POWER PVTECH

Volume 10 PV POWER PLANT TECHNOLOGY AND BUSINESS February 2017

GO EAST

A 14-page special report on solar in China, Japan and Southeast Asia

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Why US solar will not be Trumped

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Understanding snail trails on c-Si modules

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New approaches to O&M in China

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About LONGi Solar

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

LONGi Solar is a world leading manufacturer of high-efficiency mono-crystalline solar cells and modules. The Company is wholly owned by LONGi Group. LONGi Group (SH601012) is the largest supplier of mono-crystalline silicon wafers in the world, with total assets above $1.7 billion. (2016)

Armed and powered by the advanced technology and long standing experience of LONGi Group in the field of mono-crystalline silicon, LONGi Solar has shipped approximately 2.5GW products in 2016. The Company has its headquarters in Xi'an and branches in Japan, Europe, North America, India and Malaysia.

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

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LONGi Solar

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Solar Media Ltd.
3rd Floor, America House,
2 America Square,
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Tel: +44 (0) 207 871 0122
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Publisher:
Chris Riley

Editorial

Head of content:
John Parnell

Managing editor:
Ben Willis

Senior news editor:
Mark Osborne

Reporters:
Andy Colthorpe, Tom Kenning, Danielle Ola

Design & production

Design and production manager:
Sarah-Jane Lee

Sub-editor:
Stephen D. Brierley

Production:
Daniel Brown

Advertising

Sales director:
David Evans

Account managers:
Graham Davie, Lili Zhu, Matt Bosnjak

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Cover image: Yancheng solar power station, Jiangsu, China
Image courtesy of GCL New Energy

Introduction

Who'd be solar market forecaster?

Shifting sands in the two largest global markets coupled with a patchwork of emerging demand, that could as easily deliver several gigawatts as they could nothing at all, make the job a tricky one.

A swell of registered projects in China in H1 slowed progress in H2 and there are signs of more of the same in 2017. Beijing-based consultant Frank Haugwitz takes a deep dive (p.18) into China's 13th five-year plan including the real meaning behind its decreased PV targets and the benching of efforts to promote distributed generation.

Japan, a top-three solar market for several years, is now undergoing an adjustment. Severe cuts to the feed-in tariff pose a challenge of the sector, but it can take heart from the success others have had from subsidy-free solar procurement. As we discover (p.25), Japan's most recent boom is not necessarily going to be followed by a comparatively-sized bust.

Meanwhile less mature end markets like Thailand (p.31) are moving into a better position to exploit the vast potential that have been touted in the last few years. Taiwan, long-associated more with PV manufacturing than deployment, is now looking at ways to deploy a massive 20GW of solar. We take a look at the unique challenges facing the island (p.29), not least the terrain, as it takes the first steps towards this objective.

The situation is perhaps even less predictable in the Americas. No sooner had the US announced the extension of the ITC, demand dropped off with the revised, less pressing deadlines. Then, President Trump emerged victorious. It's been an eventful few months since the election. We look to cut through the fear-mongering and discover a US solar industry in bullish mood (p.34).

While the ITC is likely safe, a fondness for fossil fuels and a penchant for unpredictability have added a whole new kind of uncertainty. As we go to press, huge install figures for 2016 were being finalised. I wouldn't relish the job of predicting next year's.

As ever, we have a host of technical expertise to share with you in this issue. Fraunhofer ISE takes a look at the importance of creating a safety framework for lithium-ion battery storage products (p.81). Meanwhile Fraunhofer CSP looks at the phenomenon of so-called snail-trails on modules with a surprising conclusion on their overall potential contribution to any PV install where they occur (p.60).

The team will be on the road for the next few months and we hope to catch you at SNEC, PV CellTech and PV Expo in the coming weeks.

John Parnell
Head of content

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HUAWEI

Solar intelligence, with strings attached.

String inverters that are built to last

A bankable business that's here to stay

Local service with a global reach

A smart PV solution that works in all conditions

Always available for highest yields

Global #1 Inverter Shipment

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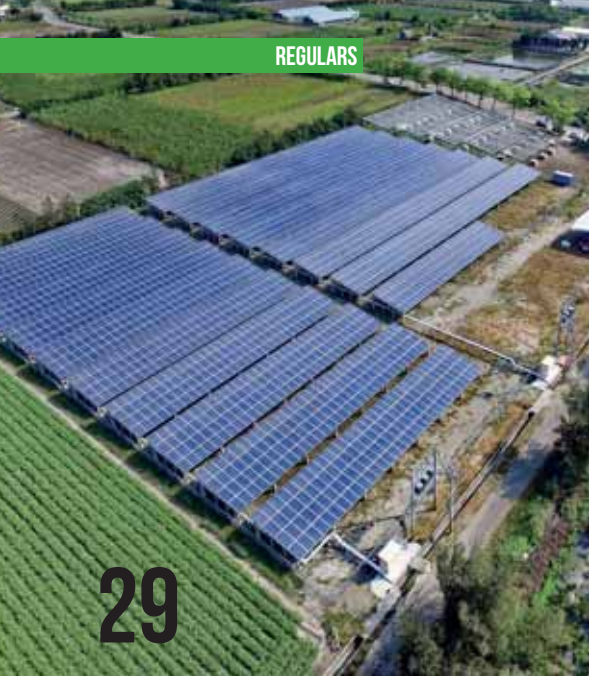
We're stable, we're bankable, and we're here for the long haul.

Huawei FusionSolar

FusionSolar Smart PV Solution
www.huawei.com/solar



info@missionsolar.com | 8303 South New Braunfels Avenue, San Antonio, Texas 78235 | 210-531-8600

EUROPE

Trade wars

'Irrelevant' MIP needs reform as extension looms

The Minimum Import Price (MIP) agreement between the EU and Chinese solar manufacturers requires urgent reform, according to several industry figures as the 3 March extension deadline drew nearer. EU member states rejected a two-year extension of existing measures and an 18-month compromise has been proposed by the European Commission. The measures would otherwise be unchanged for cells and modules. "Whilst in principle the EU should protect its own manufacturers from unfair competition from China, or elsewhere, the MIP has for most of its duration been set significantly higher than the actual world price for solar modules available from many non-Chinese sources, including European manufacturers," said Andy Pegg, CEO of PV distributer Segen. The MIP has been roundly criticised by both supporters and opponents of the trade measures. SolarWorld vice president Milan Nitzschke welcomed the Commission's efforts. "The Commission's aim to make the MIP more transparent, predictable, more enforceable and to insert a degression rate should be positive for all market participants," he said.

Credit: © European Union, 2016

The European Commission proposed an 18-month extension of the existing measures.

Secondary markets

Sonnedix to acquire 136MW PV portfolio in Spain

Independent solar power producer Sonnedix announced that it has signed off on a deal to acquire the 136MW Vela PV portfolio from Centerbridge Partners – with the pipeline comprised of 43 operating and financed solar projects in Spain. As a result of the deal, Sonnedix is now the second largest PV company in Spain. The transaction is expected to close out in Q1 and will bring Sonnedix' total operating capacity to almost 500MW globally. As part of the deal, Sonnedix and the management team that collaborated with Centerbridge to build and operate the portfolio have entered into a partnership to continue to acquire PV assets in Spain and beyond.

Etrion sells 53.4MW Italian PV portfolio to EF Solare Italia

Solar independent power producer Etrion announced that it has completed the first phase of a previously disclosed sale of its Italian solar portfolio to EF Solare Italia – a joint venture owned by both Enel Green Power and Fondo Italiano per le Infrastrutture "F2i". EF Solare Italia purchased Etrion S.p.A., which owns 53.4MW of Etrion's total portfolio in Italy, for 73.1 million euros and the assumption of related project-level debt of 198 million euros. Etrion plans to use the proceeds from the sale to build up its solar development activities in Japan and to repurchase a portion of its outstanding corporate bond. In Japan, Etrion has 34MW operational, 23MW under construction and approximately 250MW in its development pipeline.

TerraForm Power's 365MW UK portfolio changes hands for $585 million

The 365MW UK solar portfolio owned by SunEdison yieldco TerraForm Power has been sold to Vortex, a European renewables investment platform of private equity firm EFG Hermes. The portfolio, comprises 24 operational solar farms developed under the country's Renewables Obligation scheme. The sites also benefit from 14-year PPAs. EFG Hermes has emerged victorious from the tender process, paying circa £470 million (US$585 million) for the sought-after portfolio. Karim Awad, group CEO at EFG Hermes, said the acquisition would turn Vortex from a market "newcomer" into a platform managing more than 800MW of renewables assets across the UK, France, Spain, Belgium and Portugal.

The deal will take Vortex's UK renewable asset portfolio to more than 800MW.
Credit: SunEdison

Spain

Spanish minister confirms 3GW renewables auction but lack of detail still concerning

Spain's energy minister has confirmed plans for the much-anticipated 3GW of renewable auctions, but concerns remain over the parameters of the tenders. Newly appointed minister Alvaro Nadal said that the auctions will be carried out in the first semester of 2017 and he will attempt to do this "as soon as possible, in the following weeks", said Daniel Pérez, attorney at renewable energy specialist law firm Holtrop S.L.P. Despite announcements by previous energy minister, his twin brother, Alberto Nadal that 1GW would be tendered this year, Perez was correct in forecasting that tendering would not take place until 2017. Alvaro Nadal has now confirmed that the auctions will be technology neutral and capacity will be handed out on a competitive auction basis.

Spanish islands renewables auction confirmed for early 2017

Spain will hold a renewable energy auction for its islands in the first quarter of 2017, according to the Ministry of Energy and Tourism. The extra transportation costs associated with island projects would have made it very difficult for them to compete with projects located on the Spanish peninsula. Few details have been provided by the government release, but Holtrop attorney Daniel Perez said that local reports rumour the auction capacity to be set at 400MW. Perez added that there has been some confusion over locations as it is not yet clear whether the auction will account for all the Spanish islands or just the Canary or Balearic Islands.

O&M

European PV at risk of O&M race to the bottom

The intense competition in the European O&M sector is driving down quality putting some solar investments at risk. The increasingly crowded sector has seen prices fall dramatically. O&M provider greentec services has warned that some investors could find that they are out of pocket in the long-term if they opt for the lowest quote on offer. "For an owner of a PV plant a small price for O&M seems to be good, but if for example the O&M company did not carry out its duty in preventive maintenance then the costs of failure, idle time and repair can easily be much higher than just the base price for O&M," said Paul Chaloupka, head of sales and operations, greentec services. "In the end, it is highly important to make the client understand, that saving a few bucks up front, definitely does not make this investment a better deal in the long run."

BayWa r.e. acquires Green Hedge O&M division

German solar company BayWa r.e. has acquired Green Hedge's UK O&M portfolio, taking its standing in the UK renewables O&M market to 620MW. Matthias Taft, board member at BayWa AG, said the company was delighted to close the acquisition and said it would "considerably strengthen" its position in the UK and Europe. All 13 Green Hedge Operational Services employees are to be retained and BayWa said they would become an "immediate asset".

AMERICAS

Trump

Trump administration energy plan revealed: 'Fossil fuel industry wish list'

A memo written by Trump's transition team entitled 'What to expect from the Trump Administration' reveals the future energy plans of the US, which amount to a "fossil fuel industry wish list". It depicts Trump's intention to replace the Obama administration's "harmful policies" by withdrawing from the Paris Agreement, "hitting reset" on the Clean Power Plan and reducing energy subsidies. The memo also reveals plans to target progress on renewables; increasing the leasing of federal lands for the exploitation of coal, oil and gas, and approving pipeline projects as well as rolling back federal fuel economy standards.

If Trump kills Clean Power Plan, legal action ensues, warn 15 states

If Trump goes ahead with his threat to scrap the Clean Power Plan, legal action will ensue, according to 15 state attorney generals from California, New York, Hawaii, Washington and others who penned a letter to Trump. After Trump vowed to cut all federal spending on climate initiatives, a 24-state coalition responded urging the president-elect to withdraw the Plan immediately with a "day one" executive order, prohibiting the EPA from enforcing it. In response, New York Attorney General Eric Scheiderman, together with 14 other states, has promised litigation should Trump take such action.

State news

Maryland: Clean energy victory for Maryland with veto override

Maryland has officially achieved a clean energy victory as governor Larry Hogan's veto of the Clean Energy Jobs Act was overturned in a 32-13 vote. Maryland can now procure more renewables with a higher RPS of 25% by 2020, up from 20% by 2022. This is expected to create demand for 1.3GW of new renewables, including 250MW of solar, and thousands of clean energy jobs.

The bill has experienced a tough road, first passing in April last year before being vetoed by governor Hogan who cited a tax burden of between US$49 million to US$196 million by 2020. *Source: Flickr/Fort George H. Meade Public Affairs Office*

Ohio: Governor vetoes attack on Ohio's clean energy

Ohio governor John Kasich vetoed a bill that sought to make compliance for investor-owned utilities with the state's energy standards voluntary, as opposed to mandatory, for a further two years. HB 554 was successfully vetoed after a two-year suspension that began in 2014. Ohio utilities will then be required to procure 12.5% of their energy from renewable sources by 2025.

Arizona: APS rate hike & grandfathering

Net metering ended at the end of December in Arizona, with the retail rate being replaced with a wholesale one for residential consumers. However, the Corporation Commission is in the process of deciding whether to alter its decision on grandfathering to include customers with pending applications and not exclusively apply to those already connected.

Hawaii's largest solar park now online

HECO has commissioned the Island's largest solar park, the 27.6MW Waianae Solar project. It generates enough clean electricity to power around 11,000 homes annually. Located in West Oahu, the park will sell its energy to HECO at the rate of 14.5 cents/kWh.

Latin America

Mexico solar to increase 20-fold by 2019

Mexican PV is set to increase 20 times the current installed capacity by the end of 2019, the country's energy secretary (SENER) has said. In a Progress Report, SENER said that Mexico reached an installed capacity of 20,160MW of clean energy in H1 2016, representing over 28% of the total national capacity; growing by 6.29% compared to H1 2015. Solar was the winning clean technology overall, growing by 100MW by June 2016 with a projection to reach 5.4GW by the end of 2019 due to projects won in the first and second energy auctions.

Chile expected to add 1.5GW of renewables in 2017

Chile is forecast to add 1.5GW of new renewable energy capacity in 2017, according to Carlos Finat, the executive director of ACERA. As of 31 December 2016, the Chilean electricity system had 4,150MW of renewables installed, surpassing 1GW of solar at the beginning of 2016. ACERA expects renewable deployment in 2017 to maintain a growth rate similar to that of 2016 and predicts that renewables generation will reach 30% in 2030 and 100% by 2050.

Parting shots

Obama to Trump: Clean energy will happen whether you like it or not

Barack Obama argued that the momentum of wind and solar is "irreversible", in a last-ditch attempt to tout clean energy. In an article for the journal Science, he launched a defence of emissions regulations and climate action, in the face of Trump's denial of global warming and plans to scrap the Paris Agreement and Clean Power Plan. Obama argued that reducing greenhouses gases can help economic growth. On the heels of his article came a petition signed by more than 600 collective businesses and investors who also argued that clean energy and a low-carbon economy is good for business.

Trump's energy plans which include a rollback of federal subsidies, plans to expedite coal and gas and scrutiny for renewables have said to amount to a 'fossil fuel industry wish list'

Source: Flickr/Gage Skidmore

Brazil cancels only solar and wind auction of 2016

The Ministry of Mines and Energy called off its 2nd Reserve Energy Auction after an expected power oversupply in the country. After solar was removed from Brazil's first reserve auction of 2016 in July, the second auction for wind and solar was then set back to 19 December and has now been removed altogether.

Market watch

US solar jobs grew 25% year-on-year in 2016

The US solar job force had a year of exponential growth in 2016, increasing 25% year-on-year and constituting one in every 50 new US jobs, according to the Solar Job Census. It found that solar outpaced the overall US economy by 17 times as it increased by more than 51,000 jobs for a total of 260,077 solar workers. The number of solar jobs increased across the majority of the nation in 44 out of 50 states.

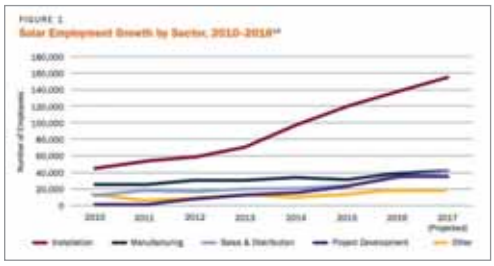


Figure 1 Solar employment growth by sector 2010-2016. *Source: The Solar Foundation*

GTM: US community solar to surpass 400MW in 2017

The US community solar market is emerging as a promising source of demand, and has quadrupled between 2015 and 2016 and is set to double in 2017, reaching 400MW. According to GTM Research's latest report 'US Community Solar Outlook 2017', this emerging market sector will reach 410MW this year. Lead report author Cory Honeyman describes the market as "on the cusp of becoming a mainstream driver of US solar market growth."

MIDDLE EAST & AFRICA

South Africa

Eskom: We'll sign PPAs, if the price is right

Eskom is conditionally committing to follow through with South African president Jacob Zuma's announcement that the utility will indeed sign the remaining PPAs under the government's renewable procurement programme (REIPPPP). The president reaffirmed South Africa's commitment to renewable energy in his State of the Nation Address, and also emphasised that the government remains committed to signing PPAs – including the outstanding ones under the programme. Eskom responded to the announcement telling PV Tech: "The price of projects in round R4.5/kWh are generally reasonable, so yeah, we will sign them. In fact, the projects we signed during round 1 and 2 thereabouts, those were very expensive. When we first started this project, some of the projects were costing up to R3/kWh. The new ones are actually less than that, so there shouldn't be any worry now."

Enel brings 165MW of new South African PV online

Enel Green Power has brought online two new utility-scale PV plants in South Africa, at 82.5MW each. Together the plants are capable of generating more than 300GWh per year. The Adams and Pulida solar PV plants are located respectively in the Northern Cape and Free State provinces, and are supported by a 20-year PPA with Eskom. The projects were won under the third round of the government's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). The programme's fourth round has been in jeopardy after Eskom has refused to sign any more IPPs, citing overcapacity.

Nigeria

GreenWish Partners and Oriental work together on 50MW Nigerian solar project

Oriental Renewable Solutions, a subsidiary of the Oriental Group, has formed a 50:50 equity partnership with GreenWish Partners to co-develop a 50MW solar PV project in Jigawa State, Nigeria. Oriental has already signed a 20-year, dollar denominated Power Purchase Agreement (PPA) with the Nigerian Bulk Electricity Trader (NBET) in July 2016. This was part of NBET's wider process of signing PPA's to deliver 1.2GW of solar generation capacity to the Nigerian grid – the first solar PPAs ever signed in Nigeria. The Jigawa solar project will have an output of around 96GWh per year and will create 300 jobs during construction and 25 permanent jobs during operations.

Scatec Solar's 100MW Nigeria PV project nets financing from new investors

Norwegian solar developer Scatec solar has secured investment for its 100MW Nova Scotia solar PV plant in Dutse, in the Northern Nigerian state of Jigawa. Funding has come from equity investors Africa50, a local infrastructure fund sponsored by the AfDB, and Norfund, Norway's development bank, who all signed a Joint Development Agreement (JDA) with Scatec. In addition, OPIC, the Islamic Development Bank and AfDB are expected to be senior debt providers for the project. "New local power generation capacity is a key element to attract sizeable investment into the State and region, especially into new industries such as light manufacturing and agricultural processing" said Ibrahim Hassan Hadejia, deputy governor of Jigawa State, at a signing ceremony.

East Africa

Power Africa partner breaks ground on 1GW solar programme in Burundi

Gigawatt Global, a multinational renewable energy company and partner of Obama's Power Africa initiative, has broken ground on its 1GW solar programme with the 7.5MW solar plant in Burundi. The US$14 million facility was inaugurated on Thursday in Mubuga, just outside the Burundian capital of Bujumbura. The new plant will add 15% to the country's electricity generation capacity. Power will be sold under a 25-year PPA to REGIDESO, the national electric company. Construction and interconnection of the project to the country's grid is expected to be completed in Q4 2017.

East Africa's 'largest' solar plant now in operation

What is claimed to be East Africa's largest solar offering is now online in the form of the 10MW PV plant in Soroti, Uganda. Located on just over 13 hectares of land and comprised of 32,680 modules, the facility is also the country's first grid-connected plant and will provide enough clean energy to power 40,000 homes. According to Access Uganda Solar Ltd, a partnership between Access Power and EREN Renewable Energy who own and operate the plant, it has potential to expand by a further 20MW.

Middle East

Saudi Aramco contemplates US$5 billion of renewable energy deals

As oil prices plummet, Saudi Arabia's state oil and gas company mulls over a transition into a clean energy future. HSBC, JP Morgan and Credit Suisse are among the financiers who have been invited to pitch a role helping Aramco identify potential acquisition targets and advise on deals in order to help the oil-rich Kingdom embark

Zuma

Eskom will sign outstanding renewable PPAs, says South Africa's president

President Zuma's personal intervention offered some hope for developers.
Credit: Flickr/Linh Doh

Jacob Zuma, the South African president, announced that the country's biggest utility Eskom will indeed sign the outstanding PPAs won in the fourth round of the successful Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Backlash had abounded once Eskom refused to sign any more renewable energy PPAs with IPPs under the programme back in late July. The utility initially told PV Tech that its reason for defaulting on the projects won were because all the variable generation integration was putting a strain on the grid. The South Africa Renewable Energy Council (Sarec) threatened legal action over the refusal. During his State of the Nation Address, Zuma emphasised that the government would remain committed to signing PPAs with IPPs for all forms of energy, including coal and gas. "Eskom will sign the outstanding power purchase agreements for renewable energy in line with the procured rounds," he confirmed.

on a low-carbon economy. A source from Bloomberg New Energy Finance (BNEF) said that the oil company is planning on bringing in foreign expertise in clean energy into the Kingdom, adding that first investments under this new plan could occur as early as this year.

Masdar, DEWA to break ground on 800MW phase in Dubai

UAE company Masdar announced that construction on the 800MW phase three of the Mohammed bin Rashid Al Maktoum Solar Park in Dubai is expected to begin at the end of January 2017. A Masdar-led consortium was selected in June 2016 by Dubai Electricity and Water Authority (DEWA) to develop what will be the world's largest solar park on a single plot upon completion. The EPC contract agreement has been awarded to an international consortium led by specialist renewable energy contractor GranSolar of Spain, alongside Spanish specialist Acciona and Ghella of Italy.

ASIA-PACIFIC

China

China to invest US$361 billion in renewables by 2020

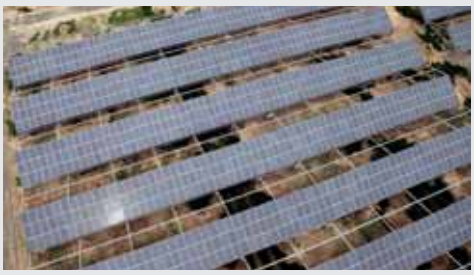
China is set to up the ante on renewables in a new 'Five-Year Plan' that will see a total investment of RMB2.5 trillion (US$360 billion) by 2020. The NEA is making a bid to reduce the country's reliance on fossil fuels. The investment will be used to procure clean energy including wind, solar, hydro, biomass and geothermal. The Plan will also create jobs in clean energy for around 13 million people. The country has set a goal for 110GW by 2020. NEA has separate plan designs to tackle curtailment, improve project quality and further reduce its feed-in tariff. Specifically on solar, 11 provinces have been assigned preferential status for solar deployment.

China trials wind and solar certificate scheme in move away from feed-in tariffs

China will trial a green energy certificate trading scheme as it looks to reduce its exposure to feed-in tariff (FiT) payments. A nationwide

China installs

China connected more than 34GW of solar in 2016



Almost two thirds (22GW) of China's installs in 2016 were installed in H1. *Credit: United PV*

China added 34.24GW of solar to its grid in 2016, according to China's National Energy Administration (NEA). There is now a total of 77.42GW of solar PV. The 126% increase in annual installation outstrips the NEA's cumulative market growth figure of 81.6%. A surge in connections occurred in the first half of 2016 as developers looked to guarantee their feed-in tariff before a planned drop. Almost two thirds (22GW) of the 2016 total was installed in H1. Project completions have increased since November. A slump in the wake of the H1 push had triggered fears of a drop in demand. This would appear to be easing. As a result, forecasts suggest that China could again see 20GW of PV projects added to the grid in H1 2017.

pilot will begin in 2018 for onshore wind and solar projects only. A green electricity certificate will be generated for each MWh of electricity produced. These will then be auctioned with payment replacing any FiT payments. The National Development and Reform Commission (NDRC) said the new voluntary system would "help promote the efficient use of clean energy and reduce direct subsidies" to the benefit of the national economy.

India

Solar becomes 'cheapest new power source' in India as auction winners revealed

Mahindra Renewables, Acme Solar and Solenergi Power emerged triumphant in the 750MW solar auction in India's Madhya Pradesh, with the lowest price smashing records at just INR2.97/kWh (US$0.044). Developers bid for the three projects of 250MW available at the Rewa solar park, but the tariff has an escalation of INR0.05/kWh (US$0.07) for 15 years, resulting in a levelized tariff of INR3.29/kWh for 25 years. Indian tariffs over the last two years for wind, gas and even new thermal plants were well above the Rewa solar prices, meaning that solar energy is the cheapest new source of power in India.

Indian solar finding new access to capital

A number of financial encounters have shown that Indian solar firms are finding new access to capital. The Asian Development Bank (ADB) has approved a US$390 million for India's ReNew Power, a leading independent power producer. The funding will enable ReNew to develop more renewable energy projects including 398MW solar in Jharkhand and Telangana. IFC, part of the World Bank Group, will also invest US$125 million in Indian renewable energy firm Hero Future Energies, which is an arm of Hero Group. The investment will help Hero set up 1GW of greenfield solar and wind plants in the next 12 months across India.

High interest in India's first utility-scale solar-plus-storage tender

India's first grid-scale solar-plus-storage tender from Solar Energy Corporation of India (SECI) has received very strong interest with a total of 13 developers submitting initial bids. The tender called for 5MW/2.5MWh battery enery storage systems to be added to two separate solar projects of 50MW each in the Kadapa Solar Park in Andhra Pradesh. SECI will soon announce five successful developers to go through the next round of reverse bidding in an e-auction.

Rest of Asia

Taipower to commission 500MW solar, but delays timeline

Taiwan state-owned utility Taiwan Power Co. (Taipower) has delayed plans to commission 500MW of solar by 2020 by two years, now scheduling 300MW of that solar to be online by 2022. The company cites cabling engineering at its Tainan Salt Field as the reason for the delay. A total of 100MW will be constructed on land and buildings owned by Taipower and some idle and subsidised lands owned by the Taiwan Water Corporation and government. A further 100MW will be constructed on the greenfield site of the Changhua Thermal power plant. The remaining 300MW will be constructed at the Tainan Salt Field.

Spain's Grupo Clavijo supplies trackers to 12.56MW PV plant in Sri Lanka

One of Europe's leading tracker vendors Grupo Clavijo has expanded its footprint into Asia by supplying trackers to the 12.56MW Solar One Ceylon solar PV plant in Sri Lanka. On behalf of developer Windforce, Grupo Clavijo installed 624 single-axis trackers. The project also features JA Solar polycrystalline panels. The plant was completed in five months and is located in the local town of Welikanda.

Australia

Multiple PPA signings for large-scale PV in Australia

Global utility-scale solar developer Fotowatio Renewable Ventures (FRV) has signed a power purchase agreement (PPA) with Ergon Energy – the Queensland Government-owned electricity retailer – for the proposed 100MW (125MW DC) Lilyvale Solar Farm project. Major power firm EnergyAustralia has also signed a 13-year PPA to take 80% of the energy produced by a 142MW solar PV plant near Townsville in Queensland, Australia, which is jointly owned by infrastructure manager Palisade Investment Partners and solar developer ESCO Pacific. EnergyAustralia has also confirmed it will soon sign PPAs for 500MW of wind and solar projects across eastern Australia.

Flurry of big solar plans in Australia

The Western Downs Regional Council has approved the largest solar project in the Australian region to date. Luminous Energy will develop the 300MW PV farm, which will be located between Miles and Chinchilla and will create 400 local jobs during construction. Meanwhile, French developer Neoen will develop 130MW of large-scale solar in Australia, with the backing of the Australian Renewable Energy Agency (ARENA). Furthermore, Perth-based PV company Sun Brilliance is set to develop a 100MW PV project in Western Australia. The installation will be developed on farming land on the outskirts of Cunderdin and will be built using single-axis tracker technology.

LOWLIGHTS

Lowest solar PPA's in various geographies worldwide. Some of these tariffs involve escalations:

Country	Developer	Capacity (MW)	Tariff (US$/kWh)
UAE	JinkoSolar/Marubeni	350	0.024
Chile	Solarpack	120	0.029
Mexico	Enel	427	0.035
US	NV Energy	100	0.039
India	Acme Solar	250	0.044

Product reviews

Inverter — Growatt's 8K-11KTL3-S three-phase inverter maximises energy harvesting

Product Outline: Growatt has launched its new-generation, three-phase solar inverter series, the Growatt 8K-11KTL3-S. The new inverters are designed with maximum efficiency of 98.4% and MPPT efficiency of 99.5%, as well as a wide DC voltage range of 160-1,000V (DC), which maximises the comprehensive efficiency of the inverter and provides longer electricity generation.

Problem: To reduce cost and save time for installers inverters with smart technology are required to improve the economics of PV installations and lifetime operation, notably with the capability to provide online smart monitoring.

Solution: Growatt's 8K-11KTL3-S series

inverters provide high maximum and MPPT efficiencies to provide overall efficiencies gains. The new inverter series provides a maximum DC/AC ratio of up to 1.2, and the 1.1 overload enables the system to be more flexible and maximise energy harvest. In addition, the new series inverter employs IP65 ingress protection and natural cooling, without the need for fans, as well as being maintenance-free, making it well adapted to extreme environments. Other 8K-11K TL3-S series features include high power density design, lighter weight and smaller size, making it easy to install.

Applications: Residential PV systems as well as smaller-scale industrial and commercial PV systems.

Platform: Growatt 8K-11KTL3-S is compatible with Growatt monitoring devices and cloud platform, and integrates on-line smart service system, so service engineer can handle 60% plus problems by remote configuration & firmware update without on-site service.

Availability: February 2017 onwards.

Mounting — NEXTracker's 'NX Fusion Plus' system extends energy output and duration for solar power plants

Product Outline: NEXTracker has launched a solar-plus-storage solution for US and international markets. 'NX Fusion Plus' integrates the latest in solar tracker design, battery, inverter and software to deliver better return on investment.

Problem: Prior to the advent of solar trackers, fixed-tilt systems were the only mounting option for PV and delivered a single output profile. Cost had also been a major barrier to battery integration in mainstream solar projects. By incorporating battery storage technology into its product, NEXTracker is further increasing the energy output and duration of solar power plants, just as tracking technology did for fixed-tilt solar applications.

Solution: With NX Fusion Plus, the tracker generation curve is broadened, by shifting

excess energy from peak periods to later in the day. Users can now dispatch uninterrupted clean energy in the most effective manner possible as the tracker becomes the data acquisition backbone of the plant, offering complete system analytics and monitoring. NX Fusion Plus is claimed to offer higher return on investment than solar alone because more 'clipped' energy can be harnessed and used to offset demand charges for end users. This is particularly attractive to customers such as farms in the Central Valley of California and countries such as India, where power fluctuates.

Applications: PV power plants.

Platform: In order to bring solar-plus-storage into the mainstream, NEXTracker leverages Flex's secure data platform with NEXTracker's predictive smart control software, which is already embedded in the tracker's electronics. Complementing this product portfolio is machine learning capability, acquired through the purchase of BrightBox earlier this year, which optimises solar power plant performance and reduces operations and maintenance costs.

Availability: Already available.

Products in Brief

PVMC and SUNY Poly launch 'Solar Energy Optimization Testkit'

The U.S. Photovoltaic Manufacturing Consortium (PVMC), lead by SUNY Polytechnic University, has launched the Solar Energy Optimization Testkit, a new set of evaluation capabilities aimed at providing real-time data to industrial and academic partners to analyse ways to optimise their PV power plant system capabilities and costs. The testkit can obtain and provide actionable solar energy cost and PV performance information from PVMC test and consortium member sites to improve solar cells, components, modules, systems, and operations and maintenance protocols. It can be applied to any currently deployed PV system and allows the PVMC to collect and model data and perform key measurements at the sites to validate predictive models.

Talesun new dual-glass panel offers higher reliability in harsh environments

Talesun has launched a new double-glass module with an aluminum frame that has received TÜV certification. The module uses a silica gel to seal the edge with the frame, which offers higher durability and is said to come with a 30-year weatherability warranty. The module has relatively safe transportation with less than 0.3% breakage rate of arrival goods, and flexible and solid installation. The dual-glass panels are applicable to all types of power plants, including ground-mount power stations, rooftop solar plants and floating plants. ▶

Product reviews

Module JinkoSolar's Eagle MX panels replace bypass diodes with high-yielding cell-string optimisers

Product Outline: JinkoSolar has introduced the Eagle MX solar panel, its next-generation smart module for the high-volume mainstream PV panel market that incorporates an innovative new cell-string optimiser technology.

Problem: Solar modules that are expected to be exposed to the environment for at least 25 years can be affected by conditions such as shading, soiling, ageing and temperature gradients. Mismatch caused by these factors in a panel or among various panels can cause a system to lose power. Unlike conventional bypass diodes, solar cell optimisers do not bypass weak cell strings, eliminating the on-off response to performance mismatch and reducing the risk of hot spots; every cell-string contributes maximum power without interfering with the power production capability of others.

Solution: The Eagle MX module allows PV panels to harvest significantly more energy and simplifies design complexity for solar installation projects. The highly distributed MPPT architecture affords improved tolerance to shading, reduction in power degradation, and even enables denser system design on ideal un-shaded rooftop and ground-mount systems. The module is claimed to produce up to 20% more energy under such unfavourable conditions and is compatible with any inverter brand.

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

Platform: JinkoSolar is offering the Eagle MX module in both mono- and multi-crystalline configurations. The top-line mono Eagle MX JK07A panel (275-355W) 60 & 72-cell configurations deploys four busbars and PERC technology, offering panel efficiencies of 18.31%. The Eagle MX JK07A (poly) (260W 60-cell panels have a positive power tolerance of 0~+3%. The Eagle MX JK07B poly panel comes in 255-330W 60-72-cell configurations with 10-year product and 25-year linear power warranty.

Availability: Currently available. Assembled in Europe.

