapid unscheduled disassembly). A battery fire at a grid energy storage project is the last thing this industry needs while it is just gaining momentum. Further, a project's revenue may also hinge on how good the controls are. For example, as the PJM market becomes saturated with energy storage the system operator has changed the market rules to rank and call storage resources by their performance score. A few percentage points can make the difference between being called into the market, or sitting on the sidelines.

There are many control systems within a typical energy storage system (ESS). Each string of cells has a battery management system which reads individual cell conditions such as voltage and temperature. Each power conversion system (PCS) has its own control system. The ability of these components to work together lies in the site controller.

RES has developed a proprietary site controller, RESolve, which interfaces with the OEM battery management system and PCS controllers and allows greater visibility of and control over the overall system (Fig. 1). The site controller's functions are twofold: first it must aggregate many PCSs and strings of cells into a single site and second it must make dispatch decisions given any number of internal and external pieces of data. Aggregating many cell strings and PCSs requires the site controller



Credit: RES

Figure 1. How site controllers monitor and maintain the health of energy storage systems.

to ensure that both components are available to operate safely and without damage to either component.

Next the site controller must split the dispatch signal between all of the PCSs and cell strings while optimising state of charge (SOC) balancing, PCS efficiency curves and degradation. The site controller will also take input from the energy storage system, the network and remote signals to make real and reactive power decisions and commands which will allow the ESS to optimally perform its service in the now, but also positioning the SoC to be ideal for what is likely to happen in the future.

While the site control requirements in PJM frequency regulation projects are relatively straightforward, as the revenue is generated by a single application, future project applications will require far more sophisticated control strategies to maximise the value created by the ESS.

RES' recently announced project with Western Power Distribution, the largest distribution network operator in the UK, is a good illustration of the importance of advanced control systems in developing multiple layers of value from a single battery asset. The project will see a 300kVA/640kWh lithium-ion battery installed at an existing UK solar park, and will demonstrate nine different use cases for integrating energy storage with solar PV. These are set out in Table 1.

RES will use RESolve to provide 24/7 management of the battery's operation for this project, to allow scheduling of services and ensure the different value streams are delivered as expected. RESolve has been developed with these requirements in mind, and includes a wide range of operating modes as diverse as voltage control, solar ramp rate control and demand charge management, alongside a sophisticated scheduling system that allows for multiple operating modes throughout the day, or even concurrently. In addition, advanced SOC management techniques are employed to ensure the ESS is able to deliver the service when it is most valuable.

RES is actively developing several projects in the UK where we will optimise multiple storage assets across several values streams. These include frequency response, distribution constraint management and peak charge avoidance across a combination of grid connected energy storage projects and energy storage located behind the meter on generation or industrial sites.

2 - Integrated solutions are essential for cost-effective design, successful operations and commercial simplicity

A complete ESS is far more than just batteries and an inverter – numerous components are integrated to make the whole (Figure 2). All are important, and most are essential to good performance and longevity. Despite efforts underway to make the components "plug-and-play", the industry is not there yet. The integrator role remains essential for end users who want a project with few headaches and where one party is responsible for its ultimate success, from design and engineering through to long-term operations and maintenance.

Some of RES' projects to date have been done with a single vendor supplying the entire integrated battery and inverter system, and RES engineering, procuring and constructing the balance of systems (transformers, wiring, civil works, and controls). RES also has experience with full integration of an ESS using different vendors for the batteries and inverters. The latter approach introduces complexity but can be well worth the effort for certain projects, depending on the intended use case, and it gives more flexibility to achieve a design that will result in a safe and reliable system.

Integration of the ESS with the local electricity grid is critical. The grid connection process can be time consuming and challenging, so intimate knowledge of the process, network standards and operating protocols are key for on-time and on-budget project delivery. The ESS must seamlessly interact with the complex grid environment of protection schemes, metering and controls. These requirements will change on a project-by-project and client-by-client basis. For example, utility customers will often request significant changes to standard designs in order to meet their particular definition of "utility grade". This is something that many battery and inverter vendors are not familiar with, and to successfully deliver a project, holistic engineering and expertise with the intricacies of the local electricity grid is essential.

