PV POWER TECH

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STEADY AS SHE GOES

How European solar is moving beyond boom and bust

12-PAGE STORAGE SPECIAL

- Tesla takes on the business model problem
- Off-grid: combining storage and hybrid systems
- Which batteries for which applications?

DESIGN AND BUILD

First Solar's new PV plant energy assessment software

SYSTEM INTEGRATION

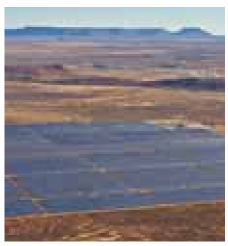
Understanding the PID effect in large-scale PV power plants

PLANT PERFORMANCE

TÜV Rheinland on minimising the risk from plant defects

MARKET WATCH

Is South Africa's solar programme becoming a victim of its own success?



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Introduction

In recent weeks the benefits of coupling solar with battery storage technology have gone from being a niche topic to the talk of the chattering classes. Thanks to some slick publicity work from Elon Musk and his PR team, tales of the Silicon Valley stalwart's first forays into the world of stationary storage have found their way on to newspaper front pages the world over.

Hype there was aplenty, and only time will tell if Tesla's bid to revolutionise the solar-plus-storage offer lives up to it. Yet if nothing else, the company's high-profile launch has shone a light into one of the less glamorous but fundamentally important corners of the storage debate – namely the business models that will enable the technology to pay its way.

The conundrum is that the deployment of storage is not so much a question of technology as it is of coming up with clever ideas about how to make it profitable within the constraints of current grid and regulatory regimes. In itself, the Tesla announcement does not provide an immediate answer to this question. But the involvement of the likes of SolarCity and others in trialling Tesla's Powerwall units hints that one of the models now being given serious consideration is that of aggregation.

As we explore on p.73, aggregation is a simple term for a relatively simple concept that is anything but simple to execute. In essence it means combining separate residential and commercial batteries to create larger systems that could provide potentially profitable grid balancing services. But as with all new grid-edge concepts, aggregation is one fraught with potential difficulties and will only ultimately take root if ways are found to deliver it at scale. That said, don't bet against Tesla and friends finding a way to do just that.

It's fitting that storage finds a prominent place in the pages of this journal as the technology in its many guises will be one of the key focuses once again at this year's Intersolar Europe. This is a reflection of its growing importance, with some estimates predicting annual storage installations could reach 40GW by 2022.

This year's annual Munich extravaganza (profiled on p.28) coincides with what could be a pivotal time for European solar. It is now an undeniable fact that the days of Europe's FiT-fuelled solar frenzy are now over, with Germany and a host of other EU countries winding down the model that arguably took solar to where it is today. But that's not to say Europe is no longer a force to be reckoned with, and as our special report on p.31 reveals, many observers now believe the continent is moving into a phase characterised by steady, predictable growth rather than the crazy boom and bust cycles seen before.

As always, this issue of *PV Tech Power* is also packed with some of sharpest current thinking on PV power plant design, integration and operation. On p.52, researchers from Fraunhofer CSE tell you everything you need to know about the impact of potential-induced degradation on large-scale PV power plants. On p.41 First Solar walks us through its new PlantPredict energy assessment software. TUV Rheinland delves into methods for minimising plant defects on p.63. And on p.58 we look at how drones and other automated technologies are becoming increasingly common in PV plant management.

The *PV Tech Power* team will be at Intersolar holding fort at booth A2.112. We hope you enjoy this issue of the journal and hope to meet you there.

Ben Willis
Head of content

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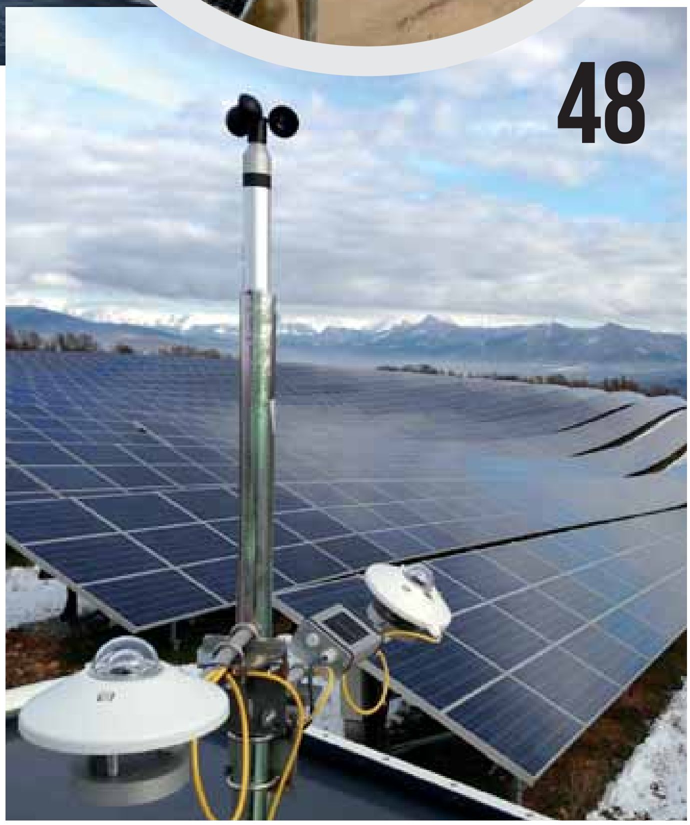


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EUROPE

Trade

EU-China trade dispute: the saga continues

The European Commission has launched an investigation into its trade agreement with China that imposed a minimum import price (MIP) on PV modules and components. The price is benchmarked against Bloomberg spot prices, which SolarWorld-led trade body EU ProSun has claimed is unsuitable. EU ProSun said in late April that it intended to lodge a complaint, focusing on the functioning of the negotiated agreement between Chinese manufacturers and the Commission rather than on the existing trade tariffs. At the heart of the review request is the alleged rush of Chinese companies to register prices since the MIP was established. The Bloomberg index relies on module manufacturers reporting their prices. The supposed rush increased the weighting of Chinese firms in the index. With Chinese prices lower than their rivals', spot prices fell, and so did the MIP. As of the beginning of May, the EC had 15 months to complete its latest investigation, extending the life of existing tariffs.

Credit: flickr user tiseb

Europe's long-running trade dispute shows no sign of dissipating with the method of calculating the minimum price level for Chinese firms now under review.

Storage

Storage is silver lining for Germany's residential market

Research firm EUPD has predicted that 12,500 residential PV storage systems could be installed in Germany in 2015, more than the total number of systems installed with support from a government scheme in its first two years. May marked the second anniversary of the introduction of Germany's financial support measures for battery-based energy storage systems. The country's development bank, KfW has given out loans for the installation of just over 10,000 systems, compared to around 4,000 in the first year. "For 2015 we estimate 12,500 new systems will be installed – with and without KfW support," Markus Hoehner, head of EUPD Research, said.

Tenders

'Intense competition' in oversubscribed German PV tender

The first round in Germany's controversial tender process for ground mount solar was held near the end of April, with the country's regulator admitting that there was "intense competition" in the auction. Part of a plan to cap the market size of the ground mount segment to 1.2GW over three years, bids were received in the middle of this month with BNetzA awarding just 150MW for ground mount projects this year, limited to 10MW capacity maximum per project. The regulator said prices averaged out to 9.17 Eurocents (US$0.10) per kWh for project bids, with the proposed project sizes averaging out at around 6.3MW capacity each.

Policy

No UK solar farm projects in 2015/16 under new incentive mechanism

The only two PV projects that secured support under the UK's contract for difference (CfD) scheme for the financial year 2015/16, will not go ahead. It was widely predicted that Wick Farm Solar Park and Royston Solar Farm – which both secured a strike price of £50/MWh, would not be viable, given that the wholesale cost of electricity is set at the same level. Developer Low Carbon later confirmed the news. Three projects won contracts for later years. Support for solar projects over 5MW under the previous Renewable Obligation (RO) scheme was withdrawn on 1 April 2015, with the government citing unexpected take up from solar causing budget limitations. According to research firm IHS, the scrapping of RO for solar developments over 5MW triggered a rush of projects in the first quarter, estimating that 1.6GW of capacity was shared between a minimum of 110 PV projects.

Market

UK minister wants 'solar revolution'

The UK's new Secretary of State for energy and climate change, Amber Rudd, spoke of her desire to increase the deployment of solar PV under her watch. Rudd told a local newspaper following her appointment in mid-May that she was "honoured" to land the top role at the Department of Energy and Climate Change (DECC), where she was previously a climate change minister. Rudd said: "I want to unleash a new solar revolution – we have a million people living under roofs with solar panels and that number needs to increase."

Tender

France launches tender for smaller sized systems

In March, traditionally nuclear-hungry France launched a 120MW tender for PV systems between 100kW and 250kW. This was followed by a separate 50MW auction for projects combining solar power with energy storage systems on Corsica and its overseas islands territories. In the first, projects were judged not only on price but also by their carbon reduction potential, launched in three batches of 40MW with each batch available for a period of consultation between the government and the industry. The final block of the auction will close in March 2016. In November 2014 a tender for 400MW of projects over 250kW in size was launched. France is targeting a 23% share of renewables by 2020.

CSP

Abengoa Yield boosts portfolio with 450MW purchase

Abengoa Yield, the yieldco part-owned by Spanish solar developer Abengoa, has acquired 450MW of assets from Abengoa after reporting its Q1 EBITDA to have more than doubled year-on-year to US$105.2 million. The yieldco is to pay US$669 million for the assets with a 9.4% CAFD yield, paid for by US$670 million in proceeds from a capital increase of US$33.14 per share, dated 8 May.

Market

Italy's Enel looks elsewhere

Italy-based renewables developer Enel Green Power has announced plans to add 7.1GW of project capacity by 2019, a 50% increase on its previous plan.

It plans total capital expenditure of €9.6 billion (US$10.7 billion) between 2015-19, of which 27% will be dedicated to solar projects. €8.8 billion will be entirely dedicated to growth. In a statement, the firm cited its intention to "seize the current global growth in renewables", referring to its 2015-2019 Strategic Plan. Of the total capital expenditure in the period, 53% (€4.7 billion) will be allocated mostly in Brazil, Chile and Mexico given these countries' current potential for growth, according to the firm. The percentage of the company's total pipeline grew from 19% in Latin America in 2011 to 50% by 2015.

AMERICAS

Policy

Brazil cuts red tape to help net metering

Brazil's energy regulator, ANEEL, is easing up net-metering regulations for distributed generation. The measures are intended to encourage participation in the scheme, which has so far been hindered by various bureaucratic hurdles. Depending on which revisions are approved, ANEEL forecasts that up to 700,000 consumers could be using the net-metering system by 2024, amounting to 2.7GW of capacity. The bureaucratic 'red tape' removed could include allowing people or entities living in shared buildings such as apartment blocks and commercial blocks to be able to share net-metering benefits, instead of needing a separate system for each individual.

Market

BNEF's bold 9.1GW US forecast

Booming renewable energy deployment, the shuttering of coal-fired generation and increased natural gas consumption will combine to make 2015 a "watershed" year for decarbonisation of the US power sector, according to Bloomberg New Energy Finance (BNEF). US renewables deployment in 2015 will hit a record 18GW, with solar leading the way at an all-time high of 9.1GW, BNEF has forecast, closely followed by wind with 8.9GW. In parallel, BNEF said 2015 would be a record year for coal retirements, with 23GW expected to come offline in the US this year, around 7% of the country's coal capacity. The US is expected to burn more natural gas then before in 2015 as a result of low prices. BNEF said the confluence of these factors would result in 2015 CO_2 emissions from the power sector ending up 15.4% lower than 2005 levels. The country is targeting a 28% cut all its CO_2 emissions by 28% relative to 2005 levels by 2030.

Market

Latin America PV installations could rise 350% in 2015

Latin America is forecast to install 2.2GW of PV in 2015, a 352% increase from 625MW in 2014, according to the latest edition of GTM Research's quarterly 'Latin American PV Playbook' report. Half the projects will be in Chile. Meanwhile Honduras is forecast to undertake a huge rise to 460MW installed capacity in 2015, up from 5MW in 2014, overtaking Mexico as the region's biggest market, while Brazil could fall out of the top five. The region's total pipeline is now 34GW, with 25GW announced, 6.8GW contracted, 1.9GW under construction and 943MW operational. In Q1 2015, the region installed 207MW.

Chile

JA Solar launches Chile JV with Soventix

Interest in Chile as a region for PV has been intensifying for some time, with big players clamouring to step up efforts. In the past few weeks, Chinese tier-one PV giant JA Solar has recently formed a joint venture with the Chilean subsidiary of German developer Soventix to develop large-scale PV projects in the Latin American country, with an initial 130MW pipeline. Enel Green Power has started building 176MW of capacity across two projects, investing US$180 million, while Swiss independent power producer Etrion Corp has signed a long-term Power Purchase Agreement (PPA) with Chilean power trading company Empresa Eléctrica ERNC-1 (EE-ERNC-1) for the 70MW Project Salvador solar plant in Northern Chile.

Off-grid

Peru's remote regions get 150,000 off-grid PV systems

Peru's Ministry of Energy and Mines (MEM) has signed a 15-year investment contract with local power provider Ergon Peru SAC for the installation of 150,000 solar panels to provide electricity to remote areas of the country. Ergon Peru, which is run by Tozzi Holding Group, also signed service contracts with 11 energy distribution companies to manage a network for the users. Operation and maintenance of the solar facilities will be transferred to these distribution companies at the end of the 15 years in 2031. The contracts are worth around US$28.7 million in total.

Grid

Hawaii clears 20MW solar backlog with Enphase grid report

Microinverter maker and energy management provider Enphase

Storage

Tesla moves on stationary storage market

Tesla has been unmissable in industry and mainstream media coverage this past quarter. The EV maker of course launched a range of energy storage batteries, including Powerwall, its batteries for the home priced from US$3,000 for a 7kWh system and a utility scale system which promised a price point of US$250 per kWh, as well as a commercial system with peak demand charge reduction and backup supply as its main value propositions. Lowering the bar for price across the industry, the company has also inevitably taken forward its pilot scheme with SolarCity towards commercialisation. In keeping with CEO Elon Musk's simultaneous liking for democracy and scale - Musk has famously open-sourced the IP behind Tesla's cars - Tesla is also working with a number of other solar installers in the US including Sunrun and the rooftop solar division of utility Southern California Edison (SCE).

Credit: www.mysketchpad.co.uk

Hype surrounding the launch soon spread globally.

However some analysts highlighted that the prices given do not include inverters and other power electronics. Tesla's initial inverter suppliers are SolarEdge and Fronius, although Tesla said it is looking for more partners. One analyst, Dean Frankel of Lux Research, said that Tesla might benefit from "Gigafactory-like efforts dedicated to inverters" without it the company could be "limiting its growth potential". In the wake of the announcement, Musk said Tesla had been faced with "overwhelming demand".

was contracted by Hawaiian Electric Company to help it clear a backlog of solar consumers waiting for interconnection on the island of Oahu. In wake of making a pledge in October 2014 to clear 90% of the interconnection backlog by April 2015, Hawaiian Electric reached out to Enphase in order to receive a detailed report regarding grid conditions in neighbourhoods across the island. Around 25,000 Enphase projects have been installed on Oahu and make up about 70% of all PV systems on the island. After looking over "heat maps" – designed by both groups in order to measure voltage and frequency data in certain areas – approximately 4,000 PV installations, or over 20MW, of solar interconnections were enabled.

MIDDLE EAST & AFRICA

Big players in South Africa

Italian multinational Enel Green Power and SunEdison and SunPower, both headquartered in the US, have been active in South Africa of late, with Enel starting construction on 231MW of capacity across three power plants last quarter. Enel won tenders under South Africa's third phase of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), while SunEdison was awarded an 86MW DC solar project in the programme's fourth round. SunPower, meanwhile, has won three contracts through the scheme, including another 86MW through the Prieska project, in the Northern Cape.

Credit: Sunedison.

South Africa announced the results of its latest tender round with several large companies cleaning up.

Policy

Turkey targets spur action

Turkey has been a source of interest for the international PV industry of late. The country wants to harvest one-third of its power needs from renewable energy sources by 2023. Developers Conergy and Juwi have been among the latest to launch operations in the country. Conergy has formed Turkish joint venture, RKT Conergy, with local construction and telecoms firm, CO Group. It will provide engineering, procurement and construction (EPC), and operations and maintenance (O&M) services for commercial rooftop and ground-mount projects in Turkey. Juwi has started work on a project comprised of seven separate plants – generating a combined capacity of 7.4MW – located in the municipality of Denizli.

Net metering

Dubai launches net metering with a US$400 smart meter

The Dubai Energy and Water Authority (DEWA) will bring net metering to the emirate through the launch of Shams Dubai, a new initiative aimed at encouraging and regulating the development of commercial and residential solar projects. The programme, launched in March, will encourage building owners to fit solar PV panels through the Shams Dubai framework, enabling them to submit planning applications to DEWA directly through a free online portal. Rather than paying for a connection to Dubai's grid, applicants must foot the AED1,500 (US$400) cost of a smart meter to calculate and verify usage. In April, DEWA also confirmed the next 800MW phase of development at the Mohammed bin Rashid al Maktoum Solar Park, with a tender expected to be launched in Q3 2015.

Off grid

100,000 solar systems for off-grid homes in Ghana

Pay-as-you go solar systems are to be installed in 100,000 off-grid households in rural Ghana. The initiative, led by UK company Azuri Technologies with local firm Oasis African Resources and the Ghanaian government, was launched at Solar Media's Solar & Off-Grid Renewables West Africa event in April. Ghana is currently experiencing problems with power blackouts in grid-connected areas while a large swathe of the currently is still without access to any grid power at all. Meanwhile, the government was forced to put a temporary cap on its utility-scale solar market of 150MW, after being overwhelmed with applications for generation licences under the country's fledgling feed-in tariff programme.

Tenders

Egypt signs off for 220MW of PV

The Egyptian government has signed binding memoranda of understanding for solar projects totalling 220MW. The agreements, which also included 100MW of wind, are worth a total of US$500 million. The projects were awarded feed-in tariffs (FiTs) under a 4,300MW tender process that included 2,300MW for solar projects. Available solar capacity was oversubscribed twice over. The deals were signed at a trade mission to Egypt organised by the Middle East Solar Industry Association (MESIA).

Market

Chad's first IPP-built project

A 40MW project that is in line to become Chad's first independent power producer-built solar project was in March granted US$780,000 from the Sustainable Energy Fund for Africa (SEFA). The grid-connected Starsol project will be built near N'Djamena, the capital city of the Central African country. SEFA, an arm of the African Development Bank funded by foreign donors, said the grant would finance costs related to technical assistance for the completion of the plant design and grid study, as well as advisors for legal and financial structuring of a bankable IPP. Starsol Chad is being taken forward by a consortium of foreign firms.

Cost watch

IRENA points out solar and wind as cheapest options in UAE

A report from the International Renewable Energy Agency, the UAE Ministry of Foreign Affairs and Masdar Institute of Science and Technology claims solar and wind energy could now be the cheapest sources of energy supply in the United Arab Emirates (UAE). The UAE could achieve a 10% share of renewable energy in its total energy supply and a 25% share of renewables in the power sector by 2030, the report said, also pointing out that solar PV costs in the region have dropped 80% since 2008.

ASIA-PACIFIC

Policy

Doubts remain over key Australian renewable target

Hopes of Australia reaching an agreement over its Renewable Energy Target were left in tatters after the opposition Labor Party backed away from talks with the Tony Abbott-led Coalition government over demands for biennial reviews. It had looked like an agreement to reduce the RET to 33,000GWh had been reached, however opposition environment minister Mark Butler said the Coalition's insistence on two-yearly reviews would hinder investment and cause uncertainty. John Grimes, CEO of the Australian Solar Council, said further reviews would "devastate" the country's solar industry and backed Butler's stance on the matter.

Big deal

United PV claims to have signed 'world's largest' project deal

Chinese solar investor United PV signed what it claimed to be the 'world's largest' solar deal, acquiring 17 sites from developer Hareon Solar with a total capacity of 930MW for a sum of RMB8.8 billion (US$1.42 billion). The deal, which is made up of cash and bonds, was announced just two days after United PV acquired 210MW of solar projects from Guodian for RMB190 million (US$31 million), capping off a busy May for the firm.

M&A

Canadian Solar wraps up deal for Recurrent Energy

Canadian Solar finalised its US$265 million deal to acquire Sharp's solar energy development firm Recurrent Energy before shaking up its senior management team. David Brochu, having served at Recurrent since 2009, was immediately appointed as its new chief executive to replace the departing Arno Harris, and the firm's CFO Michael Metzner also left, however a replacement has yet to be confirmed.