Inverter Ingeteam's new 100kW three-phase string inverter offers higher power density

Product Outline: Ingeteam has launched its new PV string inverter, which will make it possible to achieve a power output of 100kWAC in a single, 75kg unit. This new three-phase inverter, the 'INGECON SUN 100TL' and is primarily directed at commercial, industrial and large-scale projects.

Problem: PV installers are seeking to reduce the total number of inverters required for a PV power plant as part of balance-of-system cost reduction strategies.

Solution: The INGECON SUN 100TL's high power density means it is possible to reduce the number of inverters in an installation and, therefore, the total amount of cabling. Furthermore, no combiner boxes are required (either in DC or AC) and nor is a neutral cable, thereby reducing the total AC cabling cost by up to 20%. The inverter also has lower operating costs, thanks to the wireless communication which permits the startup, monitoring and control of the PV system through a mobile phone, tablet or laptop.

Applications: Commercial, industrial and large-scale PV projects; indoor and outdoor installations.

Platform: The INGECON SUN 100TL's other main features include its high maximum efficiency (98.8%), maximum DC input voltage of up to 1,100 VDC and advanced grid support functionalities, with a low-voltage ride-through capability and reactive power capability. It is also suitable for three-phase self-consumption systems, with or without the injection of excess energy into the public grid. Two different models for this PV inverter (STD and PRO) are available in order to adapt to the technical requirements of as many projects as possible. The 3Play family models available up to now, with output powers ranging from 10 to 40 kW, are already installed in many countries.

Availability: Currently available.

REC's TwinPeak 2 series module rated up to 295Wp in 60-cell format

Integrated PV module manufacturer REC has launched its TwinPeak 2 Series module that uses evolving in-house technologies including cells from larger wafers (156.75 mm), PERC cells in a half-cut configuration as well as five busbars. The panels also have a split junction box that spreads across the middle of the panel. Together, these help the REC TwinPeak 2 Series deliver at least 20Wp more per panel compared to standard 60-cell multicrystalline panels and lower balance-of-system costs and higher yields, due to increased power output and improved performance in shaded conditions.

KACO's 'blueplanet' 20.0 TL3 INT inverter features decentralised plant concept

KACO new energy's 'blueplanet' 20.0 TL3 inverter fits commercial systems as well as large-scale, industrial-sized power plants, offering plenty of flexibility in designing decentralised PV systems of different sizes – rooftop or open space applications alike. It is a wall-mounted device operating on the threshold between commercial and utility applications that feature a decentralised plant concept. The system uses two separate MPP trackers that can handle both symmetrical and asymmetrical loads. East/west facing roofs (symmetrical load), factory roofs which are shaded or inconsistently designed and open spaces (asymmetrical load) can thus be dealt with.

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Product reviews

Module | Sharp launches high-efficiency back-contact 48-cell PV module

Product Outline: Sharp is making available its NQ-R256A (256W) monocrystalline PV module to the European market, which incorporates back contact cell technology for efficiencies of 19.8%.

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

Solution: With back contact cells all connectivity is removed from the front to the backside. Sharp's back contact technology reduces the losses from 6% to 3%. The NQ-R256A module can generate more power than with conventional 60-cell modules on the same given roofing area, helped by the compact dimensions (1,318 x 980 x 46 mm). The compact and lightweight 48-cell module is easy to handle, and can be installed either in portrait or landscape orientation.

Applications: European residential rooftops.

Platform: The NQ-R256A module has IEC certification (IEC/EN 61215 and IEC/EN 61730). The module has a frame with two additional support bars and has passed a snow load test of 5400Pa according to IEC61215. The junction box is protected against contact damage, overheating and water with fixed cable connections, heat sinks and resin filling. Sharp has developed its own sophisticated test procedure, which in important areas is more stringent than the IEC requirements. For example, the temperature test is carried out with 2,000 cycles, instead of only 200 cycles.

Availability: Already available.

Inverter | SMA Solar's turnkey central inverter container solution is optimally suited for 1,500V PV power plants

Product Outline: SMA Solar has launched the MVPS 4400SC/5000SC-EV, a central inverter for 1,000 and 1,500V DC applications in a turnkey container solution with two Sunny Central 2200 or 2500-EV central inverters and a coordinated medium-voltage solution comprising transformer and switchgear.

Problem: Across the world there is an increasingly strong trend towards building centrally located PV power plants with DC voltage of 1,500V. The systems need to have short commissioning times, as well as safety, long-term reliability and high energy yields to maximise return on investment.

Solution: The new Medium Voltage Power Station from SMA uses two Sunny Central 2200 or Sunny Central 2500-EV inverters. The turnkey station can be used in large power plants all over the world for all grid voltages, even in challenging ambient temperatures of up to 55°C. The MVPS 4400SC/5000SC-EV's high power density and compact design significantly reduce transport, installation and operating costs, according to SMA. Power plant operators, EPCs and investors also benefit from lower system costs for entire projects and from the reliability and long-term availability of the new MVPS 4400SC/5000SC-EV. The station is optimally suited for 1,500-volt PV power plants, providing the opportunity to oversize the PV field by up to 150% and offering greater availability, a longer service life, minimised risk of failures and consistently high energy yields in PV power plants.

Applications: Utility-scale PV power plants.

Platform: The new Medium Voltage Power Station as a whole, as well as all the individual components, are type-tested. With its optimised block size, the MVPS 4400SC/5000SC-EV achieves a noticeable reduction in the specific price per watt, according to SMA.

Availability: The new Medium Voltage Power Station is available to order now, ready for delivery starting May 2017.

SMA Solar 'Power+ Solution' is first inverter to include integrated monitoring

SMA Solar Technology has started offering the SMA Power+ Solution, which combines SMA inverter technology and intelligent PV module optimisation. The basis of the intelligent SMA solution is the new Sunny Boy 3.0-5.0 with the new SMA Smart Connected service, which together are claimed to offer the first inverter with integrated monitoring and an automatic notification function for servicing without delay. This ensures that PV system owners benefit from maximum system availability and installers from an even easier service business.

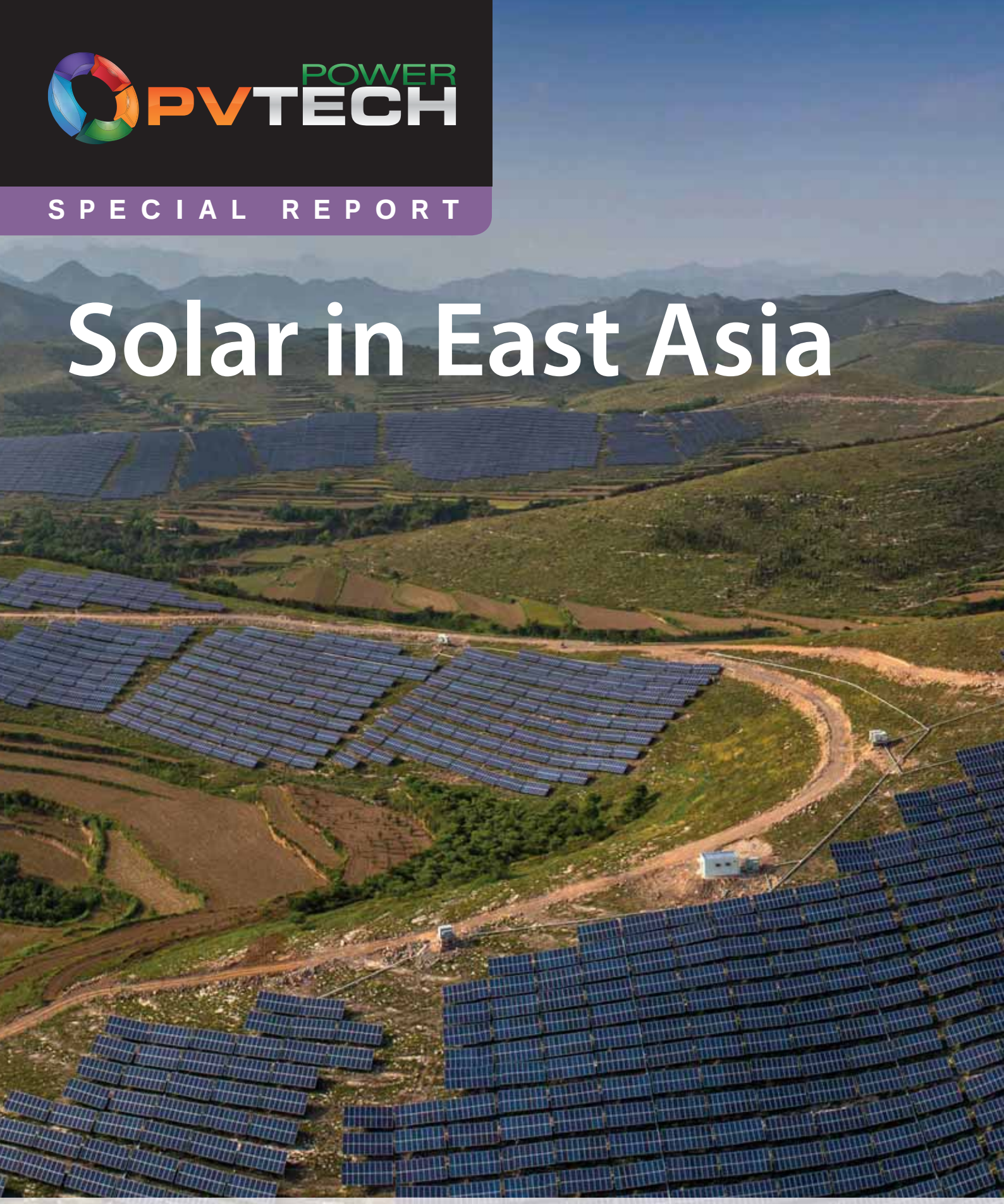
Oracle's latest utilities network management system caters for renewable energy integration

Oracle has introduced its 'Oracle Utilities Network Management System 2.3', a network management platform that enables utilities to make the transition to a customer-centric grid by giving operators real-time visibility across all grid and pipeline assets and eliminating the complexities of siloed data and applications. Utilities are facing major shifts in their operations caused by a rapid increase in distributed energy resources such as solar PV, storage systems and electric vehicles. The Oracle Utilities Network Management System 2.3 now enables utilities to aggregate data from various network assets into a single interface with more detailed visibility into network operations.

POWER PVTECH

SPECIAL REPORT

Solar in East Asia



China's 13th Five-Year Plan for solar – a look at 2017 and beyond

Market update | At the end of 2016 China published a long-awaited plan that will determine the course of PV deployment for the next five years. China solar industry expert Frank Haugwitz unpicks the plan and assesses the country's chances of surpassing 100GW of capacity this year

China's National Energy Administration (NEA) officially released its 13th Five-Year Plan (2016-2020) for solar development on 16 December 2016. The plan stipulates targets, measures, regulatory issues, challenges and focal areas, and reconfirms, for example, China's 2020 solar target of 110GW, split into 105GW of solar PV and 5GW of concentrating solar power (CSP), which was already included in China's "Power Sector Reform Plan" released in October 2016. The plan re-confirms further that by the end of 2020 the total installed solar PV power generation capacity will exceed 105GW, which according to AECEA is considered a minimum target. Selected highlights of the plan are discussed below.

Distributed generation

Interestingly, the plan no longer contains a specific target for distributed generation, contrary to the October announcement, in which a 60GW target was communicated. In light of today's total of less than 10GW of distributed generation, a more than six-fold increase in the coming four years would have very likely proven to be unrealistic. Nevertheless, distributed generation does enjoy as expected a very prominent position in the just released plan. For example, it says that up to 100 distributed generation demonstration zones shall be set up across the country and within each zone 50% of existing buildings and 80% of all new-build buildings shall deploy rooftop systems. At the same time new business models shall be created, designed to stimulate demand in the distributed generation segment.

Against this background, China is home to approximately 1,500 so-called "industrial development zones" covering approximately 10,000km^2 and an earlier conducted investigation estimated a rooftop potential of approximately 80GW, which from a quantitative perspective is undoubtedly sufficient. Despite the obvious potential, AECEA has learned that on average five to seven commercial/industrial roofs out of 10 investigated by developers are structurally not feasible and therefore will not be suitable for installing a rooftop system. Hence, the lead time to successfully identifying a proper roof is significant. Other constraints such as rooftop ownership identification are not factored in yet.

Plan key points

Introduced in 2015, the competitive bidding-based "Top Runner" programme expanded from initially 1GW in Datong, Shanxi Province, to 5.5GW across multiple provinces last year, thus accounting for approximately 30% of last year's guiding target of 18.1GW. As anticipated Top Runner remains a prominent feature of China's domestic market landscape in future. A number of previously conducted provincial top runner tender schemes that resulted in low bid levels – significantly lower than last year's FiT – will not only have been the reason for the relatively significant FiT reduction (13-19% depending on the region) effective 1 January 2017, but as well to continue and possibly expand further in future.

According to the five-year plan the FiTs are expected to drop by more than 50%


Credit: GCL New Energy

compared to 2015 levels by 2020, thus achieving grid parity. Taking the recent decision regarding the reduced FiT effective 1 January into account, the plan implies that future FiT reductions between 2018 through to 2020 will be lesser and AECEA estimates are in the range of ±10% annually. Finally, the wording within the plan equally suggests that perhaps no FiTs will be granted beyond 2020, if grid parity indeed will have been realised.

In light of China's concerted efforts to achieve a "relatively well-off society" by 2020, the so-called "poverty alleviation projects" featuring 3-5kW solar PV systems for low-income households (RMB3,000/annum) across hundreds of counties led to the approval of 5.1GW during the summer of 2016. Demand for such systems is expected to remain strong throughout the 13th five-year plan period given that there are 2.8 million eligible households.

The plan equally highlights the potential of so-called agro-PV projects, where for example greenhouses and fish-ponds use solar PV for power generation, and so-called renewable energy hybrid systems, where whatever locally available renewable energy resources are simply combined. China is home to a significant number of hydro/PV or wind/PV projects already today. Against this background China's State Grain Administration announced its intention to implement the installation of 1GW of rooftop systems on its grain warehouses across the country by 2020.

Beyond being home to the world's largest solar PV manufacturing industry and the largest PV end market, China is also aiming at the bigger picture of the solar industry. In this context, the plan very prominently features proposals covering solar thermal applications, i.e. solar water heating and commercial/industrial heating and cooling.

According to the plan, in the remaining four years the combined area for solar thermal applications shall double to 800 million m^2 by 2020. Equally bullish is the NEA in promoting the development of an indigenous CSP industry, in order to realise the 5GW target set for 2020. AECEA is of the opinion that the promotion of a local CSP industry and the deployment of 5GW is driven by a number of factors such as a desire to use CSP for baseload purposes, through the scaling-up of production capacities to bring down the cost, hence being in the position to create and meet the demand outside of China.

China's solar industry is showing no signs of slowing down

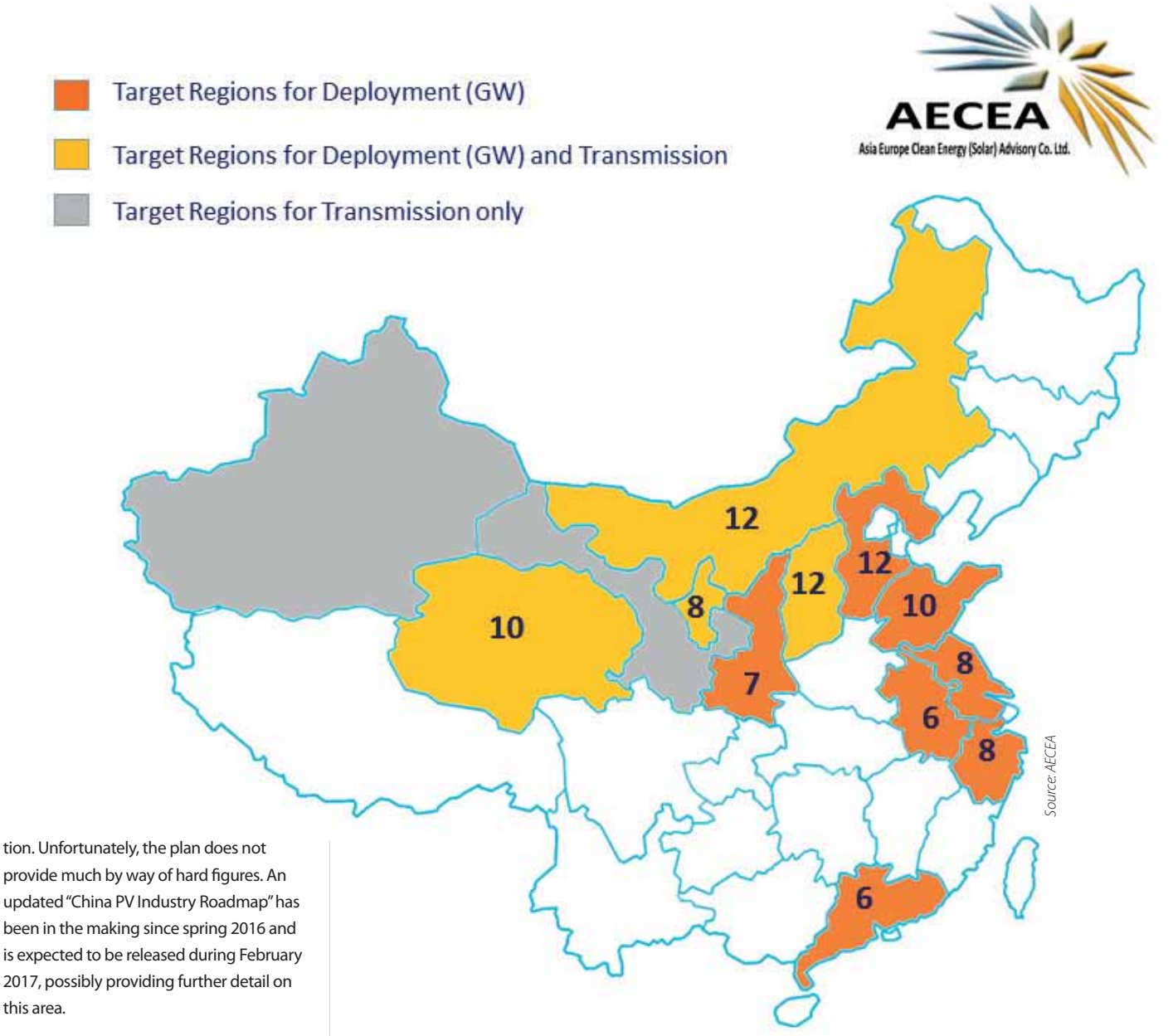
A surprise is that out of 31 provinces, autonomous regions and municipalities just 11 have been selected as so-called target regions for presumably continued large-scale deployment, i.e. both ground-mounted utility-scale and distributed generation for a total 99GW. Destinations that until now have been favoured for PV deployment, such as Yunnan, Xinjiang and Gansu Province in particular, are not explicitly mentioned. However, the latter are expected to serve as so-called "transmission corridors" from West to East China.

Unfortunately, electrical energy storage (EES) for stationary purposes was not explicitly mentioned in the plan especially since a dozen or more companies, either established solar PV manufacturers or battery manufacturers, are already expanding in this area. China's EES industry hoped that the government would introduce a market incentive programme designed to promote the local deployment of EES systems in the commercial and industrial sector, similar to other countries. The plan however does foresee activities in the area of intelligent mini/micro-grids which would impy the deployment of EES systems.

As expected, the plan emphasises China's upstream sector in terms of industrial upgrading, innovation, restructuring, consolidation and international coopera-

13th Five-Year Plan (2016-2020) for solar development

- By 2020: 105GW (PV) and 5GW (CSP) – no sub-target for distributed generation
- 11 target regions identified for GW deployment
- Four target regions identified for GW deployment including 13 West-East Transmission Corridors"
- Two target regions identified for "transmission"
- Feed-in tariff levels expected to drop by more than 50% compared to 2015 levels by 2020, then at grid parity
- FiT levels for CSP expected to drop from current RMB1.15/kWh to RMB0.8/kWh by 2020
- Technology benchmarks set for cell (multi/mono) efficiency levels to be reached by 2020
- Focal area: Distributed generation – multiple measures identified to stimulate demand
- Focal area: Top Runner programme, poverty alleviation programme, agro-PV, RE-hybrid projects
- Focal area: Solar thermal for hot water, district heating and cooling – 800 million m2 by 2020
- Focal area: Comprehensive industrial strengthening – pursue "go global" strategy (up and downstream)
- By 2020 the PV Industry expected to create 7 million jobs



Target regions identified for both deployment and transmission in 13th Five-Year Plan

tion. Unfortunately, the plan does not provide much by way of hard figures. An updated "China PV Industry Roadmap" has been in the making since spring 2016 and is expected to be released during February 2017, possibly providing further detail on this area.

China outlook

2016 was the first year of the 13th Five-Year Plan (2016-2020) period and was one that witnessed record installations amounting to 34.24 GW, representing 126% growth year on year. The cumulative installed capacity reached 77.42GW, an 81% year-on-year increase. This year will be the second year of the 13th Five-Year Plan and according to AECEA there are no signs yet indicating a slowing down of the Chinese solar PV market dynamics. In particular, the new FiT reductions of between 13 and 19% will ensure demand remains strong until 30 June 2017; according to AECEA's estimates up to 20GW of new capacity is considered realistic by then and for the entire 2017 overall 25 or possibly 30GW. AECEA is of the opinion that by the end of 2017 China will be the first country to have exceeded the 100GW mark of installed solar PV capacities.

AECEA assumes that beyond 2017 the NEA will further expand the Top Runner programme, meaning a larger share of the total market will subject to competitive bidding. Provincial tender schemes for the remaining share of projects subject to regular feed-in tariff could become mandatory. Overall, the guiding ideology will be that competition drives down prices, leads to less FIT payments, less demand and further consolidates the heavily fragmented market. An increase of industrial benchmarks would help too. The launch of a national emission trading scheme scheduled for 2017 will serve as an additional tool or source of potential revenues where again the market forces will play a significant role. In terms of market segments, future policies will rather address the promotion of distributed generation. From 2018 through 2020 AECEA anticipates the setting of lower annual installation targets in the range of 10-15 GW along with a stricter enforcement compared to the past. ■

For a detailed analysis of the future of the top runner programme, turn to p.22

Author

Frank Haugwitz is an expert on PV and renewable energy in China. Based in Beijing since 2002, he founded and directs Asia Europe Clean Energy (Solar) Advisory (AECEA), a consultancy working to help European and Asian companies understand Chinese renewable energy regulation and policy. Since 2013 he has been the elected vice chairman of the Renewable Energy Working Group of the European Chamber of Commerce in China.

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TOP RUNNER

Technology | China's Top Runner PV auctions are growing from a small base to potentially representing the majority of utility solar deployment by next year. Bloomberg New Energy Finance's Yvonne Liu speaks to John Parnell about the companies and technologies gunning to take advantage

The Chinese government and indeed the Chinese solar sector have long acknowledged the need for consolidation in all parts of the domestic value chain. Aside from refusing to bail out failing companies as and when they reached the brink, it was difficult to see how this might be achieved. When Beijing stepped back, local governments, keen to protect jobs, were liable to step in.

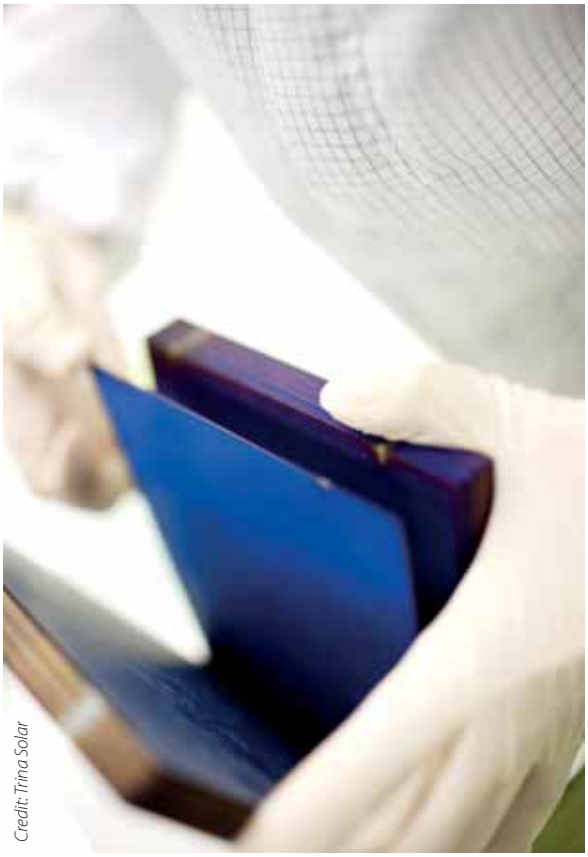
Enter the Top Runner programme. It has received modest interest from overseas but since its inception its influence has ballooned.

Let's go back to the start. What is the point of consolidation? In this instance, it was about improving the quality and so the reputation of Chinese-manufactured solar products and the companies that are charged with the task of building out the 100GW-plus that the government wants to see installed. This appears to be strongly aligned with the objectives of Top Runner as they are viewed by Bloomberg New Energy Finance analyst Yvonne Liu.

"The government's reasons are three-fold," she says. "The first reason is to increase demand for high-efficiency products and also to improve the manufacturing capacity.

"China has been a manufacturing hub for PV and has more than 80% of global module capacity. The government wants to provide a larger market for the higher efficiency products. They are worried that if they do not, high-efficiency products would not be selling well and the manufacturers may not invest in R&D," she explains.

"The second point is project performance. Chinese projects have not been performing very well. A lot of grid-connected projects are under-performing. The global performance ratio is about 80% and it can be higher in markets like Germany. In China it is usually closer to 70%. That is why Top Runner projects also have a requirement to achieve a performance ratio of at least 81%.



Credit: Trina Solar

The Top Runner programme sets minimum efficiencies for modules using mono- or multi-crystalline wafers

"Thirdly, and this is my personal view, the government is trying to more or less centralise the market for large utility PV projects, similar to what we have with wind. Because we have a lot of developers right now working on utility projects, which actually creates some headaches for the government. If they centralise the utility-scale projects they can push more developers to the smaller scale PV sector, which is another thing they want to do," adds Liu.

The National Energy Administration's Liang Zhipeng, vice director-general of its new and renewable energy division told an industry event in 2016 that the goal of the programme was to accelerate "technology progress". Procurement, construction and operation are monitored by a third-party technical agency he explained, in order to assess whether the standards are being met.

Maverick no more

The initial 1GW phase of Top Runner may have looked like a niche venture comprising a small fraction of the projects built that year. This is changing rapidly and the influence of the programme on deployment in China will be significant this year.

"It is quite possible that in 2017 the quota for Top Runner projects could be larger than for regular utility projects," says Liu.

Citing any reliable data for the Chinese downstream market is a fool's errand but very broadly, in 2015 5-10% of installed solar was through Top Runner, and in 2016 this figure was 15-20%.

"In the second half of 2015 the government announced the first 1GW batch of Top Runner projects. They were all commissioned in the first half of 2016. Then the second batch was released in June 2016 and that was 5.5GW of capacity. These [projects] were awarded via an auction and a lot of low prices emerged. We expect this volume to be increased in 2017 or 2018," she predicts.

This increase beyond 2016's 5.5GW means that there was a significant portion of Top Runner projects versus plain vanilla utility schemes. China grid-connected 34GW of solar in 2016, according to recent government figures, and some of this was thought to have actually been built

in 2015. This year, China is expected to post similar figures with growth stymied by a Beijing mandated slowdown in its PV targets for 2020. If Top Runner grows beyond the 5.5GW and the total end demand remains similar, the share of Top Runner projects will continue to grow. This means it can no longer be ignored and the extent of the influence on manufacturing becomes great enough to have wider implications.

Technical requirements

Increasing standards means setting a benchmark. In the case of Top Runner, the National Energy Administration (NEA) cut right through to the wafer type, setting a minimum efficiency of 16.5% for multicrystalline-based modules and 17% for monocrystalline (see box). In addition, the auction's scoring system further rewards mono-based projects. String inverters are also preferred and, all in all, that performance ratio target needs to be met.

"Manufacturers need a certificate to supply to the Top Runner project. I believe in the first batch there were not many manufacturers getting the certificate but that number has been increasing slowly in the last few months," says Liu.

"It has been argued that it is quite easy for the mono modules to achieve the standards but not so easy for the multi modules. There are some efficiency standards also for inverters."

Add to this the requirement on performance ratios, and quality – compared to standard projects – is increased right along the value chain.

Enforcing the issue

Liu, like many in the industry, and Beijing itself, are aware that while Top Runner is succeeding in many of its goals, it is not yet the perfect system. One particular concern is whether the rules bedded into the programme will be sufficiently enforced. The NEA's Zhipeng has said: "The bidding method is through competition. The enterprise obtaining the project must adopt the products that meet the technologies of the Top Runner programme. Meanwhile, our country entrusts [a] professional technical agency to monitor and assess from its design and purchase to its construction and final operation in the whole process. Finally, we find whether it reaches the results of the Top Runner programme."

What he left unsaid was the consequences for any projects that are found to have fallen short in any part of the process from procurement to operation.

"We don't have the project data yet. The major concern, at least for me, is that, yes they have set up a standard for performance ratio, but there is no detailed punishment or penalty if you miss that. So I don't know what would happen, even if they found out that a project is not meeting the requirements," explains Liu.

With less than a year of operation for the first batch of projects, it is possible that this question may be answered in time. With projects already in the ground, could there be retroactive punishments for those that fail to make the grade?

"I think that is something they will do this year. I think they should and a lot of market players would agree," says Liu.

Changes

If the apparent gap in enforcement is not addressed in the contracts each developer has signed, it may be one area that the NEA

Credit: GCL New Energy

GCL has been able to drive down auction prices in the Top Runner programme due its vertical integration

chooses to address as the scheme continues to mature. Liu believes that one other area for adjustment could be the scale of the technologies that are promoted but is wary of the contribution from the industry's rumour mill as interest in Top Runner and its future peaks.

"Previously it was just about efficiency but they are thinking about adjusting the requirements and one possible change is to have a requirement on the manufacturing capacity so that only the technologies with less than 200MW of capacity will qualify. But this is just industry rumours and hasn't been confirmed yet," she warns before acknowledging why such a plan would make sense. "The goal of the project is to support advanced technology, so they do not want to use up the quota on very common technologies.

"There is going to be Top Runner and Super Top Runner and another [rumour] we have heard is that for Super Top Runner, no bidding will be required and the quota will be used for really niche products. It could be that the [rumoured] 200MW rule is for this [Super Top Runner] market."

Why so low?

As with most solar markets, Top Runner's auctions have elicited some very low bids and the industry is growing nervous

"They are required to use better products, they are required to have better construction through the whole EPC process but then they are bidding very low prices, which is not aligned with the original purpose of the government," says Liu.

"We're seeing more significant price reductions in the Top Runner auctions compared to the auctions for the common utility projects. We can't really explain why because from a lot of perspectives the Top Runner one should be more expensive than for common projects. The only lower cost item is the finance because the Top Runner companies are all very large, regardless of whether they are private companies or state-owned, so their financing costs are lower. This is the only cost advantage. Otherwise, on EPC, on equipment, on construction and even land cost they are actually more expensive.

Liu traces the origin of the low prices to those developers who also operate a full manufacturing chain in house, calling them "the pioneers" of the rock bottom prices. One company in particular has stood out in her view.

"GCL has everything from polysilicon to modules, they have the entire chain; they have quite a low manufacturing cost and so project cost. They calculated their prices based on a 10% project IRR then everyone else just followed. Return is not the only goal for many developers, who were also targeting a certain growth rate in asset size. So when most of them enjoyed more than 20% gross margin in H1, some of them are more willing to focus on expanding their asset portfolio in H2," explains Liu. Effectively, without the pressure on profit in H2, developers were able to focus on scale instead.

"I think most of the projects should be profitable. The average prices are not that crazy, it's just the lowest prices [that are]. If those really do meet the Top Runner standards then I don't think they can be profitable. It could be that they may not meet all the targets and as I said, if you do not meet the 81% target for performance ratio there is no punishment."

Success?

With the aims of the policy targeted at improving quality from factory to final project performance, the sight of such low bids may have had officials concerned that they had failed to put quality ahead of quantity and instead created a new premium race to the bottom. These fears appear unfounded, so far. If the NEA's technical agency is a diligent referee and sanctions for those falling short of expectations are forthcoming, then Top Runner's legacy in 2017 and 2018 could be a double-digit gigawatt volume of downstream projects. These can provide the foundation, and the impetus, for China's PV manufacturers and ensure they aren't caught standing still. ■

Mono winning out

Credit: LONGi Silicon

Top Runner has marginally favoured monocrystalline modules

While the design of the Top Runner auctions did slightly tip the scales in favour of monocrystalline modules, the clear success of mono throughout the scheme's projects is hard to ignore. Materials firms like LONGi Silicon and its related module manufacturer Lerri Solar are placed in pole position to benefit. But mono and multicrystalline technologies will always be pitted against each other and both are experiencing rapid changes.

"I would say mono PERC modules have been performing well in the scheme. That's because PERC technology is granted additional scores in one of the metrics in the bidding process, there are a lot of metrics, price is one, efficiency is another. Developers want to use PERC, especially mono PERC. Secondly, the price of mono last year was actually quite close to multi," says Liu. With the gap in price closing [using] mono becomes a relatively easy decision. The addition of PERC technology has led to PERC producers running out of capacity according to Liu.

"Right now the manufacturers are expanding their PERC lines and also their mono wafer capacity but the major reason is because they can get a higher score in the Top Runner auction. In terms of how far [those trends can] go out of Top Runner and out of China really depends on the technology development," Liu adds.

"Last year mono wafers were practically the same cost as the multi wafer, so if they can keep that competitive in the future, if you're paying the same price, why not use mono? But at the same time we are seeing higher potential for multi wafers to reduce their costs in the next few years so this advantage may not continue. It will depend on how much lower the multi wafers can go. At the end it is all about cost."

Living by a new set of rules

Market update | Japan's solar market has slowed considerably since the early days of its feed-in tariff. But as Andy Colthorpe reports, its fundamentals still look strong and there are plenty of promising policy drivers in the pipeline to keep demand buoyant

What goes up must come down. But while Japan's PV market could be said to have boomed in the immediate aftermath of the 2011 Great East Japan Earthquake, which caused the country's nuclear power stations to be brought offline and sired a rewarding feed-in tariff policy for solar from 2012, the consequent paring down of the industry seen over the last couple of years could hardly be characterised as 'bust'.

The opening period of the FiT programme saw dozens of gigawatts of large-scale solar projects applying for the scheme, leading to the building of at least 20GW of 'megasolar' (the Japanese term for a megawatt-scale utility plant). Tokyo-based analysis firm RTS PV believes that in 2015 around 10GW of PV was deployed and last year a little less, about 8GW across the various scales.