Holistic engineering also plays a part when considering how the balance-of-system marries with the OEM equipment. RES has found several examples where a design change that adds hundreds of pounds to the storage equipment cost

1.	**Sell electricity for higher price per kWh**
2.	Shape generation profile to demand
3.	Peak lop network demand
4.	Raise minimum demand to limit voltage rise
5.	Voltage control
6.	**Peak lop generation to enable larger solar parks**
7.	Smoothing/power quality
8.	Change peak lopping level
9.	Constructive interactions (between modes above)

PV owner benefits

DNO benefits

Table1. Nine use cases targeted by WPD solar-storage project.

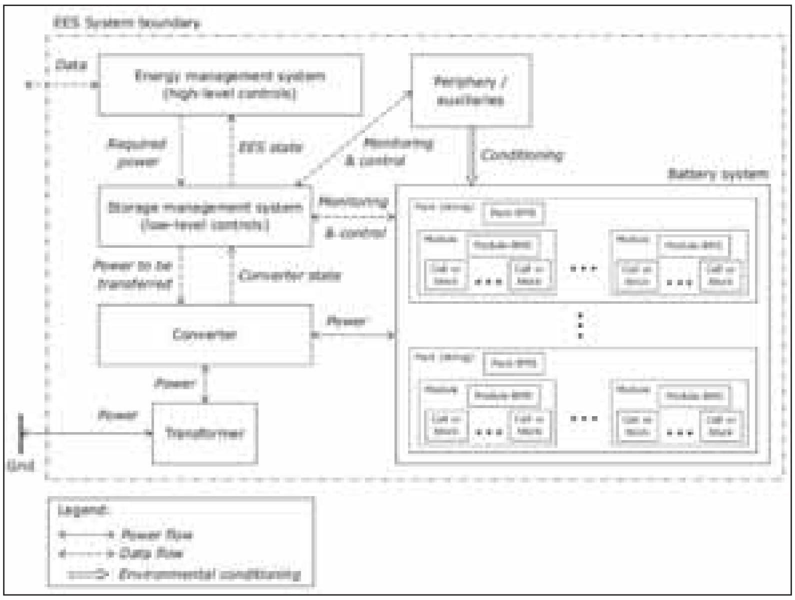


Figure 2. Diagram showing the main elements of an EES system, including device, converter, auxiliaries and management systems [1].

ends up saving thousands on the balance-of-system cost.

In order to deliver a successful storage project it is a great simplification to have a single party in control of the design, development, permitting, detailed engineering, testing, warranties and operations to ensure there are neither contractual gaps nor overlaps. This is achieved by provision of 'fully wrapped warranties' where the client only looks to a single company for all warranties on a project. Clients prefer this, especially when they do not have significant experience with contracting for and owning energy storage technologies; however, it is still quite unusual in the market as energy storage providers typically pass through manufacturer warranties and then the clients end up looking to multiple parties for warranty claims related to different parts of an installation.

3 - Financing a large-scale battery storage project is possible

Extensive deployment of storage will not happen until projects can be financed with reasonable ease. The same is true for any growing industry. The solar market has soared once given access to project finance for large-scale projects. The good news is that mainstream financial institutions are becoming familiar and comfortable with financing battery storage projects.

A great illustration of this was the announcement in October 2015 that RES and Prudential Capital Group had closed on the financing of the 'Jake' and 'Elwood' battery storage projects in Chicago. RES developed and constructed the two projects, and combined they offer a flexible power range of 79.2MW. Each project has a nameplate capacity of 19.8MW and the ability to store 7.8MWh of energy. The financing is the first non-recourse senior project financings completed for a utility-scale battery storage system in North America. The financing included a preferred equity investment representing approximately 50% of the total equity and non-recourse senior secured project financing debt representing approximately 50% of the total project costs.

A major challenge with this undertaking was that it required a great deal of education on both the technology (battery storage) and the market (frequency regulation in PJM). A great deal of education was necessary for all involved, including the insurers who were aware of the early problems that some grid storage vendors had. After the counterparties became comfortable with the technology and the market, the deal became much like other project financings.

Ultimately what made this financing successful was the fact that RES has experience with similar deal structuring with wind, solar, and transmission. The projects used a single large and well known OEM technology provider for the battery and inverter system, and were backed by a robust warranty. The project cash flows had certainty as they were backed with hedge on frequency regulation prices, with the debt raised to match the tenor of the hedge. The projects were large enough to warrant the time and cost to structure the transaction, and the same counterparty provided both the debt and equity.