Dumping

Australia dumps trade case as results find negligible harm

Australia's anti-dumping commission terminated its investigation into alleged dumping of Chinese-made PV modules imported into the country in April, declining to take further action despite finding evidence that such modules had been sold in Australia at dumped prices. It was ruled that any damage to the industry was negligible.

Japan

Japan increases rate of FiT reductions

Japan is to make larger cuts to its solar feed-in tariff, dropping the rate by 16% to ¥27 per kWh by July. A first cut made at the start of Japan's financial year in March reduced the rate from ¥32 to ¥29, while a newly-added secondary cut will lower the rate once again in July. While the larger-than-average cuts were not a surprise for the industry, they do represent a change in tack for Japan's Ministry of Economy, Trade and Industry which had previously sought to manage its degression to promote new solar installations.

Philippines

ET Solar to build 70MW Philippines project as hopes for market rise

ET Solar is to build a 70MWp solar project in the Philippines with its local partner, renewable energy developer Gate Solar Philippines. The two parties are to finance, construct, operate and invest in the project – ET Solar's first in the emerging market. Construction is slated to start in Q4 2015 ahead of the start of commercial operations by March 2016, with market research firm IHS naming the Philippines as one market to watch this year.

Tender

India reveals terms of 10GW procurement plan

India plans to tender 10GW of solar capacity over the next year, which consultancy firm Bridge to India said would be "path-breaking" if the entire capacity could be allocated. It is to be split between a tariff-based bidding system, which will receive 3GW of capacity, and a Viability Gap Funding-based initiative which will receive 7GW. India's central government is understood to have approved the block of VGF projects and the country's Ministry of New and Renewable Energy has confirmed 2.6GW of projects, while the Solar Energy Corporation of India has invited EPC firms to tender for 2GW of contracts ranging from 250MW to 500MW in size, however Bridge to India warned of land acquisition troubles in the country in constructing projects of that scale. JBM Group and Azure Power have also looked to move into the market by commissioning utility-scale projects in the country.

Credit: Welspun.

With lofty solar ambitions, further details on specific procurement plans will be welcomed.

Deals

Tier-one rivals bag series of major deals

China's tier-one suppliers were busy after revealing a number of large deals, JinkoSolar in particular signing a deal to supply 1GW worth of modules to China Minsheng New Energy over the next two years. Jinko said a minimum of 600MW would be allocated to projects being built by CMNE this year. Risen meanwhile reached an agreement to construct 1GW of generation capacity with the local governments of Wuhai City and Haibowan district, while Trina announced it supplied 116MW of modules to a project near Setouchi, Okayama prefecture in Japan, the latest solar farm claiming to be the largest in Japan.

DATA WATCH

20GW

Deutsche Bank's Vishal Shah's estimate for 2015 installs in China

Product reviews

Mounting | The DuraTrack HZ v3 from Array Technologies offers greater density and minimised components for lower LCOE

Product Outline: Array Technologies has introduced its latest single-axis tracking system, the 'DuraTrack' HZ v3, for utility-scale PV power plants. After nearly two years of development and testing, Array recently commissioned the first 1.2MW DuraTrack HZ v3 site in northern New Mexico.

Problem: PV power plant developers and owners need to reduce balance of system costs to improve their system's levelised cost of energy. Tracker systems need to minimise loads, wasted space, fasteners, number of motors, controls, columns, maintenance cost and risk.

Solution: The DuraTrack HZ v3 tracker incorporates a passively managed wind

load mitigation system to eliminate storm survival risks. The patent-pending v3 design enables a significant increase in module density and panels per row, reduces motors per megawatt, shortens installation time and lowers maintenance costs. Tighter module gaps and elimination of centre row dead-space results in a power density increase of 4.5% over v2.5 of the system. By reducing driveline and module gaps, this system maximises ground coverage.

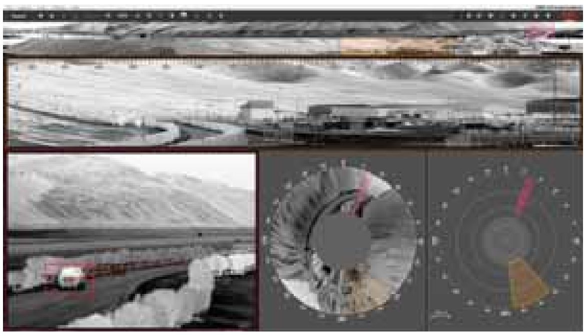
Applications: Utility-scale PV power plants.

Platform: DuraTrack HZ v3 allows 33% more modules (80) per row. Racking posts in a standard installation have been reduced by 9%. Two-stage gearing at each row allows for twice as many modules to be linked. Reducing the motor count from 4MW (AC) to 2MW (AC) and relocating the motors on service roads, near the inverter, minimises wire runs, eliminates motor wiring through the array block and provides easy access. A new clamp design with only one fastener increases install speed while reducing module-to-module gaps from 1" to 0.25".

Availability: May 2015 onwards.

Security | HGH Infrared Systems' wide area surveillance system provides automatic detection

Product Outline: HGH Infrared Systems' Spynel-M wide area surveillance system has dimensions of less than 12x20cm and a weight of only 1.8kg, and is claimed to a cost-effective and compact solution for wide area surveillance. One single Spynel-M sensor effectively replaces up to 16 traditional cameras and is able to perform 24/7 early human intrusion alerts over a 1.5km-diameter area.



Problem: Monitoring of PV power plants especially, in remote areas, requires low-cost but effective solutions. Minimising the need for large numbers of cameras and positioning systems, while providing accurate wide area surveillance, supports lower BOS and O&M costs.

Solution: The Spynel-M continuously captures full panoramic, high-resolution infrared images every second to provide real-time security against conventional and asymmetrical threats including hardly detectable targets. Easily transportable, it can be carried in a backpack and quickly deployed on a light mast or fixed atop a building for superior wide area surveillance. While requiring only 8 watts of power, Spynel-M can also be operated with solar or alternate power supply systems to allow for a remote operation. Unlike radar, the system is completely passive, requires no additional light source and cannot be jammed. The intuitive advanced intrusion detection software, Cyclope, automatically tracks and detects an unlimited number of targets from any direction at any time of day or night and under any type of weather conditions. The system can also be paired with other systems such as radars and PTZs for data integration and target identification.

Applications: Monitoring and protection of PV power plants.

Platform: Spynel-M comes with the continually updated Cyclope advanced software that performs automatic intrusion detection and tracking of an unlimited number of targets in any direction simultaneously.

Availability: March 2015 onwards.

Products in Brief

Solar Data's Solar-Log 350 integrated into GE Meters

US-based Solar Data is now shipping its first American-manufactured Solar-Log & GE Meters. The Solar-Log 350 is an ANSI certified Revenue Grade Meter equipped with Solar-Logs proven monitoring technology. The built-in cellular communication and the standardised installation process make it a plug-and-play socket meter based solution. The Solar-Log 350 can be purchased through a wide variety of distributors, installers and solar leasing companies across the nation. This summer will bring the release of the Solar-Log 360 & 370 meters. They will offer enhanced monitoring solutions, such as self-consumption metering, weather information tracking, inverter direct monitoring and power management.

tenKsolar's 'RAIS XT DUO' PV solution claims highest rooftop energy density

US-based tenKsolar has introduced the 'XT DUO', a new product in the 'RAIS' XT family of PV solutions that will reduce hardware costs and increase the energy density of rooftop solar arrays. The XT DUO is claimed to generate up to 40% more energy per square foot than similarly priced conventional solar offerings. Using the best-in-class shade tolerance of the tenK modules, the XT DUO uses tandem 410W and 450W "high-tilt" modules to capture all light without a significant yield loss. By integrating the racking system into the modules, tenK's XT DUO offers a way to capture maximum energy from a space while eliminating virtually all of the racking costs and dramatically simplifying the installation. The system is available for residential and commercial rooftop systems in North America.

Module | Hyundai offers compact 250W high-performance modules for rooftop market

Product Outline: Hyundai has launched two new 250W module types in the UK, specifically to meet UK installer requirements. The S250RF(BF) and the M250RG(BK) are 54-cell 250W modules using monocrystalline passivated emitter, rear locally diffused (PERL) cells, enabling a claimed 10% reduction in roof space to achieve a 4kW system.

Problem: Since the arrival of the feed-in tariff in 2010, the UK market has seen the 250W module become the workhorse of domestic PV. This is because 16 modules of 250W can make an exact 4kW system and comply with the best FiT rates for residential rooftop systems. However, constant cell efficiency gains have led to higher module performance levels within the standard 60-cell configuration, resulting in less system optimisation and more complex design calculations.

Solution: Hyundai's S250RF(BF) is a monocrystalline PERL, 54-cell black-framed module, retaining the UK installers' preference for 250W modules. The modules are smaller (998mm x 1,480mm) and lighter (15.4 kg), and require 20.7 square metres of roof space, 10% less than for a 60-cell module. At 215.6 kg, a 4kW system is 19% lighter to achieve, allowing smaller or weaker roofs to accommodate optimised rooftop installations that were previously too large.

Applications: Residential and small commercial rooftops.

Platform: The S250RF(BF) and the M250RG(BK) modules use monocrystalline PERL cells in a (6x9 matrix) series with cell efficiencies of 20.4% (max).

Availability: Hyundai's full range of 250W modules is available globally and in the UK exclusively through BayWa r.e. Solar Systems and Segen.

Sun tracking | 'SOLYS' gear drive sun tracker from Kipp & Zonen designed for harsh environments

Product Outline: Kipp & Zonen's SOLYS Gear Drive is a high-torque and large temperature range sun tracking system for PV power plants suited to the harshest climates and able to carry heavy loads. Its high precision gear drive system does not require maintenance, making it ideal for operation in remote locations.

Problem: A sun tracker typically holds instruments such as pyrheliometers, absolute cavity radiometers or sun photometers that must be pointed precisely at the sun by following its arc throughout the day. Low maintenance is required to support O&M cost savings, especially in wide temperature range environments and remote locations.

Solution: The SOLYS Gear Drive has a payload of 80kg and over 60 Nm of torque,

allowing for the use of multiple and/or heavy instruments. The wide temperature range is achieved due to a high capacity internal heater. For extremely cold regions an insulated cover is available that allows operation in temperatures down to -50°C and with wind speeds up to 20 m/s. For extremely hot regions the SOLYS Gear Drive can be fitted with a sun shield. This reduces heating of the housing by direct solar insolation and extends the upper operating temperature range to +60°C.

Applications: PV power plant solar insolation measurement.

Platform: Kipp & Zonen has developed new and smart 'Windows' software with an attractive user interface that allows remote monitoring and logging of the tracker status, solar zenith and azimuth angles, GPS time and date, and more, through Ethernet or an isolated RS-485 port. The integrated web Interface with Ethernet connection allows operational parameters to be viewed and set, history log files to be downloaded, and firmware updated.

Availability: April 2015 onwards.

Tigo Energy adds 'Cloud Connect' to smart module capabilities

Tigo Energy has added a communications and safety hub to its smart module platform. The Cloud Connect (CC) is an on-site interface to modules, inverters and other accessories. In addition, the CC functions as the gateway to Tigo's SMART cloud services. The CC provides a centralised safety platform for fire fighters and installers. The CC supports on-site deactivation of the array and, when combined with Tigo's smart module technology, is compliant with Rapid Shutdown requirements (NEC 2014). The CC also supports the collection of data from string inverters, AC meters and other equipment that is transmitted, analysed, and displayed by Tigo's SMART cloud services.

Vaisala offers thunderstorm tracking and lightning alert

Vaisala is now offering its 'Thunderstorm Manager,' a professional application for tracking approaching storms and warning of imminent threats from lightning, for any location on Earth. Thunderstorm Manager combines data from Vaisala's US National Lightning Detection Network (NLDN) and Vaisala's GLD360, the network that delivers quality global lightning coverage, to deliver comprehensive lightning information, designed to keep local ground construction and maintenance crews safe and operational downtime at a minimum. A desktop or mobile device browser can be used to access the real-time displays anytime, anywhere around the world. Thunderstorm Manager employs a sophisticated alarm notification capability to alert customers when their sites or assets are threatened by lightning.

Product reviews

Storage | Belectric's 'Energy Buffer Unit' provides balancing service to grids with high renewable energy adoption

Product Outline: Belectric's Energy Buffer Unit (EBU) has been prequalified by a German transmission network operator to provide frequency response balancing for reliable grid operation when taking into account large quantities of renewable energy being connected to the grid.

Problem: With increased adoption of renewable energy, grid operators have to better manage fluctuations in the transmission network. Large-scale battery storage improves the safety of transmission network operation, even during heavy fluctuations like a generator or interconnector trip.

Solution: Belectric's EBU system can be prequalified for frequency response on the German transmission network with up to 650kW, taking into account reserve capacity required by the German TNOs. The advanced lead-acid batteries were developed for a long service life and high cycling stability for high-performance applications. EBU system standardisation enabled Belectric to offer a cost-effective utility-scale energy storage system. Services from the EBU will be offered on the frequency response market on a weekly basis. Due to rising prices in this market over the last three years, attractive business models are now appearing for the use of energy storage.

Applications: Energy Buffer Unit is for frequency response and other cyclic grid applications.

Platform: The EBU is shipped with a power inverter and medium voltage transformer and features a nameplate power between 800kW and 1,400kW, depending on configuration. It has a storage capacity of 948kWh and is available starting at €560,000.

Availability: May 2015 onwards.

Monitoring | Fujitsu's cloud-based PV monitoring service, Venus Solar, allows centralised management of dispersed PV power plants

Product Outline: Fujitsu's Venus Solar system is a small-scale, cloud-based solar monitoring service that provides detailed power generation monitoring and detection of abnormalities.

Problem: Solar systems can fail for a variety of reasons, while power generation may decline as equipment ages. For plant owners, the early detection of problems plays a critical role in preventing lost revenue.

Solution: Intended for small-scale solar facilities, Venus Solar collects data by the minute on the volume of electricity generated by each power conditioning system through monitoring devices connected to each PCS. Data can then be centrally managed in the cloud. In comparison to conventional power-facility output monitoring services, which monitor on a per-facility basis, Venus Solar can provide more precise, per-PCS energy generation monitoring. From the collected data on power generation levels, the service can detect reductions in power generation, suspensions of power generation and abnormalities, and send email alerts to managers. This allows managers to discover mechanical failures or power generation problems at an early stage.

Applications: Centralised management of dispersed PV power plants.

Platform: The data collected by Venus Solar can be viewed from a variety of perspectives, including the energy generation business as a whole, individual energy generation business units (such as projects or investment funds), or individual power facilities, to enable confirmation on the status of power generation. In addition, the service can present hourly/daily power generation results in graph format, and it also offers a function that brings together the necessary data for operations managers in the form of a report.

Availability: In Japan from April 2015 onwards.

New software from TabTool enables advanced mobile PV power plant O&M services

The software provider TabTool and the PV plant manager greentech have developed an innovative mobile solution for maintenance, inspection and repair management for PV systems. With a growing need to provide fast, reliable and accurate low-cost asset management solutions for PV power plants, clients need to have all system data relating to their investment to hand and also to be kept informed of all developments. TabTool PV provides a predefined framework for acquisition, maintenance, repairs and especially extensive inspections for deployed PV systems. The standardised platform is designed to provide users with consistently high-quality data for all components, making it easier to identify systematic errors and to take the appropriate action at the right time.

Power Electronics provides easy deployment central inverter for 1500V solar modules

More and more PV module manufacturers are releasing 1500V (DC) PV modules, while EPCs and project developers are seeing 1500V as an opportunity to lower the price per-watt and gain competitiveness. Power Electronics' new utility-scale solar inverter, HEC1500V, ranges from 1MW to 3MW, offering higher yields and providing improved up-time. The HEC1500V inverter is available with the FSDK 1500V recombiner to help the beginners with a successful first experience. The FSDK is featured with fuse and contactor per input, to reduce fuse servicing.

Cleaning | Real-time and forecasted weather intelligence integrated into Ecoppia's cleaning system

Product Outline: Ecoppia, a developer of robotic, water-free PV panel cleaning solutions, has introduced its advanced E4 control system, which integrates real-time and forecasted information on precipitation, cloudiness and air quality.

Problem: PV power plant managers need a comprehensive view of site conditions to make better-informed decisions on cleaning schedules.

Solution: Data from The Weather Channel is now fully integrated into Ecoppia's web-based monitoring and management dashboard, allowing customers to access current weather conditions and forecasts for a given site and schedule cleanings. Because the data is built into E4's master control, the system can automatically retract any cleaning robots in the field during severe weather events.

Applications: Cleaning modules at PV power plants.

Platform: Ecoppia's E4 technology is claimed to remove 99% of dust from fixed mounted PV panels to maintain maximum production levels and accelerate return on investment. Each robotic E4 unit is self-charging, self-cleaning and can be monitored and controlled remotely to mitigate the need for on-site maintenance.

Availability: February 2015 onwards.

Mounting | Renusol has extended its MetaSole mounting solution to include the portrait orientation

Product Outline: Mounting systems manufacturer Renusol has extended its MetaSole mounting solution to include the new MS+ Portrait, which is capable of fixing PV modules to roofs in portrait orientation.

Problem: Depending on the roof surface available, mounting solar modules in a portrait configuration sometimes allows more panels to be fitted, enabling a greater output to be generated. It may also be preferable to install PV modules to the roof in a portrait as opposed to a landscape orientation for aesthetic reasons.

Solution: The MS+ Portrait mounting system can be used with all solar modules and the majority of trapezoidal sheet metal roofs. The mounting design enables rear ventilation of the solar modules and eliminates continuous mounting rails. Pre-assembled parts and the low number of components also reduce installation time as well as logistics and transportation costs. The MS+ Portrait allows PV panels to be securely installed on roofs with inclinations ranging 3 to 70 degrees. At 3.0 kg per kWp, the system is lightweight, making it suitable for roofs with low load-bearing capacities. The mounting material needed for 1kWp fits into a shoe box, saving both logistics and transportation costs.

Applications: Portrait mounting system for rooftops including trapezoidal sheet metal roofs.

Platform: The MS+ Portrait mounting system comes with screws that can be drilled through the rail at any point, making the rail compatible with different distances between the corrugations found in metal roofs.

Availability: April 2015 onwards.

Product reviews

Inverter | Delta extends RPI series inverter line with new smaller and lighter 15kVA and 20kVA models for Europe

Product Outline: Delta Group's new three-phase transformerless inverters, RPI M15A and RPI M20A, are next-generation models displaying improvements in power density, peak efficiency and thermal performance in comparison to the previous generation 15TL and 20TL.

Problem: Large commercial PV installations are put under increasing pressure to meet high power demand during the daytime that can maximise the consumption of the PV energy produced by their PV plant and reduce the volume of purchased electricity needed from the grid.

Solution: For the system planner, maximum flexibility is ensured thanks to a wide input voltage range of 200-1,000V and two MPP trackers. Asymmetrical loading (33/67 %) is also possible, ensuring maximum yield in large commercial rooftop installations with multiple roof orientations. A reduced weight and compact form provide the new M15A and M20A with improved power density. Further improvements include a high peak efficiency up to 98.4 %, an increase from the former peak efficiency of 98.0%. Thermal performance is enhanced in the new units with an increased de-rating temperature up to 49°C when the inverter is operating with nominal AC and DC voltages.

Applications: Commercial rooftop installations.

Platform: Both units ship with a versatile wall-mount bracket, simplifying installation. The units are multifaceted and are compatible with many different commonly available solar modules and system components.

Availability: Initial M15A and M20A inverters for the European market will be made available to order beginning in March 2015.

Monitoring | skytron's PVGuard 2.1 improves O&M capabilities for PV plant performance

Product Outline: skytron energy has launched a new version of its PV supervision software, PVGuard. A range of new features and improvements in data management provides PVGuard 2.1 with customised plant displays.

Problem: Investors and O&M companies, whose renewable plant portfolios are growing, require the benefits of a unified supervision platform which integrates all their different plants to provide uniform and accurate monitoring.

Solution: The highlight of the upgraded PVGuard is the newly introduced dashboard for the clear display of all performance and yield characteristics of a PV plant. The Dashboard Designer enables PV plant owners and operators to design their own customised plant displays, which show at a glance exactly the information they need. With this new tool, PVGuard users can also design their own mimic diagrams suited to their individual arrangement of plants and featuring their own branding. The PVGuard 2.1 includes improvements in the way supervision data for plants in different time zones is handled in charts, tables and in the pre-defined views. This is especially important for operators with a global portfolio of solar power systems and plants spread across different regions.

Applications: Monitoring of PV power plants.

Platform: The new version also includes significant improvements in emailing functionality and allows PV plant owners to define multiple email lists for plants, each with a different set of recipients.

Availability: April 2015 onwards.