There has been some dampening down of expectations and market size undoubtedly over the past year or two. Those early years, when the FiT stood as high as ¥42 per kWh (approximately US$0.40), as much as 57GW of large-scale projects were applied for that by last year still had not been built. We saw in our analysis published in this journal in early 2016 that there was a concerted effort from government level to avoid a 'boom and bust' scenario where stricter rules were introduced for new projects and deadlines given for developers to secure the necessary rights to proceed with projects in that 57GW backlog.

The latest development, according to RTS PV analyst Dr Hiroshi Matsukawa, is that this year the government has confirmed it will be introducing a tender system for large-scale megasolar projects over 2MW. This year will see just 500MW tendered out and next year another 500MW. As has been seen in Germany, which is taking a similar approach, it's a huge step down from what the industry has been accustomed to and the rules regarding all projects have changed too.

"Equipment certification rules have certainly changed significantly," Matsukawa says. "The biggest change is an increase in the time it takes to gain

certification. Firstly, you have to secure a connection agreement with a power company, or you won't get the FiT or equipment certification.

"Until now, you could get equipment certification without concrete details of a project's development, plans could be vague, but it's become much more difficult, now you need to get a connection agreement before you can get certification. This adds considerable time to project development."

FiT and financing

Due to the projects in the backlog and their still uncertain future, Matsukawa says the size of the market this year will be trickier to call. It is likely the government will impose a strict deadline this year on those unbuilt projects that Matsukawa estimates could lead to two-thirds to half of that full backlog being 'cancelled'.

Moving forward, Matsukawa says it is possible the FiT will be reduced even more significantly this year – degression has been somewhat accelerated over the past couple of years from what was expected at the beginning. From March last year the FiT for projects over 10kW in size stood at ¥24.

"There's a high chance the FiT will be significantly reduced – a cap rate will likely be placed on it and conditions will become strict," Matsukawa says.

"Additionally projects will have to compete for tenders to get their use of distribution lines from power companies; without both of these tenders it could be impossible to receive the FiT."

These conditions will not deter serious companies from continuing in the Japanese market, Soichiro Nakamura, president of domestic vertically integrated PV company, Looop, says. Nakamura, whose company is involved in all areas of the PV supply chain from component development through procurement, construction, O&M and even electricity sales in the newly deregulated retail market, and has developed over 160MW of PV projects in Japan, is adamant that if it can keep reducing costs it will succeed – although rivals may fall by the wayside.

"Japan's FiT price is going lower year by year…under this situation, some small PV companies have gone bankrupt. But the current FiT price is still higher than in other countries. From our view, reducing costs is key," Nakamura says. Nakamura adds that he believes "low quality" companies will pull out of the market by necessity.

Terry Zhao, CEO of Sungrow Japan, believes the Chinese inverter market leader could also benefit from competitive conditions enforced by the falling FiT. "Reductions in the FiT will force clients to choose PV inverters with innovative technologies which can ensure a profitable yield. We deem this a favourable opportunity for us," Zhao says.

Safe money

With lower returns come lowered expectations, but Japan is still a hungry market for PV. ESR/Redwood is a logistics fund developer based across Asia, currently developing what is expected to be Japan's largest commercial rooftop PV plant, a 5MW project in Osaka. The company's capital officer, Pierre-Alexandre Humblot, explains that the investor profile is changing, but that the liquid capital needed to finance new installations is still very much present.

> "Until now you could get equipment certification without concrete details of a project's development, plans could be vague but it's bcome much more difficult"

"Clearly, future investment returns from solar panels in Japan are not going to be the sort of windfall profits that you could achieve in the early years, but that's ok, the space is going more institutional," Humblot says.

"Interest rates are essentially zero in Japan, lending rates are anything between zero and two per cent."

Solar as an asset class has gained traction in Japan, Humblot says, and projects are bankable: "Three years ago people were looking at 20% returns. Potentially they will have to be satisfied with 8% or 10% returns now and that will mean a different investor base but there's so much capital sloshing around in Japan that there's no need for foreign capital to finance solar."

RTS PV's Hiroshi Matsukawa agrees with ESR's view that commercial rooftops will continue to present an attractive opportunity for PV, even in straitened circumstances.

"There is a big possibility [commercial rooftop] will become a significant target market or market opportunity. They may not even be interested in getting the FiT; there may well be other models such as self-consumption of power onsite that provide ample opportunity for PV development."

Market liberalisation

Also giving hope to the PV market is the expected impact of electricity market liberalisation. Since last April Japanese consumers have been given the freedom to choose electricity suppliers. Looop, involved in that newly created market, is optimistic about its promise, Soichiro Nakamura says.

"Looop started selling electricity for general households in March 2016. The service has some characteristics no base fee, a simple plan and renewable-based electricity. We have got 40,000 customers."

Nakamura says that while the rate of consumers switching to a new preferred tariff is small, still only around 3.7%, market liberalisation could have a positive influence on green energy. There needs to be ongoing "public awareness campaigns" to make the benefits and choices clearer to customers, Nakamura adds.

In the near future, Japan will have 'zero energy' standards on new buildings, especially residential, mandated by law. By 2020, all new residences will have to be built to the regulations, making PV "almost mandatory", as Canadian Solar's CEO Shawn Qu points out. Canadian Solar, which is working to connect as much as 376.2MWp of projects to add to an existing 60MW in operation in Japan, is among those looking to market self-consumption solutions including energy storage to the residential market.

RTS PV's Hiroshi Matsukawa believes that Japan can exceed its – some would say modest – national target, to deploy 64GW of PV by 2030. In fact, RTS believes it will reach this target some 10 years early (see box). While it remains a perceived problem that solar generation has been greatly increased and other options such as wind remained relatively static, the government remains committed to "promoting solar sustainably – but without stirring up the market," Matsukawa says.

"We think we can exceed that (64GW by 2030) quite comfortably, but what we can do beyond that is still hard to gauge." ▶

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"Largest" in reference to the exhibitor number of trade shows with the same concept. *forecast **forecast including all visitors from World Smart Energy Week 2017.

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Installed capacity in Japan toward 2020 and 2030

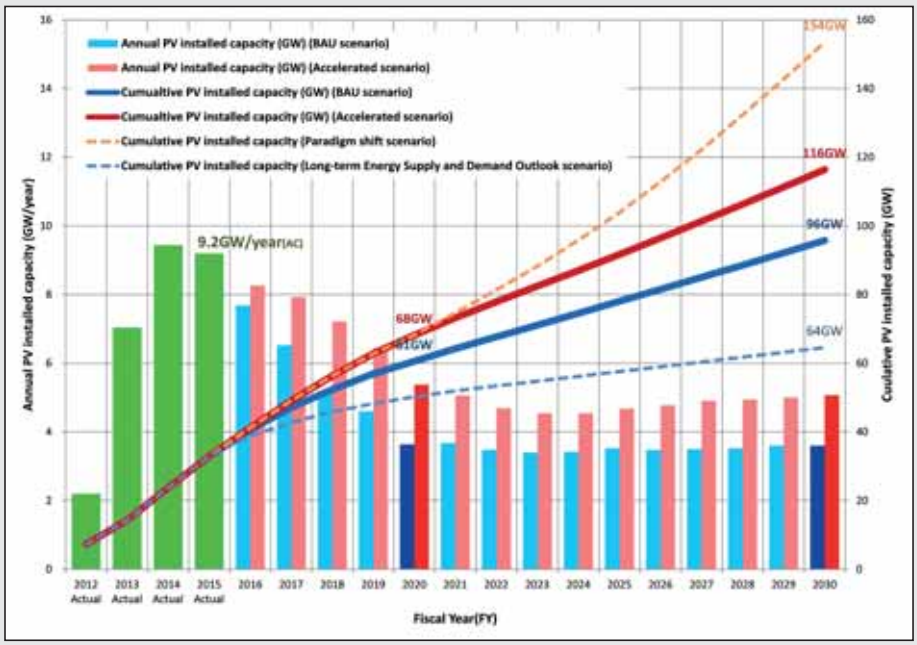
Japan's 2012 FiT programme has been revised under the revised FIT Act (Renewable Energy Act). Based on the new rules of the FiT program, RTS Corporation made a forecast on PV installed capacity by fiscal year (FY, April to March), towards FY2020 and FY2030 in an annual report entitled, "Forecasting PV installed capacity in Japan toward FY 2020 and FY 2030", through research and analysis of the latest trends of the PV power generation in Japan, covering market, industry, technology, policy and business development.

It is expected that Japan's cumulative installed capacity will reach 61 to 68GW by 2020 and 96 to 116GW by 2030. This shows that the "64GW by 2030" estimate set in the "Long-term energy supply and demand outlook" by the national government can be achieved by around 2020, 10 years ahead of schedule.

Figure 1 shows the overview of the forecast of Japan's PV installed capacity (by fiscal year and cumulative) based on the two scenarios - "business as usual" and "accelerated". The "BAU scenario" assumes the cases where policy and deregulation continue on the current trajectory, including the impacts of output curtailment by electric utilities and estimated PV system price trends. The "accelerated scenario" assumes the cases where ambitious new policy is introduced and development of various peripheral technologies advances smoothly. Figure 2 shows the PV installed capacity by fiscal year under the accelerated scenario by capacity range.

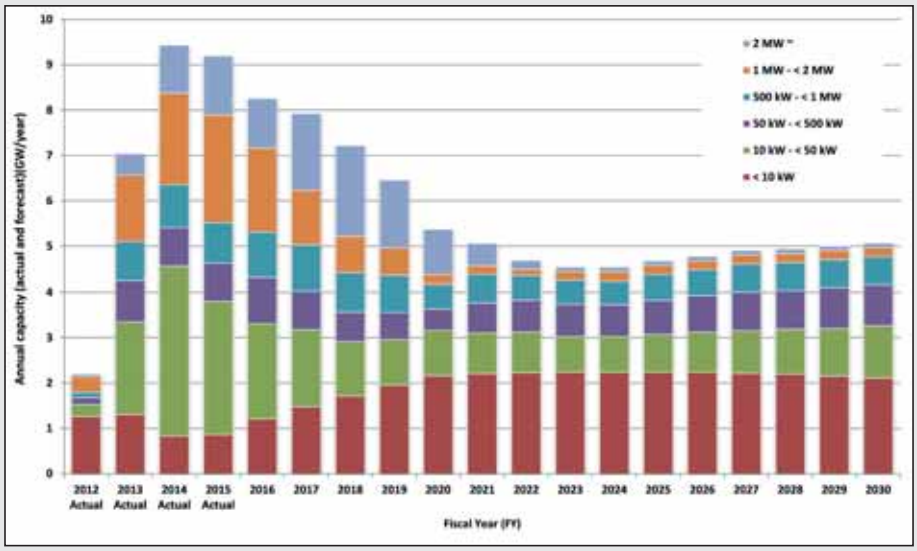
Under the accelerated scenario, PV system price, which currently ranges from ¥217-332/W, is forecast to be reduced to the range of ¥95-126/W by 2030 (in terms of power generation cost (LCOE), between ¥7.4 and ¥8.6/kWh). Also, the future PV market with newly added values and expansion of business areas (PV-related market) has also been forecast. The PV market size in terms of revenue of PV systems tends to shrink to the annual size of ¥500 billion to ¥600 billion towards 2030, due to price reduction, contraction and stabilisation of the market. Meanwhile, if the future PV-related market is considered, the market is forecast to grow again. In FY2030, it is estimated that the market size will grow to the range between ¥1.09 trillion and ¥1.52 trillion. Figure 3 shows RTS' estimate on the growth of the PV-related market in Japan under the accelerated scenario.

By Izumi Kaizuka, manager, RTS Corporation



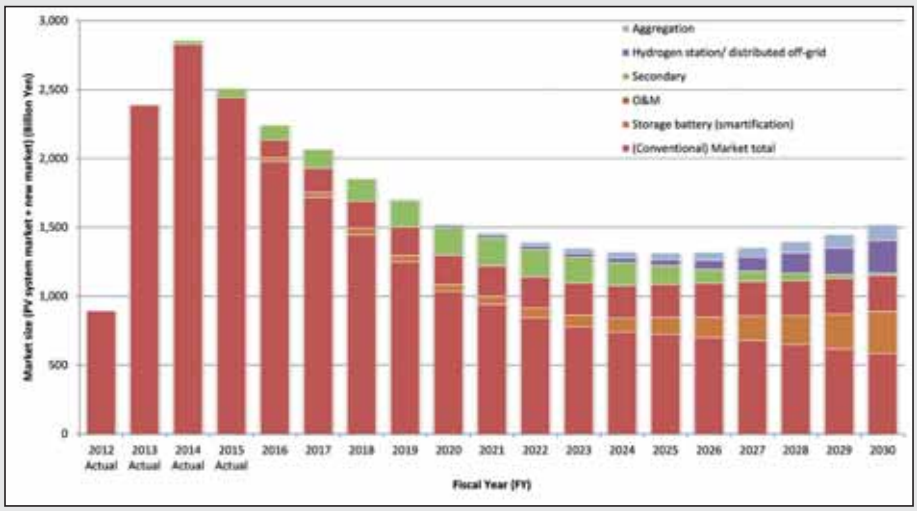
Source: RTS Corporation

Figure 1. RTS forecast on the PV installed capacity by fiscal year (FY)(BAU scenario/ accelerated scenario).



Source: RTS Corporation

Figure 2. RTS forecast on the PV installed capacity by capacity range by fiscal year (FY).



Source: RTS Corporation

Figure 3. RTS estimate on the growth of the PV-related market in Japan (accelerated scenario

Built tough for Taiwan

System integration | Taiwan has set itself a target of 20GW of PV by 2025, but standing in the way of that are acute land shortages and some extreme weather conditions. Tom Kenning reports on the creative technological and construction solutions being found to address Taiwan's unique challenges

Credit New Green Power

Land constraints in Taiwan are just one of the many issues faced by solar developers in the island nation

Taiwan has played its hand by targeting 20GW of solar by 2025 in order to move away from nuclear generation, but the island also contains some of the most peculiar and challenging environments for solar project development. Dense population and scarce land availability have led to lakes and ponds, seaside plots and even so-called "sinking land" being made available for PV deployment. As a result, developers need to invest in robust solar equipment, whether it be modules that can handle salt and mist corrosion, or strong solar inverters and frames to withstand some of the most violent typhoons in all Asia.

"The government is relying on solar to become the next economic engine in Taiwan," says Shawn Chuang, country manager for the Smart PV Asia Pacific business of inverter specialist Huawei. "Really in Taiwan we don't have much booming industry. The semiconductor industry or the LCD industry electronics are all beat by mainland China so we have to find a new economic engine. Solar is the most ready one: we have the technology; we know how to build the projects. The only thing we lack is the land resource."

The capital city Taipei, to the north of the island, where population is most concentrated, also happens to have the poorest irradiation. Meanwhile, if solar deployment is concentrated in the more favourable conditions of the south, transmission infrastructure is limited. The island population of more than 23 million also requires plenty of land to maintain a solid agricultural industry. As a result, the government has had to release uncultivable land for its 20GW solar ambitions, much of which is close to the seaside where soil has become too salty for farming. Meanwhile, "sinking land", where groundwater has been withdrawn to the extent that the land is liable to sink in various locations, has also been released.

Land matters

Taiwan-based developer and EPC New Green Power (NGP) was one of the first companies to complete a solar project on this challenging sinking land, with a capacity of 1.6MW in Yulin County. There are two major issues, says NGP director Kai Tan. Firstly, most solar farms tend to involve screws or cement for securing the plant, but sinking land is subject to extreme flooding from typhoons and every year a few points on the project land can start to sink, causing imbalance in the structure. As a result, EPCs in Taiwan have to design a completely new structure to overcome the land deviations in addition to using robust equipment.

NGP has a range of configurable structures with reinforced concrete piles and steel structures, which have the strength and flexibility to resist the severe typhoons and flood waters, says Andy Tang, chairman and president of NGP. For sinking land specifically, NGP's structures offer adjustable heights to resist the risk of land subsidence. The firm also uses equipment that can resist severe wind and rain with IP65 rating. The IP65 guarantees protection from water spray in any direction as well as dust ingress.

Maintenance also becomes very important in this kind of setting so NGP uses inverters from China-based manufacturer Huawei that have a 25-year lifetime and do not have fans or fuses, which saves time on operation and maintenance (O&M) in an already harsh environment.

Sinking land is certainly a more treacherous proposition compared to most traditional PV locations, but using such land will be almost unavoidable given that Taiwan is not only one of the most densely populated countries on earth, but two-thirds of the island are covered in steep mountainous forest and national parks; where Taipei ends, the forest begins.

An added burden is that the remaining suitable spaces for solar, such as landfills, subsidence areas, saline damaged land, contaminated land and other enclosed spaces will increase the development costs, says Tang. The conditions of these zones with salty, foggy, damp and rainy

offshore climates only strengthens the case further for prioritising sturdy solar equipment.

The second issue relating to land is that of ownership, says Kai Tan. Territory is historically divided into very small parcels of one or two acres of land in Taiwan, therefore building a large-scale project can involve negotiating with dozens of separate landowners. A single 50MW project can have as much as 100-200 landowners to deal with. This makes it very difficult to agree on the same contract with each individual. Under intense competition, these landowners also tend to be approached with many different offers.

"The major issue will be focusing on laws relating to the use of lands and solar plant development," says Tang. "We are looking for an efficient strategy to encourage and convince the landlords to work with us, in order to increase the number of solar projects."

Cell efficiency

Given the island's land constraints, it makes sense to use the highest efficiency solar modules to optimise land usage. As it happens, Taiwanese cell manufacturers tend to produce some of the highest efficiency cells across the globe. The country has roughly 2GW annual manufacturing capacity of these higher efficiency cells, and some observers have speculated these could play a central role in meeting Taiwan's 20GW target. Indeed the Taiwan government would appear to be thinking along similar lines by putting on the table a 6% feed-in tariff bonus for higher efficiency solar modules.

It may also be the reason why several Taiwanese cell manufacturers including Neo Solar Power (NSP) and AU Optronics have started to focus on vertical integration. For example, Alex Wen, senior vice president at NSP says that with cell prices dropping rapidly in the second half of 2016, the firm is increasing its module manufacturing as well as investing in solar PV projects to raise cash. Taiwan's proximity to the sea and floating solar opportunities (see box) are also driving innovation in modules, with NSP, for example, releasing a double-glass module that benefits from water reflection.

Typhoons

Water in the form of typhoon rains can be less beneficial. The Taiwan market has already been troubled by typhoons so modules need to be able resist rain and high wind loads, says Sascha Rossmann, vice president, solar global sales at Taiwan-headquartered module manufacturer Winaico. Taiwan has wind speeds of up to 260km per hour, much higher than Hurricane Matthew in Florida for example where winds were 160-170km/h.

"That's nothing in Taiwan. The Typhoons are very scary here," adds Rossmann. "There is a lot of damage to the PV systems here because of the poor designs of the panels and also the mounting system. If the mounting system resists the wind speed, the panel must resist the vibration."

The solar cells can crack as a result of high winds, so Winaico, for example, has developed a silicon carbide paste to print on the back of the solar cell to prevent this.

Another issue is the increasing reluctance of insurance firms to cover solar systems as the market is so small in Taiwan. "That is also a risk to this industry because when insurance doesn't cover […] the bank is not going to finance, so the project is not going to happen," Rossmann explains.

20GW progress

To kick off the 20GW programme, the short target is to reach 1.52GW deployment in two years, including 915MW for rooftop and 610MW for ground mount, says Hung-Sen Wu, deputy division director of non-profit R&D organisation the Industrial Technology Research Institute (ITRI). The industry is waiting for Taiwan's energy ministry to formulate a concrete policy; however, Michael Sun, vice president and general manager, solar business group, AU Optronics, believes that overall 3GW will be allocated to rooftop solar, with 17GW left over for ground-mount projects.

Despite the multiple challenges around land, transmission and natural disasters, the regulatory environment can at least be trusted.

"The FiT is good; the regulatory framework is very good. Taiwan legally is a very safe place to invest," says Rossmann. "I would rather invest in Taiwan than UK, Spain or Italy, that's for sure. They can never do retroactive cuts here. There is a similar culture like the Japanese; there would be a total loss of face." ■

Potential for 500MW floating solar

Credit Taitra

A floating solar solution on show at the recent PV Taiwan exhibition in Taipei

Land restrictions mean the Taiwanese government has had to be creative, for example by encouraging floating solar. Government figures do not indicate a specific target for floating PV, but Thomas Hsu, vice president, SAS Sunrise, says that more than 2,000 lakes and ponds have been identified as having the potential for this technology, which he estimates could lead to around 500MW of such installations. The feed-in tariff also includes a special rate for floating solar, receiving a TWD4.94/kWh (US$0.157) FiT rate, which is higher than the TWD4.547/kWh rate for ground-mounted projects.

Michael Sun, vice president and general manager of the solar business group at AU Optronics, says that the firm has recently released a humidity- and salt-resistant module, the SunPrimo PM060PW1, which suits Taiwan due to its prominent coastline and the new push for floating solar. It is also important to be resistant to typhoons.

However, floating technology is "still in emerging stages" and cannot be installed at every reservoir, says Sun. Small and medium-sized reservoirs are the most suitable. He understands from some customers that Taiwan may expect roughly 50MW to 100MW floating solar to be installed in 2017, but the industry is waiting for a clearer picture from the government before progressing.

Charles Huang of floating solar mounting rack producer Plus Renewable, which has already installed a 100kW floating system in southern Taiwan, says the government has started to "open up" for this kind of PV floating system and the opportunity for this technology is imminent.

However, Winaico's Sascha Rossmann, says: "Every manufacturer needs to consider if they want to carry this liability or not. If you do floating solar, you cannot use standard components in the panel, because there is always a certain amount of humidity that is leaking into the laminate. This will cause corrosion on the soldering and this will cause long-term reliability issues."

Financing Southeast Asian solar

Credit: Sonnedix

Finance | The emerging solar markets of Southeast Asia each present their own unique set of conditions from a financing perspective. Reporting back from the Solar Finance & Investment Southeast Asia conference in Thailand at the end of 2016, Tom Kenning looks at how a promising solar region is bringing in the investors

Theoretically any country in the Southeast Asia region could become a major solar hub in the long term, but most of these PV markets are in their infancy. Thus, it can be a hard task to pick out which of them represent the best investment prospects of today, taking into account unpredictable events such as the recent death of King Bhumibol of Thailand and other political factors.

Delegates at the latest Solar Finance & Investment Southeast Asia conference in Bangkok, Thailand, were mainly optimistic, but at these early stages, there was an appeal for the industry to use high-quality solar equipment from the off to maintain the sustainability of PV in Southeast Asia.

It was revealed that Thailand-based developer PS&S and Indian EPC firm Mahindra Susten would turn a 1MW solar plant, which uses six different combinations of inverter and module technologies, into a test bed to help develop best practice in solar development across the region. It will act as an "open platform" for other renewable energy firms to visit and learn from, with all data published.

Meanwhile, Franck Constant, co-founder of France-based Sonnedix Group, announced that he would be launching an open fund named 'Constant Energy' for solar energy and energy storage that would have a strong focus on the Southeast Asian nations of Thailand, Malaysia, Indonesia, Laos, Cambodia and Myanmar, as well as other Asian and African markets. The fund aims to reach US$100 million by the end of 2017.

These positive news lines at the conference were followed by roundtables on financing solar in some of the most interesting markets with the following key takeaways.

Thailand facing dry spells

Industry observers believe that although Thailand, the most developed of Southeast Asia's solar markets, will see a natural slowdown for a few months while the country mourns the death of the late king in October last year, it should begin to pick up again from around mid-2017.

The Thailand government recently integrated the alternative energy plan with the country's main Power Development Plan (PDP) and it targets adding 10GW of renewables in the next 15-20 years out of which 6GW is to come from solar.

Solar has gained a solid foothold in Southeast Asia, but is still some way from fulfilling its potential

"There is clearly a plan in place which shows seriousness from the government," says Manish Singhal, head of business development at India-based EPC firm Mahindra Susten. "The first driver for solar is the increasing tariff. Currently, it is in the band of THB3-4/kWh (US$0.084) and the expectations are that it will touch to the THB 5-6/kWh range in another three to four years, which is a positive driver for the market.

"The financial system is pretty much developed. Banks have already participated in some of the big ticket-size [solar] developments undertaken. Meanwhile, some of the prominent banks are not averse to participating in the debt schemes.

"The third market driver is an over dependence on gas. At present, 70% of energy is coming out of gas and this fuel is getting costlier, so the country has targeted a reduction in this reliance on gas."

Another factor is the low availability of


Credit Bouygues Construction

The completion of a 132.5MW PV plant in the Philippines in 2016 has whetted investor appetites, but some hurdles remain

coal in Thailand, which means that if the country uses coal-based plants, it becomes dependent on Indonesia, which could lead to import issues.

This all means that Thailand is going to be a strong market over the next decade, adds Singhal. Large-scale projects have been proven possible, illustrated, for example, by a 90MW plant built by Thai firm Energy Absolute and a 63MW project by Asia-Pacific power company CLP. Another Thai outlet, SPCG, has also developed 34 projects of 7MW each. This shows that the market is almost mature.

One of the biggest developers in Thailand, the renewable energy arm of Thai oil refiner Bangchak Petroleum, has already tried green bonds successfully by raising around THB3 billion (US$84 million), proving that such a market is available and developers with large-scale plans can tap into this.

Interest rates are holding at a base rate of around 6.25%, says Singhal. However, if the developer has a strong credit rating and has the right EPC partner, it can expect a reduction from the base rate to around 4.7% to 5.5%. Less strong developers can expect an additional 1% to the base rate, with typical tenures in the range of 10-12 years. Banks can also fund up to 80% of projects, if the cash flows are healthy.

However, the next round of solar FiTs, for which only government agencies and agricultural cooperatives will be eligible, puts restrictions on plant sizes to a maximum of 5MW, so Singhal believes the government must seriously consider another regime where at least 20-40MW size projects are allowed.

Another consideration is the amount of bureaucracy involved in the permitting process. "The biggest challenge facing the Thailand market is the number of approvals that are required before signing the power purchase agreement (PPA)," says Singhal. "The kind of coordination and documentation required is extremely slow and bulky. There has to be some kind of an advocacy required where this problem is brought to the notice of the government and they must simplify these processes and reduce the completion time."

Meanwhile, delays from the government also put the bulk of the pressure on the developer. Other issues include there being no open access policies in place nor any large-scale projects in the current pipeline as of December, says Singhal.

On the plus side, the grid is very stable and there have been no reported examples of curtailment so far, which means that the take-or-pay arrangement, where the utility must take the power supplied or pay a penalty to the developer, is working well in Thailand. However, since the grids are stable and widely available, Singhal claims there will be few opportunities for micro-grids with energy storage in Thailand.

Rooftop solar is considered to be another big thrust area and most of the 6GW of solar targeted is expected to come from rooftop systems. The government has already moved on this by piloting a 100MW self-consumption scheme. Based on the success of this scheme, it may even come out with a net metering policy.

Philippines banks eager for renewables

The Philippines started last year with Singapore-based firm Equis commissioning a 132.5MW solar project in Cadiz City, Negros Occidental, which it claimed to be Southeast Asia's largest PV plant. It demonstrated the country's great potential for clean energy, but there are various hurdles ahead.

"There are three main concerns," says Celeste A. Burgos, first vice president of Northern and Central Luzon Lending Group, Land Bank of the Philippines. "Firstly, foreigners cannot own land in the Philippines at present. We require investors to set up a company to stay in the Philippines, because we can only lend to those companies that are at least 60% Filipino.

"Secondly, the president has approved a moratorium on the conversion of agricultural lands to other purposes to ensure food security, which will hinder solar developers who will need vast tracts of land to set up projects.

"Thirdly, there are also concerns with the feed-in tariff (FiT) based on the Department of Energy (DOE) [saying], it is not likely that a third round of FiTs will be approved."

At present, DOE figures report that the share of renewables in the energy mix is 25.6%, standing at 90,809GWh generation; however, under the renewable energy programme this capacity should be increased by 200% over the next 20 years, which is a strong driver.

In terms of domestic financing, the Philippines banks are now able to finance large renewable energy projects without having to source funds from foreign multilateral agencies such as the Asian Development Bank (ADB) or the World Bank, says Burgos. Meanwhile, domestic banks are well capitalised and very liquid and are keen to have more exposure to the renewable energy sector, she adds.

"We don't have a minimum or maximum loan," says Burgos. "But, if there are projects which require a huge amount of financing, we can syndicate it with other banks in a form of co-financing."

Land banks can finance up to 80% of the project costs, leaving 20% for equity, she says. For other banks it will be closer to a debt-to-equity split of 75:25 or 70:30, depending on the risk. The cost of debt depends if the interest rate will be fixed or floating.

"For fixed rates there has to be a premium so it bears a higher interest rate," says Burgos. "It could either be fixed for the first five years and then go variable, or fixed for the entire term of the norm which can be 10-15 years. Variable interest rates will be around 7-9%."

To lower the cost of capital, developers need to establish a track record with the bank by being able to pay on time without any instances of default, adds Burgos. The best time to approach local and mainstream banks regarding projects is when a developer already has the documentary requirements, has identified the site and has already made some negotiations with the various agencies involved in renewable energy.

However, Burgos says start-up projects will have more difficulty tapping into the capital market since investors will of course favour project developers with a track record.

Myanmar's early days

Myanmar looked to be making progress with a date set for the ground-breaking ceremony of a 220MW solar plant at Minbu in December 2016, but this faced delays. In any case, there is a great opportunity in this fast-changing country for both on-grid and off-grid solar, says Wandee Khunchornyakong Juljarern, chairwoman and chief executive, SPCG, the largest solar installer in Thailand. This is because Myanmar's population of 60 million has only around 3-3.5GW of installed generating capacity.

For solar to help meet the evident demand for power in Myanmar, development needs to take place at authority, company and consumer levels. The positive is that there is an enormous willingness to develop and a strong entrepreneurial spirit in the country, says Gert-Jan Monster, senior investment officer, energy, at Dutch development bank FMO. The population is also willing to pay for electricity, although this ability to pay is clearly reduced in rural areas.

"So far there is a focus on larger grid-connected projects," says Monster. "But there is also a strong focus on the mini-grids and the solar home systems, which is having a very important role in the electrification of the country."

However, more work is needed on finding the optimal funding structures for the projects, especially when it comes to mini-grids and the solar home systems to help consumers pay for them. Furthermore, there are suggestions the market is being dumped with cheap Chinese solar equipment of poor quality.

Indonesia should be ideal market

Indonesia could be the most promising country for solar in the ASEAN region, situated right on the equator with 300 million people and around 18,000 islands – an ideal environment.

The government is targeting having around 25% of renewables in the mix by 2025 with a fifth of that portion coming from PV. The current goal is for 1GW of solar by 2020.

"The biggest issue right now is how to get the governance going so that solar can be progressed via the government," says Sam Yamdagni, chairman and chief executive of Thailand-based developer PS&S. "The country did have many programmes, such as a 1,000-island programme to replace the use of diesel, but these programmes did not work out."

However, the last two years have seen significant policy change and progress. There is now a framework for power purchase agreements (PPAs), which means developers can have a PPA with all the requirements seen in the top global markets. It is also possible to get a concession on off-grid solutions. Developers can also approach the utility PLN about such off-grid projects. The cost of electricity on some islands can also be very high, making solar an attractive option.

However, development finance institutions (DFIs) are not yet participating in the sector, says Yamdagni. The domestic banking system has very little idea about solar and remains risk averse in terms of financing this technology.

"The best chance is for somebody to do an equity-based financing and implement the project. Then look at refinancing the project and thereon build credibility and implement more projects in the country," adds Yamdagni.

There are plenty of risks and the banks are looking to cover 90-95% of that risk so developers must get all the correct insurances, both in construction and operation, with the right contracts.

Ultimately, the best locations to target are those where solar can offer a cheaper price of electricity than that of the grid, says Yamdagni. "While doing that, try to make sure that you have a model wherein you either finance everything by equity or the other option is trying to make sure that you work with the larger EPC companies that can actually take the investment for the entire plant and after commissioning they actually get their money back."

Either way, Indonesia's multiple isolated grids represent opportunities for intrepid solar developers, according to Andre Susanto, Clean Energy Consultant at Bluejay Energy.

A recent Asia Development Bank report found that the country has 600 separate grids, not including the smallest sized systems and mini-grids. Of the 600, Susanto says there are around 150 different isolated grids of 50MW size or larger where renewables could be injected.

"Grid integration is one challenge where you will have to be creative with both the technology and the financial engineering of it," he adds. "You've got to really talk to PLN, which is the state-owned utility company, and figure out how can I be a partner? How can I help you run the grid better and cheaper with my system?"

While developers coming in to build 100MW capacity projects are likely to face problems from PLN due to the limited isolated grid capacities, large solar plants offering tariffs in extreme lows of US$0.04/kWh could sign PPAs with PLN in Java where the grid size is 33GW, claims Susanto. But, this price threshold for PLN to get on board is so low in Java-Bali that PV developers' opportunities are in other areas.

Elsewhere, Sumatra has installed power capacity of 8GW across four separate isolated grids, leaving around 5-6GW in the rest of Indonesia.