4 - Regulations and (the lack of) market rules continue to create uncertainly, which places additional burden on the early projects

Despite strong progress over the last several years, lack of clarity on certain regulations and with market rules continues to hinder progress in the grid storage industry. For example, as RES developed its first project in Ohio, it was clear that the US Federal Energy Regulatory Commission (FERC) would consider the project as a generator, but it was initially unclear whether the State of Ohio would determine it to be generation, transmission or distribution. This led to significant uncertainty around both property tax and sales tax leading to material differences in projected return on investment. The next hurdle was with the IRS, the US tax authority. The rules were unclear as to what

The Jake and Elwood battery storage projects attracted the first non-recourse senior project financings for storage in North America.

Credit: RES Corporation

depreciation rate could be applied, which also made a measurable difference to the projected economics.

Unfortunately the same regulatory uncertainty and unsuitability of existing network and market arrangements for storage is strongly evident in other markets, such as the UK. Given that the UK has historically had very few operational electricity storage sites, UK energy policy, market arrangements, network access and charging rules are not adequately designed for storage. This results in a number of unnecessary and no doubt unintentional barriers to the uptake of electricity storage.

For example, the application in the UK of 'final consumption' levies to energy that is imported by an ESS only to then be exported for use by its actual final consumer creates a situation where energy storage needs to 'buy high and sell low'; hardly a route to a sustainable business. In addition, while the regulatory position of storage is unclear (is it generation, is it demand, or is it another new category?), it is difficult to develop the necessary solutions to industry codes to enable the uptake of storage. In any market, until such situations are clarified is clarified it will be hard to realise the value that storage can provide.

5 - Long-duration lithium-ion is becoming viable

It is commonly assumed that lithium-ion batteries don't work for long-duration applications. RES believes otherwise and is proving that point. The company is constructing a six-hour energy storage project for a US utility in a dense urban pocket of a major East Coast city and lithium-ion technology has proven to be the best choice across a range of considerations including cost, safety and noise performance, and land use.

The driver for the project was a particularly challenging transmission and distribution constraint faced by the local utility. Demand growth in a specific area began to overload two sub-transmission feeders serving two substations. The traditional solution would have been a new substation, switching station and sub-transmission feeders at a total estimated cost of roughly US$1 billion. The utility chose instead to procure an innovative portfolio of energy efficiency, demand response, distributed generation and energy storage to defer the need for the upgrade. The energy storage system serves an important role in the overall solution given its flexibility in being able to fill any gaps from the less predictable and dispatchable resources such as the energy efficiency measures.

Notable price declines in lithium-ion battery cells make help make projects like this possible and continued projected price declines will open up even more opportunities for batteries. The future offers much potential for new energy storage technologies that will drive down the cost of long-duration storage, e.g., flow batteries, but considering that most alternatives are currently not seen as 'bankable', lithium-ion remains the best bet in the near term. Many of the press releases for new storage technologies generally refer to pilot projects or demonstration systems. Innovation and demonstration projects are essential, and certainly one of these technologies will replace lithium-ion at some point, but grid-scale systems being deployed today must operate with high reliability and safety for at least 10 to 20 years. Utilities have high standards and all new technologies will need a substantial period of vetting before they can be deployed on a broad scale.

Safety is paramount and, especially given the dense urban location in this case, fire safety received intense attention. Some, but not all, lithium battery chemistries are subject to a rare but possible condition called thermal runaway, which can create a fire that destroys the entire battery system. Cell and system design can and must be used to reduce or eliminate the potential for thermal runaway. Monitoring systems can identify and warn of potential safety issues, and properly designed protection, monitoring and fire suppression systems can assure that any fault does not cause danger to life or property.

Noise can also be a significant consideration. While the batteries do operate silently, certain ESS designs can feature large fans and air conditioners that can create a surprising amount of noise. This can cause permitting challenges and must be considered early on during the design process.