Commercial storage | ZBB Energy offers behind-the-meter energy storage for commercial buildings

Product Outline: ZBB Energy Corporation's Agile Hybrid series is an energy storage system developed specifically for behind-the-meter applications in commercial and industrial buildings.

Problem: Energy storage combined with distributed generation can enable the owner of the building to perform many more applications that can both reduce electricity expense and generate revenue. Much of the energy storage deployed to date in the C&I building market is limited to short duration power applications. The Agile Hybrid series is claimed to offer new ways of realising reduced operating costs and generating revenue for the owner, all while delivering safe, low-cost energy.

Solution: Some storage technologies are good at short discharge, high frequency cycling and some are good at deep discharge, long duration cycling. The Agile Hybrid system has been designed with all of these scenarios in mind, allowing it to cover applications ranging from short-term back-up for uninterrupted power supply, through to longer-term outages.

Applications: ZBB energy storage and power control platforms are used in grid-interactive, grid-independent and grid-conversion environments for a variety of applications within the commercial/industrial sector.

Platform: The Agile Hybrid system brings together ZBB's flow battery platform, the Agile Flow Battery, with the optimum complementary storage technologies required to meet any application. The Agile Flow Battery is designed for longer discharge, high-energy applications, so ZBB then integrates complementary storage technology best suited for the balance of the applications, such as super-capacitors, flywheels or aqueous storage

Availability: Already available.

Module | Panasonic launches compact PV module for UK and European markets

Product Outline: Panasonic Electric Works Europe has launched the compact N285 PV module designed specifically for the European residential and commercial rooftop markets.

Problem: Increased compactness of PV modules is required for a number of residential rooftop applications in the UK and Europe. Smaller rooftops can be optimised for matching feed-in tariff (FiT) sizes more closely to provide maximum system yield and performance.

Solution: The N285 features a reduced module length designed specifically for the European residential and commercial rooftop markets. By integrating the company's high-efficiency 'HIT' technology into a shorter panel design, the N285's compact size makes it possible to install an additional module row on a conventional small and medium-sized rooftop, thereby significantly increasing the output of a PV system.

Applications: UK and European residential rooftop market.

Platform: The N285 is optimally suited to the thriving UK market and the country's 4KWp residential FiT. Based on the rooftop space required by the average UK residential solar PV system of 3kWp, a comparable N285-based array will have an installed capacity of 3.99KWp, thus aligning with the FiT requirements and maximising the energy and earnings generated.

Availability: March 2015 onwards.

Major PV manufacturers' downstream project ambitions in 2015

Business | A growing number of tier-one PV module manufacturers have been changing business models in recent years from once being dedicated module suppliers to becoming project developers. Mark Osborne analyses the progress made by major PV manufacturers in their downstream ambitions in 2014 and expectations in 2015

Source: SunEdison.

The photovoltaic energy provider (PVEP) business model was first developed a few years ago in the US, led by its two largest integrated PV manufacturers, First Solar and SunPower. The success of the model, initially devised to ring-fence module manufacturing operations from competition from China-based producers, has led not only to more North American-based companies adopting it but also attracted the majority of tier-one Chinese producers as well.

In simple terms, becoming a PVEP enables a module manufacturer to better match production to end-market demand by generating an increasing amount of demand through internally developed PV projects that cushions against demand volatility.

Another key benefit relates to financials, as there are higher margins per megawatt to be had by selling a completed project than by simply selling modules. Even greater potential returns are possible from long-term retention of projects on the balance sheet or in the form of a yieldco vehicle, through which the full value of the asset can be recouped over its lifespan.

Module manufacturers are increasingly moving into downstream territory via the 'PV energy provider' business model.

Unsurprisingly, the PVEP model has not only attracted module manufacturers but the likes of US residential installer SolarCity and former polysilicon producer

Table 1

	2013	2014
First Solar	1,180	1,640(E)
SunPower	1,035	1,300(E)
SunEdison	536	1,048
Shunfeng (SFCE)	890	644
SolarCity	280	502
Canadian Solar	131	300
Yingli Green	128	261
JinkoSolar	230	290
Trina Solar	66	232
JA Solar	0	100
Hanwha Q CELLS	0	70(E)

Table 1. PV project completions in 2013 & 2014 include utility, commercial and residential.

Table 2

	2014 Guided	2014 Actual
First Solar	1,900	1,640(E)
SunPower	1,300	1300(E)
SunEdison	1,000	1,048
Shunfeng (SFCE)	2,000	644
SolarCity	500	502
Canadian Solar	400-500	300
Yingli Green	400-600	261
JinkoSolar	300-400	290
Trina Solar	400-500	232
JA Solar	200	100
Hanwha Q CELLS	200	50(E)

Table 2. Comparison of 2014 PV project completion guidance and actual and estimated completions.

MEMC, now renamed SunEdison. The twist with both SolarCity and SunEdison is that as their downstream success has gained momentum they have realised that having their own dedicated module manufacturing arms would potentially provide overall lower system costs, driving higher margin business.

Currently, SolarCity is building a 1GW integrated module manufacturing plant in the US, which will be completed most likely this year and on stream in 2016. SunEdison, meanwhile, outsources in-house designed modules to the likes of Flextronics but has publicly announced ambitions with potential partners to build large-scale integrated production plants in key emerging markets such as India and the MENA region. Therefore, both companies have been included in the analysis ahead of them both becoming module manufacturers and thus PVEPs.

However, the PVEP model is still evolving, and technically SunEdison and Shunfeng Clean Energy (SFCE) have already gone beyond PV to include wind energy in their project development portfolio. The data compiled for these 'clean energy' providers only relates to their PV operations.

In respect to First Solar, the company has been expanding its revenue opportunities within the EPC and O&M sectors and hopes to be a player in the residential market with the acquisition of n-type monocrystalline start-up Tetrasun, following SunPower and its strength in the commercial and residential markets.

Indeed the PVEP business model is at an early stage and rapidly evolving along with the channels to low-cost project financing.

Leaders and laggards

As shown in Table 1, the first-mover advantage enjoyed by leading CdTe thin-film producer, First Solar, followed by high-efficiency n-type monocrystalline module leader, SunPower, means the two companies were significantly ahead of their nearest rivals in project completion terms in 2013 and 2014.

> "There are higher margins per megawatt to be had by selling a completed project than by simply selling modules"

Both companies surpassed 1GW of project completions in 2013 for the first time, propelled primarily by large-scale utility projects in the US. However, several other US-based companies have expanded their downstream businesses at a faster rate, such as SolarCity and SunEdison. Both companies have doubled installations between 2013 and 2014.

Table 3

	2013	2014	2015 Guidance
First Solar	1,180	1,640(E)	2,230(E)
SunPower	1,035	1,300(E)	1,670(E)
SunEdison	536	1,048	1.56GW-1.9GW(E)
Shunfeng (SFCE)	890	644	1.2-1.9GW(E)
SolarCity	280	502	920-1,000
Canadian Solar	131	300	695-765
Yingli Green	128	261	400-600
JinkoSolar	230	290	600-800
Trina Solar	66	232	700-715
JA Solar	0	100	200-350
Hanwha Q CELLS	0	70(E)	128-300

Table 3. PV project completion guidance for 2015 (including estimates)

SunEdison is notable for surpassing the 1GW mark for the first time in 2014, becoming the third largest of the PVEP firms by project completions.

It is interesting to note that both First Solar and SunPower have been capacity constrained during this period, while SolarCity and SunEdison have remained unshackled from any in-house manufacturing altogether.

Technically the fastest growing PVEP is China-based SFCE, which started as an EPC before acquiring the manufacturing operations of Wuxi Suntech. SFCE has grown more by project acquisition than pure project development, helped by being focused on the Chinese market, the largest in recent years and set to continue for several years to come.

In contrast, several major global top-10 module producers have lagged behind the first movers. Although Canadian Solar had undertaken projects before 2013 as well as Hanwha Q CELLS and Yingli Green, the quantity and scale of the projects rarely matched those undertaken by First Solar and SunPower.

In fairness to Yingli Green, Trina Solar, JinkoSolar and JA Solar, downstream project ambitions have come later than most others and are therefore in a catch-up mode over the course of the next few years.

Project challenges in 2014

Despite the wide disparity in projected completions between the first movers and the other leading PVEPs, 2014 proved to be a year of momentum building for most of the currently lower ranked companies (Table 2).

Canadian Solar, Yingli Green, JinkoSolar and Trina Solar completed more projects in 2014 than in the previous year. However as Table 2 shows, guidance given by many of these companies for project completions in 2014 were significantly higher than what was achieved.

Although Trina Solar, for example, was successful in accelerating project completions from 66MW in 2013 to 232MW in 2014, completions fell well short of its guidance range of 400MW to 500MW.

A key factor behind this trend was that these companies were building projects almost exclusively in China. It has been well documented that delays in project planning approvals, grid connections and a late-year surge in building, which was impacted by cold weather in certain


Source: First Solar.

regions, contributed heavily to the shortfalls in 2014.

Canadian Solar was impacted by delays to projects not only in China (though smaller exposure) but also in Japan due to a number of grid operators halting PV power plant connections in fear of claimed grid overload.

It should also be noted that continued growth in global downstream PV demand, meaning greater demand for tier-one producers' modules, could have played a part in dampening in-house project development, particularly given the recent stabilisation of module prices.

Producers such as Trina Solar, Canadian Solar, JinkoSolar and JA Solar reported record module shipments in 2014, considerably outpacing rivals.

Conversely, it could be argued that First Solar and SunPower's significantly lower dependence on third-party module business enabled them to better match project guidance with completions than other module producers in 2014.

Project guidance momentum in 2015

When analysing project completion guidance, and estimates where guidance has not been given (see Table 3), it is clear that the vast majority of PVEPs are planning to expand project completions in 2015. As shown in Table 3 estimates are given for several of the top PVEP developers for 2015.

The joint First Solar/SunPower yieldco could substantially boost their project activity.

In the case of First Solar and SunPower, 2015 guidance has been withheld due to both companies joining forces in establishing a yieldco and floating it on the US stock market.

Analysis of PV projects both parties have said will be rolled into the yieldco, coupled to ongoing projects and previously disclosed project plans for the year, as well as the fact the companies are working together with in-house manufacturing capacities, enables an educated estimate of project completions in 2015.

However, in respect to First Solar it should be noted that the strong project completion forecast takes into account higher capacity and utilisation rates than the company could achieve in 2014, coupled to its significantly rebuilt project pipeline that was previously articulated at its Analyst Day event in 2014.

In regards to SunPower's increased project completions, despite remaining capacity constrained through 2015 with only a small incremental increase in cell/

Table 4

	2015 Guided	2014 Pipeline	2015 Pipeline
First Solar	2,230(E)	13.7GW	13.5GW
SunPower	1,670(E)	8GW	10GW
SunEdison	1.56GW-1.9GW(E)	5.1GW	5.7GW
Shunfeng (SFCE)	1.2-1.9GW(E)	4GW	6GW
SolarCity	920-1,000	2GW	3.0GW
Canadian Solar	695-765	3.2GW	8.5GW
Yingli Green	400-600	1GW	1.6GW
JinkoSolar	600-800	1.1GW	600-800
Trina Solar	700-715	1.GW	1.0GW
JA Solar	200-350	400MW	200-350
Hanwha Q CELLS	128-300	950MW	2.17GW

Table 4. PV project pipelines 1Q 2015.

module capacity, it should be noted that it has a strong 1GW pipeline of 'C7'-based technology (low-concentrate CPV) in China.

SunPower therefore can utilise its 'Maxeon' solar cell production capacity to provide CPV systems built in China under a JV arrangement that technically exceeds its conventional solar cell/module nameplate capacity.

With regard to SunEdison, which remains fabless, the estimated project completions are due to the company acquiring First Wind and only guiding combined completions in the range of 2,100MW to 2,300MW. SFCE has also not provided a breakout of guided PV and wind project completions for the year.

An overriding factor in the expected project completions in 2015 for First Solar, SunPower, SunEdison and SolarCity is the looming tax credit (ITC) reduction at the end of 2016.

Recently, market research firms IHS and Bloomberg New Energy Finance (BNEF) have forecast total PV installations in the US to reach over 9GW in 2015, up from around 6.4GW in 2014.

The remaining companies listed in Table 3 have all provided guidance during March and early April when releasing fourth quarter and full-year financial results for 2014.

Clearly the likes of SolarCity, Canadian Solar, JinkoSolar, JA Solar and Trina Solar are all expecting to double completions in 2015 over actual completions in 2014.

This is not a surprise when considering that those heavily dependent on the Chinese market experienced delays in 2015, enabling projects in 2014 that were already designed, financed and initiated to provide a strong base for completion growth in 2015.

A good example of this factor is JinkoSolar. The company's management noted in its Q4 earnings call that it expected module shipments to its own downstream projects in China to be in the range of 160-180MW in the first quarter of 2015 and was in line to have 350MW of projects on the subsidy catalogue in China in the same quarter.

One of the late starters in the project business, Trina Solar, failed meet the low end of completion guidance in 2014, yet has guided project completions 200MW higher than the high end of last year's guidance.

The strategy employed by Trina Solar is to sell plants built overseas, primarily those in the UK, while holding the Chinese projects on its balance sheet. Management noted in its Q4 earnings call that it already had 300MW of projects under construction.

However, the company was more confident this year in meeting guidance, noting that it expected 50MW of projects to be completed in Q1, around 50MW in Q2 and approximately 200MW to be completed and grid connected in Q3. Though completions are still loaded to the back end of the year, management noted it expected around 450MW to be completed in Q4, 2015. It should be noted that the figures far exceed the clarity given for projects in 2014.

Shunfeng was another company that recently reported in Q1 2015 that it had over 1.4GW of PV projects currently under construction.

"Once-dedicated PV module suppliers have found alternative revenue streams and in some cases quickly divorced themselves from upstream market volatility"

Project pipelines and pipedreams

Any serious analytical study of what a PV project pipeline actually means is almost impossible as there is no financial and industry standard benchmark as to what a pipeline constitutes in terms of future project completions and revenue.

The fixation with pipelines by the larger project developers, compared to the smaller rivals that rarely divulge such data, should be noted.

However, such is the care and attention given to pipeline divulgence compared to actual annual completions, it is worth logging what the key PVEPs are saying about this aspect of the downstream business.

As shown in Table 4, actual guided completions in 2015 bear little correlation to the pipeline figures. The majority of companies listed have a pipeline figure higher than that of the previous year, which is intended to illustrate the future growth of projects as they move from a planned stage to an implementation stage.

Though simple in context, there is little correlation year to year to the pipeline and actual PV project completions. Although companies attempt to qualify the terminology surrounding pipelines, those listed have yet to reach any common ground and therefore further interpretation is almost meaningless.

That said, it is worth noting that several companies, hopefully using the same in-house metrics, have grown their pipelines significantly in the last 12 months.

SunPower has added 2GW to its pipeline, which includes 1GW in China and assumptions over translating projects in the US to completions due to ITC expiration. SunEdison on the other hand has more than doubled its pipeline, fuelled by the US, China and overall overseas expansions.

Although it seems First Solar's leading pipeline figure may have slightly declined year on year, it has promised 5GW of potential projects in India after the Indian government issued new and aggressive targets through 2020.

As mentioned earlier First Solar's potential yieldco JV with SunPower could catapult project development along the same trajectory that SunEdison has proved possible after establishing its own yieldco in 2014.

PVEP evolution

The migration to a PVEP business model is clearly underway for a number of companies but the model itself is likely to evolve and morph as companies leverage the successes or failures of the pace of the transition.

Once-dedicated PV module suppliers have found alternative revenue streams and in some cases have quickly divorced themselves from upstream market volatility and competition.

Momentum is building for 2016 and beyond with the news that Canadian Solar plans to initiate its first global yieldco financial vehicle, bolstered by its acquisition of project developer Recurrent Energy from Sharp Corporation, and yieldcos planned by the likes of Trina Solar and JinkoSolar and the already mentioned JV plans of First Solar and SunPower.

Based on the above analysis, PVEP project growth has not been without short-term challenges but near-term growth projections indicate the path to further financial security, manufacturing scale and global footprint migration. ■

Larger projects, fewer players:

Is South Africa's solar programme becoming a victim of its own success?

Source: Scatec Solar.

Competitive bidding | Now into its fourth round, South Africa's national renewable energy programme has successfully driven down the price of solar energy. But there are growing concerns that this has been at the expense of fostering a diverse local market, writes Tom Jackson

In April, the South African Department of Energy (DoE) finally announced the selection of six PV projects under the fourth round of its flagship Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Yet, as prices continue to fall and projects get bigger, there are concerns smaller developers are being shut out of the process.

According to DoE figures the pricing of solar under the REIPPPP has been on a downward trajectory since the first round in 2011. Back then, according to the Department of Energy, solar PV-generated electricity cost ZAR3,288 (US$273) per MWh. This fell 40% in round two to ZAR1,961/MWh, 46% in round three to ZAR1,050 and 25% in round four to ZAR786, an overall price fall of 76%. Prices could yet fall by another 19% in the next round.

The Department of Energy attributes the fall in prices simply to competition. "The REIPPP programme is a rolling window and it attracts continued market interest which induces increased competitive pressure amongst bidders to offer reduced pricing," the department says.

Yet this is only part of the story. Dirk De Vos, chief executive officer (CEO) of QED Solutions, a consulting firm that has advised a number of REIPPPP participants, believes there are two sides to the falling prices.

"I think it is a positive thing, but not as positive as everyone says it is," he says. "The world is looking for yield, so it is less attractive from that point of view. It has pushed the returns right down. But the competition has been good."

Competition has certainly increased. The Department of Energy calls the growth "dramatic", and the figures concur. Whereas REIPPPP round one was 65% oversubscribed, this grew to 306% in round two and a huge 733% in round four.

Some believe this increase in competition can only be a good thing. Former shadow minister of energy Lance Greyling says overall the costs of using solar have come down in South Africa, meaning households and businesses wishing to pursue embedded generation options can now afford to do so.

"In fact in a municipal context, many office blocks are now finding it cheaper to source their electricity from PV than to buy it from the municipality," he says.

But there has been another effect of the fall in prices and the corresponding growth in size of the projects. Five of the six projects selected in round four are 75MW (see table); only three developers feature on the list, and of these two are international firms. Smaller – and primarily local – developers are being shut out of the process.

"As the average size of projects has increased, naturally the number of preferred bidders has dropped. This has also meant that only the participants with strong balance sheets have reached the preferred bidder stage in rounds three and four," says Moeketsi Thobela, chief executive of the South African Photovoltaic Industry Association (SAPVIA).

"Smaller projects cannot compete on the same basis as larger ones. The outcomes are therefore not favourable for investors and project developers that have put forward projects with capacity that is lower than 60MW."

Thobela says though the effect of the REIPPPP in boosting the competitiveness of the PV sector in South Africa is welcomed, it does matter that smaller firms have been left out as the mid-scale market is not sufficiently de-risked.

The Department of Energy admits there has been a drop in the average percentage of local equity participation in the projects since round one, but argues all project companies are required to have a minimum of 40% South African shareholding. Greyling supports these localisation requirements, saying they have ensured big international players partner with local manufacturers. But De Vos believes round two, when companies began to finance projects through their balance sheets, signalled the end of local developer participation, leaving them simply as "glorified estate agents" for bigger firms.

"They funded the whole project themselves. They were able to avoid the whole process of due diligence that local banks require, so their cost of bidding was lower. They could put a lot more in," he says of the large foreign firms that now dominate.

But does it matter if local players are left out of the process, if projects are being completed and the price of solar power is lowering for individuals and businesses? Not in theory, says De Vos, but it does leave South Africa in a potentially risky situation if interest rates were to rise or South Africa were to be downgraded.

"Success is a question of people looking for yield, but if South Africa gets downgraded, a lot of these things will become problematic, and a lot of these guys are going to leave," he says, adding that this would be a scenario where the lack of local capacity would hurt the country.

Thobela is also concerned about the financial viability of projects given the declining prices, even if the sector has been rendered more competitive. "It's not good to the extent that it affects financial viability, and increases the risk that projects may not reach financial close," he says.

Project name	Size (AC)	Lead developer
Sirius Solar PV Project One	75MW	Scatec Solar
Droogfontein 2 Solar	75MW	SunEdison
Dyason's Klip 1	75MW	Scatec Solar
Dyason's Klip 2	75MW	Scatec Solar
Konkoonsies II Solar Facility	75MW	BioTherm Energy
Aggeneys Solar Project	40MW	BioTherm Energy

Winning projects in round four of the REIPPPP.
Source: South African Department of Energy.

"Furthermore, the increase in average project size points to the existence of a gap in the range 5-50 MW, where ready projects are not able to proceed because there is no suitable programme that can accommodate their cost structure."