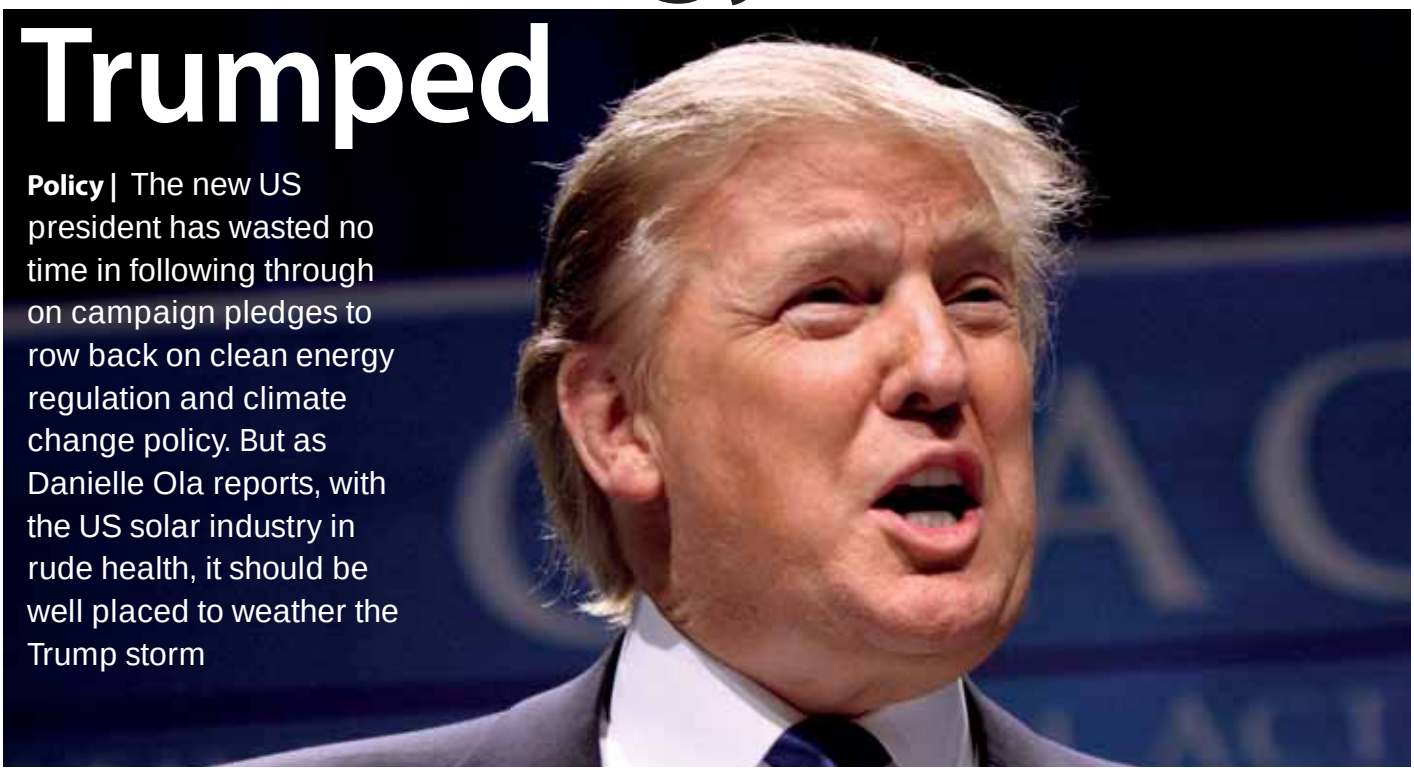
The challenge of having to achieve low solar costs then becomes an opportunity, because developers can look at the generation costs on each individual isolated island grid. Some of these island system costs can be as high as US$0.30/kWh. These are in remote areas, but they are not too remote to access by sea to install solar systems.

Susanto says: "Your EPC costs may be increased by 60%, but you can get more than twice on the tariff. If you are willing to do that and take that risk, that's an opportunity for you."

In terms of off-grid there is also potential for 1GW of solar installations given that there are 12,500 un-electrified villages, not including those villages where only a fraction of the population has access to electricity, Susanto says.

"Indonesia is complex and if you are going to back away from it you will be along with the rest of them," adds Susanto. "So you have to be the one who is willing to say I see the challenges and I'm willing to find a solution for [them]." ■

Clean energy can't be Trumped



Credit: flickr/Gage Skidmore

Policy | The new US president has wasted no time in following through on campaign pledges to row back on clean energy regulation and climate change policy. But as Danielle Ola reports, with the US solar industry in rude health, it should be well placed to weather the Trump storm

As Donald Trump finishes his first month in office as the 45th President of the United States, the clean energy industry has a pretty good idea of what to expect from the new administration. Decidedly optimistic, even if cautiously so, the general consensus seems to be that solar and energy storage will continue to thrive uninterrupted, but climate action will be taking a back seat.

"Though headline news is generally negative with statements made by Trump on renewables, we do not see any meaningful impact on near-term fundamentals in both the US and global solar and other clean energy markets," Vishal Shah, analyst at Deutsche Bank, said at the time of the election. "That said, we acknowledge that until there is clarity on specific policies from the new administration, stocks could remain under pressure."

Apprehension

Under pressure indeed, shares of renewable energy companies including wind and solar providers plummeted on the back of Trump's election as investors feared a rollback of federal incentives for such energy. Leading residential installer SolarCity closed at 4% down on election day, with Vivint Solar ending the day off 6.3%, while SunPower tumbled 5%. SunEdison was down almost 9%, at 16 cents. According to stock market watchdog Investors, IBD's 21-company Solar-Energy industry group was down 8% at a nearly four-year low.

Initially, the solar industry would not have been wrong to think it was up against it. During the presidential race, Trump was not shy in conveying his views on solar and other clean energy technologies, telling media outlets that solar "doesn't work so good" and that wind turbines were responsible for "killing our birds". In addition, he branded solar as expensive, despite it being one of the cheapest energy resources, reaching parity with coal and natural gas in some parts of the world.

Trump made his distain of solar known in the first presidential debate, citing how the now bankrupt solar company Solyndra took more than US$500 million in taxpayers' money before going bust. "[Clinton] talks about solar panels. We invested in a solar company, our country. That was a disaster. They lost plenty of money on that one," he said.

That set the tone for the beginning of the Trump administration, characterised by proposed subsidy cuts, executive orders and climate-sceptic nominations galore. But US solar remained cautiously optimistic regardless.

"Nine out of ten Americans support solar energy regardless of their party affiliation. The economics of solar remain strong and will only improve each year. So the US could very well reach [Hillary] Clinton's ambitious goal of installing half a billion solar panels by 2020 even without her in the Oval Office," says Amit Ronen, director of the George Washington Solar Institute.

Incoming US president Donald Trump has signalled his hostility to clean energy but may find its momentum unstoppable

America First Energy Plan

Aside from inflammatory and uninformed comments about renewables during the election, the only other clues for what energy policy under a Trump Administration would look like were found in his 'America First Energy Plan'.

Pushing for a focus on 'energy independence', Trump intends to create new energy jobs and energy security, but via fossil fuels, unleashing the potential of what he says is US$50 trillion in untapped oil, natural gas and coal reserves. With coal being a firm crowd favourite among Trump and his cabinet, the Republican president has also vowed to resurrect this dying industry, which experts have confirmed is practically impossible.

Furthermore, the plan marks a stark contrast between the Obama administration – which has been credited for pioneering utility-scale PV projects in the US – by immediately blotting out any mention of

climate and renewables and decrying the accompanying "burdensome regulations on our energy industry".

This was followed up by a budget blueprint that included slashing funds for the Department of Energy's Office of Energy Efficiency and Renewable Energy and associated clean energy programmes. This would also place the SunShot Initiative in danger – which had contributed to building a stable solar industry supporting 375,000 direct jobs since its inception and contributing US$25 billion to the US economy.

Regardless, the administration appears serious about this threat. Shortly after Trump took office, it a government-wide freeze on new or pending climate-related regulations was issued and DOE staff were barred from communicating with the press or using social media. The White House justified the attack on the climate and renewable works of the DOE, insisting that the actions would "greatly help American workers, increasing wages by more than US$30 billion over the next seven years".

This runs contrary to the available evidence. Renewable energy appears to be becoming a major engine for employment in the nation, with solar specifically outpacing the overall US economy by 17 times as it increased by more than 51,000 jobs for a total of 260,077 workers in 2016 according to the National Solar Job Census.

"I don't think anyone who looks at the data can argue against it. We have hard data that shows it's working. If you want to go backwards then you turn that off," says Minh Le, former head of the SunShot Initiative, speaking in a strictly personal capacity. "It's creating jobs, it's growing our GDP. The only rational argument is to continue on but there are a number of ideological reasons why this administration might want to cut it. But if they do so, they'll be shooting themselves in the foot because it would be harmful to the US economy for them to do so."

Fossil fuels

In spite of the evidence and economic progress the industry has made to date, Trump has so far continued to make good on his designs to promote fossil fuels as outlined in the America First Energy Plan. In fact, a memo written by his transition team and the Washington-based think-tank known as the Institute for Energy Research, which has strong links to the fossil fuel indusry, and its advocacy arm, the American Energy Alliance, entitled 'What to expect from the Trump Administration', revealed 14 key tenets of the new energy policy – many of which engendered anti-climate change and pro-fossil fuel sentiments.

Fossil fuels looks set to form the basis of energy policy under the Trump administration

Credit: Spondylolithesis/Getty Images

In particular, it noted the administration has plans to target subsidies for renewables and all other energy sources, subject wind energy to "increasing scrutiny", increasing the leasing of federal lands for the exploitation of coal, oil and gas, as well as approving pipeline projects including the controversial Keystone XL and Dakota Access Pipeline. Just a few days after his inauguration, Trump signed executive orders to do just that. The plan also includes intentions to roll back federal fuel economy standards. Tellingly, perhaps, Trump's pro-fossil fuel policies have garnered praise from oil kingdom Saudi Arabia, with its energy minister Khalid Al-Falih telling press that his plans are good for the oil industries.

Climate change

Trump is a self-proclaimed denier of climate change, tweeting in 2012 that the phenomenon was simply a "hoax" created by the Chinese "in order to make US manufacturing non-competitive".

Furthermore, his cabinet picks share in his climate change scepticism and have a kindred affinity for fossil fuels. Former Texas governor Rick Perry, Trump's Pick for energy secretary, dubbed global warming a "contrived phony mess". Similarly, Scott Pruitt was selected by Trump to head the Environmental Protection Agency (EPA) – the chief architects of the Clean Power Plan that was designed to lower greenhouse gas emissions by up to 32% on 2005 levels by 2030. Pruitt, an attorney from Oklahoma, is himself suing the EPA on climate change – citing overreach for its state regulatory incentives in reducing emissions. To top it off, Trump placed Exxon Mobil's Rex Tillerson as secretary of state, where he will be responsible for shaping international climate policy, among other things.

Given the individuals placed at the forefront of the nation's energy policy, it is unsurprising that the administration is following through on its intent to erase former president Barack Obama's clean energy policies, with the Clean Power Plan one of the first to go. On day one of his presidency, Trump said he would cancel any restrictions on US energy production – of which the Clean Power Plan is one as it puts restrictions on coal-fired plants for their harmful emissions.

This was not taken lightly by the industry, with 15 state attorneys general penning a letter to Trump promising to go to court if the plan is cancelled. However, the plan itself has been frozen by the Supreme Court since February 2016 due to the contentious backlash from fossil fuel companies in several states.

In addition, Trump also plans to withdraw the US from the historic UN Paris Climate Agreement, as this falls under prior Obama policies Trump wants to eliminate. But the industry is confident that this will not impede the growth of renewables.

The US Energy Information Administration (EIA) reported that even without the Clean Power Plan, renewable energy will still be on the rise, as federal subsidies in the form of tax credits will continue to ensure that solar and wind are the primary sources of new generation capacity. The EIA expects almost 70GW of new wind and solar capacity to be added by 2021, with utility-scale solar being the main driver for renewable capacity additions, spurred on by declining costs and the ITC.

Whilst EIA predictions for both renewables and emissions looked better under the scenario with the plan, many feel that the decline of fossil fuels is more economics-driven than regulatory. In fact, outgoing

Utility-scale solar has been the man driver of growth in PV in the US in the last five years

Credit: SunPower

EPA administrator Gina McCarthy said critics give the Clean Power Plan "too much credit" during a speech in November, noting that it was designed to follow "a clean energy transition that was already underway" and that the market will continue to demand. Indeed, 24 states already had lower emissions in 2015 than required by 2022 under the plan.

Further, despite rhetoric portraying climate initiatives being scrapped as a death blow to the energy industry, the truth is that the Clean Power Plan has not been in implementation for a long time now, and even then, had only been supported by 18 out of 50 states. Indeed, analysts at Deutsche Bank rank the elimination of the plan as having a "limited near-term impact" and "no impact to the long-term development" of renewables.

In a similar vein, observers point out that US is unlikely to be able to walk away from the Paris Agreement as easily has Trump has made out, given its many complexities; it is a three-year binding agreement that would require the US to give one year's notice after those years, if it wanted to leave.

Federal subsidies

Evidently, the enormous growth and achievements of US clean energy will not be halted merely by opposition to climate change and emissions regulations. The core of the value proposition of solar and other technologies comes from its economic value proposition as one of the cheapest sources of new electricity generation, and the associated economic boost from the employment it generates.

Solar has however been given a big push through the 30% investment tax credit (ITC) that was extended in 2015. It is the fate of this federal incentive that is most feared. However, like with the Clean Power Plan, energy advocates have faith in the legal process that removal of this will be easier said than done.

"I am cautiously optimistic that [the ITC] will remain intact," says Abigail Ross Hopper, president and CEO of the Solar Energy Industries Association (SEIA). "It was forged from a bipartisan agreement and many of those same members continue to remain committed to it. It creates jobs in their districts, it creates lower prices of energy in their districts. The agreed-upon step-down process means there is no great need to change it, so I'm not inclined to speculate about what would happen if it were taken away."

"The ITC is a bipartisan deal that was agreed across the aisle, and that is important to note," agrees Graham Smith, CEO and founder of Open Energy, a solar finance platform. "It has been extremely successful at job creation. It could suffer, but given its status as a bipartisan agreement and the fact it would involve the export of oil/gas, there's good confidence. It is not a never-ending tax credit either; it is due to last another three years before it drops to 10%. Ultimately it is dropping within the term of this administration, so it's a relatively short-term thing."

Even in the worst case scenario where the ITC is revoked, the end result may not be so bad, given that many in the industry were starting to get comfortable with the cost of equipment falling so much, so it was easier to consider a world without the ITC.

However, the ITC is not the only incentive under fire, with tech entrepreneur and energy investor Bill Gates confirming after a telephone call with Trump that the industry would likely see less federal incentives for renewables under this administration. This contrasts sharply to the prior administration, which supported a portfolio of more than US$30 billion in loans, loan guarantees and commitments, supporting more than 30 closed and committed clean energy projects.

But as to how hard a blow this will be to the industry is also optimistically debated.

"I think we would be lying if we said [subsidy cuts] wouldn't be disruptive, because if you change the structure of a market, there will be ramifications. However, in the long run that's a situation that because of the cost of energy, that would be something that the sector would deal with," says Smith.

In addition, the majority of solar progress is achieved at a state level, with any federal incentives being an added bonus. The solar industry has achieved a lot through good state policy and renewable portfolio standards, economies of scale, as well as innovation at the private level that have all contributed to driving costs down.

"Each state has its own attitude and set of policies towards renewable energy, irrespective of the overall, for example the ITC which is a federal country-wide subsidy. Those state and regional programmes in some cases are extremely strong, extremely alive and well and because they are on a legislative basis, states are really in control of those," explains Smith.

States such as California and Massachusetts have an extremely high amount of wind and solar relative to other states, the majority of which has been procured solely through state-level policy. It is very much in their self-interest to continue their programmes, and they have complete control over the subsidies and incentives.

A sound economic proposition

In spite of a fossil-fuel heavy energy policy, a concerted attack on climate action and purported federal withdrawal from clean energy, industry stakeholders maintain that the sound economic proposition of solar and other technologies is strong enough to carry it forward regardless.

Four and a half million Americans are now employed in and around clean energy. Meanwhile, costs continue to decline. A 2016 report from consultancy Lazard said the

Former president Barack Obama has described the momentum of solar as "irreversible"

Credit Flickr/White House

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Opportunity for energy storage

In the Trump Infrastructure Plan is a focus on homeland security and grid resiliency that Matt Roberts, executive director of the Energy Storage Association, feels presents a unique opportunity for energy storage.

"The thing about energy storage is that it's very adaptable. Whatever front this administration moves on, there is a sizeable opportunity for storage to be a big part of that conversation, especially as the focus is on infrastructure – which includes roads, bridges as well as grids."

It is interesting to note that the original Republican platform during the presidential campaign did highlight electricity energy storage as part of its grid modernisation objectives. Other than that, there are few, if any, instances of Trump mentioning energy storage. Roberts maintains that grid resiliency is a great place to start.

"There's an appetite I think to learn about it and to understand it but the way that it is being approached is from the homeland security kind of angle; the resiliency angle – more so than say storage's ability to augment generation or something like that," he says.

"We haven't seen an extensive dialogue around energy storage, but that being said, historically, we haven't seen any energy storage dialogue from any administration. We were very fortunate to engage the Obama administration towards the end to host a White House summit around the topic of markets and energy storage, but that took us a few years to pull together. We are going to put the same level of effort in if not more in to working with the Trump administration to bring more opportunities to light."

The White House summit did result in a pledge of US$1 billion of new private sector investment as well as a commitment for around 1.3GW of additional energy storage. But so far storage has not seen any major policy shift, regulation or executive order from the federal level to date.

It is still hoped that the storage ITC can pass through Congress under a Trump administration, but it is likely to be a long process. Should it get through, Ii would help bring market and regulatory certainty to the industry. In addition, the industry would benefit from liaison with the Federal Energy Regulatory Commission (FERC), which oversees the regional wholesale markets. It is currently in the middle of three different proposals that are all very germane to and would help accelerate energy storage. One in particular would seek to require all the wholesale markets that have treatment for storage to have participation rules and find ways to compensate the technology.

Grid resiliency is a focus for Trump, which could provide a boost to storage

Aside from those objectives, energy storage hopes to garner any kind of support from the federal level. "We are probably the one industry out there saying hey, please regulate us!" says Roberts. "We want to be regulated because to be regulated is to be recognised. Someone has to put pen to paper and go, what is this thing? How much is it worth? How much of it do we need? We are seeking federal regulation and asking for regulation, as opposed to maybe other industries that are saying, 'Hey we are a little over-regulated'.

"In my more cynical kind of voice, there is really nothing they can take away from this industry. We've been striving to get the engagement from the federal government. The worst they could do is not talk to us. And they've already indicated and shown interest in engaging with this industry and talking to this industry so all signs point to some sort of opportunity to advance storage within this administration" Roberts adds.

But much like renewable energy technologies, storage has achieved incredible feats independent of any federal input, installing 250MW nationwide in 2016 and on track to install 470MW in 2017 alone.

"This industry is succeeding and there are headlines every other day, and that's all without any sort of dedicated kind of programme at the federal level driving it. It's succeeding because it has an inherent value and the use case and value proposition is very clear," adds Roberts.

cost of large-scale solar has fallen 85% since 2009, making it competitive with natural gas on levelised cost of energy terms.

Obama himself has dubbed the momentum of wind and solar "irreversible", even in the absence of near-term federal policies. "The mounting economic and scientific evidence leave me confident that trends toward a clean-energy economy that have emerged during my presidency will continue and that the economic opportunity for our country to harness that trend will only grow," he wrote in an article for prestigious journal *Science*.

Renewables coincide with Trump's Infrastructure plans

That being said, beyond the realm of being good for the environment, solar is good for business. Employing the most out of any other energy resource in the States and its falling costs is a case hard to be ignored by a seasoned businessman like Trump.

The president has expressed designs to focus on improving the nation's infrastructure, including transportation, water, energy and grid modernisation – with US$1 trillion of investment specifically allocated for this. If the Trump administration realises its infrastructure-related objectives in any significant way, there should be a wave of new opportunities for the likes of solar and energy storage (see box).

SEIA's Hopper therefore feels that solar is the perfect fit for the administration's focus on infrastructure, and contrary to being in jeopardy, has a "very bright future" under Trump.

"Clean energy and solar energy in particular have had an incredible 2016 and anyone who cares about jobs, who cares about consumer choice, who cares about low energy prices, looks to solar and thinks, there's the trifecta. This is a great industry, a great technology to bring lower power prices, investment and communities and job creation. I do not think we are under attack, I think solar has been growing and will continue to have a very bright future."

If Trump really is focused on providing "jobs for all Americans", it does not follow that he turns a blind eye to the soaring job growth in the US renewables sector – which now employs far more people than the coal or oil and gas industries. Investors are on board too: the US is now the world's second biggest investor in renewable energy, with US$44.1 billion invested in clean energy development in 2015, closely behind China.

Unable to be deterred

Ultimately the momentum of solar and renewable energy, which does not owe its success to any given administration, should equip it to continue to thrive regardless of Trump, subsidy cuts, fossil fuels and climate change denial. Renewables were the number one source of new electrical generation in the US last year and have created thousands of jobs and economic activity, allowing them to coincide perfectly with Trump's plans for job creation and infrastructure upgrades. Even surveys of Trump supporters demonstrate strong support for solar.

"I do feel very strongly that the market is mature enough that it can stand on its own two feet," says Jeff Krantz, senior vice president of Array Technologies. "I don't foresee out of my own lens that anything too detrimental will happen. This is a real industry; it no longer needs subsidies – it competes head-to-head with traditional energy sources, and I'm definitely confident in that."

To be sure, the effects of scrapping federal clean energy incentives and cutting funding to key programmes and institutions such as SunShot and the National Renewable Energy Laboratory, as has been threatened, should not be underestimated. However, importantly, most of the near-term market drivers are rooted firmly in state-level policies such as net metering and RPS. Such drivers are the self-contained prerogatives of individual states, and given the progress thus far, it is unlikely that even president Trump will be able to reverse this. ■

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Chasing shadows

Trade wars | The EU-China trade row appears to be entering its swansong but its impact has been eroded and overridden by global solar market dynamics. We look at the divisive policy's future as it plays catch up

Europe and China's solar trade war is nearing an end. It has pitted different parts of the solar value chain against one another. It created fresh layers of bureaucracy for importers. It sucked money out of solar and into the pockets of lawyers. It contributed to a downturn in deployment and it failed to provide a substantial turnaround in the fortunes of Europe's remaining solar manufacturers. It even caused a rift between Brussels and Beijing that led to retaliatory trade measures on exports of other goods including European wine.

The precise shape of the conclusion was still being formulated at the time of press. But all the signs are that rather than an amicable peace, we are looking at another 18 months of debilitating stalemate.

After a lengthy and thorough investigation, the European Commission determined that there remained evidence of Chinese solar modules and cells being dumped at below market prices into the EU. By the letter of its own laws, the commission had to continue on with the punitive tariffs and the price undertaking that allows participating companies exemption from those additional duties. At the same time, the commission is wrestling with the political pressure that comes with being viewed as being the party limiting the rollout of renewable energy.

Eventually it decided to extend the duties for two years, rather than the usual five years. When voted on, member states narrowly rejected the two-year extension and in early February, an 18-month continuation was suggested instead, with plans for a degression and eventual phase-out. At the time of press there were three weeks until the 3 March deadline and the compromise on the table didn't appear to be keeping anybody happy.

EU ProSun, the original complainant in the case back in 2012, was already disappointed with a two-year extension.

"The commission made clear that the measures on cells and modules need to be extended," says Milan Nitzschke, president of EU ProSun and vice president of manufacturer SolarWorld. "This in the first instance is positive. But in order to sustainably establish fair competition and to allow further investments in manufacturing and technology a longer exten-

Mixed reviews - the industry's verdict on duties

"The MIP brought old Communist style price fixing and quantity controls to Europe – and simultaneously bankrupt hundreds of our EU customers. Who is the EU working for?"
Anonymous director, manufacturer

"The aim of solar duties failed, which in turn destroyed thousands of jobs and large parts of the EU solar market. Protectionism is always the wrong answer when it comes to global competition. On that basis the EU commission should not let duties be phased out, but should stop them entirely."
Udo Möhrstedt, CEO and founder, IBC SOLAR, Germany

"It is a sad day for all EU citizens when the European Commission, as the bastion of legality in the EU, waters down its own rules – normal procedure being to prolong measures for five years, (when review finds that dumping is still occurring) – first proposing just 24 month extension of the measures while in their latest proposal cutting that further down to only 18 months. This is not about Bisol. We have been profitable each and every year of our operation ever since our foundation. So even during the years of heaviest dumping [2010 – 2012], we operated profitably – as I am sure we will also in the future, no matter how the EC decides. It's about standing up for principles and values – but then again, I guess, EU has long ceased to represent those."
Dag Kralj, board member, Bisol, Italy

"We have been able to expand our production by 60% since the anti-dumping measures came into force. If the initial commission proposal for the extension is confirmed, we will continue this expansion and create further jobs. If the commission changes this according to current reports, this is endangered immediately. Anti-dumping is not about protectionism. It is about enabling fair competition."
Benjamin Trinkerl, CEO, Heckert Solar

Credit: sturti/Getty Images

sion period would have been urgently required."

European trade group SolarPower Europe was none too pleased either. "This is the extension of a prison sentence for the sector, we have no view of when this will end as no mention is made of the phase-out announced by [EC] vice president [Frans] Timmermans today," said the group's CEO James Watson. "The measures will continue to stifle demand and leave Europe far behind in the annual deployment league tables for the next two years. The EU had a chance to grab global climate and international trade leadership in one go and instead has blown it."

One area where everyone agrees is on the need for reforms to the MIP itself. An interim review will be launched by the trade commission that could see alterations made to how the minimum price level is set.

"The commission's aim to make the MIP more transparent, predictable, more enforceable and to insert a degression rate should be positive for all market participants," says Nitzschke.

In correspondence with the Irish MEP Brian Crowley, trade commissioner Cecilia Malmström said the review would look at "the form and level of the measures to examine and, where appropriate, address a purported shortcoming of the existing measures that allegedly prevents efficiency gains and decreasing cost of production in the solar sector from being duly taken into account".

At present, the price level is based on a dollar-denominated, voluntary price index compiled by Bloomberg. Currency fluctuations when converting it into a euro amount for the MIP have been blamed for holding the price above global averages. This left products from China either subject to the punitive duties or sold into Europe at an uncompetitive price point.

It is our understanding, again, at the time of press, that a proposal to abandon use of the Bloomberg price index in favour of a degressive rate starting out at €0.46/W had been presented to member states.

Relevance

Stepping back from the technocratic issues concerning the mechanics of the system and taking a more analytical view of the solar market and the relevance of the duties, the MIP seems a little flimsy.

"During the past few years, there has been a strong build-up of cell and module capacity across Southeast Asia, including Malaysia, Indonesia, Thailand and Vietnam," says Finlay Colville, head of market research at Solar Media. "The capacity located there is now capable of serving the entire European and US markets, making the arguments for or against MIP somewhat irrelevant.

"Aside from the Southeast Asia issue, the EU has struggled with MIP pricing levels, constantly being behind the curve on global ASP declines."

This is the very issue that the commission is now seeking to address with the reported redesign of the MIP-setting mechanism. Colville suggests the real interest in trade disputes is arguably shifting.

"Given the timing of the EU entering into the made-in-China solar cell import debacle, coming after the US had laid down markers for them to follow, the attention ultimately turns to the US and any changes that may be tabled now President Trump has taken office," says Colville.

Fresh duties on Southeast Asian countries may now follow to stop cheap imports from flooding in there. If that happens, then the US will again lose access to a chunk of module capacity at the lower end of global prices, making it a premium market for manufacturers still able to supply it.

Decision time

As the commission finalises its proposal ahead of the 3 March deadline, the odds that all in the solar value chain, or indeed anyone in the value chain, will be satisfied look slim. In defence of the Eurocrats, legislating for an industry undergoing such rapid change and fluid market dynamics is a daunting task. Solar is a mainstream and mature part of the energy industry but it is has not developed to a point where it offers a degree of predictability. With so much regulatory interference in all aspects of the energy sector, stability is relative. There are very few certainties.

We can say that Europe wants to and needs to deploy more solar. We can say that Chinese manufacturers have operated at scales not possible elsewhere and in many cases with substantial state support. Beyond that we stray into opinion, interpretation and speculation. Could European solar markets have ridden out cuts to support mechanisms if ASPs in Europe had dropped at the rate they have globally? Would European PV manufacturing be flourishing at multi-gigawatt scales if Beijing had never identified solar as a strategic industry?

A more fluid MIP mechanism is to be welcomed and it could be the best result anyone can hope for, but whatever the outcome, dissatisfaction is guaranteed. The story will rumble on, but the depth of its impact is dwindling. ■

"During the first two to three years after signing the EU undertaking, the MIP led to unnecessary high margins for modules imported from China, which helped the leading Chinese manufacturers' profitability a lot, but prevented the EU market from growth due to too-high PV system costs. Then with the global market price coming down over the years the MIP at the end was 40% higher than the market price, which made most of the major Chinese suppliers step out of the price undertaking and offer non-Chinese product to the EU market at competitive global market prices, which recently stimulated EU market growth significantly and made the MIP irrelevant. Hence, at no point has MIP made any sense and made the European market consolidate while any other region of the world grew significantly."

Frank Niendorf, general manager Europe, Jinko Solar

"Whilst in principle the EU should protect its own manufacturers from unfair competition, the MIP has for most of its duration been set significantly higher than the actual world price for solar modules available from many non-Chinese sources, including European manufacturers. This has caused significant damage to the whole European solar PV installation industry. If the MIP is to continue then measures must be taken to improve how the price is calculated to be in line with world prices."

Andy Pegg, CEO, Segen

"Since the middle of last year, we are again experiencing massive dumping from China in the solar sector. China's overcapacity is specifically directed to export and is financed by the state, which threatens investment and jobs in Europe, also in France. That is why the EU Commission initially proposed the extension of anti-dumping measures, which should not be restricted now. This would be a fatal signal to all who want to comply with rules and produce in Europe."

Michel Jouan, CEO, Sillia VL

Emerging market briefing

GOING LARGE IN SUB-SAHARAN AFRICA

Credit: SunFunder

Utility PV | Despite enormous potential, Sub-Saharan Africa still has only a handful of operational large-scale PV power plants. Ben Willis reports on the ongoing efforts to help utility PV take root in a part of the world where it makes perhaps most sense but faces the biggest hurdles

If you were to look no further than the headlines coming out of Africa of late, you would be forgiven for thinking that the continent was by now bristling with large solar power plants. The past two or three years have seen a glut of news stories proclaiming the imminent deployment of hundreds of megawatts of grid-tied solar across the continent as foreign investors flock to its fertile new markets.

The reality on the ground is quite different, however. Leaving aside South Africa, whose independent power producer (IPP) programme for renewables is frequently held up as a model for the rest of the continent (even if for the time being it is mired in legal wranglings), the number of utility solar plants built and operational in Sub-Saharan Africa can be counted on the fingers of one hand. In terms of PV-generated electrons on the grid, the widely proclaimed solar revolution in Africa for now remains agonisingly out of reach, with governments still putting up barriers to investment and investors consequently struggling to finance and realise projects.

"There's a whole raft of difficulties that arise in terms of getting a fair allocation of risk in order to be able to put together a project financing," says Peter Hutchinson, executive director of Green Africa Power, a UK-based donor-funded investor in renewables in Sub-Saharan Africa. "The problem is you've got the underlying complexity…within particular countries, where in a lot of cases governments are sceptical about private sector involvement and ownership, and don't trust incoming investors not to rip them off."

That in a nutshell is the ongoing problem for utility solar in Africa: no lack of opportunity, no shortage of investor interest and no lack of the necessary know-how to actually build and operate projects – but a whole range of political, regulatory and institutional barriers which together mean that for now although projects may be easy to conceive they are much harder to execute.

Rwanda's 8.5MW grid-tied PV project was completed in 2015, the region's first outside South Africa

Pathfinder projects

Nevertheless, there are plenty of reasons for optimism, and indeed some notable bright spots that point to an imminent sea-change in the trajectory of utility PV in the region. For starters, the fact that plants are beginning to be built at all in countries outside of the widely lauded South Africa is in itself highly significant. Beyond South Africa, four other countries – Ghana, Rwanda, Uganda and Senegal – have now joined the large-scale solar club and now boast their first multi-megawatt grid-tied PV power plants (see box).

Another cause for optimism is that there is a second wave of projects coming

up behind these trailblazers that look likely to reach financial close imminently. Some of these have the backing of serious international players, and there are high hopes within the industry that successful closure and completion of these projects will help kill off once and for all any lingering doubts that large-scale solar is a viable option in Sub-Saharan Africa.

Some of these projects are very much in the mould of their forebears, in so far as they are being driven by relatively small, agile developers that are more willing to take the risks associated with going into new markets and pursuing projects that don't necessarily fall within any formal renewables procurement programme. Most of the utility PV projects built outside South Africa to date could be said to fall into this category, and it looks likely that many of the projects currently in the development pipeline will follow that model – of one-offs.

A good example of this is the 100MW Nova Scotia project in Nigeria being taken forward by the Norwegian IPP Scatec Solar. Scatec has been one of the standout players so far in Sub-Saharan Africa's early utility PV adventures. The company is behind three operational PV plants in South Africa procured under the country's IPP programme. It was also responsible for the 8.5MW project in Rwanda completed two years ago. It has a number of other projects under development across Sub-Saharan Africa – in Mali, Mozambique, Burkina Faso, Senegal and Nigeria.

Nova Scotia is one of the company's more mature African projects, having secured the backing of the infrastructure investment fund, Africa50, at the end of 2016 and with a PPA in place. The company's chief financial officer Mikkel Tørud explains how in new markets such as Nigeria, a key aspect of Scatec Solar's role as a pioneer IPP is in educating local stakeholders.

"It's of course of vital importance that governments understand what is needed in terms of contract structures, PPAs and government guarantees backing the programmes to make them bankable," he says. "I think we see that maturing in terms of understanding of that. We are of course trying to be active in advising governments. It's a responsibility for all stakeholders to provide sound advice and also to ensure there are realistic expectations of what can be put in place."

Indeed, the educational role played by Scatec and other first movers in Africa's emerging solar markets is likely to have a significant impact on how those markets will develop. Tørud says that by educating stakeholders, managing expectations and showing what is possible, Scatec is helping prove the concept of solar so that further projects and programmes can follow.

"It's important to demonstrate the viability of some of these projects now and get them off the ground," he says. "And I think governments see that that is required before they launch larger programmes and invite the broader set of investors in. There's always a discussion on when to go for tenders, for instance, and that is typically the second wave for some of these countries; to get into that they have to prove the concept first and we like to be part of that, but it's not for everyone."

Scaling Solar

Another important effort helping prepare the ground for large-scale solar in Sub-Saharan Africa is taking place under the banner of the Scaling Solar programme. This was launched two years ago by the World Bank Group's International Finance Corporation (IFC) with the stated aim of unlocking private sector investment in utility PV.

Speaking to *PV Tech Power*, Yasser Charafi, principal investment officer at the IFC and the architect of the Scaling Solar programme, explains the rationale behind the programme: "We were seeing strong interest from financiers to invest in solar PV in Africa. Yet, outside of South Africa and a couple of places in North Africa, we were not seeing much uptake and growth in the PV market. We started wondering how to resolve that – and we quickly zoomed in on a couple of factors which seemed to us quite credible.

"One is the perceived risk of investing in Africa. And we were also hearing quite a lot about the lack of certainty around procurement processes, and people spending a lot of time and energy into developing projects but without any certainty on outcome. So when we put all of this together, what we thought is if we can come up with some way of resolving these issues we could perhaps help create a bigger market for solar PV in Sub-Saharan Africa."

Scaling Solar seeks to address these issues through three main activities: advice on procurement processes and documentation such as contracts; risk mitigation through a partial risk guarantee from the World Bank; and a general offer to finance projects that have bankable PPAs in place.