Finally, land is at a premium in big cities and as such this project needed to fit in a very tight footprint. As of today, lithium-ion batteries represent the highest energy density of all commercially available batteries, which means smaller enclosures and foundations, less balance of plant (conduits, junctions, etc.), and overall smaller project sites, and fewer fire suppression systems. Additionally, given the high efficiency of lithium-ion batteries (88%+), cooling loads are minimised, reducing the size of heat rejection equipment such as vent fans and air conditioners that is required.

Conclusion

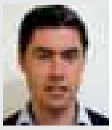
It is an exciting time for the energy storage industry. The technology has firmly demonstrated the role it can play in electricity systems and the value it can bring to consumers. But this is just the beginning and there is much to be done before the industry is considered fully established. The industry must prove that it can consistently provide utilities with high-reliability and predictable operations, asset owners with 'bankable' returns, services buyers with high performance and consumers with value for money.

For RES, the lessons learned about the need for high performing controls and monitoring; the value of a highly integrated design and delivery approach; the success factors needed to secure energy storage finance; the importance of really understanding local regulations and how they can create unintended impacts on energy storage business cases; and the viability of lithium ion for much more than just short duration business cases, will be crucial as we seek to play a leading role. ■

Authors

Patrick is responsible for US energy storage business development & strategy, with a focus on the economics of battery storage. Before joining RES, Patrick developed two battery storage projects for Puget Sound Energy, an investor-owned utility in the Pacific Northwest. He also worked on large-scale power plant development and acquisitions.

Andy Oliver is chief technology officer for the Americas and global head of storage for the RES Group. He has been involved in over 3,500MW of operational wind and solar plant. Over six years ago he set up an energy storage division within RES and the company now has 88MW/52MWh of energy storage either operational or under construction.



John Prendergast leads energy storage project development for RES in the UK and Ireland. This includes the recent signing of RES' first UK energy storage project; a battery system integrated with solar PV and delivering nine different operating modes. Prior to this, John worked on RES' first UK solar PV projects.

References

[1] DNV GL. December 2015, "DNVGL-RP-0043: Safety, Operating and Performance of Grid-Connected Energy Storage Systems", https://rules.dnvgl.com/docs/pdf/DNVGL/RP/2015-12/DNVGL-RP-0043.pdf

Energy storage in 2016: Where do we go now?

Market outlook | Many have predicted 2016 will be the year when energy storage starts to live up to its hype. Andy Colthorpe canvases views from some of the leading figures and companies in the sector on the next developments a market that could help take solar and other renewables to the next level

Tesla's Powerwall helped energy storage enter the mainstream in 2015 and position the market well for further growth.

Credit: Tesla

If 2014 was a mostly behind-the-scenes series of Eureka moments and 2015 was the year energy storage started to go mainstream, where does it go from here? The obvious answer is out of the factories and into grids, micro-grids, businesses and houses the world over. It will happen at a different pace in different regions, and each market will have its own drivers – and barriers – to adoption. Here are seven distinctive takes on what the industry is predicting – and hoping for – in 2016 and beyond.

Analyst's view: Cosmin Laslau, head of Energy Strorage Intelligence, Lux Research

Business models start catching up with technology

More and more battery developers are looking to find solar partners, but for us one of the biggest questions looking to 2016 and beyond is the amount of vertical integration and cost curve savings that these guys can pull off. A solar player could buy a battery developer, or vice versa, and offer a fully integrated product that shaves a lot of costs off.

When we look at the use cases for storage, there's not a killer application to justify solar-plus-batteries with a single use case. This is where benefit stacking between multiple services is tremendously important. That points to a couple of things. One of them is the importance of clever software. So in 2016 and beyond, we expect even more activity to be driven in terms of investment into start-ups, developing software for solar-plus-storage integration and use-case management, as well as potentially some acquisitions in this space or some serious internal R&D by the larger corporations.

We're not seeing any major breakthroughs coming up in the near term that will rock the industry in terms of cost reductions. Probably the much more important thing will be financing arrangements and realising that in certain geographies, you want to deploy as many batteries as possible with financing because these are projects that can make sense for everybody involved and generate some pretty good revenues. So although things like the Tesla Gigafactory are going to do great things for cells and packs, and then we've got some balance of system (BoS) and installation costs that are also going to see some reductions, what's really going to drive the bulk of activity in getting to the next level of deployment is financing and new business models.