De Vos says there is another issue, in that the rules allow bidding companies to "game" the system, quite legally. Though energy minister Tina Joemat-Pettersson has said she expects successful bidders to begin commissioning in November next year, precedent suggests this is unlikely, given there was a gap of more than a year between the announcement of the successful bids in round three and those projects reaching financial close, never mind the commissioning stage.

The delays last time were around grid connection constraints, and De Vos does not believe anything is likely to change this time round. With the winning solar PV projects based in the Northern Cape – where the best solar conditions are – he says most of them can only be connected when this part of the grid is strengthened by Eskom, something that is unlikely to happen before 2018. Therefore, companies are in theory able to lock in the 2015 tariff and "sit on their hands while panel prices continue to fall". Delivering as late as 2019 has become a perfectly legal financial option.

"I don't think that is optimum at all," he says. "I'm not saying it is illegal, but it is gaming the system. If they had to deliver it in the next 18 months, would they have bid the same price?"

De Vos says these delivery delays are hurting the renewable energy sector in South Africa, and denying the country electricity it desperately needs given the shortcomings of the grid.

"South Africa is short of generating capacity. When you are short, if there was solar, it would be great. We would avoid having this load-shedding. We need electricity," he says.

"You can say what you like about solar, but it is the quickest of anything else in terms of bringing a project to completion. You can build a power plant in 18 months. That's the value of renewables. It builds capacity, it is clean. But then we have projects that can't even start for three years. It is so bad for renewables."

De Vos also highlights financial wastage in the bidding process, though he notes with all these concerns that the rules have been and will be further amended as the programme goes on.

"What we saw from round two on, particularly round three, was round three had 93 compliant bids. If each bid costs ZAR15-20 million, to the point where you are bidding, and you've got 17 that won it, you've got a one in five chance. All the way down to 50 are very good projects, they just didn't make it in the end," he says.

"You've got all these great projects that didn't make the cut. That's a pity. I think it's quite wasteful in a way. Nobody thinks about how much money is getting lost. I don't think it is being managed as well as it could have been."

Suggestions of revolutionary alternative programmes are few and far between, but most agree tweaks are necessary. De Vos has called for the rules to be changed to allow for only projects that can begin immediately to be considered.

"After round four, you can't say you can build it when Eskom strengthens the grid. When you get the thing, you start building," he says.

For smaller developers, there are possibilities in the programme amendments advanced by Thobela. He calls for the process to be changed to allow smaller developers to participate more than they have in rounds three and four, most likely in projects within the underserved sub-50MW range.

Joemat-Pettersson has already said the bidding process will be redesigned in time for the fifth round next year to allow for various issues, while it will issue a "request for further proposals" from previously unsuccessful bidders in advance. Just how substantial these changes will be, and whether or not smaller and local companies will benefit, remains to be seen. ■

Author

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Mexico struggles to thaw solar market chill

Emerging markets | Mexico remains a market of undoubted potential, but there's a growing opinion that it will struggle to live up to its hype amid regulatory uncertainty. Liam Stoker asks if last year's sweeping energy reforms will continue to hold the market back, or result in a solar explosion by 2018

Source: Isofoton.

With an approved project pipeline totalling 3GW, enticing irradiation rates and an energy market that's expected to be in considerable need of new generation capacity in the coming years, Mexico is an international market on many solar developers' lips. Analyst firm GTM Research expects Mexico's solar capacity to soar from last year's 66.7MW to as much as 3.3GW over the course of the next three years, and all without the support of government subsidies.

But this is a market not without its problems and solar, despite being almost custom-built for Mexico's arid conditions, has yet to take off. Sweeping energy reforms enacted last year in the country are still coming into force, resulting in what GTM Research analyst Adam James refers to as a "chilling of the market", but the problems preventing a much-anticipated solar explosion in Mexico may be deeper rooted.

In June 2014 Mexico's government looked to reform its ailing electricity sector, opening the market to competition with the state-owned utility Comisión Federal de Electricidad (CFE). While CFE might still own and operate more than 80% of the country's energy generation, anybody is able to build generation capacity and sell it into Mexico's wholesale market, named the Mercaro. "It's a totally level playing field and there are no advantages for renewable energy compared to anything else, apart from very low impact clean energy certificates," James says. Stefan Blum of German development bank KfW subsidiary KEG Investment says this liberalisation of the market has opened the floodgate for "a lot of catch-up investment" that Mexico has missed out on for decades.

It's hoped that more competition in the market will drive high energy prices in the region down. There are 40 separate tariffs in the country but prices are generally high across the board, even more so in remote locations such as Baja California, which suffer at the hands of constrained grid issues and sky-high diesel prices. Sebastian Schierenbeck of renewable energy advisory firm Apricum says it's little wonder the lion's share of solar projects to get off the ground so far in Mexico are located within the western peninsula state.

And James says these tariff prices are a key reason as to why solar PV is now considered to have reached grid parity, at least in part, in Mexico. "There are plenty of customers for whom PV makes economic sense if you don't have the capital to purchase the systems up front," he says.

But solar has yet to take off. It may have reached grid parity with specific tariffs but Schierenbeck says solar PV cannot currently compete on a wholesale level in most of the country, a fact which he says is preventing almost 95% of the approved project pipeline from being constructed.

Relatively few of the projects from Mexico's 3GW pipeline have reached completion.

Mexico's energy reforms

In June 2014 Mexico enacted sweeping reforms of its energy sector, aimed at driving investment in the country and revitalising what had become an ailing electricity market. The old regime was a vertically integrated model with CFE as the sole, state-owned utility. The reforms opened up Mexico's energy market and now any company is free to build power and sell into the wholesale market. The only subsidies or advantages open to renewable energies are government-issued clean energy certificates, however these are very low impact.

A lack of support

Unlike other markets across the world, Mexico's government offers no meaningful subsidy programme for renewable energies. Clean energy certificates are available but have very little impact, and Blum says his own firm considers them merely as a "potential upside" rather than of any tangible value, stating their current value to be "basically zero".

Unfortunately for solar and indeed the entire renewables market, Schierenbeck says this is unlikely to change in the foreseeable future. "When we talk to government-related agencies or the government itself, we didn't get the feeling there would be any additional subsidy aside from the certificate market," he says.

James adds that solar is also being restricted by demand charges on electricity bills paid for by commercial and industrial firms, which are calculated between the hours of 7pm and 9pm when there is no solar production. As a result, solar cannot offset those particular charges. "That's a big

Source: SolarGIS.

Mexico's arid, sunny conditions offer the ideal conditions for solar power.

problem because it means the economics for PV are much less attractive for commercial and industrial than they would otherwise be," he says. The Mexican government has been made aware of the issues, but the likelihood of this changing – or the addition of subsidies to compensate for solar's inability to compete on the wholesale market – remains slim, at least in the near term.

This can be attributed to what Schierenbeck says is a lack of concerted and strong lobbying efforts in the country. Other technologies and means of generating energy, particularly the wind and gas industries, have been present in the country for considerably longer than solar and, as a result, have far louder voices.

It's an issue which Schierenbeck believes is changing – a lobbying group set up last April is beginning to make great strides in the country – but he believes there are still deep-rooted misunderstandings within the government. "My personal opinion is that they still believe solar is expensive and not a mature technology," he says. "The mind they have at the moment is to get cheap gas from the US and really lower the electricity costs by relying on more conventional generation and mature renewables, which they consider as only wind."

Cheap gas from the US continues to present its own issues. Southern US states have been proactive in drilling for shale gas and a number of projects are due to come on stream in the next two years. Pipelines into Mexico are also due for completion, which Schierenbeck says is creating volatility in the wholesale price. Blum concurs that the prospect of cheap shale gas being piped into the country presents one of the biggest threats to Mexico's nascent solar market.

And James adds that it only furthers the perception within Mexico that rates will eventually fall, leaving off-takers in the country reluctant to commit to long-term power purchase agreements associated with solar PV projects. Off-takers in the country are scarce with some municipalities unviable, and those off-takers are tending to prefer short-term PPAs which in turn create problems with obtaining financing.

Hope on the horizon

There are mixed views as to what effect the country's energy reforms will have and to what extent they will impact its potential for solar. James is of the opinion that ending CFE's monopoly and opening the country up to competition will eventually result in a market quick to embrace the cheaper generation rates solar can provide, but is understanding of the scepticism from other parties. He expects 2016 to be a crucial year for solar in the country and one that will see the market explode, and GTM is forecasting 1GW of installed capacity. Blum, however, does not share the optimism and says it won't be until mid-2016 at the very earliest until developers embrace Mexico as a legitimate market, and possibly into 2017 until it is considered a "financeable market".

But while utility-scale PV has been slow to take off, the distributed generation market has been experiencing explosive growth rates. Free of the wider regulatory uncertainties that have led to private off-takers being unwilling to engage in long-term PPAs, Schierenbeck the situation is almost the complete reverse for distributed generation, which stuck far quicker than other sectors.

"There's a good opportunity on the commercial side to use the net metering scheme that's available and has been well received so far, and you can directly approach commercial customers, or someone needing a system of something between 20 and 50kW on the roof to lower energy consumption," Schierenbeck expains. "This is going forward and there are also a lot of developers active in that region, especially those coming from the US and seeking new opportunities."

James estimates that between 13 and 15 developers are responsible for 80% of the country's distributed generation market, and given its relative immaturity there is no clear market leader. That could change should the US giant Solar City expand into the region as has been anticipated, but for now at least there is ample room for market entrants. Blum considers now to be the prime time for any interested parties to commence any entrance strategy, before it becomes saturated with developers seeking to jump on the bandwagon.

Those who do will have to enter with caution. James says pipeline acquisition will be a key problem for developers, despite the relatively sizeable 3GW of approved projects sat dormant. Schierenbeck estimates that as much as 40% of these projects could be built under the new regime as compared to just 5% under the old one, but acquiring projects that are simply unviable will be a significant risk for new entrants to the market, despite Blum's prediction for some bargains to be had.

Mexico's status as a potentially sizeable market for solar is one currently in flux, hindered by a general lack of government support, regulatory uncertainties stemming from last year's sweeping reforms and the problems these two factors have created in tempting private off-takers into long-term, secure PPAs.

"In general it's a very attractive market that attracts a lot of international players, but we need to see," says Blum. "We don't really see the big utility-scale projects on the debt side because of the insecurity, but what we do see is more on the equity side, players that are betting more generally on the Mexican market not with a one or two-year perspective, but five to ten years." ■

GTM Research Mexico market predictions 2014-2018

2014 – 66.7MW
2015 – 295MW (cumulative capacity: 361MW)
2016 – 560MW (1GW)
2017 – 940MW (2GW)
2018 – 1.3GW (3.3W)

Two steps forward, one back

Conference report | In April, the deployment of solar in West Africa came under the spotlight during a two-day event in Accra, Ghana. Reporting on the event, Ben Willis heard huge excitement over the prospects for solar in the region tempered by the realities of scaling up a new technology in a challenging part of the world

The inaugural Off-Grid Solar and Renewables West Africa event held in Ghana in April offered some tantalising glimpses of what could be in a part of the world that arguably stands to benefit most from PV technology. With some of the lowest electrification rates on the planet, solar in all its forms – grid-connected, off-grid, hybrid – has huge potential to light the region up, and this optimism was much in evidence.

Yet also plain to see were frustrations over the realities of translating that promise into projects on the ground. Factors including inadequate grid connections, slow-moving policy and a paucity of financial incentives were all highlighted during the course of the event as being major challenges for the region. Overall, the message was that while West Africa is ripe for a solar revolution, a number of hurdles – political, logistical and fiscal – must first be overcome.

The event was opened by Ghana's deputy power minister, John Jinapor, who spelled out why his country is looking to solar and other forms of renewable energy to bolster its ageing energy infrastructure. Over half of Ghana's power comes from hydro, notably the 1960s-era Akasombo Dam. Back-up power is provided from a fleet of thermal plants powered by gas largely imported from Nigeria. Both sources of power have of late become unreliable, the dam because of lower water levels in Lake Volta and the thermal plants because of fluctuating gas supplies.

"That is why as a government we took a decision to pass the Renewable Energy act 832, in order to diversify more – through wind, through solar, biomass, mini-hydro and all the other sources," Jinapor said. "That way we have a much more diversified energy mix. If water levels go down, if gas flows have a problem, we can depend on solar and wind."

Source: Nathalie Bertrams.

West Africa is a promising region for solar at all scales.

The act sets a 10% renewable energy target by 2020 and is backed up with feed-in tariff and net metering policies. The FiT has already proved partially successful, particularly where solar is concerned, eliciting project proposals totalling over 2GW from prospective solar developers.

On one level this is an astounding success for a country where renewable energy so far only accounts for some 0.2% of the generating capacity. But equally, it has presented Ghana with something of a headache, as the amount of solar proposed and provisionally licensed by its Energy Commission is almost as much as the country's entire current generation capacity of 2,845MW. Compared to some West African countries, Ghana's electricity grid infrastructure is fairly well developed, with electricity access approaching 80%. But the prospect of integrating over 2GW of utility-scale solar capacity into a comparatively weak grid system is clearly one that has Ghana's authorities in a fix.

This fact was explored by Wisdom Ahiataku-Togobo, director of renewable energy at Ghana's Ministry of Energy, who pointed out that countries such as Germany that have high levels of solar penetration also have reserve power capacity to back up variable sources such as solar. "This unfortunately is not the case in Ghana. We have our peak load in the evenings between 6 and 12 midnight, when the sun is not available," he said.

This scenario has prompted Ghana's authorities to impose a brake on the country's utility-scale solar market, even before it has taken off. Ahiataku-Togobo explained how following a study of Ghana's grid capacity, the decision had been taken to impose a temporary cap of 150MW on utility solar development. Within this cap, projects will be limited to 20MW if connected to the transmission network or to 10MW if feeding into the distribution network. The exceptions to this rule are solar projects that are planned with appropriate storage or back-up power provision.

"We have set this limit to see how it will impact on the grid. And once we get this done successfully and there is no significant impact on the grid, then the target will be increased to levels that the grid will be able to afford," said Ahiataku-Togobo.

Off the grid

Of course utility solar is only one part of the equation in West Africa – perhaps more exciting for a region with only limited grid capacity are the prospects offered by distributed and off-grid technologies.

Mahama Kappiah, executive director of the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE), said that to meet the UN's 'sustainable energy for all' objective, which aims to improve both access to and cleanliness of power, West Africa would need to see the mass deployment of stand-alone power systems, mainly powered by solar.

"At the ECOWAS level, to meet the targets of sustainable energy for all we would need 262,000 stand-alone systems," he said. "Within this region we have countries like Liberia Sierra Leone, Guinea or Mali with only one transmission line – not like Ghana, which is one of the few with a transmission network.

"In most countries it is a lot more expensive to get power through the grid than to have stand-alone power. So that is how we estimated we would need up to 262,000 stand-alone systems in order to attain the target. And most of it in this region is going to be from solar."

This theme was taken up by Simon Bransfield-Garth, CEO of UK off-grid technology firm, Azuri. Bransfield-Garth used the event to launch a programme that will see 100,000 of Azuri's pay-as-you-go solar systems installed in households across rural Ghana.

Speaking separately to PV Tech Power, Bransfield-Garth said recent years had seen a growing recognition that grid power will remain a distant prospect in some parts of rural Africa for some time to come. "If you were to ask governments three to four years ago what was electricity, they would have all talked about grid electricity," he said. "I think there's a realisation now that there's going to be a variety of different electrical services to people and there are going to be people for whom grid electricity is going to be some way off. So rather than have a world of haves and have-nots, what we're trying to do is to provide an appropriate level of power to people who aren't going to get the grid."

Political framework

In Ghana, the renewable energy act makes provision for off-grid renewable power systems, including a renewable energy fund aimed particularly at rural areas. The country also has a net metering policy in place to encourage businesses and public institutions such as hospitals and government departments to deploy solar systems.

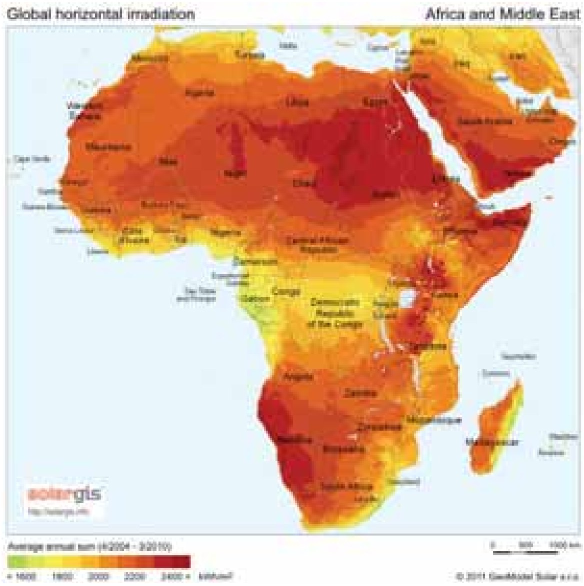
Kappiah underlined the importance of policy frameworks such as Ghana's to entice the investors needed to propel forward the deployment of renewables in West Africa. "I can assure you no utility will do this, no ministry will do this – it will be the private sector," he said. "And for private sector to come in, we have to create the necessary environment within our countries."

Kappiah described the work his organisation, ECREE, is doing to support ECOWAS governments to draw up renewable energy plans and frameworks. Most countries in the bloc now have such plans in place, he said, and a few – including Liberia and Niger – even have feed-in tariff policies.

But using the example of Ghana Kappiah pointed out that even having such policies in place was no guarantee of success. "The [FiT] we have in Ghana is not actually implementable. As we have seen with Ghana, lots of people have come in, but nothing is moving because there are too many question marks attached to the FiT," Kappiah said.

Clearly this struck a chord with members of the audience, with one representing a major Chinese module manufacturer suggesting moves such as the one by the Ghanaian government to put the brakes on solar deployment would be damaging.

"People started to come to register projects, and then all of a sudden the ministry and energy commission say look, this isn't going to happen, so put on the brakes. It's quite difficult for developers – these are developers who play in the megawatt and large scales, so they come and make feasibility studies and things, and all of a sudden they're told their project they cannot do it and it has to be 20MW. It becomes a disincentive; it doesn't matter how peaceful the country is, that's still a risk factor for developers to consider," the delegate said.



Source: GeoModel Solar.

West Africa has attractive irradiance resources

Professor Abubakar Sani Sambo, chairman of the Nigerian Member Committee of the World Energy Council, echoed these concerns over the continued prevalence of risks for would-be renewable energy investors in West Africa. Alluding to the situation in his home country, Sambo highlighted a number of constraints "that bedevil the sector".

"Essentially it's a lack of law, lack of financial incentives and a problem of capacity building and infrastructure deficiency that has not allowed this situation to move on," he said.

In Nigeria he said renewable energy currently only accounted for a fraction of one percent of the country's total generation capacity. He said he hoped Nigeria under its new president, Muhammadu Buhari, would recognise the importance of renewable energy in boosting the country's erratic power supply. There are some positive signs, with a renewable energy law currently in draft form awaiting approval and enactment by Nigeria's national assembly and a draft FiT proposal expected soon, Sambo revealed.

Summing up the prospects for solar in Nigeria, Sambo said: "It's a very big task, but once the political will is there we'll get there."

That could indeed be said for much of the rest of the region.

Solar & Off-Grid Renewables West Africa was organised by PV Tech Power's publisher, Solar Media. For further information on Solar Media's international portfolio of events, visit **www.solarenergyevents.com**

intersolar EUROPE PREVIEW

Intersolar Europe Conference: 9-10 June
Exhibition: June 10-12, 2015

Europe's largest solar industry gathering kicks off in Munich once again this year, with an expected 42,000 people joining Intersolar Europe's conference and exhibition at the ICM – Internationales Congress Center München.

The exhibition, which covers a full range of solar products and services, offers the chance to get up close and personal with some of the biggest companies and potential game-changers in the industry and to seek out future and niche markets. Meanwhile the conference will discuss an extensive series of topics while pinpointing key trends in the sector.

The event acts as platform and catalyst for presenting solar innovation and development to delegates from around the world, with many international companies coming to learn from and do business in Europe, one of the world's largest PV markets.

In Europe, subsidies for solar continued to fall this year, with the era of feed-in tariff support appearing to be drawing to a close across the board. The German government, for example, is progressively reducing funding in accordance with its Renewable Energy Sources Act. Meanwhile government support for large-scale PV completely ended in April for the UK, one of the more dominant solar markets last year.

As a result, new PV installations in Europe were down 36% in 2014, from 11GW installed in 2013 to just 7GW the following year, with only the UK showing improvement, according to the European Photovoltaic Industry Association (EPIA).

Nevertheless Europe has already installed considerable amounts of solar capacity, so it is now looking at new ways of integrating solar power into the grid. Furthermore the decline in subsidies has led to a demand for new business models, set to be a major topic of conversation at this year's show, as businesses look to new ways of financing operations without leaning on the traditional means of funding.