In the two years since Scaling Solar launched, four countries – Zambia, Senegal, Madagascar and Ethiopia – have signed up to the programme, and towards the end of 2016 it scored its first major success when a PV tender in Zambia that the IFC had advised on achieved a record low price of just over 6c per kilowatt-hour. The tender was also notable for attracting some heavyweight bidders – among them France's Neoen in partnership with US giant First Solar, which together won a 47MW (AC) project and Italian utility Enel, which won 28MW.

This low price, achieved in a part of the

Credit: Tom Kenning

Xiaocheng Technology's 20MW PV plant in Ghana is one of only a few operational utility solar plants in Sub-Saharan Africa

world with no track record of large-scale solar, has since raised a few eyebrows. During a recent panel debate at a solar finance conference organised by *PV Tech Power* publisher Solar Media, participants questioned whether it was feasible to deliver projects at such a low price in a country where the bankability of solar has not yet been proven.

Charafi acknowledges the surprise the tender provoked, but says that when put in context it does not seem so out of place. "We know what the prices were in South Africa for round four [of its procurement programme], and for a number of other recent auctions, be it in Peru, Mexico, Morocco, GCC and other emerging markets," he says. "So taking the broader picture, if you put the Zambia prices in perspective, they seem to us more of a continuation of global prices in decline. The prices [in Zambia] were low but not outliers."

At the time of writing, the Zambia projects were moving forward with Neoen saying it expects to achieve financial close in the spring. Meanwhile, coming up behind Zambia in the Scaling Solar programme is Senegal, where a 200MW tender programme is being planned. Charafi says he expects the Senegalese authorities to put out a request for proposals for the tender within weeks. The other two countries where Scaling Solar is currently active, Madagascar and Ethiopia, are a little further behind, with projects being scoped out, but again Charafi says he expects movement on both programmes in 2017.

Ultimately, Charafi's hope for Scaling Solar is that it helps utility PV in Sub-Saharan Africa generate sufficient momentum to start sweeping away some of the lingering institutional barriers and indeed prejudices that have so far stopped it from fully taking root. "One of the things I care about personally is beating back on the scepticism towards solar PV," he says. "Some people still think that PV is an outlier technology, something that is not baseload, not dispatchable, is too expensive… So if we can only prove that PV has a role to play in the energy mix of any country, it has great potential particularly if on the storage side things continue on the path we're seeing, that prices are not the prices of the early 2000s, we have PV that in some case is the most competitive generation technology full-stop compared to any other alternative in Sub-Saharan Africa... If we can achieve that and if people start doing it by themselves, that really is our mission."

To be sure, though, getting to that place is still going to require a concerted effort. As GAP's Peter Hutchinson points out, the low number of financed or completed projects in the region is a clear indication that "none of them is easy".

One significant issue for Hutchinson is that, in his view, the size of projects being pursued in Sub-Saharan African countries is in many cases too large. Not only is this potentially problematic in terms of the stability of national grids – which in many cases are quite weak in African countries – but can also be a headache from a financing perspective. "The larger a project becomes, the more interested parties have to be involved in the financing," Hutchinson explains. "And when you start adding more players into the mix the complexity becomes ever more pronounced and that just slows the whole process down."

Nevertheless, there are signs that the critical mass described by Charafi is beginning to build. Beyond the four countries already signed up to Scaling Solar, he says the IFC is in advanced discussions with several more and has had some kind of dialogue with "a good third of countries in Africa". Not only that, but countries beyond Africa – in Asia and Central America – have made inquiries about the programme and what something similar could achieve in their part of the world.

"I don't know of any country at the moment that is not seriously looking at options for solar PV right now," Charafi says. This is partly a consequence of the Zambia tender, which has "made a lot of people sit up and take notice".

"It's a very different thing if people can hope for prices between 6 and 10 cents or if they're looking at 15 c ents and above," he says. "It changes the nature of the discussion." ■

The opportunities for solar and other renewables will be under discussion at Solar Media's Clean Energy Summit: Africa event on 4-5 April 2017 in Accra, Ghana. Further details are available at ***africa.solarenergyevents.com***

The financing conundrum

Completed at the end of 2016, Senergy 2 is a 20MW grid-connected PV power plant located in northern Senegal. It will play an important part in Senegal's energy mix, providing power for up to 160,000 homes.

In many ways Senergy 2 is illustrative of the precarious nature of the solar IPP business in Sub-Saharan Africa, particularly where finance is concerned. The French developer behind the project, Greenwish, was left facing the prospect of having to shelve the project after a financing deal with the African Development Bank (AfDB) fell through.

Senergy 2 came online in 2016, becoming Senegal's first utility PV power plant

Fortunately, with backing from UK and Norwegian donor money, Green Africa Power was able to step in and offer Greenwish bridging finance that allowed it to build the project and gave it some breathing space to find a long-term financial backer.

"We came to conclusion that the best solutions was that we stepped into the role of the AfDB but only on a short-term, bridging-finance basis," says GAP's Peter Hutchinson. "We would loan 75% of project value and they would refinance us through proper long-term senior debt when they'd had more time to arrange it and when the construction risks had gone. The senior debt provider then only had to look at off-taker risk and political risk, not construction [risk]."

It was a neat solution to a problem that the relatively low number of projects that have actually reached financial close in Sub-Saharan Africa underlines: financing utility PV in Africa remains a tough game.

For Hutchinson, that fact raises questions over the extent to which traditional utility-scale PV projects can be built fast enough to play a key role in Africa's rapidly ballooning demand for power.

"At which point one starts to think a little bit about, well, how did electricity become readily available in Western Europe," Hutchinson says. "And in almost all western countries I'm aware of they all started with localised mini-grids, andd the national grid came much later in development. Maybe the answer for Africa is going to be to use the same path and not to go down grid-scale production, but to go for mini-grids. That again would play to the idea of smaller projects being easier to get off ground. That may end up being a way forward which can go alongside the big grid projects – a combination of the two which forms part of overall solutions."

The outlook for PV in 2017 - the true dawning of the solar age?

Business models | Solar is forecast to have another strong year of growth, but in spite rather than because of political support in many parts of the world. Simon Currie and Rob Marsh assess some of the commercial drivers for solar in 2017 and beyond as it finds itself increasingly at the mercy of market forces but arguably better placed to become a true global competitor

Perhaps the most surprising statistic in the renewables sector for 2016 will be that global investment into renewable energy generation decreased for the first time in many years (though final data is yet to confirm this downward trend). But this is not bad news for solar PV (or, indeed, other technologies), as the reduction in investment is not indicative of slowdown in deployment; it represents the exponential technological and efficiency improvements, driving down costs. Market commentators and analysts are measuring this decline in cost for solar PV to be 90% when compared to 2009, which is a staggering achievement in just eight calendar years.

Prices achieved in various auctions across the globe are certainly evidence of the above. Sixty-seven countries had used auctions for renewable energy by mid-2016, compared with 10 a decade earlier. The average price fell to US$50/MWh, compared to an average of US$250/MWh in 2010, with the record low price being broken almost auction by auction until Abu Dhabi achieved a price of US$24.2/MWh last September. However, in certain circumstances these low tariffs are not always indicative of true project efficiencies – host state support (in the shape of providing designated sites or meeting grid connection costs) and concessional funding have helped achieve these prices in various jurisdictions. Indeed, the prices bid in these auction processes are not necessarily valuable indicators in their own right. It is the levelised cost of energy (LCOE - measuring the price required over the lifetime of the project to break even) that is the true measure of solar PV's ability to compete seriously, not just with wind but with fossil fuels. Last year saw sharp declines in this regard, with solar PV matching conventional generation on a LCOE basis in certain jurisdictions.

Credit: First Solar

The third phase of Dubai's Mohammed bin Rashid Al Maktoum Solar Park was one of a number of record-low tenders in 2016

There are strong indications that 2017 will see this trend continue one country at a time. Coupled with the ease of deployment and flexible application that the technology offers and viewed in the context of the wider trends driving the future of the energy sector, 2017 is likely to see the paradigm shift that has been predicted for some time; the question turns from whether solar can compete and whether it makes sense, to how to redesign the world's energy systems to accommodate the inevitably high (and varying) levels of deployment.

Reality check

Twenty-sixteen was not an unmitigated success story in the solar PV sector. Certain European jurisdictions (the UK most recently notable among them) saw a sharp decline in development plans and activity, owing to governments significantly reducing or removing subsidies or other forms of support for utility-scale solar PV projects. These cuts will likely continue as jurisdictions increasingly regard the technology as mature and take note of the prices being achieved in auctions around the world. There have been examples of this in Africa, with utilities delaying the agreement to tariffs and causing projects to stall (though perhaps not fully appreciating the circumstances that underlie prices they are seeing bid elsewhere, as mentioned above). The situation in the US is uncertain post-election, particularly with a view to any mid to longer term development strategy.

This reaction is (at least in part) a response to surprisingly high levels of deployment and perceived windfall profits. The prevailing public sector view in such jurisdictions is that solar is a fast maturing technology that should compete on a level playing field with conventional generation and that the market should be left to determine the price for the power it generates. That message is a hard one to swallow among numerous companies that have fallen away and employees that have faced redundancy in the face of development pipelines drying up. However, others have adapted and refocussed their business

Credit: Belectric

models, the services that they provide and/or the jurisdictions where they are deploying their development resource. Such decisions also need to be considered in the context of the political backdrop. The demand for access to affordable electricity is a sensitive issue in many countries and one that wins votes in elections.

Varying combinations of technology efficiencies, reducing costs of capital, sharpening of pricing in both construction and O&M agreements and the presence of corporate off-take solutions could yet see solar PV successfully developed in these jurisdictions in the future without any form of government support. The use of co-located storage solutions may also allow projects to deliver sufficient return – the recent Industrial Strategy published by the UK government is championing energy storage as a solution and other governments in Europe are following suit. If this is achieved, then arguably such governments will have been proved correct, demonstrating to the electorate that clean energy can be generated and delivered with no extra costs on utility bills.

Solar PV+

The adaptability of solar PV as a technology is going to be a key theme driving development in 2017 and beyond, and we see a trend developing which we term "PV+" - by this we mean a system or solution that delivers more than just AC or DC electricity on a standalone basis. We have already seen solar PV being utilised or integrated with other technologies in varying and innovative ways around the world.

'PV+', where solar is integrated with other technologies such as storage, offers numerous potential new commercial avenues for the technology

Combining solar PV with battery storage is one of the more obvious examples of this approach and is hardly an innovative solution. Many companies have already come out with products which provide different solutions for industry and remote communities, while large-scale solar PV projects are being developed with associated batteries which have the advantage of allowing solar PV owners to shape generation profile to meet demand, reduce peak network demand and increase voltage control. However, integrating solar PV and storage creates the inevitable regulatory challenges.

Regulations and (the lack of) market rules create uncertainty, which places additional burden on the early projects. For example, in the US the Federal Energy Regulatory Commission may consider a storage project to be a generator, but at state level they may classify that same project as transmission or distribution. In the UK, it remains unclear whether the generator still owns the power once transferred to a third party storage provider and continues to qualify for the associated subsidies, particularly if the power is being transferred directly to the grid by such third-party storage operator. It is regulatory dilemmas like this that we will continue to encounter as we grapple with integrating battery storage into a regulatory regime where network operators have not yet developed the technical standards to address the issues of connecting batteries to the system. It should also be noted that the costs of batteries aren't falling at the same rate as solar PV. However, the overall system costs continue to fall and we believe this is helping to make the battery storage option increasingly viable. An increased appetite among the lender and investor community to finance these technologies may see their deployment accelerate with leveraged models making solutions more workable.

Solar PV is also providing affordable and quickly deployed generation solutions to various industrial processes, particularly in areas where grid connection is a problem or absent altogether. The mining sector is good example of this, where energy intensive processes usually powered by fossil fuel baseload plants are turning to solar solutions. Large manufacturing and industrial companies across the globe are now realising the benefits of utilising their real estate and developing on-site solar generation solutions. Structured correctly, these solutions reduce year-on-year energy bills and in some circumstances generate a spill that can be sold into the market, thus further reducing the overall cost of energy. That is before one accounts for the environmental, social and governance (ESG) and branding benefits that such a strategy brings.

Desalination is another energy-intensive process that is increasingly looking to solar as an alternative to fossil fuel baseload plants. Some countries are requiring desalination plants to incorporate renewable inputs in order to make the process more sustainable and solar powered water desalination has the potential to dramatically increase access to fresh water in arid locations. While solar PV as a technology is not always aligned to the load requirement of desalination plants, with it becoming one of the cheapest options on an LCOE basis in many places, it has to make sense where there is a limited supply of potable water, high irradiation and a non-arable land mass.

Remaining with the theme of water, floating solar is witnessing increasing deployment around the globe. Replacing the costs of frames and foundations with the cheaper alternatives of tethers and anchors, the technology has the potential to see exponential growth. Reservoirs in particular are ideal locations for floating solar, as the panels bring added benefits to the reservoirs in the shape of improving evaporation rates and reducing the risk of algae and weed.

In the agriculture sector, solar PV is offering an integrated energy solution to agricultural environments, without creating a food versus fuel debate like we have seen with biofuels. Solar greenhouses are already deployed at scale in a number of countries, while solar PV projects don't need to be developed in a way which sterilises farmland (as has sometimes been the case in Europe). Farmers can increasingly look to maximise the use of fence lines, driveways, barns and other non-arable land. There are other options we have seen which include elevated solar where farm animals can graze under panels.

Deploying solar in and around other solutions is likely to see increased application in 2017. Telecom towers, pylons, wind farms, CSP facilities and hydro plants all have tracts of land in and around their processes and this land is usually not utilised in any way. There is inherent sense in deploying solar PV, taking advantage of the infrastructure and connection that exists at those sites, particularly where the host process has its own energy consumption needs. This logic is beginning to prevail in many emerging markets and we anticipate a continuation of this trend.

2017 – the true dawning of the solar age?

Solar PV is already a mainstream technology. A continued downward trend in the LCOE of solar PV will see increased deployment as well as (and in part achieved by) increased scale. Industrialised and developing economies alike are increasingly demanding development on a sustainable basis, while seeking cost efficient and easily deployed generation solutions. A genuinely competitive LCOE will increasingly make solar an obvious choice.

The above analysis of PV+ demonstrates the increasing diversity of applications for solar PV. As technology continues to disrupt the world in which we live, solar PV has the ability to further adapt and integrate with our changing world.

Focus is increasingly shifting from the generation to the use of electricity; electric vehicles, residential storage, smart networks and digitalisation are all key drivers in this regard. Climate change deniers are now an irrelevant voice in the debate and the irreversible shift to a sustainable future has commenced. We view it as irreversible because the future will be consumer driven and the consumers of power demand affordable and sustainable energy. They also demand that the commercial and industrial parties with whom they interface and from whom they consume products demonstrate sound ESG principles. Google is the oft-championed example of the corporate world responding to this trend, but others are following quickly behind and it is a trend that is rapidly penetrating all sectors. To quote one of the oil majors: "We have to stay relevant to our customer base – if we fail to do that, we fail full stop".

Technology is moving faster than infrastructure and regulation can keep pace, but the increasing socio-economic sense of sustainable solutions will see any obstacles overcome. Solar PV will unquestionably be a winner. So, many of the foundations are laid and we anticipate that 2017 will see solar PV become a dominant force in the global energy mix. ■

Authors

Simon Currie is the global head of energy at Norton Rose Fulbright. He advises clients across the world on strategy and the development, acquisition and financing of assets in the energy, natural resources and infrastructure sectors. He has worked on ground-breaking transactions in over 50 countries including privatisations and restructurings.

Rob Marsh is a partner and the co-chair of the renewable energy practice at Norton Rose Fulbright. He has advised sponsors, investors and lenders across diverse sectors including wind (offshore and onshore), solar (PV, rooftop and CSP), biomass, energy from waste, tidal, bio-fuels, energy storage and energy efficiency projects.

In pursuit of accurate irradiance measurements

Part 2: Sensors and beyond

Resource assessment | Irradiance sensors are vital tools for protecting investment in valuable solar power plants and ensuring they perform optimally. In the second of two articles on a major study they are leading to better understand these diminutive components, Anton Driesse and Joshua Stein discuss how inaccuracies in irradiance measurement can be quantified and managed

Solar irradiance measurements provide essential information at all stages of the PV system lifecycle. Historical measurements are used for selecting sites, designing systems and securing financing. High-resolution measurements in the period before construction can help fine-tune planning. When it's time to commission a system, irradiance measurements are a vital tool in ascertaining whether modules are performing as per manufacturer claims. And the story doesn't end here. Only a stable independent irradiance measurement will permit long-term changes in system performance to be detected and the source of emerging faults identified. As PV arrays age, decisions need to be made about upgrades, replacements, expansion and decommissioning. Irradiance measurements put everything into perspective.

In 2014 PV Performance Labs launched a comprehensive study to achieve a deeper understanding of the differences between common commercial instruments that are used to support PV plant planning and operations. The project, called PVSENSOR, included a series of indoor tests carried out at the Joint Research Center (JRC) in Ispra, Italy, and extensive outdoor testing at Sandia National Laboratories (Sandia) in Albuquerque, New Mexico, USA, as well as at PV Performance Labs in Freiburg, Germany. A period of extended outdoor monitoring to validate the laboratory results is still ongoing. (See photo above.)

Our goal with the study is ultimately to make more accurate statements and conclusions about PV system performance. This could be simple aggregate performance or more targeted metrics such as peak or low-light performance, seasonal variations, or evaluation of performance changes over time due to various causes such as soiling or material degradation. Many factors that influence PV system output also affect irradiance sensor readings, so the latter must be understood in detail in order to make conclusions about the former.

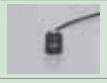
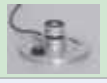
Accurate irradiance measurements are necessary, but it is equally important to *quantify* the accuracy of the measurements, in other words, every irradiance measurement should be accompanied by an uncertainty indicator such as ±3% or ±30W/m^2. Just as every performance claim or promise has a tolerance band (sometimes only seen in the fine print), so should every performance measurement have an implicit or explicit uncertainty factor. In practice the uncertainty in performance indicators is almost always dominated by the uncertainty in irradiance measurements; this is the driving force for investigating the sensors.

A report on the initial stages of the project and its aims appeared in Volume 07 of *PV Tech Power* in May 2016. In this follow-up article we discuss sensor specifications and sources of uncertainty and look at variability in measurements that can arise from systematic and non-systematic causes. We conclude with practical advice on maximising accuracy.

Instruments and specifications

To measure the irradiance in the plane of a PV array, a broad range of commercial instruments is available. These can be separated into three fundamental categories:

1. ***Thermopile pyranometers.*** These instruments have a black surface under a glass dome that absorbs solar radiation and produces a small voltage in proportion to the internal temperature rise, which is converted to irradiance.
2. ***Photodiode pyranometers.*** A miniature PV cell hidden under a translucent diffusor inside the body of these sensors produces a current proportional to the absorbed irradiance. They are designed to behave as much as possible like thermopile pyranometers.

	Manufacturer		Model	Response time	Zero offset A error	Zero offset B error	Non-stability error	Non-linearity error	Directional response error	Spectral selectivity error	Tempera-ture response error	Tilt response error	Calibration uncertainty
				seconds	W/m²	W/m²	% per year	%	W/m²	%	%	%	%
Secondary standard thermopile pyranometers	***ISO 9060 requirements***			15	7	2	0.8	0.5	10	3	2	0.5	
	Eko Instruments		MS-802	5	6	2	0.5	0.2	10	1	1	0.2	0.66
	Eppley		PSP	15	4-6	1-2	0.5	0.5	10	1	1	0.5	1
	Eppley		SPP	5	5	2	0.5	0.5	10	2	0.5	0.5	1
	Eppley		GPP	5	5	2	0.5	0.5	10	2	0.5	0.5	1
	Hukseflux		SR20	3	5	2	0.5	0.2	10	3	1	0.2	1
	Kipp & Zonen		CMP 10	5	7	2	0.5	0.2	10	3	1	0.2	1.4
Second class thermopile pyranometers	***ISO 9060 requirements***			60	30	8	3	3	30	10	8	5	
	Eko Instruments		MS-602	17	10	6	1.7	1.5	25	1	2	2	0.77
	Hukseflux		SR03	1	15	4	1	1	25	5	3	2	1.7
	Hukseflux		LP02	18	15	4	1	1	25	5	3	2	1.4
	Kipp & Zonen		CMP 3	18	15	5	1	1.5	20	3	5	1	3.31
Photodiode pyranometers	Apogee Instruments		SP-110	1 ms	0*	0*	2	1	5 %		-0.04 %/°C	0*	5
	Eko Instruments		ML-01	1 ms	0*	0*	2		5 %		0.15 %/°C	0*	3.06
	Kipp & Zonen		SP Lite2	500 ns	0*	0*	2	2.5	10		-0.15 %/°C	0*	4.6
	LI-COR		LI-200	10 us	0*	0*	2	1	5 %		0.15 %/°C	0*	
	Skye Instruments		SKS-1110	10 ns	0*	0*	2	0.2	5 %		0.2 %/°C	0*	5
Silicon photovoltaic reference cells	EETS		RC01	0*	0*	0*					0.0302 %/°C	0*	3
	Fraunhofer ISE		11311102	0*	0*	0*					0.06363 %/°C	0*	
	Mencke & Tegtmeyer		SiS-02-Pt100	0*	0*	0*					0.07 %/°C	0*	
	Mencke & Tegtmeyer		Si-02-Pt100	0*	0*	0*					0.0725 %/°C	0*	
	Mencke & Tegtmeyer		Si-02-Pt100-x	0*	0*	0*					0.0725 %/°C	0*	
	NES		SOZ-03	0*	0*	0*	0.3				0.06 %/°C	0*	3

* These characteristics are relevant for thermal sensors and are considered to be zero for photovoltaic sensors even if not explicitly reported by the manufacturer

Table 1. Manufacturers' specifications for the products included in the PVSENSOR study. Most values indicate the maximum error attributable to a certain characteristic. Manufacturers specifications are generally subject to change without notice, and we have indeed seen some of them change. We have made every effort to ensure that this information is correct, but cannot guarantee this.

3. ***Reference cells.*** This category also uses the current generated by a PV cell, but the cells are larger and the physical construction and optics are more similar to a small PV module.

The first place to learn about product capabilities and differences between products is normally the manufacturer's literature. For the PVSENSOR study we selected 21 different commercial sensor models, focusing on those that are well known and widely used. Table 1 identifies these sensors and lists their most important specifications as found in public datasheets and product manuals. The information given in most product literature reflects the ISO 9060 classification criteria, and these are therefore shown in the column headings of Table 1.

The 10 thermopile instruments are grouped by their ISO 9060 quality classification as either *secondary-standard* (red) or *second-class* (yellow) and the corresponding requirements are listed above each group. (The study did not include any ISO *first-class* instruments.) The photodiode pyranometers in the third group (green) aspire to the same ideals as the thermopile instruments but they cannot completely meet the requirements for any defined class due to their narrow spectral responses. (The ISO 9060 standard is currently under revision and one or more new class definitions are expected that will accommodate photodiode pyranometers.)

The last group (blue) contains the PV reference cells. These are not designed to behave like pyranometers so significant differences in spectral and directional response errors are normal. Unfortunately there is no 'ideal' spectral response or directional response for reference cells, so it is not possible to define how much they might be in 'error'. For other aspects like non-linearity, non-stability and calibration uncertainty the same 'ideals' can be applied as for the pyranometers.

One difficulty with these specifications is that they are presented as worst-case errors. This makes it easy to verify that the classification requirements are met, but it makes it harder to determine what the accuracy of a specific measurement or series of measurements could be. As the classification criteria labels suggest, most errors are not purely random but have specific causes that presumably produce systematic error responses. So if the ambient temperature is moderate, then the temperature response error is likely to be smaller, and if the sun is high in the sky at mid-day, then the directional error is likely to be smaller than the worst case.

When one looks deeper into the data sheets, product manuals and calibration certificates, more information about the systematic nature of these errors is usually found, but the content and form of that information are often inconsistent between sources so can be hard to compare. Over the course of the PVSENSOR project we have evaluated many of these systematic responses and some were presented in Part 1 of this article (*PV Tech Power*, May 2016). This information is now in a consistent form and helps us make more informed instrument choices as well as evaluate and re-evaluate plant performance data based on the instruments that were deployed.

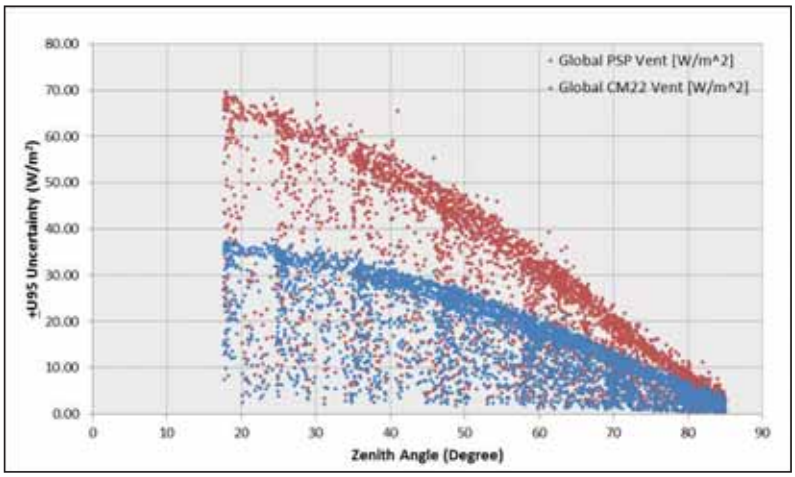
From instrument specifications to measurement uncertainty

The ISO procedure for evaluating uncertainty, the Guide to the Expression of Uncertainty in Measurement (GUM), contains clear rules for calculating an overall uncertainty for a measurement that involves multiple independent sources of uncertainty. The pyranometer specifications are in a form that makes it fairly easy to apply this procedure, and this is the basis of the newly approved and soon-to-be-published ASTM "Standard Guide for Evaluating Uncertainty in Calibration and Field Measurements of Broadband Irradiance with Pyranometers and Pyrheliometers". An important outcome of the procedure is that it assigns a specific uncertainty to each measurement rather than a global value for an instrument or measurement system. A closer look at the specifications table above shows that some of the errors are absolute and others are relative, which logically leads to larger relative uncertainties at low irradiance levels, and vice versa. As a result the same instrument and the same equipment can produce different aggregate uncertainties for different locations or even for different seasons at the same location. More complicated perhaps, but also more realistic.

Variation of systematic measurement errors over time

In the ASTM approach all error sources are treated as if they were random and independent. As mentioned earlier, however, the different types of error identified in the specifications are not purely random: many of them do have a systematic component. And if one or more of those systematic error components can be calculated, then that can potentially reduce the random error. The challenge is that this has to be done on a case-by-case basis for each measurement situation and location.

To illustrate this, we have used the temperature, directional and spectral responses measured in the PVSENSOR project to calculate the systematic measurement errors that would have occurred in Golden, Colorado when measuring the global irradiance on a surface tilted at 40°. This puts together data gathered about the instruments in the lab at JRC and on the outdoor test stand at Sandia, with environmental parameters and spectral irradiance measured at the NREL Solar Radiation Research Laboratory. Figures 2a to 2f show how each of those errors varies throughout a single sunny summer day, and throughout a whole year for a sample pyranometer, photodiode and reference cell. Some important notes: The top half of each diagram is an absolute scale, which is the same for all three instruments to facili-



Source: NREL, http://www.nrel.gov/midc/radiometer_uncert.xlsx

Figure 1. Absolute uncertainty for hourly GHI sums over a one-year period measured with a ventilated Eppley PSP or Kipp & Zonen CM22

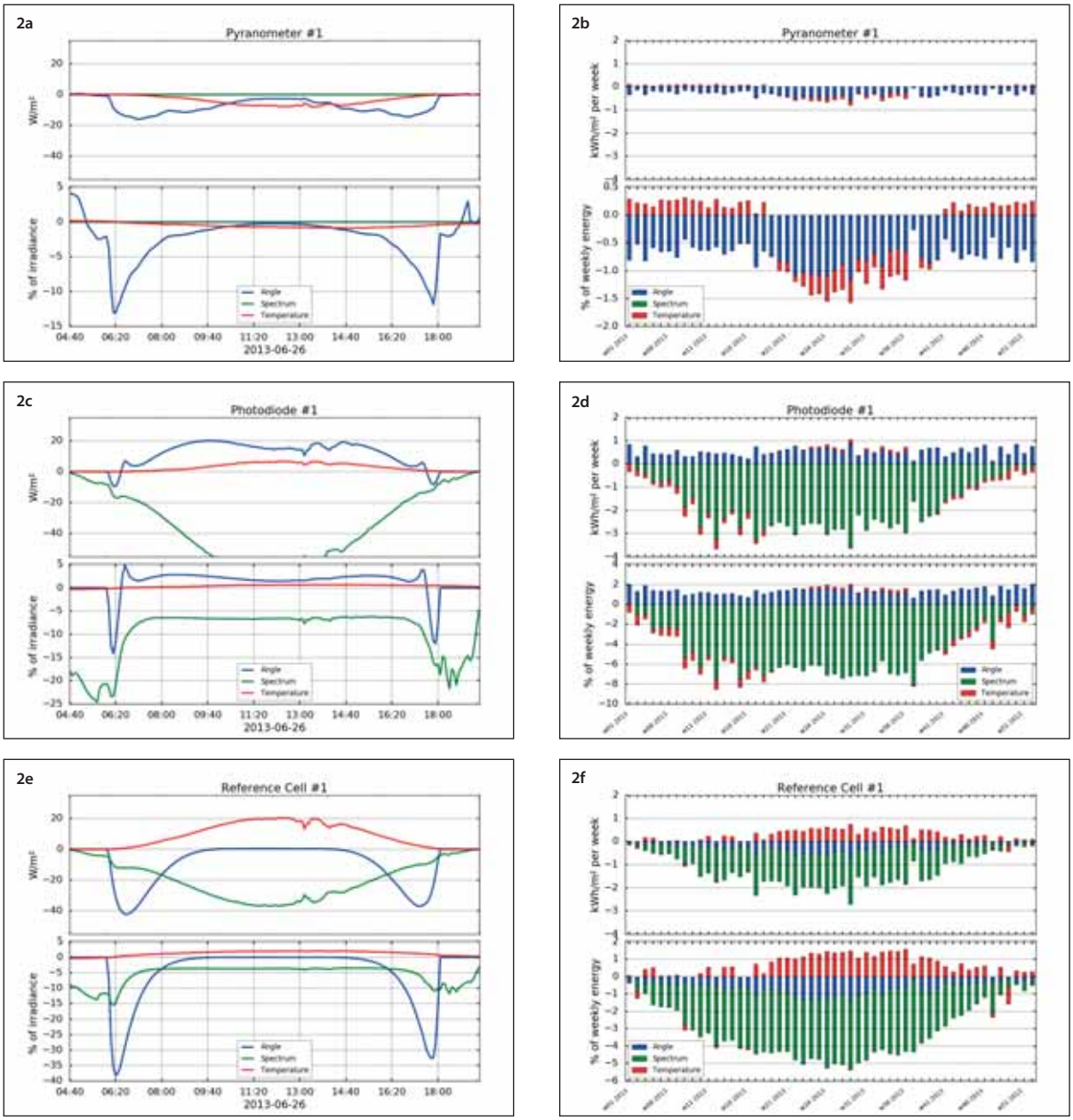


Figure 2. Daily and annual profiles of the measurement error caused by angle-of-incidence, spectrum and temperature for a thermopile pyranometer, photodiode pyranometer and a reference cell located in Golden Colorado, tilted 40° south

tate comparison; the bottom half of each diagram has a relative scale that is adapted to each instrument's data range. We are not (yet) able to calculate the systematic spectral error for thermopile pyranometer measurements, so this is not shown. Finally, the error bars that reach above and below zero cancel out partially, so the combined errors are sometimes smaller than might appear at first glance from the coloured area.

In this scenario we can see that the spectral response contributes the largest portion of the measurement error for the photodiode, whereas the reference cell—which is not intended to have a flat spectral response—actually comes closer to the pyranometer ideal. In terms of angular response, both the thermopile and photodiode pyranometers show a fairly uniform bias throughout the year whereas the reference cell's deviations are seasonal as they would be for a PV module. The errors caused by operating temperature are seasonal in all cases, but when the photovoltaic devices have a positive error, the thermopile has a negative error and vice versa. The larger temperature errors for the reference cell would usually be corrected inside the device or in the data logger using a separate temperature measurement.

There are some assumptions inherent in these calculations and illustrations. It is assumed that the directional error is zero when the sun is perpendicular to the instrument; that the temperature error is zero at 25 degrees Celsius; and that the spectral error is zero under AM1.5g spectral irradiance. These assumptions don't necessarily hold true because systematic biases are sometimes compensated for in the calibration. The pyranometer in Figure 2, for example, consistently has a negative directional error because the sun is rarely positioned perpendicular to it. If the calibration factor is determined for a 45-degree angle of incidence, as is sometimes done, much of this bias could be removed. To completely remove the bias, however, one would need a site and installation-specific calibration. Clearly a site and installation-specific *calculation* would be much more cost-effective!