Residential solar-plus-storage: Benjamin Schott, director of business development for Sonnen (formerly Sonnenbatterie)

Nascent UK market can learn from German experiences

We see that a lot of markets are becoming more and more attractive, the UK, for example. I think Germany will have a strong year as well. Although we had prepared the value proposition of SonnenCommunity, our new energy trading platform, to replace the subsidies, the government has decided to continue them.

We are now, through the subsidy programme in Germany, at the level where [energy storage] is like a commodity, so we have standard processes now. It might be the case that in the future we will come to a model where the customer will not pay for hardware, it will be service-driven. However, I think that the trading and grid service markets, which are key to that, are not there yet.

The UK, US and Germany are all very different markets, with different value propositions for energy storage in each. In 2016 we would like to see the UK take on learnings from Germany. At the levels of government and regulation, you [the industry] have to stay in discussions. And we already have fixed a lot of things in Germany about connecting a storage system to the grid. So I think there's a lot of things the UK and other new markets can learn or transfer, from Germany.


Credit: Younicos

UK energy secretary Amber Rudd visits a storage demonstration project. The UK is expected to see a great deal of storage market activity this year.

Grid-scale storage: Roger Lin, marketing director for NEC Energy Solutions

Li-ion still king as grids explore flexibility options

We will see continued settling in the energy storage supply chain. Newer technologies will continue to gain both 'mindshare' and market share as they prove themselves in pilots and more importantly, commercial projects, but lithium-ion will continue to dominate the energy storage market this year. This is due to the maturity of the supply chain and manufacturing infrastructure, and Li-ion's already overwhelming share in portable electronic devices and in electrified vehicles.

The major lithium ion battery cell manufacturers will focus on their core offerings of lithium-ion cells and battery modules to large energy industry heavyweights focused on bringing grid-scale energy storage solutions to market. Here it is becoming more and more significant not only to reduce the capital cost of the energy storage equipment, but also to increase the strength of guarantees, warranties, service, and support that back the operation of such units.

As core battery costs continue to decline – LG's supply of lithium ion cells to GM for US$145 per kWh is the most striking data point emphasising this reality – the responsibility for cost reduction shifts now to the 'balance of system' costs including enclosures, thermal management systems, control hardware and safety equipment, which today can more than double that number. Installation and commissioning costs will also be under pressure and we will see further refinement in equipment designed for quick and easy installation. Fully installed system prices will see perhaps 20% reduction in 2016, driven by a combination of all these factors, from US$800-US$1000 per kWh last year.

The speed of expansion of the grid-scale storage market is also dependent on the value that can be earned in the markets. As markets are redesigned to place further value on the flexibility of resources, the speed and accuracy of their response, it seems natural that energy storage becomes more commonplace as one of the most effective options for improving the stability of the grid while simultaneously allowing it to become more sustainable.

Regulation: Haike van der Vegte, senior consultant for new energy technologies at DNV GL

Market design and regulatory space will evolve

In Europe, we really get to much bigger integration sizes in 2016. We are in discussion with transmission system operators (TSOs) about defining new markets – for example for ultra-fast response applications, much faster than for the primary reserve market. There is a need for getting the benefits for providing even faster response times. The same goes for the distribution level where congestion issues and power quality are now accountable to the distribution network operator.

For multi-megawatt scales of storage systems, we want to see a move to a much more product-based market, where it's not tailor made for each storage system that you buy. Specifically for behind-the-meter applications of storage, we really should aim for that product-based market where there is no risk that the technology you buy is not suitable. We have definitely seen some proposals out there that provide, for example, statements on lifetime of the system framed completely differently by different manufacturers. Also, if you would buy a system now I can promise you that you will get different ways that warranties and guarantees are defined.

We work a lot on aggregation of smaller storage systems as well, and on finding the optimal dispatch algorithm to reap the benefit of such a system from different markets. The majority of such projects are still demonstration projects, where we aggregate the storage systems or demand response type of activities and make them work together as one, so we're really learning a lot, but commercial application is not [going to be happening at scale] in 2016.

More interconnection [which has been discussed in Europe] definitely has its impact on the business case for energy storage. There are big challenges ahead of us when we deploy the kind of renewables we promised ourselves in Paris. So any way to improve the flexibility of the system is very much appreciated and necessary, including interconnection.