Indeed, there are signs of the market maturing, with Italy becoming the first country to introduce grid interconnection rules for energy storage marking a significant new trend in the sector. Furthermore, under Germany's energy transition, the Energiewende, the government issued competitive tenders for the first time as an alternative allocation of subsidy support.

Intersolar will of course not concentrate solely on 'Euro-centric' matters. Despite record-breaking drops in oil prices, the enduring decline in PV module prices has allowed for a sustained demand for solar installations globally, with solar becoming the most inexpensive source of power in many parts of the world. Reflecting solar's global presence, the show will present seminars, talks and workshops on the full range of existing and emerging PV markets, featuring top analysts and senior industry figures.

Away from the continental perspective, as electricity begins to move up on the power agenda, a special 'Innovative Mobility' exhibition will be introduced, showing new electric transportation and charging technologies.

In other technological advancements, on-site consumption will remain a big issue this year as the end of feed-in tariffs means it makes economic sense to keep energy on-site rather than export to the grid. Meanwhile the industry is starting to take up the integration of energy management systems and work alongside smart technology companies.

The focus on energy efficiency goes hand in hand with the surge in energy storage innovations, another technological focus for the show. Electrical Energy Storage (EES) Europe increases its profile this year by having its own conference for the first time. The continent's largest exhibition covering battery and energy storage technologies debuted last year next door to Intersolar, reflecting technology costs and market conditions tilting in favour of the budding storage industry.

The main Intersolar Award returns for its eighth edition on 10 June alongside an innovation prize handed over to outstanding solutions in the industry. This complements the inclusion of the new 'Innovations at Intersolar Europe' session, which offers a concise glimpse into the vast amount of new products and projects launched by exhibiting companies this year.

There will also be a specific focus on the rise of photovoltaic-diesel hybrid systems. Despite being more suited to remote but sunny regions, the prospect of combining PV with diesel generators, is gaining traction especially with mining companies, who stand to gain a 70% cost advantage using by wind and solar combined with diesel generation instead of relying on diesel alone.

With momentum in Europe steadying, companies are looking to streamline the traditional energy consumption model, improve PV efficiency and find new ways of gathering capital. A year of innovation will be essential to keep moving forwards.

Solar Media will be exhibiting at Intersolar Europe. Come and say hello to our editorial and events teams at booth A2.112 and find out more about our publications and growing events portfolio. You can also pick up copies of our various publications at stand A1.393.

Big issues and new opportunities

With a volatile energy market and a fast-expanding solar sector, there are plenty of topics for the industry to stay on top of. Intersolar Europe will explore a number of issues aimed at helping the industry find new business opportunities and understand key market trends. *PV Tech Power* looks at three of these in more detail

Energy management

The benefits of smart technology can no longer be ignored, with powerful digital computer phones in the pockets of most Europeans offering the means to manage our energy usage remotely with the flick of a button.

Furthermore, emerging energy storage technologies could be combined with smart systems to provide solutions to some of the solar industry's long-established pitfalls. The intermittent electricity generation of many renewables including solar could be mitigated by improved energy efficiencies so talk of smart buildings, smart grids and smart cities is all the rage.

Energy management systems can be used to control the flow and consumption of electricity in households while keeping costs to a minimum and conserving as much energy as possible. How to design smart grids and decentralised energy storage systems is a key question for such a young, burgeoning industry.

For example, the unveiling of Tesla's Powerwall, a stationary storage system for homes, businesses and off-grid communities, made waves in the news recently with its tantalising retail price. Meanwhile, inverter manufacturers and building services companies are offering new energy management systems that combine PV, battery storage systems and heat pumps, to increase on-site consumption and boost efficiency.

The global expansion of solar in new and established markets alike requires the grid integration of both small-scale solar installations and multi-megawatt power plants. Calculations by the Fraunhofer Institute for Wind Energy and Energy System Technology indicate that the amount of electricity from renewable sources fed into the grid in Germany in 2030 could rise or fall by up to 14GW in the space of just one hour so the industry must continue developing technology to compensate for these grid fluctuations.

Watch out for the 'Smart ideas in a smart energy infrastructure' programme to stay up to date on relevant issues.

PV hybrid diesel systems

The shift away from relying solely on fossil fuels is in evidence with a trend towards combining PV technology in hybrid systems with diesel generators. PV module prices have become too low to overlook. Newer markets in South America and Africa, which have traditionally relied on diesel generators especially in remote regions, are now seeing PV successfully compete.

Solar-diesel hybrid systems already represent profitable alternatives for large-scale industrial users in remote regions with strong irradiation and they are entering the small PV application market for rural electrification and commercial uses. This applies especially to the off-grid sector.

Even the German armed forces, traditionally reliant on diesel generators in conflict areas, intends to reduce fossil fuel consumption, which can be dangerous to procure, in favour of using mobile solar containers equipped with PV modules and battery storage systems.

You can get acquainted with these issues at the 'Solar/diesel power supply: Exploring design and pushing boundaries' show at the Off-Grid Platform of Intersolar.

Business models

With cuts in state funding continuing as a major theme for the global solar industry, new business models are essential and developing new financing initiatives is more important than ever. Stakeholders need to make solar an attractive investment proposition, so new forms of financial cooperation between local energy suppliers, project developers and financial service providers are key.

Measures now range from rental and leasing models to direct marketing of solar power to listed operating companies (yieldcos) and shares in green bonds. The emergence of the solar yieldcos has been a major story on the global market this year, but has yet to infiltrate European companies on a grand scale.

Source: Solar Promotion GmbH.

The necessity for such financial innovations comes after a switch from feed-in tariffs to auction-based subsidy support, which has been championed by the European Commission and national governments. This year Germany, France and the UK issued their first competitive tenders for supporting renewable projects. This will be discussed in detail at the 'Tenders for Large Scale PV in Germany – Experiences from the Pilot Bidding' section.

A general look at the development of large-scale PV also features in combination with a look at trends in solar finance and asset management. For residential, commercial and utility-scale projects there will be a focus on costs and the role and impact of policy and risk premium for such projects. ■

Source: Solar Promotion GmbH.

Selected conference highlights

Global PV Markets: Europe: Preparing for the Next Level

9 June 2015 11:05am ICM Room 14A
Current market scenarios forecast a steady demand of around 10GW annually in Europe in the coming years. This session will examine how the markets from selected countries will evolve under their respective framework conditions. On the one hand, demand for PV is slowing mainly due to changes of the regulatory political landscape across a number of European countries, but on the other hand, these changes are driving demand for new applications such as PV systems combined with electrical energy storage which are responsible for the emergence of new business models. This session delivers a European Market Update and follows traditional utilities entering the PV sector.

Source: Solar Promotion GmbH.

EES: Predicting New Battery Technology Ideas and Usage Scenarios

9 June 2015 11:00am ICM Room 14C
With energy storage high on the agenda once again, speakers will share insights on deployment scenarios, expected cost developments, corresponding lifecycle assessments and anticipated technological milestones in the near future. A 'Battery Technology Roadmap for Stationary Energy Storage Applications' will also be unveiled by the Fraunhofer Institute alongside talks on specific battery applications and the stable integration of renewable electricity into micro grids.

PV Cell and Module Technology: New Opportunities to Cut Costs and Improve Performance

10 June 2015 9:00am ICM 13A
This event will feature both achieved and anticipated technological innovations by cell and module manufacturers. Selected component manufacturers will showcase their latest technological developments. A highlight will be a focus on new cell concepts aimed at lowering costs while achieving further cell efficiency gains. New module types including glass-glass, frameless and bifacial will also be under the spotlight.

Identifying New Ways to take Financing and Securitisation Forward across Europe

10 June 2015 11:00am ICM Room 13B
Feed-in tariffs drawing to a close has resulted in the emergence of new financing and securitisation models. Topics in this session include trends in solar finance and asset management, the cost of capital, the role and impact of policy and risk premium for residential, commercial and utility-scale solar throughout European markets. Edmée Kelsey, chief executive of 3megawatt, will give a detailed look into some solar financing case studies.

Smart Ideas and Smart Future: Smart Energy Infrastructure and Intelligent Homes

10 June 2015 2:00pm and 4:00pm ICM Room 13B
The smart infrastructure session assesses the implications for existing grid infrastructure of an increasing proportion of electricity generated by decentralised PV systems. It will also cover the design of future supply networks and the role of the 'smart city'. Meanwhile the Intelligent Homes section will discuss future combinations of ICT technologies, household equipment and both solar PV and solar thermal applications. This is all in the context of using smart internet-based applications to control the flow and consumption of energy in the home.

Source: Solar Promotion GmbH.

Beyond boom and bust: European solar grows up

Post-subsidy solar | Europe's solar market has been characterised by peaks and troughs and a good deal of pain for its industry in the process. Although the continent is not expected to see a return to anything like the explosive growth it saw up until 2012, steady forecasts for the coming years hint at solid, sustained expansion. John Parnell reports

Source: REC Solar.

Boom and bust is exhausting. The lows force good people out of the industry and do irreparable damage to its reputation. In some ways, the highs aren't much better. Good companies overstretch and set themselves up for a fall in the inevitable lean times. The opportunistic flock for a quick win but will disappear before you can say single-digit-returns.

There is a temptation to compare recent European PV deployment figures with the boom years and feel a sense of disappointment. Yes the industry is deploying far less solar and the forecast for the next few years are hovering between 8-10GW compared to a massive 17GW in 2012. But ask those working in the solar industry in Spain or Greece or even Italy if they would like to be installing half what they installed in 2012 this year, and they'd bite your hand off.

"In 2014 we have seen probably about 7GW of PV connected to the grid compared to 11GW the year before and 17GW in 2012," says James Watson, chief executive of the European Photovoltaic Industry Association (EPIA). "The rate of installation is decreasing but nevertheless the European market remains the largest market in the world in the sense that there are 180GW installed globally and more than 90GW is in Europe."

Nowhere encapsulates Europe's boom and bust solar market better than Spain, where PV has gone from hero to zero.

To coincide with the beginning of Intersolar Europe 2015, EPIA launched the 2015 edition of its Global PV Outlook report. It tells a tale of far less dramatic deployment in Europe but a much more predictable future.

"I think that we are probably going to see a small increase in the coming years and stabilise around the 10GW mark going through to about 2020," says Watson, "and then probably we'll see an increase as older power stations are decommissioned and replaced with renewables, in our case hopefully solar to a high degree."

Small and steady

Historical deployment is not likely to offer much cheer to those trying to make a living now but it does highlight that Europe is the grand dame of solar and the expertise built up in the process of putting those 90GW into European soil and onto roofs.

"European companies, wherever they are based, should have the right knowhow and the technical abilities to go out into new markets and use that expertise to their advantage," says Watson. "I was in Spain recently talking to some of the companies there. Having gone through what happened in Spain and survived, that's the kind of knowhow and ability they should be able to export to places like Latin America where they have the cultural similarities through language and other cultural aspects.

"Maybe the set-up [in those new markets] isn't as cosy as we have seen in Germany five years ago but the experience they have should be able to drive them forward. If you can survive retroactive measures in Spain I think you have a lot of resilience and character as an organisation and therefore there is much you can do in new markets emerging in Latin America, Africa and beyond."

Developers from Italy, Germany, France and even the latest solar graduate, the UK, are looking at markets overseas. Technology suppliers have had mixed fortunes in the face of intense competition from Asia.

Many European companies are doing very well overseas, many have had to, but finding success closer to home would always be preferable and for many firms this is an important bedrock on which to build international success.

So where will deployment come from in post-boom Europe?

"If we're looking at 2015 as a whole the UK is number one but most of that has been done already in Q1," says Ash Sharma, senior research director at market research firm IHS. "We have the UK at just under 3GW for 2015, out of 8.4GW for the whole of Europe; that's a massive chunk. Germany we have as flat [compared to last year's 1.9GW].

The EU's 2030 climate targets will have a key bearing on the fate of solar in the continent.

"France is a growth area; it will be over 1GW for the first time since 2011, which is pretty impressive. Other markets have some smaller increases, including the Netherlands where we expect around 500MW to be installed this year and Switzerland with fairly modest growth to around 300MW. There are some other smaller pockets of growth. One is Poland; we see Poland installing about 100MW this year. They are the main ones. The rest are fairly small – only nine markets in Europe will go over 100MW in 2015."

This pattern of many small but steady markets looks to be here to stay and Sharma doesn't see any European countries offering explosive growth any time soon.

"It doesn't look like there is going to be any new ridiculous policy that triggers a booming market, I think that is unlikely now in Europe. It seems to be much more sensible, so moderate and sustained growth seems more likely." Given the current state of markets in places like Spain and Greece, this is surely no bad thing.

Source: European Union.

Beyond boom and bust

EPIA's forecast for Europe, while far from rosy, shows evidence of a market that has turned its back on unsustainable policy support in place of more measured approaches to aiding the sector on the path to sustainability.

According to the EPIA, even Germany – Europe's solar Icarus, which has fallen by far the furthest – still has a very strong role to

Trade woes extended

At one point, any forecast or commentary on the European market seemed to have the attached caveat "the outcome of the trade case". This was soon replaced with the "potential size of tariffs" and ultimately "the uncertainty of the price undertaking".

And it seems that even now the unresolved dispute between the EU and China over the latter's apparent dumping and subsidy of PV equipment imports still looms large over any discussions of the future of European solar.

Source: Flickr/hans poldoja

The two-year tariff applied in 2013 expires at the end of the year and fresh uncertainty has mounted over what will follow. At the end of April EU ProSun, the main agitator in the case, confirmed to PV Tech that it would request a review of the process. The European Commission then announced it would investigate the way the minimum price is set in the undertaking between it and the Chinese.

The bottom line is a mandatory investigation period that extends the tariffs, and presumably the price agreement, beyond the December 2015 expiry – potentially well in to 2016. The complaint alleges that Chinese manufacturers submitted price data *en masse* to the Bloomberg benchmarking index that the minimum import price is defined by. This had the effect of lowering the resultant value of the index and dropping the price floor for Chinese firms in Europe. The Commission is considering using the Bloomberg index minus all the data from Chinese solar firms.

This would drive up the lowest price that Chinese firms can offer in Europe, posing a fresh set of challenges for European industry to contend with.

UK
Clear FiT evolution in 2015. Systems above 5MW only eligible for contracts for difference, not renewable obligation certificate since April 2015. Clear and lean administrative system.

BELGIUM
Major changes at federal level. Flanders: probable reintroduction of grid tariff in 2015. Wallonia: new support plan not yet encountered success foreseen. Brussels: new self-consumption scheme under discussion to replace net metering in 2015.

NETHERLANDS
Net metering and high electricity prices allowing for a residential market to develop rapidly together with an investment grant. Adequate support for a market close to grid parity in the residential sector.

DENMARK
Growing awareness of self-consumption scheme but possible introduction of taxes on self-consumed electricity. Market capped under FiT measure.

GERMANY
Clear FiT evolution in 2015. Risk coming from grid operators to finance the grid and overall cost of support to RES.

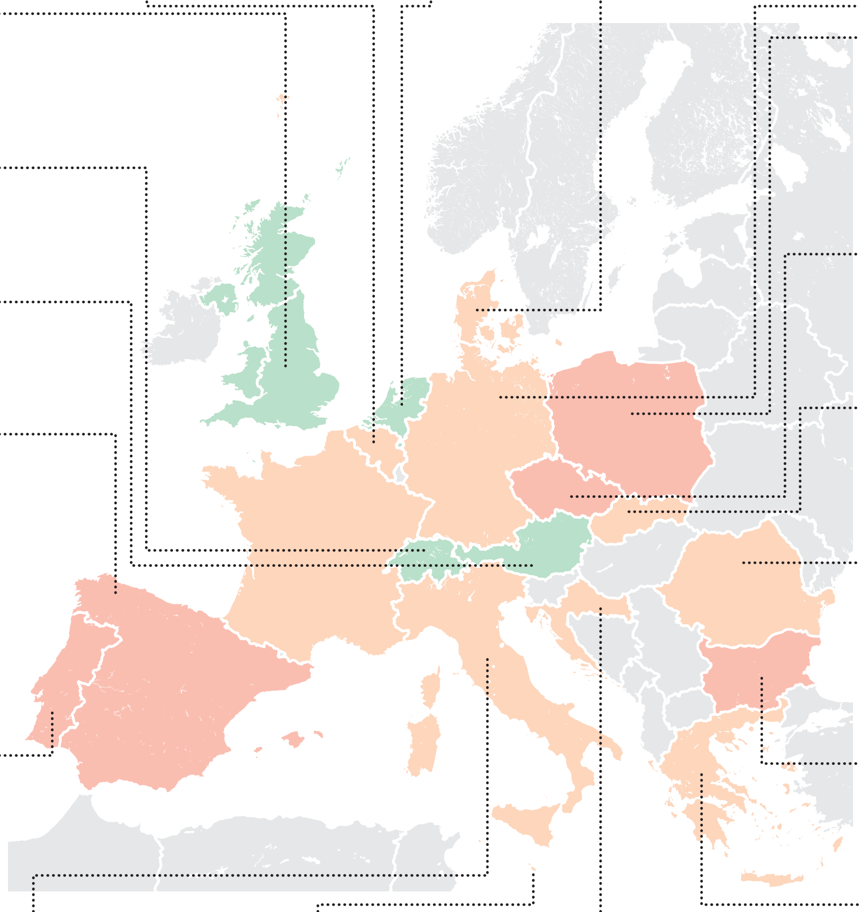
FRANCE
Clear FiT evolution in 2015. Slow administrative process still in place.

SWITZERLAND
Clear FiT evolution in 2015 for large systems. Self-consumption allowed for residential sector.

AUSTRIA
Clear feed-in tariff evolution in 2014. Possibility of self-consumption has been introduced.

SPAIN
Support for PV frozen at beginning of 2012 and not reintroduced. Overall Spanish electricity tariff deficit blocking new development, net metering long awaited. Few projects starting independently from support schemes, within an unclear regulatory framework. Many attempts to revitalise utility-scale segment, but no progress.

PORTUGAL
Drastic changes in the FiT schemes affecting small-scale PV development. Large-scale development is still slow due to administrative barriers.



POLAND
New FiT and green certificate scheme under discussion for over two years; long decision process still ahead, probably 2015. Possible lack of investor confidence due to lack of formal government decision.

CZECH REPUBLIC
FiTs no longer available for PV systems. New legislation is foreseen but no detail has been published.

SLOVAKIA
Very low FiT and heavy administrative barriers. Slow administrative process still in place.

ROMANIA
Reduced support schemes for large-scale systems due and issues due to oversupply of green certificates. Improved legal framework but uncertain from political point of view.

BULGARIA
Unstable investment environment, administrative procedure complicated and slow. Expected full liberalisation of electricity market.

ITALY
No direct support available. Possibility of large-scale PV development due to new support schemes introduced in 2014.

MALTA
Clear evolution of FiT but very low cap.

CROATIA
Clear FiT evolution in 2015. Possibility of self-consumption has been introduced. Very low cap.

GREECE
Clear FiT evolution in 2015, but no possibility to develop large-scale PV due to low level of support. Adverse financial environment limiting development of new projects. Residential PV favoured over large-scale plants. Net metering scheme introduced in 2015.

KEY
- Good
- Fair
- Poor

Source: EPIA.

Solar's prospects in some of Europe's key markets, old and new, as set out in EPIA's 2015 Global Market Outlook for Photovoltaics.

play in the new European solar market.

"We expect to see Germany again kicking off," says Watson. "Support schemes are being reduced and moving into a new world of auctioning, which has an impact on the large-scale sector but my estimation is that household level solar will be a main driving factor. In Germany, where most people have a natural environmental bent, we will see a continued important presence in the overall installations that we get in Europe moving into that new stage of stability."

Watson stresses that the age of overly generous feed-in tariffs was not for nothing. Strong support and rapid deployment triggered the wave of falling costs and increasing deployment that is still spreading today.

"We would like to see more stability in the market in general but the great thing that has been achieved so far is that government support has created a boost which has driven the market and helped more people get involved. That's brought down costs as people have been able to create larger economies of scale for systems," says Watson.

Now, however, there is a general preference towards such generous support being withdrawn. Phasing out support at a rate linked either to falling costs or increasing deployment is a more progressive way of helping the sector toward sustainability. The real wrecking ball for solar is the use of retroactive changes that tarnish the sector's reputations and scare off would-be investors.

Another challenge for the industry to contend with is the shift to competitive tendering. Auction-based schemes, as championed by the European Commission, are replacing feed-in tariffs as the de facto support mechanism for solar. While these could ultimately help the industry move towards a more sustainable footing, they are not without their limitations (see second box).