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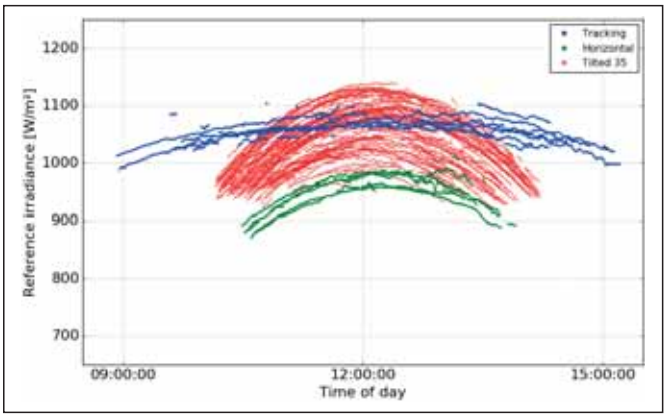


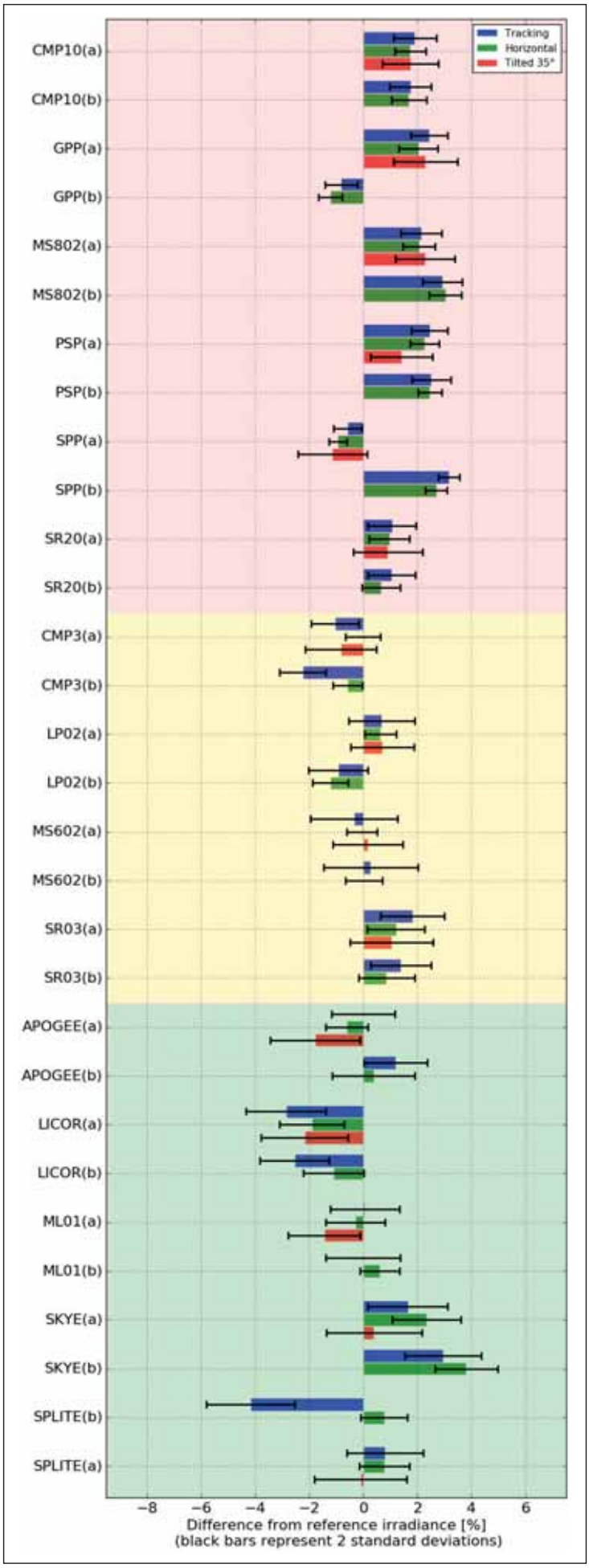
▲ **Figure 3. Clear-sky reference irradiance measured at Sandia in three orientations over multiple days. These conditions form the basis for the comparisons in Figures 4 and 5.**

Comparison of instruments under clear conditions

Outdoor calibration procedures require stable conditions with bright sun and clear skies to determine an instrument's calibration factor, also called responsivity. It stands to reason that if we compare the readings of several instruments under such conditions, they should agree within a small margin of error. Our outdoor measurements at Sandia provided ample sunny periods where we could compare each instrument's output with the others and also with the on-site reference instruments. From the available data we selected three subsets: instruments tracking the sun, instruments horizontal and instruments tilted 35° toward the south, with a total of between 80,000 and 100,000 points per sensor from multiple days in each subset. (See Figure 3.)

Using the manufacturer-supplied calibration factors we calculated each instrument's irradiance readings and the differences from our reference values. Figures 4 and 5 show the mean differences for each instrument and data subset. We also plot the standard deviation x 2 as an indicator of the spread of the values. The most important quality of the instruments is consistency—that is, they should have similar mean deviations in the three data subsets and low standard deviations. It is quite clear in Figure 4 that the second-class and photodiode pyranometers have more variability in their readings than the secondary standard instruments.

If the mean deviations are near zero that means the manufacturer's calibration agrees with our reference instruments. In Figure 4 we see that most of the secondary standard instruments have a positive bias, raising the possibility that our reference instruments themselves have a negative bias. For the reference cells in Figure 5 there is an almost universal negative bias on the outdoor tests but the indoor flash tests have more positive values across the board. These tests were done on different



▶ **Figure 4. Clear-sky irradiance measured with 20 thermopile and 10 photodiode pyranometers compared to reference values calculated from separate direct and diffuse measurements**

continents with different reference instruments—but also using different methods. The bottom line is that calibration factors should not be taken for granted. Our measurements have their own inherent uncertainties, but if we were able to detect these biases—both systematic ones and outliers—then perhaps it's also possible to reduce or eliminate them.

Best practices for obtaining accurate irradiance measurements

Irradiance sensors are the heart of an irradiance measurement system, and understanding their detailed characteristics can help in both the initial instrument selection process and the later data processing and uncertainty analysis tasks. But there are many more aspects to measurement system design and operation that affect accuracy. Some important ways to maximise accuracy are:

- All components in the measurement chain contribute to the overall uncertainty, so ensure that all data acquisition equipment accuracy exceeds sensor accuracy by a factor of 10.
- Irradiance can change rapidly, so ensure that readings are taken at intervals shorter than the sensor response time for thermopile pyranometers; and not longer than one second for PV sensors. Less frequent readings lead to lower accuracy in average values.
- Ensure that sensors are installed with the correct slope and orientation for the PV system. It is not always clear what those angles should be, for example design when and build differ slightly, but some target should be set and confirmed.
- Sensor surfaces will accumulate varying degrees of snow, ice, frost, dew, dust, dirt and other substances that can cause periodic measurement errors far in excess of any listed on the spec sheets. Ventilation and heating options can reduce these problems significantly, but periodic cleaning and inspection/maintenance schedules must be adapted to the local conditions.
- Things can and do go wrong, so add redundancy to the system with multiple sensors, data loggers, communication links and/or power supplies. Even if it is not possible to continue measuring in all cases, it is important to be able to detect problems or failures and flag suspect measurements.
- Irradiance instruments need periodic calibration. The longer the interval between calibrations, the greater the measurement uncertainty. Redundant instruments that are sent for calibration on an alternating schedule are a great way to ensure continuity in data and maximise accuracy.

All the above measures will contribute very substantially to irradiance data accuracy—but none of this matters if it is not documented. Records about specifications, design, installation, operation, inspections, calibrations, maintenance and repairs all flow into the calculation of uncertainty estimates and are tangible evidence that bolster confidence in the data.

Conclusion

Measuring irradiance accurately in PV plants is absolutely necessary, but not easy. A broad range of instruments are commercially available, which have more subtle differences than are possible to infer from the manufacturers' specifications. There is still room for improvement and the good news is that the growth in the PV market has spurred on product development and many manufacturers have introduced new or improved products in the two years since the PVSENSOR study began. Innovations that improve not only basic accuracy, but also maintainability, calibration and data availability are all helping to produce more accurate irradiance data sets and PV plant performance assessments.

The related challenge of determining the level of accuracy (or uncertainty) of irradiance measurements will not recede with more accurate instruments or other innovations. On the contrary, we need to quantify the improvements in accuracy in order to justify the investments in new instruments or procedures. Thus there is a clear need and opportunity for the PVSENSOR project to develop into a continuous testing and evaluation activity.

Understanding systematic errors and the influence of the operating environment on instrument readings is crucial to making the most of past, present and future irradiance data sets. With site- and situation-specific data analysis we can reduce uncertanties not only on irradiance values but also on important PV plant performance indicators. Currently this type of analysis requires considerable effort, but as we streamline the processing this will become our standard practice for assessments of PV plant data for our clients. ■

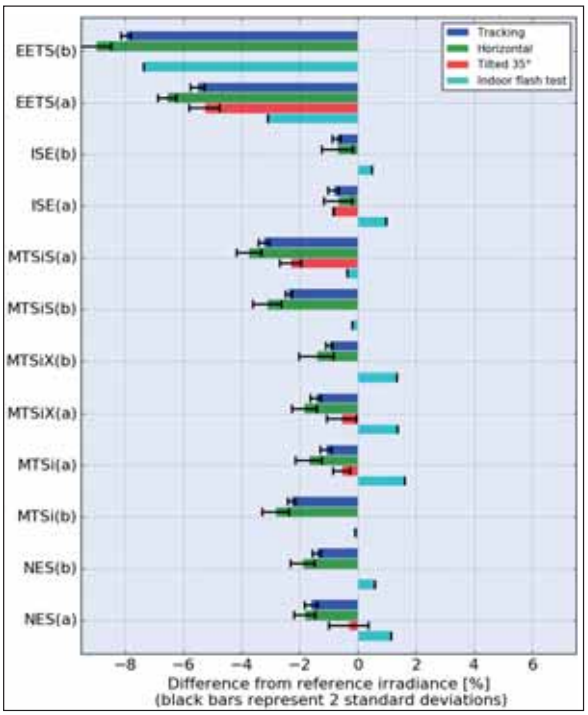


Figure 5. Clear-sky irradiance measured with 12 silicon reference cells compared to reference values determined by a WPVS reference cell. Indoor flash test results also shown for reference

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Authors

Anton Driesse is a seasoned independent consultant to the photovoltaics industry. Through his company PV Performance Labs he helps clients in Europe and North America gain deeper insights into performance through measurement, data analysis and modelling. He maintains strong links to the research community through collaborative work, such as the PVSENSOR project he leads, and through activities with organisations such as IEEE, ASTM, IEA PVPS.

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

Designs on quality O&M

O&M | Operations and maintenance has traditionally been thought of as something that happens after a PV power plant has been built and connected. But as Emanuele Tacchino writes, planning for the successful operation of a project, particularly a new PV market, begins long before construction

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Demonstrating to investors the strength of long-term commitment to a PV project is key to developing investor confidence in that investment. The time it takes to develop and build the facility is a drop in the bucket when compared to the time that the plant will be producing power.

A solar facility will ideally last for over two decades. An investor will be looking for assurance that the facility will continue to be a good investment long after the construction is complete and will be properly managed in the years to come. It is vital therefore to demonstrate at the very beginning of the development a strong operations and maintenance (O&M) plan based on the highest industry standards and to offer assurance that details of the plant's design and engineering by the EPC contractor have been carried out in such a way as to simplify its maintenance over 20 or more years. There are various solutions, for example, in height and spacing of structures, for example, that can impact plant layout, power and, of course, maintenance. Some of these, such as leaving enough space between rows for vehicle access or cleaning machines, may sound obvious but in practice have not always been considered.

Typically during the development and construction phase investors focused in the past on the construction and grid connection of the project. Once this was completed, they started making considerations about what happens next. The trend is now moving to early inclusion of the solar O&M contractor as supervisor of the EPC engineering or eventually also on development permitting, instead of waiting for five years to see what issues come to the surface and then taking action.

Considering O&M at the design stage of a PV plant can help streamline the operation of remote assets

A big part of the challenge in mature markets with operational assets is that they have not been properly maintained, but also that they have not been properly designed from the very beginning, starting from greenfield and from early stage development and permitting. There are no interests from the project developers after the project rights have been

sold or from the EPC contractor after the two-year warranty period is over aligned with the investor's interests. That is where a professional O&M contractor is a significant partner. The O&M contractor typically stays as a long-term partner of the investor, and stays with the investor in the investment for at least the next 20 years. So the asset perspective of the O&M contractor is different from the EPC contractor and from the developers, and investors are realising that O&M players are the only real long-term partners for them.

A clear O&M plan in the initial concept and development therefore offers the assurance of quality, responsiveness and reliability long after the developer and EPC has moved on to the next project.

What makes this so important to investors?

Evidence of early consideration of how a plant will be managed has a number of benefits for investors. With the global PV project development business growing geographically and several new emerging markets that look very promising, having a solid operations and management plan demonstrates a long-term commitment to the project. In fact, given the lack of existing solar capacity in these new markets, O&M and asset management are arguably more important here; if a solar developer or an EPC firm wants to improve the bankability of their project to secure investors, they must demonstrate that they have a plan for the successful long-term operations and management of a solar facility. In many cases this will involve a partnership with an outside O&M company that has the knowledge and expertise to ensure smooth operations once the system is up and running.

It also increases confidence that a project will be compliant with both local and international operational standards. Investors want to be confident that their projects will not be subjected to any undue hold ups or fines due to non-compliance with industry standards. Providing a reliable professional expert in O&M with experience in standardised contracts, and knowledge of best practices will go a long way toward instilling investor confidence.

It ensures quality monitoring of sites in distant markets. A unique aspect of solar projects in emerging markets is that they tend to be very far away from the typical resources available for troubleshooting and in hugely harsh environments, such as desert areas. Monitoring will depend on a team that is typically not on the ground at the site, with few, if any, local providers to pick up the slack. A company with a proven monitoring and response record will increase investor confidence in the project as a whole. With the knowledge of best practices to address any situations that may arise, even identifying potential problems and addressing them before they cause any damage, increases the confidence of investing in these markets. The solar monitoring system and state-of-the-art incident handling and management capabilities are crucial for successful O&M.

Linked to this is the optimal operation of a plant: a professional O&M provider's goal is to turn what is currently perceived as an operating cost – the O&M cost – into an additional source of profit for the investor. Having the right commitment and mindset is really the key not only for emerging markets, but in general for every sort of PV market around the world. With proper monitoring and alert systems in place, and proper incident and maintenance management to address the diverse environmental issues that can impact projects, investors can be guaranteed that their system will continue to provide optimum output. The extra performance derived from a good operating solar structure can make an enormous impact on system return on investment. A small increase in performance of percentage points, meaning two, three, four or five percent, creates enormous value for investors. At the end of the day, in many occasions, the O&M is actually no longer a cost for the investor; it generates more revenue than it costs.

Finally, judicious O&M planning guarantees solar delivery at the same level as in mature markets. Emerging markets often have few local solar resources. Solar investors are looking for local companies who are able to provide the services they're expecting from other markets, but they simply cannot find these competencies in all new and prospective markets. Thus there is a big gap between investor expectations and local market O&M competencies in emerging markets. The O&M team can provide training to local workers, but it will take a long time for them to learn the complex detail that goes into monitoring and managing the operations of a PV plant and relevant troubleshooting. Global solar development provides a challenge not only in the distance of projects from established solar markets and the available local resources, but also in working in unfamiliar physical conditions. An O&M company with experience working in diverse conditions has the ability to study and adapt its practices to the environment while at the same time remaining committed to upholding the standards of current market conditions. The ability to provide flexibility is crucial in addressing any unforeseen issues that arise.

Typical set up between developer, EPC and O&M contractors in emerging markets

The contractual set up among the various players involved, especially between EPC and O&M contractors must be clearly defined from the beginning, to identify the respective responsibility and warranties avoiding grey areas of uncertainty and potential overlapping among the various parties. One has to focus on construction (EPC) and the other has to commit on operations and maintenance of the PV Plant (O&M). A basic bankable term sheet can be structured as follows:

Scope

Development and engineering: The developer, EPC constructor and O&M contractor must cooperate to design the initial concept of the PV plant and the following permitting procedures and engineering, up to the detailed engineering prior actual construction, with the aim of properly operate and maintain the PV Plant. Specific attention must be paid to critical factors that could heavily impact plants operation and relevant costs and performances (roads, accessibility, availability or storage of waters, proper design of the PV arrays and inter row distances, specific climatic events (sandstorms, high temperatures, strong wind etc).

Construction: O&M contractor supervises EPC works and the proper installation of the SCADA/monitoring system.

Mobilisation period: During this period the O&M contractor undertakes the responsibility to:

- Identify, recruit, interview and hire

Integrated O&M in practice: Arabia One Solar, Jordan

Alectris and its developer partner, MASE, applied such a model to Arabia One Solar, a 11.52MWp PV plant in the Ma'an area of Jordan, apex of making solar financially bankable in emerging solar markets. Key aspects of the business case are outlined below:

Integrated, bankable O&M model: The project, locally developed by MASE, represented an opportunity to integrate an early-stage O&M models that was implemented immediately after the grid connection of the plant. Arabia One Solar project development has been supported by tier-one sponsors and internationally recognised bankable EPC and equipment providers such Hanwha Q-Cells and Schneider Electric, with financing from the International Finance Corporation (IFC) and Finnish Fund for Industrial Cooperation (FINNFUND). A local partner leads the field operations and maintenance services for the solar plant, with proper training, supervision and support from the global asset care technical expertise and plant management capabilities of Alectris.

Combined Expertise: With a track record in operation and management support of far-flung portfolios pf assets, Alectris has brought to the EPC constructor its on-the-ground experience with a wide variety of geographic environments along with its cloud-based enterprise resource planning (EPR) software platform, ACTIS, which has been implemented on the plant. MASE acted as a developer, and local partner for on field activities.

Cloud-based reporting: A critical component in the speed to market strategy of Alectris and MASE has been the utilisation of the ACTIS cloud-based solar ERP. All data monitoring streams are brought up into one login accessible platform. It is cloud based with modules to operations, maintenance and asset management, also tailored to solar PV plant optimisation. The system allows MASE team members to provide a wide range of alerting, analytics and reporting capabilities to the stakeholders in the Arabia One Solar project.

Credit Alectris

Arabia One Solar in Jordan took an integrated approach to O&M planning

all labour and professional, supervisory and managerial personnel as are required to perform all activities within the scope of contract;
- Identify and train eventual local subcontractors for on-field activities;
- O&M personnel and staff shall observe plant commissioning process and associated tests;
- O&M personnel and staff shall attend training courses provided by the EPC contractor and/or other suppliers;
- Purchase tools and equipment and vehicles as required to operate and maintain the plant.

Operation period:
- Full 24/7 operations;
- Preventive, predictive and corrective maintenance services following investors' and lenders' requirements plus relevant monitoring and monthly or real-time reporting on activities performed;
- Module cleaning with the required frequency;
- Full site management including environmental, waste and health & safety management;
- Security management (video surveillance, patrols and guards), if required;
- O&M facility maintenance;
- High-voltage substation maintenance;
- Administration and operation of the plant and stocks including implementing dispatch instructions, tests and inspections, spare parts replenishment and warranty claim management;
- Increasing performance and continuous improvement: diagnostic, assessment, engineering and execution of the proper actions and interventions that will continuously increase plant performance up to the maximum.

Spares

Consumables: During the EPC warranty period of the first two years and afterwards, only consumables shall be on charge of the O&M provider. "Consumable" means everything that needs to be replaced often for maintenance reasons, such as but not limited to: screws, bolts, fuses, sheaths, locks, light bulbs, lubricants, oils, water, freon, fuel etc. – in other words everything that is normally consumed by the normal operations and needs to be replaced.

Spare parts: All the spare parts costs under EPC or relevant manufacturer or provider warranty for the plant or the O&M facility are excluded from the O&M scope as well as spare parts needed as a consequence of proven systemic defects and force majeure events. Corrective maintenance shall always be included except the cases of *force majeure* events and systemic defects.

Guaranteed performance and key performance indicators (KPIs)

There are two KPIs clearly defined and that describe different things:

A. **Availability** is calculated down to the inverter level and calculates to what extent equipment after the inverter is operating or not. It expressly measures how good, fast and reliable is the O&M contractor.

B. **Performance ratio (PR)** calculates the efficiency of the system when all equipment from inverter upwards is running/available. PR is calculated only in available hours of the equipment. It expressly measures how well the plant has been designed and built by the EPC constructor.

1. PR is guaranteed by the EPC contractor until the end of the EPC warranty period
2. Availability is guaranteed by the O&M contractor from COD
3. PR is guaranteed by the O&M contractor after expiration of the EPC warranty. In such a case, the O&M will start guaranteeing only if the plant has been performing above the guaranteed PR and in case not, if such issues have been permanently resolved.
4. To define the line between O&M and

EPC in terms of guaranteeing availability, the plant should be commissioned and documented according best industry practices, for example according to IEC 62446.

Maximum intervention time

A definition for MIT has been formulated which segregates **between the impacts the maintenance** event has on the performance of the plant. The general structure is:

- MIT for critical incidents is set at a specific number of hours, seven days of the week;
- MIT for non-critical incidents is set similarly;
- An incident is classified as critical in cases when one inverter capacity or more is offline, or when the incident involves a connectivity or SCADA failure that impacts the contractor's ability to monitor the facility;
- In cases when the fault cannot be fixed by the O&M contractor and the equipment supplier's intervention is required, the contractor will communicate the issue in writing to the principal within a fixed number of hours from the MIT;
- If the replacement of equipment is needed, the O&M contractor commits to ensuring the availability of relevant spare parts and replacing the equipment within a certain number of hours from the MIT if the spare part is included in the portfolio of minimum spare parts or to order it within the MIT if not;
- *Force majeure* events are excluded from MIT obligations.

Minimum guaranteed availability (MGA)

MGA typically is a value around 99% with eventual bonuses for revenues as a result of availability achieved above this.

Availability liquidated damages (ALD)

The ALD rate shall be directly proportional to the losses caused by the shortfall from the guaranteed plant availability.

Minimum guaranteed performance ration (MGPR)

MGPR to be defined from guaranteed PR as per EPC schedule. Bonus granted if effective PR (PReff) shall be over 100% of the PR achieved by the EPC contractor at the end of the two-year warranty period.

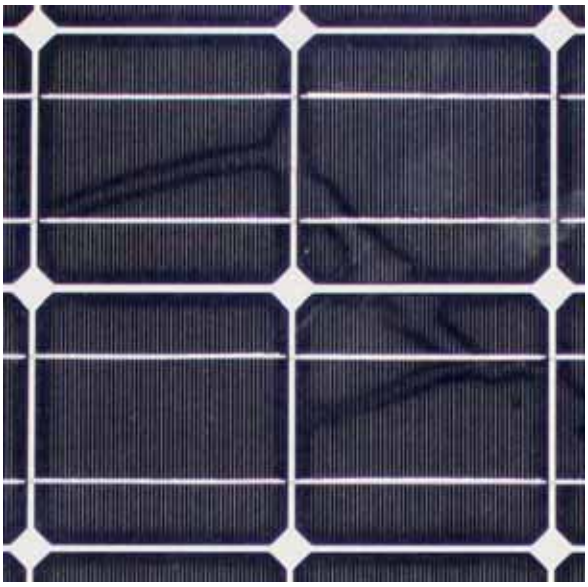
Finally this model draws on solar operations and maintenance expertise at the project design and development stage to engineer bankability and financial assurance into the plans for the investment team. It ensures long-term financial viability of the asset by structuring and deploying operations, maintenance and management of the site based on worldwide best practices. Working together the strengths of the partners are enhanced to meet the criteria of the investment community, making solar more attractive for new emerging markets. ■

Author

Emanuele Tacchino is a business development manager in the Western Europe and Middle East division of Alectris. He has over a decade of experience in solar PV project management, dealing with PV projects or plant transactions and involving the development, construction and operation of PV plants.

Understanding snail trails on PV modules

Module degradation | When the phenomenon of so-called snail trails first emerged over a decade ago, they prompted concerns of a major new problem afflicting PV modules. Sylke Meyer, Marko Turek, Thomas Manke, Stephan Großer and Christian Hagendorf, who have contributed extensively to understanding the science behind snail trails, review the latest thinking on the phenomenon and what it means for plant performance



▲ **Fig. 1: Solar cells with crossing and framing discoloration**

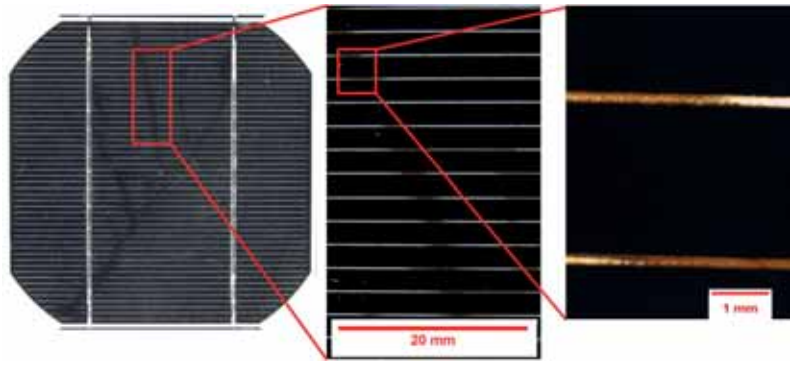
More than 10 years ago, the first owners and operators of PV modules reported the appearance of a phenomenon which was unknown and unaccountable at that time. Dark stripes crossing the area or framing the edge of solar cells were observed within a short time (several months) after installation of the modules [1]. The mysteriousness of this defect was increased by the fact that in many cases neither all cells of a module were affected nor all modules of one installation. And it is perhaps due to this initial perplexity that pictorial but misleading names were used to describe the phenomenon: snail trails, snail tracks, worm marks or framing.

Within a few years this kind of PV module defect became widespread. In 2012 it was reported that about 50% of all newly installed modules were more or less affected from "snail trails" [2]. The concern about the impact to module performance and possible long-term effects initiated a lot of scientific studies on the root cause of "snail trails". This article gives an overview of what is known meanwhile about the mechanism of "snail trail" formation and what PV operators and manufacturers can derive from this knowledge.

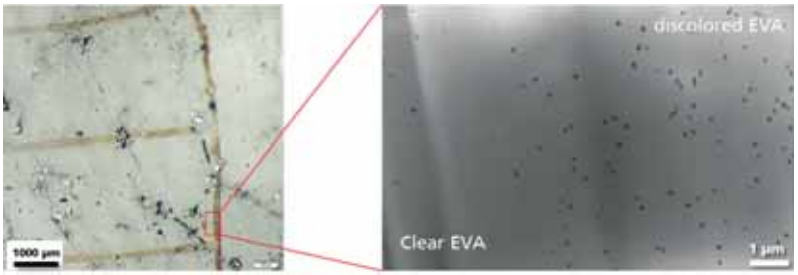
The microstructure of "snail trail" discoloration

It became obvious by simple microscopic inspection of snail trail-affected module sites that the visual impression of dark stripes on the cell surface is caused by partially discoloured contact fingers. As illustrated in Figure 2, the impression of a homogeneous dark area is a kind of optical illusion since it is solely caused by a discontinuous brownish discoloration of the silver grid fingers but not the cell surface itself. Based on this very early finding it was suggested by some authors to replace the misleading initial name by the more correct name "grid finger discoloration". However, this has not been generally accepted by the PV community.

Further analysis of the origin of brownish grid finger discoloration required a skilled sample preparation and high resolution techniques. By detaching the glass and encapsulating EVA layer from a discoloured module area it was found that the brownish traces are located within the covering EVA very near to the cell/EVA interface [3]. Finally, it was found by transmission electron microscopy that the brownish colour within the EVA material correlates with the appearance of nanometre-sized particles (see Figure 3). A chemical analysis of those nanoparticles revealed silver as



▶ **Figure 2. Microscopic inspection of a typical "snail trail" discoloration, increasing zoom factor from left to right**



▶ **Figure 3. Detached EVA piece from a solar module with grid finger discoloration. The pattern of the contact fingers is "imprinted" as brown traces (left). TEM image of a cross section through the EVA sample with the labelled position (right). The concentration of nanoparticles (dots) corresponds to the discoloured area of the sample**

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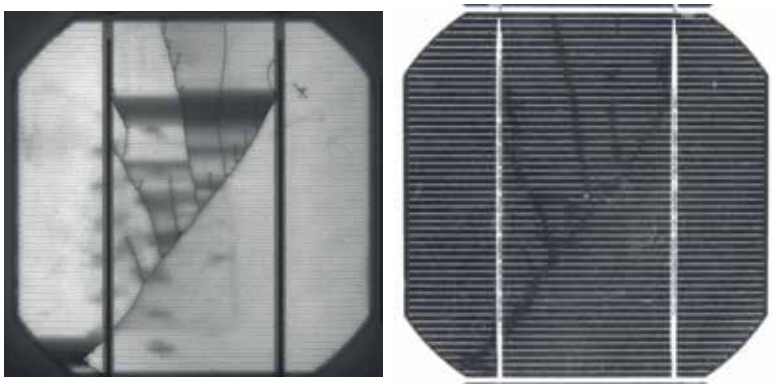

Figure 4. EL image and photograph of a solar cell affected from grid finger discoloration. The patterns of cell cracks and discoloured stripes are completely identical

their main component. Thus, it could be concluded that the formation of silver nanoparticles within the EVA layer right above a contact finger is the microstructural and chemical reason for the visual impression of discoloured cell areas.

The mechanism of "snail trail" formation

After having discovered silver nanoparticles as the microscopic origin of the grid finger discoloration the questions arise why and how they occur specifically at the sites of dark stripes or frames. One plausible explanation is supported by the observation that those grid finger discolorations which cross the cell strongly coincide with cell cracks. This is illustrated in Figure 4. The electroluminescence EL image shows that the cell has a characteristic pattern of cracks. This pattern is completely identical to the pattern of the discoloration seen at the photograph of the same solar cell. This coincidence was found for all investigated samples with cell-crossing discoloration stripes and was reported by many authors. However, there is certain confusion with the definition of cracks and micro-cracks. Cracks which are related to grid finger discoloration as described above are always *macroscopic* cracks which penetrate the whole cell. This means they are 180-200 µm in vertical dimension (the whole wafer thickness) and several millimetres up to centimetres in lateral dimension. *Micro-cracks* are clearly different in their dimensions (some micrometres in depth) and occur for example as surface damage after wafer sawing. These terms should not be mixed up.

The second form of grid finger discoloration, called framing, is located at the edges of the cell. Thus, the discoloration is correlated either to cell cracks or to the cell edges. Therefore, the probable reason for the onset of grid finger discoloration is moisture entering the PV module from the backside (through the back sheet) and entering the sunny side of the cell through cell cracks or between single cells. This assumption is supported by the observation that glass-glass modules seem to be completely resistant against grid finger discoloration, since the glass at the backside is a much better barrier to moisture than usual back sheet foils. After the invading water has entered the cell surface, a small fraction of silver from the grid fingers may dissolve and migrate into the encapsulation foil on top of the grid fingers. Through a chemical reaction the dissolved silver ions are reduced and form metallic nanoparticles exhibiting a typical brownish colour. It could be shown, that there is a correlation between the type of polymer foils used for module assembly and the sensitivity to grid finger discoloration [4]. Thus, the current hypothesis is that certain polymer foil additives trigger the formation of "snail trails" in photovoltaic modules, but this has not yet been investigated in detail.

It should be mentioned here, that there are controversial analytical results and conclusions concerning the chemical composition of "snail trail" discoloration. Mainly using Raman spectroscopy as the analytical method, a variety of silver compounds were found and attributed to the origin of "snail trails". This includes silver acetate, silver carbonate, silver phosphate or silver sulphide [5, 6]. Possibly, there are different forms of grid finger discoloration and the term "snail trails" describes a class of failures. Nevertheless, it is commonly accepted that invading moisture plays a key role and that there is a dependency on the type of encapsulation and back sheet material. Further stress factors, like UV irradiation, current or temperature may be additional triggering factors. In our opinion this disunity of the scientists does not have any practical relevance, as discussed below.

Diagnostic test procedures for grid finger discoloration

Several lab procedures have been developed to test the sensitivity of module materials for grid finger discoloration. This can be done by treatment of a one-cell mini-module with damp heat conditions under bias and subsequent microscopic inspection of grid fingers at the cell edge. As shown in Figure 5, a clear difference can be observed between samples which are sensitive to or resistant against grid finger discoloration after damp-heat treatment for 1,000 hours. In this example, the samples were different only in their foil materials (encapsulant and back sheet) but contained the same type of cell. This shows that the solar cell itself or the type of silver paste is of minor influence. The mini-module test is very useful for module manufacturers in order to qualify their foil materials with respect to grid finger discoloration. Therefore, there is an actual SEMI activity to standardise this kind of test (SEMI SNARF Document #6071). Unfortunately, this test principle is not fully applicable for standard-sized modules. It turned out in experiments that for standard modules not all sensitive material

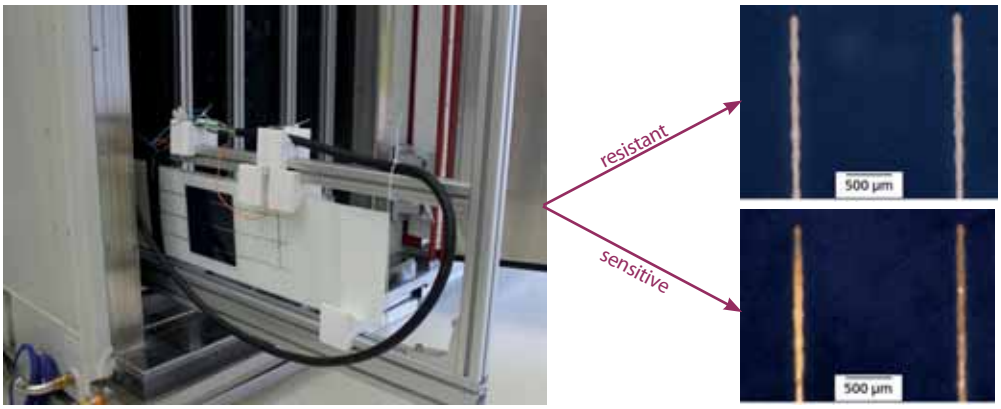

Figure 5. Test setup for mini-module samples and test results. If the colour of the grid finger remains unchanged after 1,000 hours test duration the material combination can be regarded as resistant to grid finger discoloration. In contrast, a significant brownish colour of grid fingers at the cell edges indicates sensitive foil materials

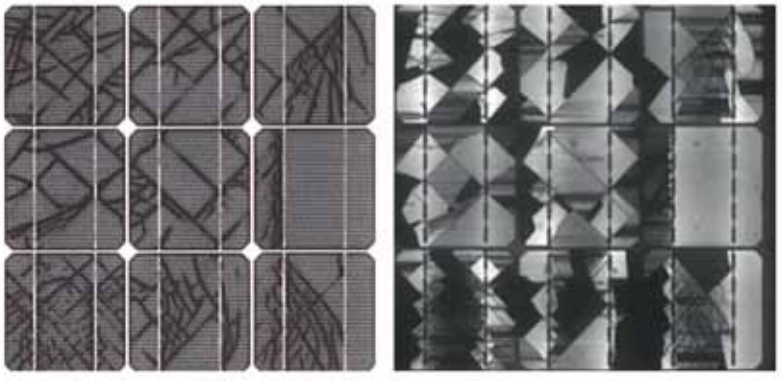

Figure 6. Section from a PV module (nine cells): photograph with excessive contrast (left) and electro-luminescence image (right)

combinations showed grid finger discoloration after 1,000 hours of damp-heat testing. Probably, the test time is too short for big samples.

Studies had shown that the susceptibility of modules to grid finger discoloration is not tested by the IEC 61215 and a combined mechanical load, humidity freeze and UV test had been proposed [12]. For "snail trail" evaluation of installed PV modules the only straightforward test procedure is an electroluminescence measurement to detect cell cracks combined with microscopic inspection of grid fingers. This requires field inspection with mobile electroluminescence and microscopy equipment or in case of ambiguity the dismounting of the affected module and transportation into a PV service lab.