Balance of system: Volker Wachenfeld, senior vice president for hybrid and energy storage integration, SMA Solar

BoS costs will come into focus

In addition to batteries, BoS costs are moving into the focus of interest. Reducing inverter costs in 2016 will not only be a question of economies of scale, but also of cost-optimised system design. Germany's prolonged incentives for solar-plus-storage should help the country avoid a drop in market figures. Requirements do not seem to have changed significantly; only the curtailment level of PV power is reduced from 60% to 50%. As a consequence, the average level of installed capacity per household might increase a little bit. Using forecast data for energy generation will become more relevant to optimise the charge-discharge cycle.

While we don't yet know the effects of changes to net metering policy, North America has a small but sustainable market for residential energy storage, mainly covering back-up applications. This segment should be expected to increase significantly. Reduced system costs in combination with growing public awareness will drive this market – at least on an evolutionary level.

Successful system offerings by big players in PV and the wider energy market will differ from European solutions. The higher energy demand will require at least double the average installed capacity, equipped with inverters of at least double the size of average European values. The need to provide back-up solutions mean AC-coupled systems will be preferred, based on power electronics with larger surge capacities to provide energy in blackout situations.

Emerging markets: Tim Hennessey, president of Imergy Power Systems, a California-based maker of redox flow battery systems

Micro-grids won't be the only application in emerging regions

It's very dependent on the market. If you said India's going to skip the base load generation and [won't have to build] lots of infrastructure and wires I think you'd be an idiot. Economies of that scale cannot exist on totally distributed islands of power. The same as the Western world, that 25% [peak] at the top where you have a lot of fluctuation and variation in demand is being exacerbated by renewables because of the lack of coincidence of generation and demand. That's where the play for storage fits in, because that's the expensive part.

In the smaller countries, in parts of Africa, or south Asia, you're dealing with micro-grids – some base load but it's not going to be a massive infrastructure, and you're going to have distributed generation with renewables heavily integrated into that. So I think this year is going to see some of that evolve more.

But it's all tied into overall general global macro-economics. If the markets are down, are they going to spend money on this? No. So the timing of this is up for guessing. You're not going to see massive projects unless they're subsidised out of Europe or the US; they just simply don't have the wherewithal to do it on a capital basis. So it's going to be in the control of the national governments, or the subsidies from World Bank, some of the programmes like Power Africa from the US. Tanzania, Rwanda, Cambodia, Thailand, Laos – they're all looking at similar things.

I think this year is going to be the education year, the year of let's do some of these projects, let's structure some to learn how to do this the right way but let's start doing this in all earnestness because the time is now, the time is right to do this. If I go back 10 years, you see these surges of "yes, yes, yes" and then it just doesn't get there.

Now, we're seeing a different picture because PV is economical, it really makes sense. Adding to that the firmness piece from storage, if we can combine those two, the levelised cost of energy will drive those kind of projects. So this year is going to be when we see the initial [projects] on scale in developing countries and that will evolve quicker after this year. So I'd give it a two to three year window to see this really ramp up on a really large scale.

Storage is now: Tesla statement to *PV Tech Power*

There is a common misconception that energy storage is coming in the future, but that's not true. Economically viable, proven residential, commercial and utility-scale energy storage is here today. The demand is too.

Of all the fossil fuel consumed in the United States, one third is used in transportation and another third goes to electricity production. In the US, the electric power sector alone produces over 2,000 million metric tons of CO2 which is like burning 225 billion gallons of gas. The EPA [Environmental Protection Agency] says it would require 1.6 billion acres of US forest to negate the environmental damage.

What if we could move the electricity grid off of fossil fuels and towards renewable energy sources? Once we're able to rely on renewable energy sources for our power consumption, the top 50% of the dirtiest power generation resources could retire early. We would have a cleaner, smaller, and more resilient energy grid.

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Solar Media is building an Energy Storage Alliance, including media and events, for their existing audience of tens of thousands of clean energy professionals. The focus will be on enabling growth in the energy storage market in the UK and beyond, drawing on extensive experience of producing international conferences and exhibitions in Europe, North America, Asia and Africa, with publishing channels that include PV Tech, *Photovoltaics International* and *PV Tech Power*.