Solar and utilities

The other avenue for a changing solar landscape is the current plight of utilities. From 2020 onward, many of Europe's largest grids will be on an investment drive. This will take place at a time (hopefully) when the new UN global climate change treaty comes into force and the EU will (hopefully) be pushing to meet its own 2030 renewable energy targets. E.On became the first utility to blink and announce that it will no longer invest in new conventional power generation. More will follow.

"I think the forward-looking and more progressive utilities are looking into their crystal balls and seeing that it's going to be a future with a lot of renewables in the grid," says Watson. "That changes tremendously the way that they'll be able to deal with their customers. It's going to be moving away from, as it has been for generations, a case of sitting by the door waiting for the bill to arrive and just paying that every month. In fact people are going to be more interested in managing their energy through apps on their phones. People are going to be more engaged.

"Our estimations are that things like nuclear and coal are reducing quite considerably in investment, more is being decommissioned than is being put into the market place. So if you're really going to be investing in that... that's Russian roulette. You've got more certainty going for renewables than grid [centralised generation] investments," says Watson.

All this of course plays into the hands of solar. Yet the scenario outlined by Watson is far from likely to be consistent, and solar will still face a fight to gain traction in some parts of Europe. This is well illustrated by the case of Poland, one of the emerging solar markets identified by both EPIA and IHS' Sharma, but one where solar faces huge obstacles from inertia in the incumbent energy sector.

Poland has tried more than once to get its PV sector off the ground but even the modest inroads it has made have been challenged by the country's coal industry. Stanislaw Pietruszko, head of the Photovoltaic Association of Poland, sees little scope for a major switch in the country's energy mix, which is dominated by coal.

"The present status quo will last. The coal lobby employs so many people that no lawmaker will act, the coalworkers would simply come to Warsaw and protest. Coal is so strong and has millions to use in support of the sector," he claims. "Poland has a high potential [for PV] but the problem is the big energy companies. I don't understand why they block PV when it would be less than 1% of the energy that they produce."

Plans for a new feed-in tariff are given a lukewarm reception by Pietruszko who says the proposed rate is too low, particularly given that income tax is levied on revenue from the FiT. With the lowest income tax rate set at 18%, this all but kills any demand. Replacing the income tax rate with a levy on self-consumed power is one change Pietruszko proposes.

Ultimately, he says, the potential for solar in Poland is threatened most by the lack of understanding among the public, the government and the energy companies, of the benefits solar can return to the country.

Beyond 2020

The problems Pietruszko describes are by no means restricted to Europe. The Paris climate talks at the end of this year will determine the shape of the climate treaty that comes into force in 2020. The EU will likely dangle the ambition of its own 2030 climate and energy package at the talks. The ambition, or lack thereof depending on your viewpoint, in that suite of policies could also evolve in Paris. The opportunity to set strong signals for renewables must not be missed, says Alex Fornal, head of project development in the UK for juwi.

"Getting political is going to be an increasingly important priority for the UK solar sector and Europeans countries generally. EPIA and other trade associations are going to need to work closely together on a collective lobbying effort at the European level to strengthen the case for strong commitments in Paris," he explains.

One of the objectives for the industry if it is to secure a major victory in Paris is to bring policy makers up to speed with the capabilities of solar so they can negotiate with the most up to date information.

"One issue is the cost, expectations and potential of solar; that is something we're wrestling with at UK level and at EU level. The industry is educating ministers and the powers that be to show the cost coming down, its potential for grid parity and to contribute to the energy mix. So at many levels and on many fronts we're all working hard to provide an evidence-based and rational approach to solar development. Once the facts are known, we're convinced ministers will follow up with appropriate policy," says Fornal.

The continent is redesigning its grid and ensuring the end result is solar friendly is yet another battle the industry faces. A sustainable future is in reach but securing even its more modest output will require the sector to pull together and fight on multiple fronts.

Boom and bust is exhausting; getting beyond boom and bust will require no less hard work, but transitioning from a constant fight for short-term survival to one final battle for a sustainable, long-term future will surely be worth it. Cost reductions continue to exceed outsiders' expectations and if solar can earn a level playing field, it will surely reach widespread, and widely acknowledged, price competitiveness sooner rather than later. Adding that weapon to solar's arsenal would surely end the war. ■

Money problems

As European countries continue to transform the shape of their renewable energy support at the behest of the European Commission, the profile of investors will change too. Unpredictable auctions and growing exposure to prices on the energy market will enforce changes.

Richard Slark (pictured), head of renewables at Poyry Management Consulting, which recently published a report on shifting solar support in Europe, says that the move on continental Europe towards market-price risk is only part of the problem.

"It's in tandem with the ageing of projects," he explains. "When valuing an asset, the life of that asset is increasingly including a period when they will no longer receive feed-in tariff support. That means not only are investors' existing portfolios becoming increasingly exposed to market prices, so too are new investments."

The switch to auctions is also creating a potential headache for investors. Instead of applying for a FiT and getting it, developers must accept that pre-construction work on some projects will be wasted if its bid is unsuccessful. Slark says that means developers need to secure a better margin from the projects that are successful.

Germany, France and the UK are all operating competitive, capped procurement rounds at present – is there now a danger that the solar industry won't be able to produce enough projects to fulfil investor appetite?

"There's undoubtedly a risk," says Slark, "and experience shows us that a move between support mechanisms tends to lead to a hiatus in projects coming forward as everyone scrambles to understand how the new mechanism will work. Investors, both debt and equity, need to get comfortable and it all leads to a slowdown in projects coming forward. The reduction in the supply of new investment opportunities will force some investors to look to put their money elsewhere."

Whose waste is it anyway?

PV waste | Europe is leading the way in efforts to regulate the disposal and recycling of old or discarded PV modules. Sara Ver-Bruggen investigates the extent to which the industry is complying with the rules and whether PV markets in other parts of the world are likely to follow Europe's lead

How sustainable is the solar photovoltaic industry? Aside from the obvious, that it is enabling countries around the world to move away from burning fossil fuels for generating electricity, the industry has no official policy on the appropriate take-back and recycling of old or damaged PV panels.

However, legislative changes in Europe in 2012 are forcing the industry to address this challenge, which could show the way for how other markets might approach this issue in the coming years.

When the original Waste Electrical and Electronic Equipment (WEEE) directive was introduced in Europe in 2003, it placed legal and financial responsibility on producers and manufacturers for the safe collection and disposal of old electrical goods and equipment. In 2012 the WEEE Directive was beefed up, strengthening member state governments' powers to ensure compliance and extend to forms of waste previously exempt, including photovoltaic panels.

The recast directive also imposes new targets that will see member states having to collect 45% of electronic equipment sold for approved recycling or disposal from 2016. From 2019 member states must demonstrate achievement of either one of the collection rates: 65% of EEE equipment sold or 85% of electronic waste generated.

While member states were given until 2014 to transpose the directive into their national legislation, most are still in the process of drafting rules. A few, including Germany, which is the largest and oldest solar market in Europe, the UK and Italy, are the furthest ahead.

Source: PV Cycle.

A PV module being shredded. The effective disposal and recycling of old modules will become an increasing priority for the solar industry.

The penalties of non-compliance

To ensure member states meet their targets, the latest WEEE Act seals up loopholes and ensures more consistency in terms of how the act is transposed across the various states. Because the act places the onus of responsibility on the producer, penalties for non-compliance are tough. Measures vary between each member state, but generally they can include fines. These are usually proportional to the amount of PV modules undeclared as quantities sold in the EU, as well as fines from local municipalities and government authorities.

In some cases a producer's panels can be barred from sale in a market. In some countries, including Germany and Austria, the representative of a company in that market – typically the general manager – risks a criminal record if the local entity has been found guilty of non-compliance. In a highly competitive market, it is hardly surprising that established players will use non-compliance as a means of taking out the competition because producers, especially from abroad, can often fall foul through ignorance, according to one company that offers compliance services to the PV industry in relation to WEEE.

However, compared to four years ago there is a growing awareness of the penalties of non-compliance and what producers need to do to ensure they do comply.

Defining a PV producer

One of the challenges under WEEE (II) is defining exactly what sort of company or entity qualifies as a PV producer.

Module take-back firm PV Cycle lists four definitions. The first is a manufacturer

Source: PV Cycle.

established in a member state that makes or assembles and sells PV modules under their own name or trademark within the territory of a member state. The next is the distributor, which resells PV modules produced by other suppliers (except where the brand of the original producer appears on the product) within a member state under their own name or trademark. Then there are the importers, in other words entities that place PV modules from a third country or from another member state into the member state they are operating in. The fourth category of producer covers any entity engaged in internet or distance sales, either to private households, or to other types of users in a member state, and is established in another member state or in a third country.

Each type of producer is legally obligated to ensure the take-back and recycling – including the related administration, reporting and financing – of their discarded PV modules.

According to Alina Lange, a spokeswoman for PV Cycle, the act ensures that the producer complies at the national level of any market the modules are sold into. Brussels-based PV Cycle was set up as a member-based pan-European scheme providing dedicated compliance and waste management services for solar energy system products falling under WEEE and Battery Producer Responsibility legislation.

One of the first steps by any company that potentially fits the bill as a producer should be to ensure that their product falls within the scope of the directive. A good first port of call is to visit the site of the Europe WEEE Registers Network (EWRN), which also has direct links to all of the national registration bodies for each member state.

In Germany, for example, this body is Elektro-Altgeräte-Register (EAR). The register obligates all manufacturers and distributes the burden of proper disposal, collection and recycling fairly, under the WEEE act. "All producers have to register and report the volumes that they have put into circulation in the market. If manufacturers fail to register with EAR or fail to report properly in terms of quantities supplied in Germany, EAR can take action such as levying fines," says Oliver Friedrichs, managing director of take-back company, Take-e-way.

Reporting and fees

Again, just as in who qualifies as a producer, requirements for reporting quantities of panels supplied in a market is not as straightforward as it might seem at first. Getting this right is important because the data is used to calculate what each producer is paying fairly, in proportion to volumes they supply in the market in question. The fees levied go towards the infrastructure required to ensure the disposal, collection and reclamation/recycling of their products that have to be discarded, through damage or when they reach their end of life.

"What makes the compliance obligations with regard to quantity reporting much more difficult is the fact that they are handled in different ways depending on each EU member state," says Friedrichs. "Reporting has to be done more than just once a year in most cases. In Germany, for example, manufacturers have to report every month, whereas quarterly in many other countries. The reporting is based on actual sold quantities. Manufacturers ensure they are reporting accurate quantities in the data of their enterprise resource planning systems. In Germany EAR can also demand the confirmation of reported quantities by an outside auditor as well."

Responsibility for the disposal of PV waste in Europe now falls on the producer.

Take-e-way provides administrative services to ensure producers comply in Germany. The company also has a database with information for each of the member states, with details of how the manufacturer has to register in each country, information on take-back schemes in each market, volumes that can be handled and which types of modules can be disposed of appropriately, as well as links with local partners in local markets.

Methods or models of financing the disposal, collection and recycling of old PV panels also vary state-by-state.

Jürgen Fuchs, a key account manager at the European Recycling Platform (ERP) in Germany, says: "For example, some use a pay-as-you go system based on sales data throughout the year. So if a company sells 20% of the PV panel demand in a market then they are expected to allocate for collection of 20%. Other countries have models in place more geared towards the future, based on financial guarantees, chipping into a pot of money that can be used to invest in the collection, disposal and recycling of panels when it becomes an issue in the future."

The ERP was set up in the wake of previous waste directives. Its founder members – Sony, Hewlett-Packard, Electrolux and Braun-Gillette – wanted to see a competitive market in Europe for offering compliance and waste management services arising from extended producer responsibility legislation as opposed to having to deal with one monopolistic organisation.

Scott Butler, from the ERP's UK branch, says: "At every other stage of the supply chain, fast-moving consumer goods brands are able to choose suppliers from a competitive marketplace. Competition engenders efforts by suppliers, be it of products, components, systems or services, to innovate and improve on costs and efficiencies. End-of-life product management should also benefit from free market forces."

The ERP offers PV companies a pan-European service for compliance with WEEE and other waste-related legislation. In recent years the PV industry has become more globalised and consolidated. To producers, Europe is on the one hand a single market made up of many. So producers are likely to be active in several member states. However, the problem with the original WEEE directive was that it allowed for too much leeway in terms of how each state transposed the act into their national laws. Even the recast directive still raises the issue of who shoulders the responsibility of compliance.

A producer will want to know what they have to do to ensure compliance across all markets they may be involved in, whether as a direct entity in a country or as a supplier to an importer in a specific country. They do not want to have to tackle the issue country by country, as this would entail a lot of admin and bureaucracy.

"ERP aims to provide simplicity and co-ordination in a complex environment, using its knowledge database to ensure that a company can provide the right information at the right time for all markets. It also provides consistency. All contracts, for example, are produced in two languages – the local language and also always in English," says Butler.

Though companies such as ERP, PV Cycle and Take-e-way, play an important role in helping producers comply, Lange advises that any producer in Europe should appoint a member of staff internally through whom compliance-related matters are channelled.

The global picture

Today volumes of waste from PV panels in Europe are relatively small, compared with volumes of panels actually installed. Since it was set up in 2007 PV Cycle has dealt with 11,000 tonnes of PV modules. However, only about 1% of this amount is due to modules that reached the end of their operational lifetime. Typically the modules have been disposed of because they are damaged, usually during transportation or installation. "In the next five years and beyond this trend is going to change in Europe as the first PV farms in early adopter markets like Germany reach the end of their operational lifetime resulting in big quantities of modules needing disposal and recycling," says Lange.

In preparation, PV Cycle, ERP and Take-e-way are working with waste management companies across Europe with the capability of industrially processing old PV modules for recycling.

Under WEEE, companies can also introduce their own take-back, disposal and recycling schemes. First Solar is a good example and has had one in place for a decade but this was set up out of necessity at the time when the industry was much smaller. In the UK, the developer Solarcentury also ensures that any modules broken during installation of projects that need to be discarded are recycled in line with WEEE. "It is doubtful that PV companies really want to be recyclers. It is highly likely that as the volumes of PV panels in the waste stream increase in the next five to eight years that the industry will warrant its own bespoke disposal-collection-recycling system," says Fuchs.

But the extended producer responsibility approach to PV recycling, already adopted in Europe, promoted as an industry-wide approach or standard would have far-reaching benefits believes Vasilis Fthenakis, a scientist at Brookhaven National Laboratory, Columbia University. He has been studying the environmental impacts of the solar photovoltaics industry for a number of years.

Compared with fossil fuel electricity production the impact of solar on factors such as the environment and also health is comparatively benign. But that does not mean the industry should not embrace measures that ensure that PV modules do not end up in landfill. "PV companies are under immense pressure to compete with fossil fuels. Margins, which used to be 30-40%, are now in the region of 5%. Such market conditions are not conducive to encouraging an industry to finance now what will be an issue in 20-30 years' time," says Fthenakis.

He sees a chicken and egg situation. The volumes of panels that are discarded are nowhere near big enough to warrant an economically profitable full-scale take-back and recycling operation in the US that will earn the buy-in of suppliers and producers. However that could change in several years' time.

But should it be left to free-market economics and enterprise to ensure old PV modules are recycled? Fthenakis and his colleagues' work in other areas show that PV module materials recovery can incur negative cost or even a small profit. However, the more difficult cost to account for is the one associated with logistics and collection. It is likely, therefore, that industry will need to finance some of this.

"With an industry collective operation, the recovery of materials can be fully optimised. For PV glass, for example, this would mean recovering the pure material for reuse in the form of culets for soda-lime glass production – a higher value commodity than reusing waste glass in fibreglass."

He is in no doubt that there needs to be some sort of federal-level legislative effort, and in the next few years, to ensure that all technological types of PV modules are properly disposed of and that will eventually lead to optimised recycling processes that can extract maximum value while minimising environmental impacts and costs. ■

PV disposal around the world

Solar industry players and associations in other countries are beginning to consider the issue of PV module waste. "We've been contacted to provide advice to manufacturers and agencies abroad, mainly the US, Canada and Russia," says Oliver Friedrichs, managing director of Take-e-way.

"Our advice is be proactive, set up an industry scheme that the producers fund and that ensures proper collection, disposal and recycling of panels before the government, be at federal or state level, imposes legislation to drive this type of activity, which could end up being most costly for the industry as a whole," Friedrichs says.

Countries taking steps in the right direction include Australia, which has introduced a policy on e-waste, and Japan, which has an established take-back system for IT equipment and more recently decided to draft new rules covering disposal and recycling of decommissioned renewable energy plants. ERP has also supplied its waste management and tracking software to the Canadian e-waste stewardship system.

However says Jürgen Fuchs: "Europe is really where the heart of this issue as it now has legislation in place that obligates the PV industry to address the issue of waste generated by old, damaged, end-of-life PV panels. The PV market in Europe is also the oldest in terms of panels in the ground and biggest by installed base."

Proper PV waste management offers the prospect of recovering materials such as glass for reuse.

Source: PV Cycle.

Author

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Why Islamic finance and solar are a natural fit

Future solar finance | Ahead of the Solar Finance & Investment Asia Conference in Singapore, Dr M. Rusydi of SGI Mitabu tells John Parnell how solar could tap into the potentially enormous investment opportunities offered by Islamic finance

As with any new solar market, and so many other things in life, money can prove to be the limiting factor. Until investors and lenders are comfortable the brakes are applied and the potential for PV to make an impact is limited.

In this scenario many parts of Asia suffer more than other regions. No one will lose any sleep over the speed at which a remote mining operation in South America is able to secure its supply, but the need for new electricity generation in blossoming economies like Thailand, Indonesia and the Philippines is more pressing. In many emerging markets, failure to invest in adequate energy infrastructure has tempered economic growth.

South Africa's government-backed procurement programme helped get early projects, and investors, into solar. Chile has benefitted from the long-term contracts projects have signed with high-calibre off-takers. Both models offer lessons to governments in Asia but there is a less established opportunity to source finance for projects that have been largely overlooked so far; given the demographics of the region, it could well make a major contribution to solar power development.

Islamic finance could prove to be a perfect fit in a part of the world that includes the country with the world's largest population of Muslims – Indonesia. There are actually three times more Muslims in south and Southeast Asia than there are in the Middle East.

It is crucial straight out the gate to dispel a few myths. You don't have to be Muslim to partake in Islamic finance or even to offer it. The UK government offered its own Sukuk – the equivalent of a bond – becoming the first to be backed by a non-Muslim government. (The £200 million bond UK release was 11 times oversubscribed.)

Dr M. Rusydi is the director of SGI Mitabu Australia, an investment and development firm behind a 50MW solar project in Indonesia. Rusydi – who will be a speaker at Solar Media's Solar Finance & Investment Asia event in Singapore at the end of June – explains the key differences for solar industry professionals to be aware of.

"The difference with conventional finance is the fact that they don't use interest rates. Islamic finance relies on the underlying projects. Instead of interest rates there is a concept of profit sharing," he says. "The project and the profits from it are linked directly to the financing process. So whatever profits are generated are shared among the parties who invested, as is the risk."

In the case of the UK government's Sukuk, the asset underlying the investment was rental revenue generated from Her Majesty's Government property portfolio. In the case of solar, the asset is the installation and an associated long-term contract to supply electricity. Rusydi argues that the nature of these contracts makes solar a great candidate for Sukuks.

"By their nature renewable projects are long term, the PPA could last for 20 years meaning the project itself and the contract to supply the electricity can be quantified as an asset," he explains. "This creates a very good opportunity to structure this financing using Islamic finance. We are also talking about clean energy; it supports a better environment and that puts renewable energy among the top tier of projects for investment under Islamic finance."

This final point refers to some of the less quantifiable features of Islamic finance. There is an enshrined prerogative to invest in "wholesome" projects and those which benefit the welfare of local communities. In some cases this is clear cut – businesses involved in gambling or the sale of alcohol are excluded, for example. But defining "wholesome" is not always straightforward. For renewables the argument that these criteria can be met is much stronger, especially for solar given that it can be built at scales that directly benefit locals and is not merely the preserve of multinational corporations.