The impact of "snail trails" on module performance

From the microstructural origin of grid finger discoloration as described above, there is one major implication to its impact on the electrical module performance: the discoloured area is exclusively at the site of grid fingers, not on the cell surface itself. Therefore, the active cell surface is not impaired and, hence, the discoloration does not lead to reduced light harvesting. Furthermore, electron microscopic studies on affected grid fingers showed that there is no significant change of material structure or cross section which might have influence to the conductivity [5]. Thus, "snail trails" themselves should not cause a reduction of electrical performance. In practice, this has been investigated at different places and published several times [6-8]. At first glance, many examples for reduced power output from "snail trail" affected PV modules have been found. However, it turned out that it is difficult to measure the influence of grid finger discolouration separately from any underlying cell cracks.

An extreme example is shown in Figure 6. A section of a PV module is shown which is significantly affected from "snail trails". The comparison between photograph and electroluminescence image confirms that each dark trace is correlated to a cell crack. In this case however, so many cracks have formed that many cell areas became electrically isolated and hence, were lost for the module's performance. In this case, one can even compare it quantitatively: the measured reduction in power output was ~40% which matches almost exactly the sum of inactive cell area.

Besides those extreme cases, it was confirmed also for modules with little or moderate discoloration that the power reduction (if any) is assigned to the cell cracks and not to the grid finger discoloration as such [8, 12].

Generally, it is important to minimise the number of macroscopic cracks already in the cell and module production. However, not every crack immediately leads to a power loss and one has to distinguish between electrically active and inactive cracks. Active cracks cause electrically isolated cell areas and result in a power loss which is detectable in the standard sun-simulator test. On the other hand, inactive cracks hardly affect cell or module power but can become electrically active later on during the module operation in the field.

EL imaging is a commonly applied method for crack detection in the PV industry. As a manual operator-based EL inspection depends on the operator's experience and skills it is of limited reliability and can hardly be used to obtain quantitative results. Therefore, the method of choice is a fully automated EL inspection, which includes automated software algorithms in order to detect nearly all macroscopic cracks timely during cell and module production. Applying modern

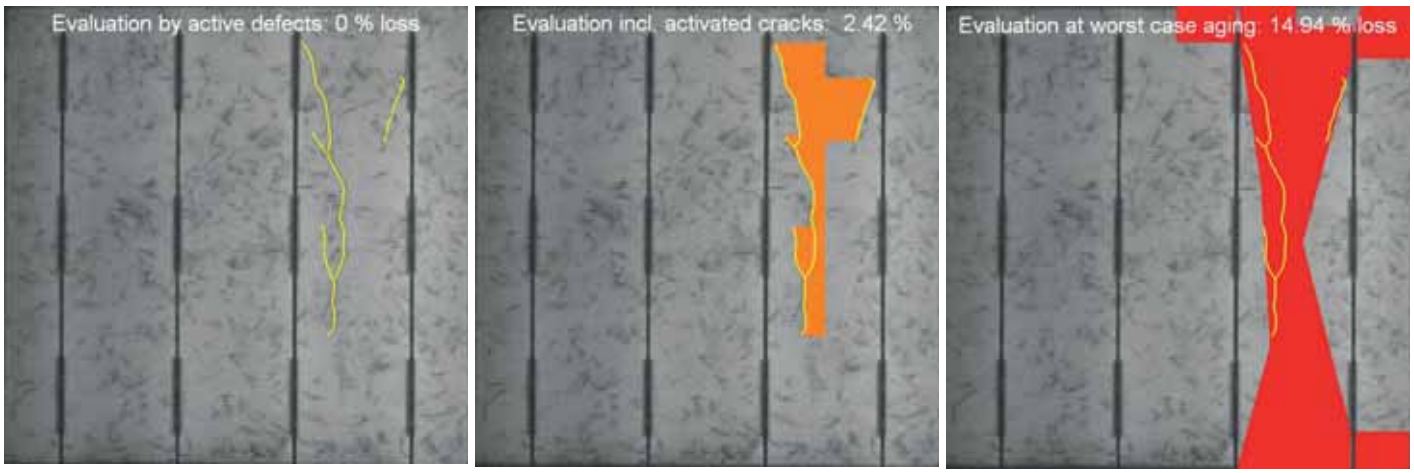

Figure 7. Automated identification of cracks can serve as a basis for the quantitative estimation of expected power losses. Left: crack detection using image processing algorithm. Middle: estimation of inactive cell area due to cell crack. Right: quantification of worst case scenario due to detected crack

image processing algorithms, it is not only possible to detect the smallest cracks reliably; the prospective power loss can also be predicted by software simulation, assuming that the inactive cracks become active later on in the field (see Figure 7). An automatic EL inspection in module production right before lamination enables the replacement of defective cells and avoids both "snail trails" and, even worse, cracks which will cause power loss in the module.

"Snail trails" and long-term reliability of modules

Only recently, the first studies on the mid-term evolution of grid finger discoloration have been published [9]. The authors investigated modules affected by "snail trails" over the period of two years and came to the conclusion that after the initial formation of discoloration in the first year no (or only very little) evolution of new traces could be detected two years later.

Moreover, no further decrease of electrical performance was observed. Thus, the good news is that "snail trails" obviously develop only at the beginning of outdoor operation and do not have any measurable long-term impact. One can even regard "snail trails" as indicator of cell cracks which were invisible otherwise. Having in mind that cell cracks may cause severe power loss and that those cracks may be the starting point for dramatic cell damage after mechanical stress like snow or typhoon, "snail trails" may serve the PV operator as guide for regular inspection. ■

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Authors

Sylke Meyer is head of the research group "Silicon Wafers" at Fraunhofer Center for Silicon Photovoltaics CSP, Germany. She studied biochemistry and received her Ph.D. in the field of structural analytics from the Martin Luther University in Halle-Wittenberg, Germany. Her current research topics are chemical analytics at PV materials.

Marko Turek leads the team "Electrical characterisation of solar cells" at Fraunhofer CSP. He studied physics at the Dresden University and received his Ph.D. in the field of condensed matter theory from the University of Regensburg. His research focuses on the loss analysis of solar cells, advanced characterisation methods, and the development of new test methods and devices.

Stephan Großer studied physics and received his Ph.D. in the field of surface science at the Martin Luther University Halle-Wittenberg. After working in the PV industry he joined Fraunhofer CSP in 2011 where he leads a team which is focused on microstructure characterisation of materials, devices and defects.

Thomas Manke is the head of solar business at pi4 robotics in Berlin. He is an educated precision mechanic and got his MA at the Humboldt-University Berlin in 2006. Afterwards he founded the company OB-Vision and developed vision systems for glass inspection. In 2010 he joined pi4 robotics.

Christian Hagendorf is head of the research group "Diagnostics of Solar Cells" at Fraunhofer CSP, Germany. He obtained his Ph.D at Martin Luther University, Halle-Wittenberg, in the field of surface and interface analysis of semiconductor materials. His research activities focus on optical, electrical, microstructural and trace elemental characterisation of solar cells and modules.

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Project briefing

ADANI OVERCOMES BIBLICAL FLOODING TO BUILD A 648MW PV PLANT

Credit: Adani

Project name: Kamuthi Solar Power Plant
Location: Tamil Nadu, India
Project capacity: 648MW

Set across a semi-arid stretch of land in far south India, the world's second largest solar plant and India's biggest to date is a pertinent symbol of India's emergence as one of the most dominant renewable energy markets on the planet. Already under intense pressure to physically construct the entire project capacity in just eight months, heavyweight Indian infrastructure conglomerate Adani also had to withstand unseasonal and unprecedented extreme weather in late 2015. Incessant rain wreaked havoc for a full three months, flooding the site and almost bringing the construction process and equipment deliveries to a halt. Even after completion, legal issues over electricity tariffs and deadlines ensued, but the project remains a remarkable achievement, one that sets the tone for India's forthcoming 'ultra mega' solar parks.

Adani's project, located near Kamuthi in the Ramanathapuram district of Tamil Nadu, required an investment of INR45.5 billion (US$679 million) and around 8,500 workers. At 648MW it represented a significant step up from the previous record-holding plant, the 579MW Solar Star project completed in 2015 in California by SunPower for BHE Renewables. However, Adani can no longer lay claim to the record, following the completion of an 850MW solar project in the western province of Qinghai, China, in January 2017.

Land acquisition in Tamil Nadu took a long time and it was finished several months over schedule, says Tim Buckley, director of energy finance studies, Australasia at the Institute of Energy Economics and Financial Analysis (IEEFA) and a close observer of renewables in India. However, the learning from this endeavour around supply chain management and logistics will have filtered into the entire Indian renewable energy system. Now even the banks and financiers are beginning to understand solar, Buckley says.

In the midst of completing the Kamuthi project, Adani's energy-related ventures have attracted some controversy. The conglomerate is still pushing to start mining operations at the Carmichael coal mine in Queensland, Australia. This is a mammoth undertaking, which has not only riled environmentalists, but has also got some economists scratching their heads over its feasibility. Indeed, Adani Power, part of the Adani Group, recently reported another net loss of US$48 million in the three months through to December, putting it on track for its fifth year of enormous losses since FY2012, according to a report from IEEFA. Ironically, this is partly the result of coal imported to India losing market share to lower-cost domestic coal and ever more cost-competitive renewable energy sources, particularly solar, which has been on a steep downward trajectory since the end of 2015.

Nevertheless, reflecting on the Kamuthi solar plant, Gautam Adani, chairman of the Adani Group, said of the project: "This is a momentous occasion for the state of Tamil Nadu as well as the entire country. We are extremely happy to dedicate this plant to the nation; a plant of this magnitude reinstates the country's ambitions of becoming one of the leading green energy producers in the world."

Land preparation

To kick off the project, Adani had to level and grade large tracts of land. This was followed by plotting the land, using surveyors to mark the ground before driving in steel piles to support the modules. An office was set up on site along with a major lighting facility to allow for work through the night. At one point the developers had to drill 1,200-2,000 piles on a daily basis. The piles were tested by exerting a pressure of 1,200kg per sqcm to see if they would remain in place to indicate that they could withstand high wind speeds and other extreme conditions.

"As a solar power producer our land requirement is huge and you know land is not an easy task in a country like India which is highly populous," says Jayant Parimal, chief executive of renewable energy at Adani. However a site with high irradiation was found 90km from Madurai,

By Tom Kenning

an Indian city that houses the famous Hindu sanctuary known as the Meenakshi Amman temple.

The site not only provided enough space, but it was also easily accessible from the nearest port town of Tuticorin. Nevertheless sourcing a workforce and equipment from Kamuthi remained a challenge given that it is a remote agrarian and non-industrial town.

Imported equipment required large storage areas so Adani built an interior warehouse of 20,000sqm and an outdoor warehouse of 120,000sqm. Inverters required enclosed space, but the storage infrastructure was not ready in time for delivery so the management had to hire other space in Kamuthi town until the on-site warehouses were complete. They were not ready until mid-October 2015, giving the firm just seven months to complete the plant by the 31 March 2016 deadline.

Modules were mounted in clusters of 4-5MW each, with the overall site divided into five sections of different capacities. Modules from manufacturers in China, Japan and Malaysia and Italy were all used. Meanwhile, 144 pre-engineered buildings were made to house the 576 inverters.

Transmission and O&M

Industrial technology firm ABB was responsible for the design, supply, installation and commissioning of the project's electrification and automation systems, which included two 230kV and three 110kV outdoor switchyards to connect to the local transmission grid.

The entire 648MW plant is now connected with the Kamuthi 400kV substation, making it the world's second largest solar unit at a single location.

ABB was also responsible for the SCADA system operating the plant. "As such a big plant, the fluctuation in [power] will be actually affecting the grid operations," says Sumeet Sharma, Adani project head of protection and metering. "So in that case the grid operators will request us to maintain the power of the plant at a fixed output, so you need an aspect in the SCADA system that will help you do that function."

Once the plant was close to completion, the team was even able to use the chance event of a solar eclipse to test out the capability of the plant to adjust to sharp fluctuations in power and respond to the requirements of the grid using the SCADA system.

"The challenge was that we had multiple suppliers of equipment; for example the relays, the inverters and all of that has to be validated with the SCADA system," adds Ahmed Khan, vice president, power generation ABB India. In some cases, the teams had to wait to get hold of the necessary equipment due to the various delays over the course of the project construction.

Israel-based robotic and water-free solar panel cleaning solutions provider Ecoppia provided its robots to Adani so that no water is required to clean the enormous plant in this semi-arid region. The robots are solar charged during the day before they start cleaning with soft-micro-fibre brushes mounted on rails. These automated systems can also be remotely monitored, managed and controlled.

Timelines and extreme weather warnings

Adani's engineers reached the site in July 2015 and the first batch of module and mounting structure containers arrived from China in late August. Modules started to be installed in October with a target of deploying 3MW a day with a necessary extra push as the deadline approached. Sections of the plant would then be commissioned gradually as the plant grew. However, later in October, monsoons from the north-east descended upon Tamil Nadu, hitting headlines across the world as flooding started to affect even the mega city of Chennai.

As the rains continued to make the land swampy and marshy, the daily installation rate reduced dramatically and targets started to be missed in most areas. The month of October saw just 1.6MW of solar modules set up versus the necessary 90MW. Meanwhile, just 10 inverters were set up against the target of 80 and zero houses for the inverters were completed against a goal of 20. November figures were equally glum followed by a full halting of work in December.

The local port town of Tuticorin was hit

Credit: Adani

Ecoppia Kamuthi uses the waterless, automated cleaning system produced by Israel's Ecoppia

Credit: Ecoppia

heavily, cutting off the supply chain to the plant, since the port was due to receive more than 6,000 containers from around the world including from Taiwan, Malaysia, Italy, China, Israel, Germany, Turkey and Switzerland.

With four months to go, an emergency meeting was held at Adani corporate offices since logistics had become the hardest challenge. The firm needed to unload 100 containers per day so it started unloading containers simultaneously in four segments and even cranked up operations to 24 hours a day instead of the intended 12 hours. Workers were also put into three separate shifts.

From the initial 3MW daily requirement, the team now had to install between 10-12MW per day, which is the equivalent of around 40,000 modules. The project timeline slowly started to recover with the team installing 163MW in January against the 126MW target, such was the upsurge in efficiency of the workforce. However, engineers were still lagging by some way with inverter installations.

Officials from Tamil Nadu Generation and Distribution Corporation (TANGEDCO) started doing preliminary checks on the site and power was able to be evacuated from at least portions of the site. By the commissioning deadline, electricity from 360MW of capacity was already being exported to the grid.

"The size of 648MW in eight months was unimaginable for anybody," says K.S Nagendra, the Kamuthi project director. "When we landed at site and realised the magnitude of the work we needed to do, we thought we had bitten off more than we could chew. During the monsoon we were in a shambles to reach our target by March – we really lost hope to reach there. In future we will see that proper pathways and drains are made so that rain gets into local drains and ponds."

Tariff dispute

Even after commissioning, the troubles did not end. In November 2016, the Tamil Nadu Electricity Regulatory Commission (TNERC) rejected Adani's call for a revaluation of the tariffs it is set to receive for the Kamuthi plant.

PV projects commissioned in the state before 31 March 2016 were due to receive a tariff of INR7.01/kWh (US$0.103) from TANGEDCO, but this would go down to just INR5.1/kWh for any delayed projects.

While 360MW of Adani's project was commissioned before the deadline, 288MW were delayed following grid connection issues. This delayed capacity was completed by Adani subsidiaries Kamuthi Solar Power (216MW) and Ramnad Renewable Energy (72MW), but both entities also filed appeals to TNERC, claiming that the cyclone and heavy, extended rainfall in the region caused significant damages and delayed project execution. Both companies also claimed they had actually completed the projects ahead of the deadline, but the necessary substations had not been provided by TANGEDCO resulting in completion after the deadline.

Nevertheless, the Adani project will receive the lower tariff after TNERC rejected the appeals. Kamuthi Solar Power and Ramnad Renewable Energy have also filed pleas as a Dispute Resolution Petition, which will be taken on at the tribunal.

Despite the troubles, Adani has continued to show strong intent worldwide with significant project plans in Australia. Furthermore, Parimal says: "We are exploring the possibility of setting up PV plant in Bangladesh. So it is still in conceptual stage. Nonetheless we are very keen."

An Adani entry to neighbouring Bangladesh would be "a truly transformative investment proposal", adds Buckley.

Reflecting on the legacy of the Kamuthi project, Gautam Adani says: "India is one of the fastest growing economies and energy is a crucial part of growing economic development. To meet this surging demand solar is the best form of energy. India has tremendous scope for generating solar energy and it is high time we concentrate more on conservation of resources." ■

Kamuthi in numbers

- 380,000 foundations
- 2.5 million solar modules
- 27,000 MT of structures
- 576 inverters
- 154 transformers
- 6,000km length of cables
- 1,012 hectares of land

Credit: Adani

New approaches to solar O&M in China

Credit GCL New Energy

Operations & maintenance | Proposals by Chinese authorities to scale back the subsidies available for grid-tied PV will require new efforts to maximise the performance of power plants. Karl Hong Wan of the GCL Design & Research Institute explores some of the innovations in O&M practices that will help China's solar industry cope with decreasing financial support

In October 2015, the National Development and Reform Commission (NDCR) of China released a discussion paper entitled "Notice on perfecting the policy about the benchmark price of onshore wind power and photovoltaic power generation" (hereinafter referred to as "2015 notice"). This stated that during the "13th five-year plans of China", the benchmark price of onshore wind power and photovoltaic power generation would be reduced with the scale of development to achieve the aim that "by 2020, the on-grid prices of wind power generation and coal-fired electricity are equal, photovoltaic power generation price and power grid sales price are equal". Its proposals are summarised out in Table 1.

In December 2016, the NDRC followed this earlier pledge by issuing a notice setting out its intentions that from January 2017 the on-grid benchmark electricity price of newly built PV and onshore wind power plants would be lowered. To continue encouraging the development of distributed PV, the NDRC notice said there would be no changes to the subsidy criteria for distributed PV power generation (Table 2).

Resource area		PV power plant online electricity price benchmarking						Accumulative adjustment for five years
		Now	2016	2017	2018	2019	2020	
Class I areas	Electricity price (yuan/kWh)	0.9	0.85	0.82	0.79	0.76	0.72	Falling 18%
	Decrease (%)	5.56	3.53	3.66	3.80	5.26		Falling 20%
Class II areas	Electricity price (yuan/kWh)	0.95	0.92	0.89	0.86	0.83	0.8	Falling 15%
	Decrease (%)	3.16	3.26	3.37	3.49	3.61		Falling 16%
Class III areas	Electricity price (yuan/kWh)	1	0.98	0.96	0.94	0.92	0.9	Falling 10%
	Decrease (%)	2.00	2.04	2.08	2.13	2.17		Falling 10%

Source: NDRC.

Table 1. PV power plant price reduction analysis as set out in 2015 notice. Note: Chinese government classifies 3 different classes of areas based on irradiation level. Each area has its own subsidy policy.

Subsidy reduction – cause and effect

Why are new energy subsidies facing these sharp cuts in China? According to National Energy Administration (NEA) officials, the development of the new energy industry will face two main areas of difficulty and contradiction. On the one hand, the increased capacity of new energy is much higher than the grid's ability to absorb this new generation, and the problem of curtailing wind and PV power is thus becoming serious. On the other hand, financial subsidies for PV and wind still face a big gap, and the original subsidy model is thus unsustainable. Decision makers are facing great pressure and real challenges on the best policy choices to underpin the future energy system in China.

Meanwhile, industrial technological progress and increased production capacity are bringing the costs of PV down; lowering the benchmark price of PV power plants and land-based wind power helps alleviate the pressure of new energy subsidies, so the subsidy cut is also an inevitable

Resource area	Now (yuan/kWh)	After adjustment (yuan/kWh)	Adjustment range
Class I areas	0.9	0.65	Falling 27%
Class II areas	0.95	0.75	Falling 21%
Class III areas	1.0	0.85	Falling 15%

Source: NDRC.

Table 2. PV power plant price adjustment summary as set out in 2016 notice.

trend of industrial development.

While price reductions are the inevitable trend of industrial development, they will cause many adverse effects. Power generation enterprises, power grid enterprises, equipment manufacturers industry and the financial industry will suffer varying degrees of profit loss. Investments in PV power plants will be significantly reduced. Owing to the complexities of renewable energy subsidies in China and the large number of different organisations involved, constant adjustment of subsidy levels may mean PV power companies do not receive payments promptly, making debt repayment periods longer.

In short, with subsidies going down, how PV companies survive is becoming a big problem. In order to keep and pursue higher profits, some companies may lower power plants' design and construction standards, resulting in plants of poor quality that will be harder to operate and maintain. Investors may be discouraged by the undulation and uncertainty of the benchmark PV price.

Operation is a long-term focus for the profitability of PV plants

In the face of the gradual reduction of subsidies, the PV industry's reliance on government support is becoming a thing of the past. PV enterprises should thus focus on upgrading the technical content and the quality of PV power plants they build to maximise their generation potential.

According to the 25-year theoretical life-cycle assessment of PV power plants, the electricity income from power plant operation is fixed and stable for a long time. The answer to declining prices lies in the application of intelligent operation and maintenance (O&M) methods and technological innovation to boost a plant's generation capacity, lower the levelised cost of electricity, improve the internal return of the power plant and protect the power plant's revenue. That will bring into reach the final goal of parity, which will be the key of the future PV power generation business.

The following is our experience in the operation and maintenance of photovoltaic power plants and technical innovation.

1 – Establish a reasonable O&M architecture and efficient management methods

According to power station investment and development, location and solar resources, a reasonable O&M structure should be formulated, and both centralised and regional O&M operations should be adopted.

The development of appropriate systems covering areas such as power plant standards, evaluation, equipment, defect elimination, emergency response, training, technical communication and other management functions will ensure the right personnel are in place and improve the overall quality of a plant's operation. Building an area detection centre combining daily operations staff and professional mechanics to design optimised programmes will help enhance plan performance and contribute to improved power generation.

Selecting a professional and experienced maintenance employee to form an effective regional maintenance core team will ensure maintenance tasks can be undertaken and completed as quickly as possible, maximising the benefits of having an efficient O&M regime.

2 – Establish a scientific and quantifiable evaluation index

As we all know, the construction period of a PV power plant is generally short and not all projects are completed to a high level of refinement. Each project covers a large area, has many different categories of equipment and is affected easily by natural environmental factors. Due to the bad matching index and poor compatibility caused by differences in the sources and technical attributes of items of equipment, equipment can be inefficient with a high failure potential.

Based on data gathered from a plant covering aspects such as system-level operation, equipment and O&M, and using numerical system evaluation, it is easy to develop relevant operating system procedures and eliminate hidden dangers and possible malfunctioning of equipment, thus making the plant safer and more reliable. Two methods for doing this are as follows:

System efficiency analysis. 'System efficiency' refers to the ratio of annual utilisation hours of a PV power station to peak sunshine hours. It is the core index to evaluate the operational level of the whole PV power system. If the

Intelligent management solutions enable large numbers of plants to be centrally operated

Credit GCL New Energy

system efficiency indicators are beyond the reasonable range, it is necessary to make a further analysis of the energy loss distribution across the entire system of the power plant, from the array, cables, power distribution equipment and so on. Any abnormalities at any of these points need to be found and eliminated.

Equivalent utilisable hours analysis. 'Equivalent utilisable hours' refers to the working hours of power generation under full-load operating conditions, which is an important index for evaluating the operational level of the power station. The system performance of the whole power plant can be evaluated through comparison with surrounding PV power plants under the same area and resource conditions, to optimise the daily management level and efficiency and equipment utilisation rate, so that the potential for generating power can be improved.

3 – Build intelligent power stations, establish an intelligent operation and maintenance system

The evolution of "Internet+", the "Internet of Things" and other advanced information platforms offers the opportunity to deploy intelligent management solutions. The need for intelligent PV power station operation and maintenance systems is growing as the scale and geographical distribution of the industry, offering companies the ability to centrally operate and manage large and widely dispersed portfolios and optimise O&M regimes across their fleet.

Intelligent systems enable equipment running data and on-grid information to be collected automatically so that abnormal equipment or system faults can be alarmed in real time and responded to immediately. This frees up operating crews to focus on maintaining equipment and overall plant efficiency.

Through the intelligent gathering and use of data, companies can continuously monitor the operating conditions of power plants, allowing them to realise the standardised, refined and automated operation of their assets. With the assistance of statistical information it is relatively straightforward to centrally or regionally operate large number of plants, remotely diagnose any problems and deploy human resources in the most efficient manner as they arise. In this way, it is possible to reduce O&M costs and increase project revenue, while at the same time acquiring a valuable mine of data as a reference for future project development.

Automatic cleaning is just one of the technological innovations emerging for improving solar O&M practices

Credit: GCL New Energy

4 – Technical methods for optimisation of O&M

Equipment inspection is the regular and basic work of the operation and maintenance process for PV power plants. Intelligent monitoring systems can assist manual tasks such as evaluating component degradation and soiling pollution and technically improving the system configuration and so on by allowing system failures and defects to be processed as soon as possible to deal with equipment system failures and improve the intact rate and efficiency.

Array dust is one of the important factors affecting PV power generation and the question of what cleaning methods are the most effective has also gained more and more attention recently in the context of optimal O&M. Common cleaning methods include manual cleaning, specially engineered cleaning vehicles and a new breed of intelligent cleaning systems. This latter category makes intelligent judgments on when to clean based on continuous monitoring of generating production and are likely to become a standard tool in the future operation of large power plants.

O&M central to competitiveness

With the rapid development of the PV market, the number of domestic PV power plants in China is rising exponentially and the effective operation and maintenance of PV plants is becoming a vital long-term consideration for the photovoltaic industry business, whose market prospects are very broad.

With the advancement of electric power reform in China, the independent development of electricity sales business has become possible; the customer group for PV operation and maintenance businesses is expanding from single power production enterprises to financial power investment owners and individual owners of distributed generation plants. Power plant O&M practices are changing too, as is the variety of different power plant types and dispatch modes. Innovation in operation and maintenance therefore lies at the core of the long-term competitiveness not just of O&M enterprises themselves but of the PV industry at large.

Although the imminent decline in on-grid tariff subsidies for PV power China is a natural corollary of a maturing industry, the challenge now for that industry will be to find the best technologies, systems and skills to ensure the safe, productive and profitable running of PV power plants over their lifetime. ■

Author

Karl Hong Wan attended the graduate school of Southeast University in China, majoring in electrical engineering, power system measurement and intelligent instruments. He has been engaged in the design, construction and operation of power substations, power plants and renewable energy generation for 30 years. He currently works in the design and research institute of GCL New Energy.

Maximising PV plant availability

Asset management | As one of the biggest utility PV owners in the UK, Foresight has extensive experience of getting the most out of operational solar plants. Its technical director Arnoud Klaren draws on some of the lessons the company has learned from minimising the risks that affect solar projects over their lifetime

Credit: First Solar

As a relatively young industry, the UK solar market is still developing when it comes to solutions on how best and most efficiently to manage asset performance and maximise availability.

For solar asset owners, the challenge lies in how best to mitigate risks that have the potential to impact upon a plant's availability – the amount of time it is able to produce electricity – during its operational lifetime after the engineering, procurement and construction (EPC) warranty. Experience from the field suggests that a simple preventive maintenance scope is no longer sufficient, but by actively looking at further enhancements, we can continue to make significant improvements.

So, as the market experiences increasing consolidation, what precisely are the preventative steps that asset owners should be taking to maximise availability?

Foresight looks at the overall preventative maintenance of plants in four stages:

1. Technical due diligence pre-acquisition
2. Technical due diligence during the two year EPC warranty period
3. Ongoing maintenance after two years defining common objectives for owner and Contractor.
4. Continuing plant improvements that help preventive maintenance measures

Maximising the availability of PV power plants is a key aim of successful asset management

Pre-acquisition

Before completing the acquisition of a new asset, it is imperative to carry out a thorough technical due diligence since this is the last opportunity to identify risks and mitigate them, hence reducing unexpected costs during the operational lifetime. If the asset is still in construction phase, there's a real opportunity to get involved and mitigate risks at an early stage. Alternatively, if involvement happens post-construction there's typically a short timeframe so it's particularly important to have a well-defined process and a dedicated team.

When a thorough risk analysis has been conducted using documentation assessment, multiple site visits, analysis of plant data, laboratory tests and the possible involvement of other third-party specialists, mitigation can be achieved in several steps.

If the risk is deemed too large, it may be preferable to abandon the acquisition altogether. However, if the risk is considered manageable, the second step is to minimise those risks which can often be achieved by proposing changes in the design or equipment, or to the construction process. For example, if a certain inverter brand is known to be unreliable, the parties can reach agreement jointly to switch to a different brand which would reduce the risk of excessive corrective maintenance during the lifetime of the plant.

Once risks have been reduced as much as possible, it then falls to transferring risk to other parties. It is typical in the UK solar sector, for example, to establish a performance and defects guarantee by the EPC backed up with, for example, a retention, where a percentage of the acquisition price is held in an account during the EPC period to guarantee payment of liquidated damages, if applicable. In addition there is always insurance and product warranty. For example, inverters frequently come with a five-year product warranty. After those first five years it becomes statistically more likely for inverter parts to fail, which can be quite costly. This is especially the case when components become obsolete. It will be challenging for the owner to decide at each failure whether it's worth spending money again on a replacement part, or whether it's more economical to have the whole station replaced. To mitigate this risk the owner can try to negotiate a long-term warranty with the manufacturer which transfers these responsibilities and associated risk to the manufacturer while the owner pays a fixed annual fee, reducing risk and assuring more stable returns.

The remaining risk of course has to be accommodated, and is commonly dealt

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with through financial budgeting and planning.

This risk mitigating process at acquisition can have an important impact on the operation and maintenance during the lifetime of the plant and can therefore be seen as part of the overall O&M strategy.

EPC period

The two-year EPC period provides the next opportunity to assure that the plant is fully prepared for a lifetime of reliable operation. This is achieved by reassessing the asset and making sure that it still fully complies with all the contractual requirements of the EPC contract before the EPC warranty expires.

At Foresight, our in-house specialist technical team manages this process where every aspect is reassessed, often assisted by external specialists like accredited laboratories, technical advisers or high voltage specialists.

Questions considered include: are all the plant's data available on the monitoring system? Are the key performance indicators (KPIs) in line with the expectations and guarantees? Are all planning requirements correctly discharged – for example, has the landscaping and ecological management plan been followed up on? With the plant fully operational can we now confirm that the grid connection requirements are being respected, including the actual import capacity and power factor?

Sometimes small findings can be an indication of significant defects. After two years of operation it's not uncommon to find that a few strings have been left disconnected by the contractor. This can easily be dismissed as an oversight, but it can also mean that these strings are causing insulation faults on the inverter. If that is the case it is highly recommendable to check all strings on site for damage since this may be an indication of poor cable installation during construction.

Another example is potential-induced degradation (PID), a technical defect where stray currents in PV modules cause degradation. PID hasn't yet manifested itself on a large scale in the UK but this may be due to the fact that it can take a few years to develop. Whenever it does, it may cause power losses of up to 30% at plant level. It is advisable to take a proactive approach and test all modules before the EPC warranty expires. If PID is detected, a technical solution may be available depending on the plant-specific design, but such a solution is unlikely to recover

Predicting failures in PV power plants before they occur is one way of maximising availability over its lifetime

Credit: SMA Solar

full performance of the plant. Furthermore it changes the plant's design, which can lead to changes in its operational regime. If PID is detected, Foresight would take all the above into consideration and engage with the EPC contractor to have a solution implemented that makes the project whole again, either through technical or financial means, or a combination of both.

Any defects that are discovered as a result of this rigorous process are notified to the EPC with the request to be rectified under the EPC warranty. This is crucial because after the EPC warranty comes to an end, the plant will face a lifetime of operation under an O&M contract only. With all defects resolved, we have mitigated the risk of excessive failures during the operational phase, which is why this can also be considered as part of the overall O&M strategy.

O&M period and plant improvements

During the EPC period, the plant owner is generally covered by a performance ratio (PR) and defects guarantee with the EPC contractor. The challenge now is that since many UK solar assets have seen their EPC warranty period expire, plants are only covered by an O&M contract, often with lesser guarantees and a lower liability cap. This can leave the plant owner much more exposed to operational risks which can lead to more volatile returns.

The main hurdle to overcome when negotiating with O&M contractors is the fact that the owner and contractor have opposing objectives. The owner is looking for the highest possible performance of the plant at the lowest cost, while the contractor is looking to increase his income though additional services and reduce his expenses. So how can it be possible to align the owner and the contractor to ensure they work towards the same goal?

Let's first look at the costs that are incurred whenever there's a failure at a solar plant.

The first cost is related to the labour the contractor spends on assessing and fixing the failure. By assuming this within the scope under the fixed fee, call-outs no longer present a profit opportunity for the contractor. Instead, the contractor becomes incentivised to continue with preventative maintenance to a good standard to avoid costly call-outs.

The second cost is related to replacement parts. Replacement parts can be expensive, and it's also difficult to predict how often parts fail and how their purchase price evolves over time. Contractors would need to increase their flat fee significantly to cope with this unknown risk. By reaching agreement with the contractor that these parts can be recharged without a margin, the owner effectively removes the risk for the contractor but again avoids turning corrective maintenance into a profit centre for the contractor.

The third cost is represented by the loss of production during the failure. Typically this is covered by the availability guarantee offered by the O&M contractor. Although owners may feel protected by this guarantee, it's often the case that many scenarios are excluded from this guarantee, or the associated liquidated damages are low or capped to a low amount. It is only if the contractor feels the financial pain of the outages associated to the failures that he will be fully incentivised to correct the failures as soon as possible. He would also put more emphasis on maintaining relationships with his suppliers to receive replacement parts sooner, receive training from the manufacturer to fix equipment

himself and reduce dependency of the manufacturer's aftersales department, and adequately manage his stock.

Notwithstanding the strategy described above to align both parties, the owner still needs to supervise the contractor's performance. Again, the above-mentioned exclusions from the availability guarantee can cause some discussion between the parties in the case of a failure-by-failure. An example is when O&M contractors are able to claim exclusion on the basis of the grid being unavailable. In this instance, the contractor would want to see proof of this in order to accept the claim, which is achievable by contacting the relevant distribution network operator (DNO). It is hence advised to come to an agreement on a monthly basis to avoid escalation when the annual availability calculation is due, especially when liquidated damages are at stake.