As well as the website Energy Storage News (previously PV Tech Storage), major new initiatives in the space from the alliance will include the Energy Storage Summit and the Energy Storage 100, taking place in April this year and dedicated strands at the Solar Energy UK show, co-located with Clean Energy Live in October.

Members include: British Solar Renewables, CCL, Ecotricity, Hyperion Executive Search, SMA Solar, Sonnen, Younicos, Sunamp, NEC, Smart Power Systems, RES Group, Rexel Energy Solutions, Wattstor, ChargeSync, Green Acorn, Cumulus Energy Storage, Circuitree, Power Electronics, Origami Energy and more.

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Would BP be doing better if it had stuck it out with solar?

BP's latest financial results underline the extent to which it has been hit by the recent fall in oil prices. John Parnell asks if the company's fortunes might have looked a little brighter had it not abandoned its position as one of the early pioneers of solar power

Credit: BP Solar

BP was early to get into solar and early to leave.

BP has posted some pretty terrible financial results as the falling price of oil bites. Its oil sands projects need oil to be well over US$100 a barrel, so sub-US$35 is going to create issues. Meanwhile divestment from fossil fuels has matured from a statement on climate change activism to a strategy pursued by financial services giant Allianz and its peers. On Monday ratings agency Standard and Poors lowered its view of Shell and issued a negative outlook for BP, Repsol, Total…you get the idea.

The outlook for solar is a little different. Demand is booming and the governments of China and the US have signalled that their double-digit gigawatt deployment rates are here to stay. The stock market has linked solar's fate to high oil prices but in terms of the demand for deployment, the future is very bright indeed. Even if oil is cheaper than the barrels it comes in.

So will BP be regretting its decision to bail on the solar industry back in 2011? Maybe, maybe not.

BP Solar was a very, very early mover on solar and was part of the efforts in the 1970s, 80s and 90s to drive prices down in that early part of the cost curve. After that phase, once solar began to become more efficient and high volume production took off, BP Solar jettisoned its manufacturing assets and intellectual property and the die was cast. It didn't want to get sucked into a price war with Factory China. Speaking at the time CEO Bob Dudley said "we worked at it for 35 years, and we really never made money".

Given the fierce competition that eventually came from China and the pain that caused many parts of the industry, that call, in isolation, seems like a smart idea. But what if BP had transitioned the company out of its research roots instead? What if it had partnered up with a Flextronics or a Foxconn, kept its IP and used its balance sheet during the days of US$100 oil (up until mid-2014) to get cheap finance for a solar project pipeline? In 2014, BP's weighted average interest rate on its debt was 1.62%. At that price, or anything remotely close once the "risk" of solar was added, its projects would have been wildly profitable.

With shareholders' dividends so strongly tied to the global oil price, what value would a little good news from a separate part of the business have offered the company?

The obvious issue here is scale. BP has just reported an annual loss of US$6.5 billion. The biggest solar companies are working with figures about an order of magnitude smaller.

Trina Solar, the largest module manufacturer by volume in 2015, has been notching up quarterly profits of between US$100-150 million but it is not as far along with its downstream plans as some of its competitors.

Let's not forgot that when BP Solar exited the business, it had manufacturing assets in India. If we assume that they would have expanded from 2011 onwards, the company would have been able to offer trade-tariff-free panels into the US and EU, where Chinese modules are facing a harder time of it.

It's likely that even if BP Solar had graduated from superb research breeding ground to competitive manufacturer and profitable developer, at this stage in the industry's development, strong figures would not have got close to offsetting the damage done by oil prices that hit a 13-year record low.

But a black line of numbers on the results sheet next to BP Solar, and the promise of more to come, may have been enough to cheer investors. As it is, like most oil majors, BP lacks diversity and seemingly the dynamism to attain it. Power generation firms have embraced renewables with EDF, Enel, RWE, E.On and Engie among those seeking to refocus. In October 2014 BP's CFO warned that US$70 oil would "put peril in future growth". Lacking a plan B, sub-US$35 oil must be terrifying.

Suddenly, with the benefit of hindsight, that decision to dissolve BP Solar might not look so clever. ■

This is an edited version of an article that first appeared www.pv-tech.org


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