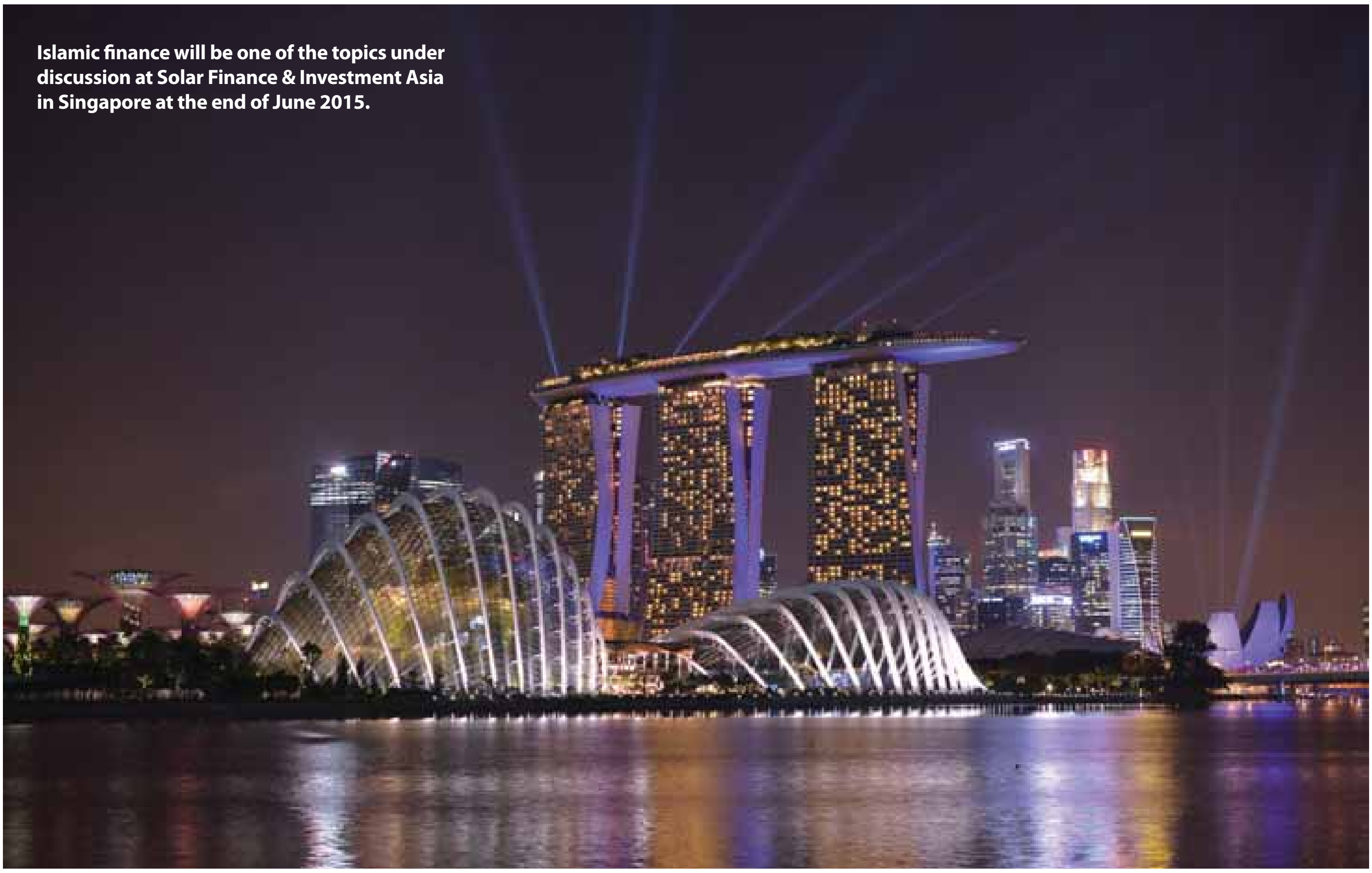
At the same time, Rusydi says, the collaborative nature of Sukuks makes them a great fit for solar. "People bring their contribution to the table, the person who had the idea, people that can bring skills or contribute the business model and investors can come to the table with money as their contribution. So it's like a collaboration between different parties but the bottom line is that everyone will share the profits accordingly," he says.

This model is being borne out on his own solar projects with partners from the solar industry keen to translate work as contractors or suppliers to the power plants, into an investment in the Sukuk consortium that owns them.

"The EPCs want to be partners rather than just provide a service...they can also invest in the project if possible so they are more than just an EPC. They can see the potential of sharing the profit. This is very interesting because it gives them an opportunity to go beyond operating as a standard EPC and can co-own the plant and share the resulting profits," Rusydi says. He argues that this is a good strategy for firms to acquire some longer-term revenue, even if they don't have the scale to invest in projects outright in the way that the industry's larger players are doing through yieldcos and other forms of conventional finance.

So far he says the reaction from the industry has been very good, with Sukuk's often proving a smaller administrative burden given their independence from the vagaries of conventional market dynamics and of course, interest rates.

Without the presence of traditional banks, the issue of bankabil-



Islamic finance will be one of the topics under discussion at Solar Finance & Investment Asia in Singapore at the end of June 2015.

Source: Nicolas Lannuzel/Flickr.

ity also changes. Instead of products and contractors being scrutinised by a lender with a fairly rigid set of criteria, the group offering the Sukuk assesses the credibility of suppliers. With nothing to gain from poor choices being made, all the investors are as motivated as each other to see the project succeed.

Much of the recent success of solar has been attributed to the maturity of the sector and the finance world's increasing comfort with solar as an asset class. With that in mind, the introduction of a new source of financing could be viewed with some scepticism. The sector has worked hard to achieve securitisation of lease contracts, to make ultra-conservative institutional investors comfortable with the technology and even persuaded high street investors to back solar.

The benefits Rusydi describes are very real but what is the scale of this seemingly niche opportunity in comparison to traditional finance and can it really compete?

The ratings agency Standard and Poors estimated that US$100-115 billion of Sukuks will be issued in 2015. This figure has plenty of scope to ramp up in the future.

"With Islamic finance in general we are talking about a global market with excess liquidity of US$1.5 trillion. This excess liquidity is very large; it's as large as the combination of a number of sovereign funds. It's no longer a niche market, it's a huge market, and infrastructure projects in Asia are currently at close to US$1 trillion. Islamic finance has to be channelled into real projects and infrastructure projects, especially in Asia, offer a very good opportunity for Islamic finance to play a role," he says.

There is little question over the scale of the financing available; investors in the Gulf have shown their appetite for renewable projects at home and abroad. A pipeline of projects backed by Islamic finance would surely be very appealing to the sovereign wealth funds of Abu Dhabi and Doha.

On the topic of competitive returns Rusydi is a little more coy, pointing instead to other advantages of the model.

"The selling point is slightly different, the way Islamic finance approaches the creation of assets and the way investors become partners is different and can overcome some of the barriers in conventional consortium funding that force a number of banks to finance one project. It allows big infrastructure projects to get funding in this part of the world where the parties come together into one special purpose vehicle. The selling point is different." ■

The Solar Finance & Investment Asia Conference in Singapore on 29-30 June 2015 will explore Islamic financing and conventional funding in the Asian solar market in more depth. Confirmed speakers include Credit Suisse, SPCG, Armstrong Asset Management and the Economic Development Board of Singapore. Further details are available at financeasia.solarenergyevents.com

PlantPredict: Utility-scale PV modelling software for solar project life-cycle assessment

Modelling | First Solar has developed an energy assessment software platform that models the electrical generation of utility-scale PV power plants. This software, called *PlantPredict*, is an enterprise application that streamlines and fulfils many energy simulation needs throughout the project development life cycle, from the site prospecting, through design and optimisation, and contractual commitments, to power plant monitoring. Bodo Littmann and Alex Panchula of First Solar discuss some unique models required for characterising CdTe power plant performance, and outline the PlantPredict tool's use throughout the project development phases, with the goal of ultimately lowering the total cost of ownership of PV power plants

The solar industry is equipped with a variety of PV modelling software packages – such as PVsyst, NREL's Solar Advisor Model, and Helioscope by Folsom Labs – for simulating the energy generation of PV power plants. All of these products allow a PV power plant developer or owner to estimate, with varying degrees of fidelity, the energy generation. First Solar has developed a tool called *PlantPredict* that is integrated with First Solar's information technology and business systems in order to address all four stages of a PV power plant's life cycle. In this paper the core attributes of the PlantPredict tool are discussed, along with how its business integration is used to refine the energy estimate over the life cycle of a PV project. The validation of its accuracy in estimating power plant energy generation is also presented. An in-depth analysis of PlantPredict's accuracy when compared with operating power plants has been performed by Passow et al. [1].

Power plant life cycle

The life cycle of the PV power plant includes four distinct stages: 1) site prospecting, 2) design and optimisation, 3) definition of contractual commitment and 4) operation. Each of the stages has distinct energy assessment requirements. During the site prospecting stage, achieving a go/no-go decision on a particular technology or site is the primary focus; this is enabled by fast, repeatable and simple comparisons. During the design and optimisation stage, the chosen site and technology are economically optimised for the actual costs and engineering constraints. Here, the requirement for modelling is a physical representation of an actual layout and the ability to vary parameters so that the lifetime energy output can be fed into economic models. During the contractual commitments stage, the losses assumed in the power plant must be documented and agreed to by means of a complete engineering review, requiring a bankable energy assessment. During the actual operation of the PV power plant, the ability to repeatedly represent the current state of the power plant and easily input actual weather data into the model enables the reporting of actual generation and its comparison with expected generation.

Tool description and architecture

PlantPredict is a cloud-based web application that allows the user to set up and execute individual energy simulations from a library of components. The inputs and outputs of the simulation are shown in Fig. 2.

The weather is a time series of meteorological data, which may be a typical meteorological year of 8760 hourly records of irradiance, air temperature, etc. (e.g. from the NREL TMY3 database [2]). One distinguishing feature of PlantPredict is that the weather input is *not* limited to hourly data; sub-hourly weather measurements from on-site meteorological stations can also be used for power plant

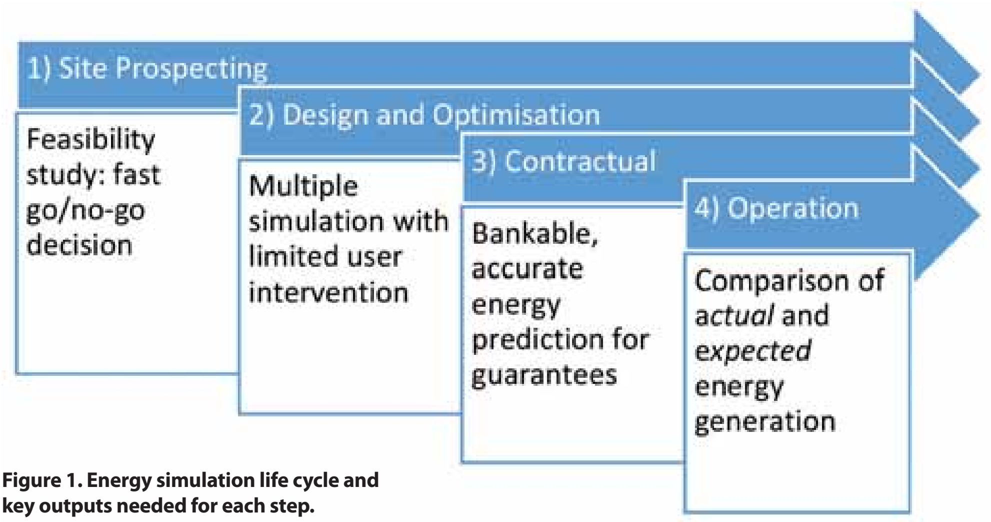


Figure 1. Energy simulation life cycle and key outputs needed for each step.

performance monitoring. The power plant is represented by a nested hierarchy of subassemblies, representing a collection of PV modules → DC arrays → inverters → power conversion stations → transformers → transmission lines.

Following standard design practice, the power plant is divided into any number of 'AC power blocks', each of which can have distinct parameters, such as module type, orientation, DC capacity and inverter model. The energy flow is aggregated in the simulation, with energy dissipation factors accounted for and reported in the tool's output. Attributes that are not physical properties of a power plant design layout – such as degradation

> "The model of the power plant can be stored as a reusable component in the software and mated with any geographic location or weather record set"

profiles, module mismatch and spectral response – can also be customised at a block-by-block level.

One unique feature that integrates the energy prediction platform with business practices is that the model of the power plant (as well as its subcomponents) can be stored as a reusable component in the software and mated with any geographic location or weather record set. This allows power plant developers to quickly compare the energy of a suite of customised power plants having a wide variety of inputs, directly addressing the 'site prospecting' stage of project development. This flexibility in the overall hierarchy of a PlantPredict simulation is illustrated in Fig. 3.

Business systems integration

PlantPredict can function as a standalone energy simulation software package with a dedicated web user interface; however, its true power is harnessed when coupled with other business systems (see Figure 5). To this end, PlantPredict services can be called via a collection of web APIs (application programming interfaces), either by internal First Solar tools on the server side or by external, customer-facing client web applications. The creation of separate applications via a web API makes the exposure of customised portions of the core simulation toolset possible.

For example, business development partners can log in to a simplified interface that satisfies the site-prospecting needs. At this project evaluation phase,

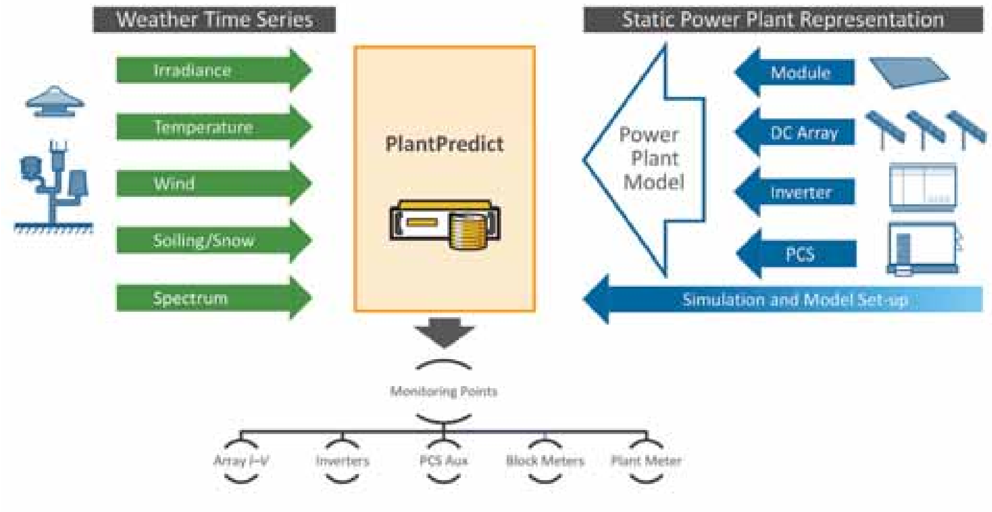


Figure 2. PlantPredict energy simulation overview.

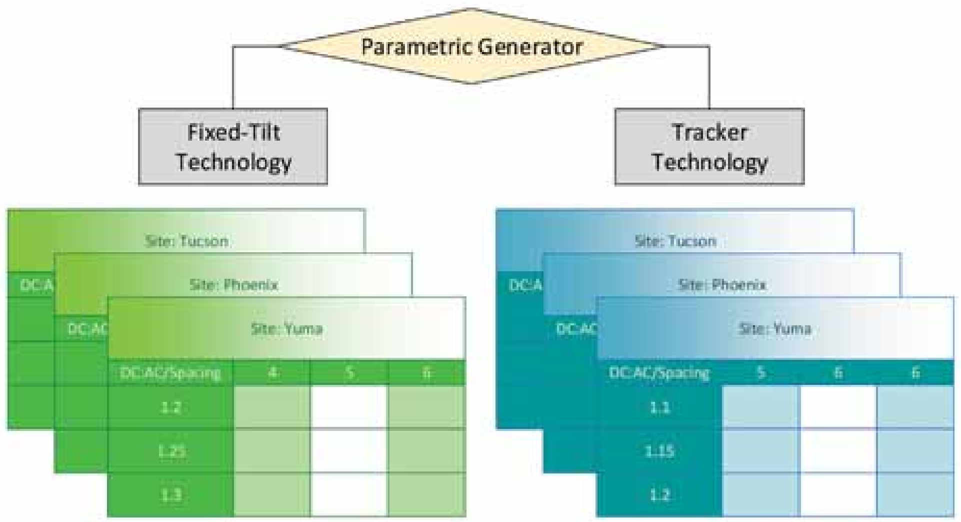


Figure 3. Components of a PlantPredict energy simulation for use in site prospecting with parametric variation.

PlantPredict is available in the guise of an 'indicative energy model', an external web portal which restricts the user inputs to basic parameters, such as type of PV technology, mounting technology, AC and DC capacity, ground coverage ratio, and a few select components (e.g. inverter types). Geographic location and weather source selection are map based. There is not a steep learning curve for creating the 'apples-to-apples' comparison: significant training on complex energy assessment software is not required. Despite this simplified interface, the results are generated from a fully fledged hourly energy simulation with many secondary input parameters preconfigured.

Additional functionality can be enabled that allows an automated parametric analysis for design and optimisation. PlantPredict has a library of 'reference power plants' that function as base cases for *parametric* analyses, which allow the variation of DC:AC loading ratios, row spacing, tilt angles, etc. The parametric analysis, through the web API, can be performed by economic optimisation goal-seeking engines that contain project cost data and site boundary conditions. An example of such an optimisation is illustrated in Fig. 4, where an energy simulation is run for a fixed-tilt system, with varying combinations of DC:AC and spacing between collector rows, and all other factors kept constant.

The interplay between tightened row spacing (increased shading loss) and larger DC:AC loading (more total generation at the expense of increased inverter clipping losses) is readily apparent. An optimisation tool that contains a database of project costs and other project information might choose to sweep only the combination of DC:AC and row spacing

Quality Assurance and Risk Management of Photovoltaic Projects

Who should be interested in risk management and why?
Good risk management can reduce project failures at a very early stage. Whether on-site, regarding safety, technically, logistically or legally: All of them can result in financial risks. When building large-scale photovoltaic power plants it is essential for stakeholders to look far more closely at how to **minimize risks, assure quality and profitability.**

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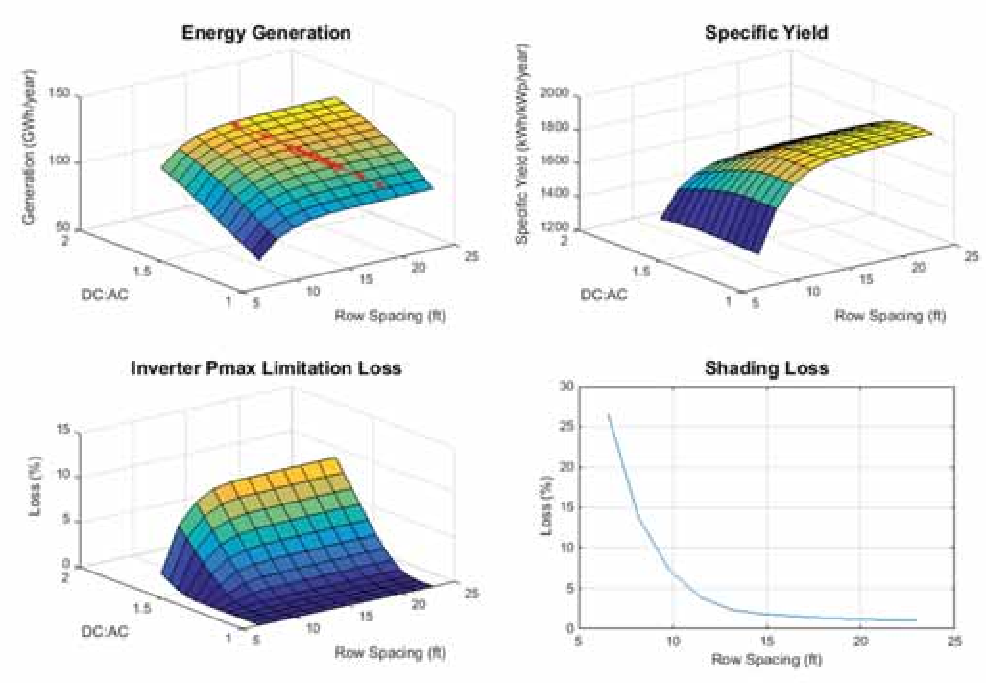
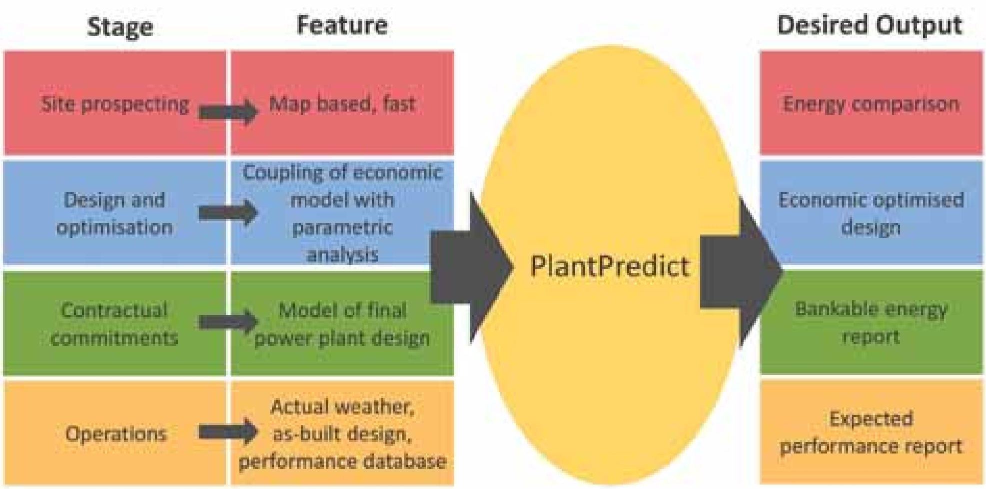
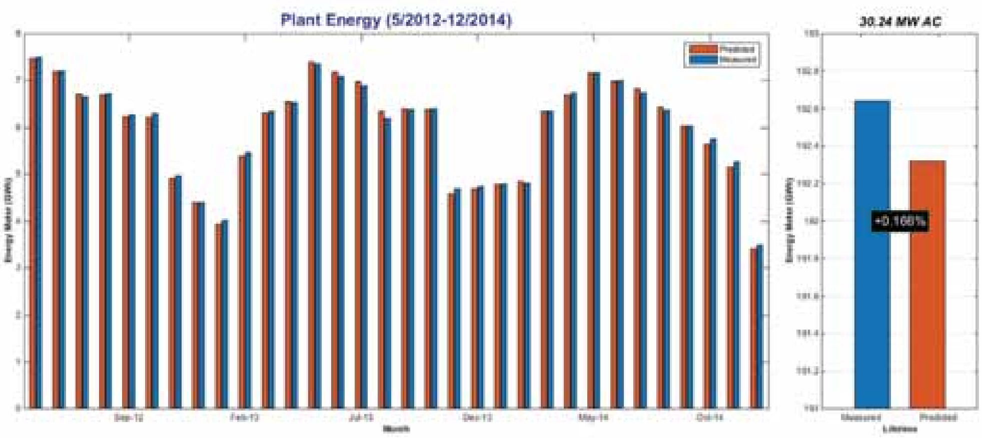


▲**Figure 4. Example of a parametric energy optimisation study for an area-constrained site.**



▲**Figure 5. Tool integration with other business functions.**



▲**Figure 6. Example of weather and outage-adjusted monthly energy report, showing differences between the contractual model (blue) and the actual performance (orange).**

that satisfies an area-constrained site, as indicated by the red line on the top left image of Fig. 4, or the contour of constant land area.