The ideal situation for PV owners would be to eliminate corrective maintenance altogether and maximise the plant's availability over its operational life. One way of working towards this objective is by trying to predict failures before they occur, allowing time for correction before damage occurs.

An example is the use of temperature sensors in transformers. In the early days of solar, such sensors were not always installed which left the transformer exposed to overheating and failure. It soon became common practice to install these sensors which would switch off the transformer automatically in case of overheating. It would be even more useful however, if the temperature values were also logged onto the monitoring system and their evolution over time analysed, it would be possible to predict failure before it happens. Similarly, sensors that detect potential discharge (PD) activity could be used to predict failure in high-voltage equipment.

Finally, if we take a peek into the near future we see National Grid and the DNOs taking an interest in the capabilities of solar plants in providing stability to the grid, for example through the provision or consumption of reactive power. New service opportunities may be implemented to take advantage of these capabilities, which require further collaboration between the owner and the contractor.

With more and more UK solar assets coming out of their EPC warranty, the O&M market is very active with many new contracts being signed. Owners will need to become comfortable with this new operating environment where the EPC warranty is no longer providing overall cover. Both the owners and contractors should consider carefully the approach they want to take, their ongoing relationship and how to cover their operational risks. On top of this the future presents new opportunities, like the ability for solar plants to provide services to the grid.

At Foresight, we believe that there is still scope to improve the maintenance and associated performance and availability of solar plants in the UK and beyond. At the same time the landscape in which solar sits keeps changing, which requires foresight and flexibility from those involved. ■

Author

Arnoud Klaren is Foresight's senior portfolio manager and technical director for UK and Spain. He joined Foresight in 2011 from SolFocus, where he spent four years managing solar projects in Spain, Saudi Arabia and Greece based on concentrated PV technology. Prior to SolFocus he founded and managed ThinkSpectrally, a spin-off company of the University of Valencia in Spain, dedicated to quality assurance in PV manufacturing.

Cloudbusting

Forecasting | Short-term PV forecasting offers a multitude of benefits, from trading on wholesale power markets to improved plant operation. Sara Verbruggen reports on some of new the technologies driving forward improvements in the accuracy of forecasting techniques

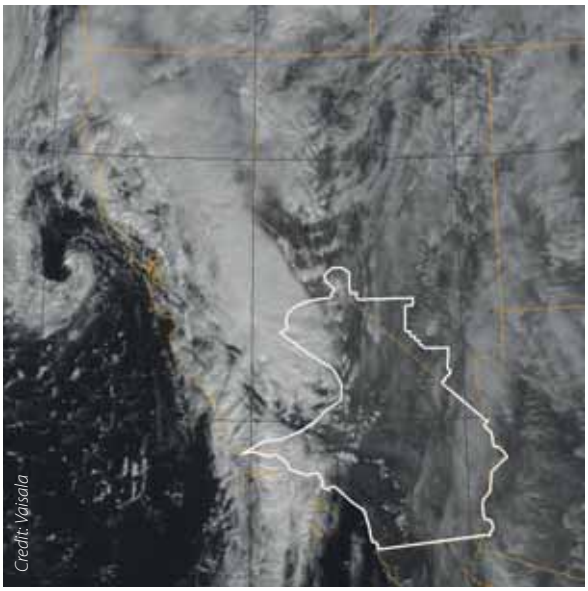
Short-term forecasting bridges the gap between the inherently intermittent nature of renewables such as solar and wind, and power systems and markets, designed around fossil fuel power generation output, which is controlled to match demand. Before the advent of wind and solar PV generation, consumption was the only variable component in the power system balance and forecasting techniques have been used for many decades to predict changes in power demand.

Though there are many emerging use cases for short-term solar PV forecasting, in a nutshell the more accurate this type of forecast, the better the planning of the energy mix, which usually results in the use of lower-cost energy generation. Short-term forecasting spans predictions in weather activity, ranging from one week ahead, to one day ahead, down to intraday, which can be hourly, or sub-hourly, such as every 15 minutes.

Advances over the past two years in several areas, including data analysis, satellite imaging, simulation modelling and sky imaging using ground cameras, have underpinned improvements in the accuracy of short-term PV forecasting. But, according to proponents of short-term PV forecasting tools and services, there still remains untapped opportunity for the technology's use across the global PV market.

Numerical weather prediction (NWP) models are the main tool for making forecasts with horizons of six hours to one week ahead. Key sources of NWP models include the European Centre for Medium-Range Weather Forecasts (ECMWF), which has developed the Integrated Forecasting System. The other is the US-based National Oceanic and Atmospheric Administration's Global Forecast System, a vast dataset, comprising measurements of temperatures, winds and precipitation to soil moisture and atmospheric ozone concentration, all over the world.

Several independent providers of short-term PV forecasts take NWP models and splice these with statistical methods, known as Model Output Statistics, to produce a more accurate forecast. These post-processing algorithms can use historical ground measurements. For instance, Solargis, a Slovakia-based provider of solar forecasting tools, has a database of historical solar irradiation data from different global regions, and can use this to improve the accuracy of its day-ahead or several-days-ahead forecasts.



Satellite image of cloud cover over the southern portion of the CAISO service area, California. Improvements in short-term forecasting capabilities are bringing benefits to energy traders, grid operators and PV plant owners

To make intraday solar PV forecasts providers such as Solargis and Reuniwatt will buy images taken regularly, every 15 minutes or less, from five geostationary satellites, which cover the world's surface. The images are fed into companies' own datasets to calculate regional or global irradiance.

Solargis is one of a few companies that can provide this type of short-term forecasting for most global regions, as opposed to a specific region, such as Europe or North America. The company provides intraday forecasts and day-ahead forecasts in Europe, Africa, Japan and North America and plans to expand these to Southeast Asia in the next few months.

Integration of solar PV

Regulators across Europe, including Germany and Italy, are changing regulations in order to make renewable energy plants part of balancing operations. Forming a balancing group is a requirement of taking part in wholesale power markets. Transmission system operators (TSOs) ensure trades are balanced and balancing group managers are penalised if contracted generation fails to match demand. Short-term forecasting can provide TSOs with data on PV capacity on the grid, so that operation reserves can be more accurately determined.

Improvements to integration of renewable energy is needed as feed-in tariff (FiT) incentives give way to market-based systems, such as auctions for new renewable energy capacity, and direct marketing of output into wholesale markets, which is how conventional forms of energy are traded.

In a growing number of countries in Europe, including Germany, Spain and most recently France, owners of PV plants must also trade output via the wholesale market. These trading block horizons vary, from every 15 minutes in Germany to every 30 minutes in France and every 60 minutes in Spain as well as day ahead markets on the European Power Exchange Market (Epex).

Like energy traders, TSOs, which operate wholesale power markets, benefit from more accurate forecasting because they know how much power from renewable energy sources is required to meet demand.

"More accurate forecasting ultimately allows TSOs the scope to have more energy from renewables traded in the market, as opposed to underestimating the amount in the likelihood that renewable output falls short. This leads to better integration as more renewables that might otherwise be curtailed are actually injected into the grid," says Marion Lafuma, marketing manager, at Reuniwatt.

For TSOs, Reuniwatt's forecasting can provide a global forecast, which requires aggregating satellite images, various regional forecasts and for energy traders and PV

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Reuniwatt has helped manage the production profile of a rooftop solar-plus-storage facility owned by Albioma in Saint-Leu using short-term forecasting tools including sky imaging. Such technologies have helped Réunion Island exceed 30% renewables penetration

Credit: Reuniwatt

plant operators, it uses regional forecasts, including satellite images.

In markets where solar PV makes up a big proportion of the energy mix, which is the case in several European markets, including Romania and Bulgaria, owners of PV plants have to provide a schedule of production to the grid operator. Mismatch in demand and output, as a result of inaccurate forecasting, can lead to financial penalties in some of these markets. Penalties usually consist of a fixed euro amount per megawatt of output over- or under-produced.

Harsh Goenka, business development manager at Solargis, says: "We also see opportunities emerging in India, where central and state-level regulatory commissions have produced draft guidelines, which when implemented could lead to penalties if output and demand from PV plants fail to correspond."

Karnataka has published final regulations, while several states including Odisha, Madhya Pradesh, Tamil Nadu and Rajasthan have produced draft regulations, according to Goenka

"Similarly, in emerging PV markets, in several developing economies, where relatively small amounts of installed capacity can account for a comparatively large share of the overall energy mix, in places such as Kenya and Panama, grid operators could also impose fines if output does not match demand, in order to avoid imbalances in the system. Accurate short-term forecasting may be required," he says.

Solargis has also been operating some demonstrations and pilots for grid operators around the world, which need aggregated forecasts for a region or area in order to get a precise understanding of how much PV output there is in relation to actual demand. Meanwhile, Vaisala, which has started offering short-term PV forecasting tools and services, in addition to wind forecasting, has created a short-term solar PV forecast for the California Independent System Operator (CAISO) market, which it introduced in April 2016.

"This type of forecast contributes to making energy markets more liquid and efficient. The more market participants there are and resultant trading that occurs, the more efficiently the market operates. If the market rules are designed well, price volatility and the day-ahead real-time price spread will be reduced. We do not have much diversity in the ways markets handle solar energy to date but from looking at how wind energy is traded in different markets there is a range of possibilities," says Gwen Bender, product manager for solar assessment services at Vaisala.

Tesolva was set up a year and a half ago to provide custom-made software for companies in various sectors. Its customers for short-term PV forecasting include an energy trader in Europe.

"After a test phase, we were able to convince the client of our service, because he was able to compare us to similarly priced options. Through improved quality the trader was able to make better trading decisions and increase profits," says Joachim Falk, Tesolva's managing director.

While there have been improvements across short-term PV forecasting, the accuracy of intraday forecasting has improved the most. "The inclusion of live data, such as measurements from the PV site and live satellite images, allow for additional improvements that just weren't widely available a few years ago," says Falk.

Goenka says: "In case of intraday forecasting, we are starting to process satellite imagery from newly launched satellites that provide higher resolution imagery and more frequent updates. The newly launched HIMAWARI satellite, for example, provides satellite imagery every 10 minutes. Previously it was every 30 minutes. We also try to reduce the delay with which we are

receiving satellite imagery – this helps us improve forecast in time horizon of next one to two hours."

New developments – sky imaging and simulations

To provide forecasts in time horizons of several minutes, a few providers have also developed tools that use ground cameras installed at PV installations. Sky imaging from ground cameras can take images every few seconds, which in combination with other datasets can predict when and how long clouds will move in front of the sun, which causes a drop in PV output.

Vaisala is prototyping a ground camera for sky imaging because it is looking at the ability to combine images taken of the sky from individual solar PV plants in combination with its own intraday forecasting methods. According to Bender, initial tests indicate sky imaging can significantly improve the short-term forecasting.

She says: "We see this demand for very precise site-level forecasting, for up to 15 minutes, for grid integration of PV plants where PV ramps on and off very rapidly, which can include locations where one or two very large PV plants can account for a very large proportion of the local grid, in emerging US state-level PV markets, where penetration is currently low, such as in south-east US and parts of north-east US."

Tesolva's tool uses PV plant simulation modelling as well as statistical methods to create its intraday forecasts. The simulation modelling, a relatively new approach, can be used in areas where the density of PV plants is relatively low, where there is a lack of available data that can be fed into calculations.

The PV plant is simulated on a cloud server, as a virtual reconstruction with inputs from key components such as modules and inverters and details on array configuration. The advantage of this approach is that not only weather but other site-specific factors that can impact output can be taken into consideration to produce the forecast.

Reuniwatt, which was established on the French island of Reunion in 2010, has developed its own sky camera technology based on infrared imaging that is able to produce images without blurring round the sun, and which can also provide an accurate estimate of cloud height and cloud density.

Images taken at dawn and dusk using the technology are also more accurate, compared with other ground cameras. Overall Reuniwatt claims its Sky Insight technology is able to produce forecasts that are 30% more accurate than other ground cameras.

Sky imaging deployments

Sky Insight is useful for owners of on- and off-grid PV and hybrid plants, which combine PV and diesel or PV and storage. A remote farm in Australia, which generates its own electricity from two 300kW diesel generator sets and a 250kW solar PV farm, has had the camera installed for two years and has been able to achieve savings of AUS$20,000 (US$15,300) a year, because the camera has enabled it to optimise its use of solar PV electricity, while only relying on diesel at night time or when there is a drop in output from the solar plant.

On Réunion Island, Reuniwatt has installed its infrared camera with a 1MW rooftop solar PV installation which is coupled to a 1MW battery storage system. Using the camera, satellite images and NWP to provide forecasts a day in advance, the owner of the installation is able to see how much energy can be injected into the grid, or how much needs to be stored in the batteries, and when to release the energy.

The solar and storage installation owner is obliged to send the TSO a day-ahead forecast, which is fed into the battery storage facility's energy management system, in order to avoid incurring fines for over- or under-production. "The producer used to inject 87% of total electricity output into the grid. With the Sky Insight camera and our forecasting services, the producer is now able to inject 95% of output into the grid," says Lafuma.

A more recent customer for the Sky Insight technology is French oil company Total, which along with utilities and partners, including EDF, is setting up a smart grid test bed just outside of Paris, called IssyGrid. Forecasting starts

How Vaisala's intraday forecasting is giving traders the edge over the CAISO public forecast

The California Independent System Operator (CAISO) market solar 'zone' forecast developed by Vaisala is similar to what has been done for wind energy TSO/ISO-level forecasting.

"This is an hour-ahead forecast that gets updated every five to 15 minutes. To do this we use historical observation and metadata, then train our statistical models on the historical observations and changes in the installed capacity," says Gwen Bender, product manager for solar assessment services at Vaisala.

Energy traders that want another opinion on the forecasted grid-connected solar energy output are using the forecast for an information advantage. CAISO publishes its own grid-connected solar energy forecast. "Everybody can see this, but customers want to know when our forecast is different than the CAISO public forecast because this gives them a competitive advantage and added insight about how solar capacity on the grid may influence energy prices. We show both forecasts in our tools to help clients make decisions quickly," Bender says.

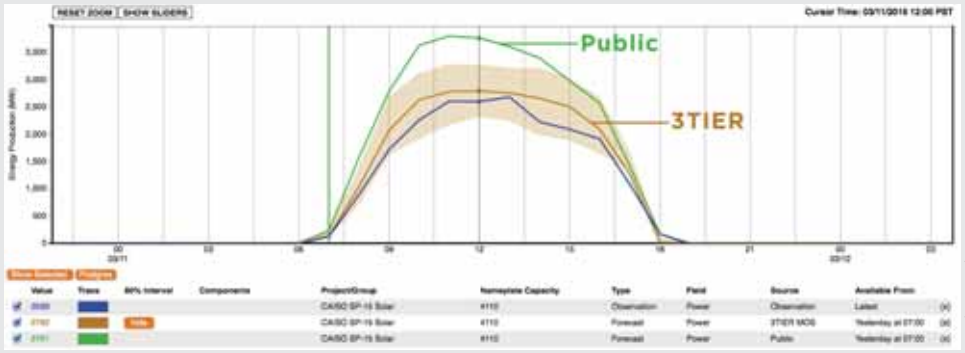
For the time being the forecast is inclusive of utility-scale solar in the region but does not include distributed solar sites, though the plan is to include these resources in the future.

"In California, the Renewable Portfolio Standard (RPS) for utilities is a big driver and that's why we see large-scale solar plants. In other US states, we may see more distributed small solar PV systems due to incentives in place. ISO/TSOs will be much more keen on both grid-connected and behind-the-meter short-term solar forecasts as penetration levels increase. We're only seeing this today primarily in California, but hopefully that will change as RPS target deadlines approach," says Bender.

To validate the tool ahead of launch, Vaisala used over six months of data from CAISO's public forecast, to compare the performance of its forecast.

"Ours was consistently more accurate than the day-ahead public forecast. For example, in CAISO SP-15 [which accounts for a majority of the California's utility-scale solar capacity] Vaisala successfully predicted reduced solar production days 60% more often than the public forecast," says Bender.

Vaisala is also looking at other regions in the US where solar PV capacity is increasing, such as Texas, where there is potential for a short-term – several-minute horizon – forecasting tool. "PJM is also seeing more solar penetration in parts of the grid it operates, which is the biggest in North America with high solar resource variability much of the year unlike CAISO," Bender says.



Credit: Vaisala

CAISO's public PV generation forecast plotted against the more accurate forecast from Vaisala/3TIER

in the first quarter of 2017.

The camera is installed at a building housing a law school, which has a rooftop PV system and also a battery system. The camera will help the school to optimise self-consumption, so that most of the electricity is used on site, during the week. "In smart grids, or solar-plus-storage projects, solar forecasting represents the low-hanging fruit," Lafuma says.

Historical weather and irradiation data is of importance when it comes to the system's design because it helps to determine how productive the PV installation is going to be. From that, it can be calculated how much energy storage may be required, based also on other parameters such as the energy consumption of different loads. The storage component can be more accurately sized, reducing capital expenditure.

"However, when the smart grid is operational, short-term forecasts can be fed into the energy management system to enable more efficient operation of the whole system, so if there is a drop in PV output loads can be powered by the battery. Another, better option might be to turn down or switch off a load, or use electricity from the grid," Lafuma says.

More accurate predictions also mean the battery is only likely to be charged up when necessary, so preserving the performance of the battery cells.

Further opportunities for short-term PV forecasting

Despite progress made in improvements to short-term PV forecasting, the technology is underused and there may be several reasons for this. One is that until comparatively recently forecasting technology has been expensive.

However, along with falling costs of solar PV modules, balance of system components and other costs, providers of forecasting software tools have also been forced to look at ways to reduce their costs, according to Falk. "When we set up our simulation model two years ago it took a while, now we can do it very quickly and it is self-learning."

Typically contracts are for a year or two and the client will pay a monthly subscription, which can range from a thousand to tens of thousands of euros, dependent on whether the forecasting package is for one, a few or a fleet of PV plants, which can be equivalent to hundreds of megawatts of capacity.

But there is also the other challenge of clients' abilities to process and act on the data that short-term forecasting provides.

Falk says: "For the direct marketing of electricity most energy traders work with data based on day-ahead forecast. If one wants to use the intraday data effectively, then who is going to be tasked with dealing with all that data? When we've spoken to energy traders and they see the amount of data that is generated at 15 minute intervals over a 72-hour period, across many PV plants; that's a huge amount of information and they don't have the resources to use it and act upon it."

And although intraday forecasting potential offers higher profits, it also requires increased spending on internal resources. "While some market participants are already taking the opportunity to include intra-day forecasts, others are having problems expanding their structures to accommodate a cost-effective intraday trade. But as the forecasting costs come down then it will make this market segment accessible to traders," says Falk.

However, over the next two to three years market pull for short-term PV forecasting is likely to continue to come from energy traders. "Probably traders are the only group that can afford short-term forecasting. But with costs coming down, it opens up more applications. Two years ago this technology would be too expensive for an O&M service provider, but it is changing," says Falk.

In Bender's opinion the jury is still out on the demand for short-term forecasting in the future. "As technological advancement continues to occur, the processing, distillation and delivery of short-term solar forecasts may change dramatically and it is not clear yet if this will be done by EPCs, solar module companies, ISOs, or independent forecast providers." ■

Storage systems for renewable energy under scrutiny

Battery storage | Lithium-ion batteries are becoming a popular choice stationary storage systems but so far lack any consistent standards governing safety and performance. Matthias Vetter and Stephan Lux from Fraunhofer ISE report on two major research projects that could pave the way for new safety standards for li-ion batteries

Credit: Sonnen

The safety of lithium-ion-based storage systems is coming under closer scrutiny

In 2016 in Germany 34.2% of electricity was generated by renewable energy sources. A major topic is the fluctuation of photovoltaic systems and wind turbines. Increasing the flexibility of the power system through storage systems is therefore being addressed by science and industry at all levels.

Currently Germany, with its large-scale dissemination of roof-mounted PV systems, is becoming a leading market for so-called home storage systems. These storage systems can significantly increase the self-consumption of the PV energy produced by rooftop arrays and are becoming more and more economically feasible as storage prices are dropping very fast.

As these storage systems are installed in private households, they have to be durable, safe and efficient. A study by RWTH pointed out that as of spring 2016 approximately 34,000 systems had been installed in Germany with a storage size between 2 and 10kWh. There are different storage technologies on the market, but the majority of these systems are based on lithium-ion batteries. However, adequate standards and testing procedures do not exist for this technology. The Fraunhofer Institute for Solar Energy Systems ISE is now working on two research projects which address the aspects related to the acceptance and dissemination of the technology. The German Federal Ministry for Economic Affairs and Energy (BMWi) is providing funding for both projects.

Lithium-ion under the microscope

In principle also other established technologies such as lead-acid batteries and promising new technologies such as sodium-ion batteries are an alternative for residential applications. However, those new technologies have to compete with lithium-ion batteries, which have longer calendar and cycle lifetimes, provide higher efficiencies, are able to provide a huge range of services and require less space, compared, for example, to conventional lead-acid batteries. Therefore lithium-ion batteries are gaining popularity for use in stationary applications (grid-coupled and grid-independent), as well as for their use in electric mobility applications. Synergy effects can be realised here that quickly lead to economies-of-scale effects although the requirements for these two applications differ.

Safety, a central issue for lithium-ion batteries, depends on different factors weighted according to the application. Heat localised over a small area at defects will dissipate slowly and can lead to material failure or fire in the worst case, as lithium-ion batteries contain flammable electrolyte and may produce their own oxygen in case of a so-called thermal runaway. One burning cell may ignite the adjacent cell (propagation effect), leading to a hazardous event. Functional safety of the battery system, consisting of battery management, cells, switching units and power electronics, is another issue as overcharging and deep discharge has to be prevented for each single cell in the system.

Many different approaches to ensure safety exist. The basic prerequisites are the selection of cells with high quality and a reliable battery management system, as well as an efficient and effective thermal management.

Whereas for example lead-acid batteries have been tested in practice for many years and a huge amount of information on field experiences is available, lithium-ion batteries must first prove themselves as stationary

Credit: Fraunhofer ISE

storage systems in order to win the trust of consumers. Long-term experience has not yet been available in such applications and therefore cannot be applied.

Standards

One important issue is that fixed standards for home storage do not exist yet. If the current situation is considered, a mixture of rules is used being partially in a draft version up to now.

Currently used standards for certification (as of January 2017):

- Transportation: UN38.3
- Safety: AR-E 2510 – 50, AR-E 2510 – 2, EN62619, EN61000, EN61010-1
- "Safety guidelines Lithium-ion home battery storage systems" (rev. 1, NOV 2014)

The "Safety guidelines Lithium-ion home battery storage systems" were developed under a voluntary scheme organised by German trade association BSW-Solar. Leading research organisations, manufacturers and test institutes worked together, but the safety guidelines are not a legal standard today. The Application Rules AR-E 2510-50 and AR-E 2510-2 are intended for stationary storage and published by electronics association VDE but unfortunately they have remained in draft form only for some years. The EN62619 focuses mainly on industrial applications such as fork-lift trucks while the standards EN 61000 and 61010-1 are not made for systems containing lithium-ion batteries. So the UN 38.3 Transport directive is still one of the most trusted standards for those devices.

A final standard should cover aspects of functional safety, propagation and especially the safety behaviour of aged systems as lifetimes of more than 10 years are the target in stationary applications.

Fraunhofer ISE's test rig for PV home storage systems. Before battery storage tests start the set-up as well as all necessary process steps are checked once again

Project 'Safety First': Safe grid-supportive storage for households

In the joint research project 'Safety First', Fraunhofer ISE is partnering with the Karlsruhe Institute for Technology (KIT) and the Centre for Solar Energy and Hydrogen Research (ZSW) to investigate the current safety, quality and grid suitability of commercially available residential battery storage systems. In this project, scientists develop recommendations for manufacturers, standardisation bodies and authorities based on their investigations on home storage systems for increasing self-consumption. These home storage systems based on lithium-ion batteries are becoming increasingly inexpensive and thus more attractive for the end user. Up to now, however, standardised, verifiable criteria for assessing the efficiency and safety of these systems have been lacking. Therefore the goal of this project is to assess commercially available PV home storage systems in order to prepare future safety standards.

In the project, 20 home storage systems undergo long-term tests, carried out on test rigs that imitate actual operation in private households (Figure 1). Using special load profiles, it is not only possible to analyse the safety of new batteries direct from the factory but also at later ageing stages. Data is collected on the safety properties and the expected lifetime of the storage systems. Also the change of the efficiency over the lifetime will be registered.

Complementary to the analyses on the home storage systems, singular lithium-ion battery cells are selected and analysed at Fraunhofer ISE and at ZSW (Figure 2). Fraunhofer ISE analyses and evaluates the ageing properties of various cell types and the entire system in parallel. With this acquired knowledge, information about ageing and safety can be collected in the future by merely performing short investigative tests. Based on the results in the laboratory, the research team compiles recommendations so that the properties of modern lithium-ion batteries are factored into the standards, test specifications and funding.

Beyond those, internal parameters like temperature distribution, single cell voltage and current distribution in modules that are switched in parallel are collected to capture inhomogeneity in the storage systems. This inhomogeneity tends to increase over the lifetime of the system and may lead to failures and safety issues.

In the example in Figure 3 the power of a commercially available battery module is depicted along with the temperature of seven temperature sensors that are mounted in the battery module. The measurement was done at an ambient temperature of 25 degrees Celsius and the battery module is passive-cooled by natural convection. It is obvious that at very low power levels the temperature distribution is

Credit Fraunhofer ISE

Figure 1. Storage systems under test at Fraunhofer ISE

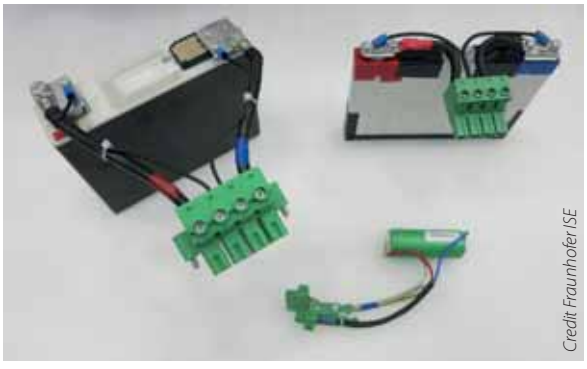


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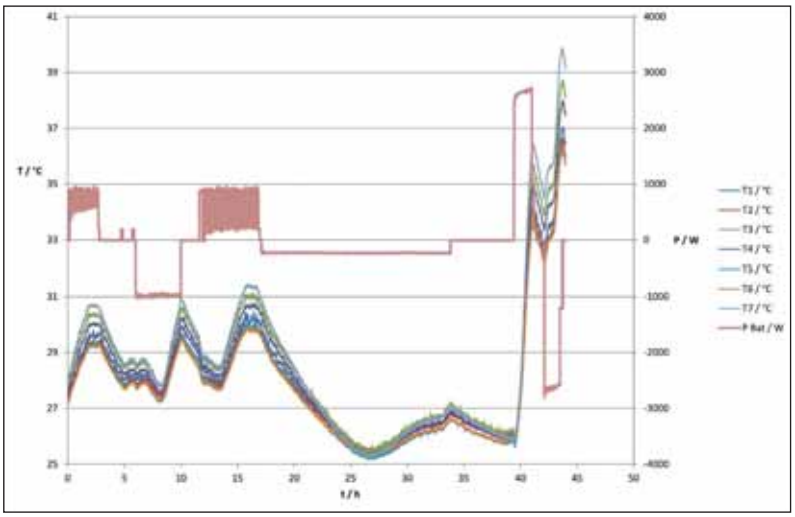
Figure 2. Lithium-ion cells used in home storage system prepared for test



Credit Fraunhofer ISE

Figure 3. Power profile with temperature distribution in a typical lithium-ion module of a commercial available home storage system

very equal, but if the battery is operated at maximum power, the maximum temperature is 14 degrees kelvin above ambient temperature and the temperature spread inside the module reaches 4 degrees kelvin between cells. In the event of operating these systems in a Mediterranean or tropical climate, for example, fast degradation and inhomogeneous ageing effects are expected.

Project 'SpeiSi': Safety of stationary storage systems for solar electricity

Fraunhofer ISE is additionally working on a research project, headed by TÜV Rheinland, on the topic of safety and reliability of PV systems with storage. Project 'SpeiSi' investigates the safety of such systems, which are installed mainly with the aim of increasing self-consumption.

In cooperation with TÜV-Rheinland, the German Section of the International Solar Energy Society and the Centre for Solar Energy and Hydrogen Research (ZSW), the project will analyse weak points in the handling, installation and operation of solar-plus-storage systems. Existing regulations for stationary battery systems consider separate battery rooms for systems with emergency or back-up power or for systems with an uninterruptable power supply (UPS). The regulations must be adapted to accommodate a broader use of stationary energy storage with higher energy content like lithium-ion batteries in private homes. Beyond this, the project will aim to develop criteria for determining the performance of PV storage systems, allowing further information about the quality of the energy management to be gained.

At Fraunhofer ISE three aspects affecting the safety of stationary PV storage systems are being considered as part of this programme. For one, a study was carried out on suitable storage technologies and their respective potential hazards. Secondly the probability of light arcs developing in the system and their detection – or better yet the avoidance thereof – was investigated. Thirdly the behaviour of switching and safety devices undergoing pronounced cyclical stress was analysed. In particular, the researchers would like to find out if the electrical connections become weaker over the course of time, which would lead to a higher fire risk.

SpeiSi is building a network between the different stakeholders involved in storage technology such as producers, operators, insurance companies and fire brigades. In January a workshop with fire brigades was organised in Cologne to exchange information about technology, incidents with storage systems and directives that are existing and that might be needed in the future. One point of discussion was if we need a register of installed storage systems so that relief forces are informed if they will find batteries or PV installed.

The main task of the projects SpeiSi and Safety First is to examine new storage technologies especially in home appliances, and by finding the weak points improve the technologiy to make it safe and reliable. We want to disseminate knowledge to customers , fire brigades and extend standards and amend directives to cope with the progress in technology. ■

Authors

Dr Matthias Vetter is head of the department of electrical energy storage at Fraunhofer ISE. He is an electrical engineer of 19 years' experience, having undertaken his PhD thesis in the field of modelling and development of control strategies for fuel cell systems. Among other topics, his work focuses on autonomous systems and mini-grids, decentralised grid-connected PV battery systems, development of battery systems for stationary and automotive applications.

Stephan Lux serves as head of the battery modules and systems team at the Fraunhofer ISE in Germany. He received his degree in communication technology from the University of Applied Sciences Offenburg in 1994 and his degree in electrical engineering from the University of Hagen in 2008.

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The risks and returns of African PV

Finance | Danielle Ola looks at some of considerations of investors looking to capitalise on the opportunities for solar in Sub-Saharan Africa

Investors from Solarcentury and Actis imparted wisdom on how to manage the risks and reap the benefits of African PV at Solar Media's Solar Finance & Investment Europe event in early February.

Africa is still a difficult solar nut to crack, given its grid limitations and lack of appropriate government policy. However, the chronic lack of electricity access and its high irradiation hours means that solar is an ideal and much needed solution to the continent's electricity access problem.

Despite being a rockier proposition than elsewhere on the globe, additional layers of scrutiny and proven means of risk management demonstrate that there are the necessary formalities in place to build a stable solar sector, as demonstrated by the progress made by South African PV. There is also plenty of demand.

James Mittell, investment director at investment firm Actis emphasised patience is key given that the investment cycle in Africa is a lot longer than for projects elsewhere on the globe, and further that the typical equity returns might not look as high as expected.

"Africa is more risky so yields higher returns than in the UK. There is also a trend of increasing competition in Africa – which might be indicative of investors moving elsewhere," he said.

However, Africa is a big continent with 54 countries, so the broad brush approach is not appropriate here. Returns will be unique to a given country. South Africa, for example, is one of the stronger PV markets, accounting for 65% of the continent's cumulative installed capacity at approximately 1.4GW, according to IRENA.

The country's successful Renewable Energy Independent Power Procure Procurement Programme (REIPPPP) has elevated returns on solar projects from being "frontier" back in 2011 to "guaranteed and safe", according to Mittell, who puts returns at 12-14% IRR on a rand basis; constituting "the lowest you'll see across Africa".

With the rise of corporate PPAs across the continent, with Nigeria being the latest market to enter this field, the scale of PV projects is rising slowly from the smaller-scale solar that was previously warranted due to grids being generally unable to integrate anything more than 10MW.

Although larger-scale solar is developing through various tenders, one problem is currency risk. "Tenders won't be a huge market but it will bring decent-scale stuff," said Mittell. "It is difficult to get over that currency risk, given the depreciation in emerging market currencies, and who takes on that risk? These problems make the process slow moving."

Solarcentury's head of Africa business and project development, Tassos Christakis, agreed with this point, citing the IFC's Scaling Solar tender in Zambia, which achieved some of the lowest tariffs ever seen in PV at sub 6.02 cents/kWh.

"Mining in Zambia took a big hit, which opened up the way for more renewables. But even with long-term PPAs, most want 10 years, which ends up being a vicious cycle because you need to pay more to make returns over 10 years."

South Africa on the other hand is a favourable market as its tenders are available in local currency funding, meaning the tariff is indexed to local currency. 70% of the debt is in local currency with 30% equity in dollars, and all the inflation going to equity. For these reasons, most investors are comfortable with the currency 'risk' in South Africa. But at the end of the day, the exchange risk is something an investor will have to shoulder as it cannot be completely alleviated, explained Christakis. South Africa is also an ideal market not only for its bankability, but its rare local content requirement.

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Financing solar in Africa presents some unique hurdles for investors

"This is a positive because you embrace local community, but at the shareholder level this can cause problems," said Christakis. "There are not many countries in Sub-Saharan Africa with a local content requirement. It's all about scale and has to be in a category where you have operation already. It is a logistical nightmare to make it happen if you are not in the country already."

Corporate PPAs aside, the risk issue is still prevalent as development financial institutions (DFIs) which are the main financiers in the African market, still require the same guarantees a commercial bank would, Christakis said. The allocation of risk does not get any easier with local companies and distributed generation.

"Potential 'sharing power' schemes with mini-grids are a logistical and off-take challenge. There is the risk with local companies; how can you guarantee payments long term? You need security on payments," said Christakis.

To alleviate these risks, investors will need to be selective with picking a market.

"Wherever the government has a good track-record and is willing to work with the private sector, we will work there," said Mittell.

He also went on to emphasise that the focus should not necessarily be on where the tariff can be the lowest, but instead to ensure bankability and government contracts.

"Defaults in Africa are at around 1% because the contracts are so scrutinised by everyone," said Mittell. "In the US it is at around something like 10%."

This is an edited version of a blog post that first appeared on pv-tech.org

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