Because of the integration of the toolsets used in the optimisation, the total engineering effort has been substantially reduced, as compared with third-party tools.

At a later stage in the project development life cycle (Fig. 5), as the project design parameters are refined, the layout produced and the solar resource assessed through ground-adapted weather data, the project simulation can be re-executed, continuously preserving a history of all previous simulations in the database. Once the contracted energy model is defined, it is important that it can be reproduced at any time to monitor the performance commitments of the power plant, even as the capabilities of the core PlantPredict algorithms are enhanced in later future software releases.

For operations and maintenance (O&M), PlantPredict has been coupled with the power plant performance database. Meteorological data collected by the on-site sensors are spatially and temporally aggregated, and then batch processed for consumption by PlantPredict. This provides an automated means of reporting the actual daily energy generation, comparing with the contract model and correcting for availability outages and actual weather conditions (Fig. 6). First Solar's O&M team then have at their disposal a comparison point of actual with expected generation for eliminating potential false alarms and improving the allocation of O&M resources.

Algorithms

First Solar has invested heavily in understanding CdTe product performance in the field through a series of models describing its spectral response, module temperature, degradation, etc. The culmination of this work is the implementation of models in a toolset that can be used to assess the value of First Solar power plants in all aspects of the business as well as in its customer base.

The core PV module is represented by a single-diode equivalent-circuit model, with a recombination term in order to better match the *I–V* curve characteristics of CdTe semiconductors. The model used is nearly identical to that implemented in PVsyst [2], but with additional numerical precision extracted for sensitive coeffi-

Table 1. Key tool features.

Feature	Description
Solar position	• Implementation of the NREL Solar Position Algorithm [7]
Irradiance	• Erbs, Reindl and Dirint-Disc diffuse/direct irradiance decomposition models [8] • Hay and Perez diffuse irradiance transposition models [8] • Custom incidence angle profiles for reflection and refraction losses, evaluated using a cubic-spline interpolation
Spectral correction	• Precipitable water-based spectral enhancement of FS-3, FS-4 and FS-4-2 CdTe product • Air-mass-based correction for Si technologies
Soiling	• Uniform losses by calendar month • Ramped soiling accumulation model with rain-triggered and manually-triggered cleanings
Degradation	• Multi-year performance estimates
Module temperature	• Simple static model for hourly simulation intervals • Transient model, taking into account heat capacity and all heat fluxes at sub-hourly intervals
Module	• Single-diode equivalent-circuit model with a recombination current term • Non-linear temperature coefficient with a polynomial correction to the diode ideality factor
Inverter	• User-selectable maximum power set-point, derated as a function of temperature and elevation • Efficiency curves at multiple DC voltages
Plant architecture	• Block-by-block breakdown, with independent module models, inverter models, and DC and AC capacities • Staggered block installation and energisation schedule to model sequential power plant block commissioning and independent treatment of degradation
Timescale	• Sub-hourly modelling to avoid modelling artefacts due to weather averaging (inverter clipping)
Weather map	• NREL TMY3 [9] and similar • Web-service access to Meteonorm [10] and SolarAnywhere® [11] • Custom formats for manual upload

cients during the curve-matching process; in consequence, the module characterisations are interchangeable. Ramped soiling profiles [3], the First Solar-specific spectral response of CdTe [4] and a dynamic module temperature model [5] are also available in PlantPredict; these drive improved accuracy of the energy estimation. A diffuse-shading model that simultaneously accounts for incidence angle and occluded sky-view is also included, similarly to the calculation reported by Westbrook et al. [6]. Collectively, these algorithms represent the best known mathematical description of a PV power plant. A description of algorithm features is shown in Table 1.

To overcome some of the limitations of commonly used algorithms in other energy assessment platforms, PlantPredict uses an advanced suite of recently developed algorithms that more accurately represent the physics involved in PV energy generation. One technology understanding that can drive significant value in a project's total return is highlighted below, namely *spectral correction*.

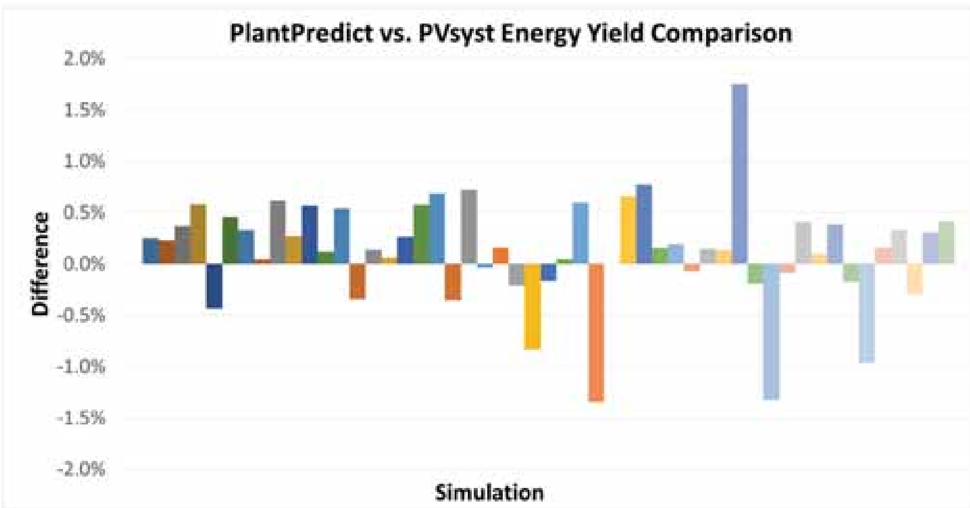
The nameplate power of modules is specified at standard test conditions (STC), which include the ASTM/G173 spectrum, commonly called AM 1.5 [REF]. However, the spectrum of incident light on the module in real-world conditions does not follow this reference spectrum [12], particularly in locations distant from the equator and in high relative humidity environments. Most publicly available tools completely fail to address the fact that the wavelengths of light absorbed by a PV module are a subset of the total incident light, and that this ratio changes with atmospheric conditions. To address this shortcoming for the CdTe module, First Solar developed a correction factor that modifies the broadband measured light to the reference spectrum based on precipitable water in the atmosphere [5]. This methodology has been widely circulated in the industry to developers and independent technical advisors, and has been incorporated in bankable energy assessment for the last two years. For First Solar's Tetrasun monocrystalline Si modules (and other silicon-based technologies), PlantPredict uses the well-known air-mass-based correction factor for Si technologies [13]. These corrections can have a significant impact on performance of up to 2–5%.

"The core PV module is represented by a single-diode equivalent-circuit model, with a recombination term in order to better match the *I–V* curve characteristics of CdTe semiconductors"

Tool validation

The validation of a simulation tool is a complex undertaking and needs to accomplish two goals: 1) ensure the compatibility of the simulation results

Figure 7. Comparison of energy generation between PlantPredict and PVsyst for 51 simulations.



Validation type	No. of sim.	Mean	Standard deviation
Independent assessment	20	+0.20%	1.5%
Comparison with PVsyst	51	+0.13%	0.52%
Expected vs. actual power plant performance	20	-0.41%	2.0%

▲**Table 2. Validation results.**

with those of equivalent tools in the industry; and 2) ensure that the tool's estimates represent the true performance of a real-world power plant. The first can be achieved by unit testing individual algorithmic components (e.g. solar geometry, tracker positioning and module *I–V* curve solving) and comparing the results with those of other tools, insofar as the same fundamental mathematical models are used. The

"PlantPredict, through its integration with business practices and a web API interface, provides unique flexibility in addressing all stages of the project life cycle"

validation against actual power plant performance requires a well-behaved, data-complete and well-characterised power plant, as well as a tight coupling of measured meteorological data with power plant performance data (e.g. module temperature, array current and voltage and inverter efficiency).

In order to demonstrate the bankability of PlantPredict, First Solar has performed a three-pronged validation of the accuracy of the tool against actual power plant performance and industry-standard simulation tools. An independent technical assessment was performed by DNV GL [14], which evaluated PlantPredict at four geographic locations under various geometrical orientations (fixed-tilt, horizontal tracker, various azimuths). PVsyst [2] was used as the tool of reference. A more in-depth in-house assessment was performed which compared energy conversion loss factors between PVsyst and PlantPredict for 51 simulations, comprising a mix of recent CdTe product lines including Series-3, Series-4 and Series-4-2 modules, and different inverter models, array orientations, geographic locations and climates, as shown in Fig. 7.

PlantPredict's energy estimates were also compared with the cumulative performance of 20 operating First Solar power plants commissioned between 2009 and 2013, comprising more than 950MW_{DC} of installed product across a wide range of climates [1]. This is an expansion of work on a single hot-climate site presented previously [15]. DNV GL also independently validated the techniques used in filtering and preparing the power plant data prior to applying it as an input to the simulation tool (see Table 2).

One final aspect, from a bankability perspective, is the ability to regenerate performance models based on past versions of the tool, or on other, older configurations of model settings. A tight revision control system, along with an accompanying regression test suite, is required, as contractual performance models need to be maintained and executed for many years, even as the core tool functionality evolves.

Conclusions

As the deployments of PV power plants become more frequent, reducing the life-cycle cost of these projects is increasingly important to their total economic value. First Solar, as a major provider of utility-scale PV power plants, has developed a leading-edge prediction toolset that underpins the expected performance of these assets in real-world conditions. PlantPredict, through its integration with business practices and a web API interface, provides unique flexibility in addressing all stages of the project life cycle. The advanced algorithm suite also offers a superior level of energy assessment accuracy that is not found anywhere else in the marketplace. PlantPredict is available to select First Solar partners in 2015. ■

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Authors

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Alex Panchula has been with First Solar since 2009 and is the director of prediction, performance and field reliability monitoring teams, who are responsible for developing and validating technology and performance models. He has a BS in physics and mathematics and a BA in English from Iowa State University, and a PhD in applied physics from Stanford University, California.

The art and science of pyranometers

Irradiance measurement | Pyranometers play a crucial role in gathering irradiance data for PV yield and performance modelling. Ben Willis explores this sometimes-overlooked piece of technology and efforts by researchers to improve our understanding of its characteristics

Source: PTS Mesures.

Pyranometers are a vital part in the planning and ongoing monitoring of PV power plants.

About the size of a dinner plate and resembling something akin to an alien spacecraft, the humble pyranometer is an understated but essential element in the design and operation of a PV power plant. While irradiance data from satellites offers a useful broad-brush assessment of the potential profitability of a proposed PV plant, it is no match for measurements taken directly from the site itself.

Pyranometers are precision instruments that measure global horizontal irradiance, the amount of electromagnetic radiation from the sun falling on a flat surface at a given location. Although it will not always be economically viable or indeed necessary to have a pyranometer installed at every prospective PV site, in the further-flung parts of the world where the data is patchy, or in areas with specific climatic conditions, they will be essential in helping make the business case for a project.

"There are some unexplored areas in the world where people cannot make use of the solar atlas, they cannot make use of solar satellite information," says Kees Hoogendijk of EKO Instruments Europe, a manufacturer of pyranometers. "Satellites are not very precise on radiation quantities. So you can say 10-15% uncertainty is normal. And for many investors it's not sufficient to plan a big project."

The power of pyranometers lies in their ability to tease out inherent uncertainties in the data derived from satellites. As explored in the previous issue of *PV Tech Power*, prevailing practices in the use of satellite data do not allow for a particularly nuanced picture of the variability of site irradiance conditions, leading to either excessively conservative or overly optimistic energy assessments. But by combining datasets – from satellites and from ground stations – some of those uncertainties can be if not eliminated then significantly reduced.

"[Combining datasets] can change the overall irradiance values up or down," says Gwen Bender, an energy assessment engineer for forecasting firm, Vaisala. "You see benefits from that because it's pretty much a one-for-one relationship between irradiance and power. So if I can raise the estimate by 2% that's 2% more power you're going to see in modelling.

"But the biggest impact is in the reduction of the uncertainty. So if we have a full year of observational data and the correction process goes well we can see a reduction of half or even more in the uncertainty that we could assign to the [energy assessment] model. There are very few things where you can reduce the uncertainty by half."

Cleaned up

But as with a PV power plant, which can be subject to any number of external factors, the effective operation of a ground station incorporating pyranometers requires similar care. Bender says all too often she receives datasets from ground stations where it is evident from the quality of the information being presented that the proper procedures to ensure its accuracy have not be observed.

"The care and maintenance of equipment and reviewing your own data on occasions is pretty critical to having at the end of the year a dataset you can use to materially reduce your uncertainty," Bender explains. "It is continuously surprising to me how many people never look at their data, and are then surprised at the end of a year when months of it is unusable."

Two basic practices that are not always followed are cleaning and keeping the ground station site free of vegetation. "I've seen stations where they mowed down vegetation, installed the station and then things grow back up," Bender says. "So the first couple of months are ok, then you start to get this weird shading.

"People tend sometimes to not look at the data as often as they need to. And the problem is you've spent the money but you don't have the data – or you have to wait another year because you have to catch that season again."

On cleaning, the right regime will depend on a site and its particular conditions, but the message from experts is that more rather than less is preferable. "If you talk about reference equipment it's better to clean it more frequently," says Hoogendijk. "It's really critical – like your module, your sensor instrument will also be subject to soiling and the output will be subject to that."

According to Dmytro Podolskyy, business manager at pyranometer supplier Kipp & Zonen, for a high-quality ground station, the ideal regime would be daily cleaning, particularly of the pyranometer's glass dome, on which a build up in soiling could be detrimental. But for sites in deserts or other remote locations, daily cleaning clearly becomes more complicated. In such cases, other equipment may be needed.

"What we recommend is you use a ventilation unit," Podolskyy explains. "It blows air around the dome continuously and prevents dust accumulating, and also water. It helps keep the pyranometer clean for a much longer period of time – weeks or even longer. Of course when you have dirt already there, it cannot clean it, but it keeps normal dust and pollen from accumulating."

Another approach used to mitigate the impact of soiling is to have more advanced stations that combine a number of different instruments to allow for the collection of comparative data. Typically says Podolskyy, such a station would combine two pyranometers and a pyrheliometer, which is pointed directly at the sun to measure direct radiation.

"What people do is compare the data from all these three, because they're all related to one formula. And if you compare them, if they're same, everything's fine. If it changes, then probably you've got a soiling problem and you will not get the same data from all of them," Podolskyy explains.

Whichever cleaning and maintenance regime is followed, Bender says proper recording is essential from the point of view of interpreting the data that eventually comes out of a ground station.

"Even when cleaning and maintenance are being done, they're not being recorded," she says. "So then you're looking at a data stream of two years day by day and wondering if this data is dirty or if it's just not that sunny. I would love to see better records – calibration certificates, maintenance records ... if anyone goes out and touches the equipment there should be a record of it."

This is a crucial point, as without the sort of records Bender refers to, there is little to tell the data analysts what is going on in a dataset and therefore how to handle it.

"If you know a client cleans every two weeks, you'd see the peak numbers getting a little bit lower, a little bit lower, then they would jump [after the cleaning] and we'd know not to use data from the previous two or three days when the level starts to drop; removing two or three days in course of month will not have an impact on our ability to do the corrections," Bender says. "But if we don't know they've cleaned, or it's not obvious, then we're relying more on guesswork and our experience than on hard facts."

Pyranometer characterisation

Aside from the vagaries of soiling and the appropriate maintenance, as sensitive instruments, pyranometers themselves display particular characteristics that can affect the data they collect. Precisely what these are will depend on the type of instrument in question.

Broadly speaking there are three categories of instruments used to measure global irradiance – thermopile pyranometers, photodiode pyranometers and reference cells (see box). Because of the different quality of these instruments and different technologies they use, each will display sensitivities to a greater or lesser degree to certain environmental factors that will affect their performance.

For example, says Anton Driesse, founder of PV Performance Labs, a Germany and Canada-based consultancy, the angle at which the solar irradiance strikes the instruments can have an effect. "If sunlight comes in at an oblique angle to the instrument surface and some of the light is reflected, then the instrument is not going to give a true reading of the available energy. The better instruments will have smaller errors in that respect."

Another issue is so-called non-linearity, where the strength of the signal coming out of the pyranometer becomes disproportionate to the signal coming in. "The [thermopile] pyranometer is a thermal instrument: it measures the rise in temperature of a black surface in response to sunlight. But you have heat losses in various directions, and within the glass dome you can even have air currents because of the small temperature differences," Driesse explains.

"Such effects can lead to an instrument becoming non-linear. So if at full sun you were to get a reading from one of these instruments saying you've got 1,000W/sq metre, at half that intensity you would expect to have a signal that says 500, but if the instrument is non-linear, it might say 490 or 510."

Indeed, Driesse says that even a gust of cold wind on an instrument can impact its output, even if the irradiance falling on it does not change. "Designing a pyranometer is a bit of an art as well as a science"' he says. "Fortunately we have companies that have been at it for a very long time and developed both aspects, and as a result we do have very good instruments available. But they're not perfect."

Understanding these imperfections and how they affect the performance of different instruments is an entirely new field of study into which Driesse is leading the way. He says that although manufacturers are aware their instruments demonstrate different characteristics and provide customers with some data on this to help them compensate, this information is incomplete.

"People are aware there are different quality instruments available. But if you look at the [manufacturers'] specifications, you can't really get a sense from those of what's going to be your margin of error, or uncertainty, when you use this instrument to assess your PV system. It's very hard to make that link," Driesse explains.

"So if you have a bit of budget, you tend to go for the best because you can't do any better. And otherwise you rely on what the supplier tells you about their instrument choices. But it's very hard to put your finger right on what the trade off will be in terms of percentage of uncertainty."

Source: Kipp & Zonen.

A major study is underway to characterise some of the main brands of irradiance sensor on the market.

Driesse has embarked on a major study of some of the main brands of irradiance sensors on the market today in an attempt to amass some hard data on their relative characteristics. About half are thermopile pyranometers and the others are photodiode pyranometers and reference cells. He has already carried out one round of indoor tests at the European Commission's Joint Research Centre in Ispra, Italy, and is working with Sandia National Laboratories in the USA for a round of outdoor testing. After that the instruments will be deployed side by side and carefully monitored for at least a year – half of them at Sandia in the USA, and the other half back in Europe.

The result of this will of course be a huge amount of data. Driesse says he is collaborating with his testing partners to analyse this data and will try to publish results and observations as they become available rather than wait until the last round is completed. He is convinced that the findings from the study will be beneficial to the solar industry and will "help people select instruments and understand where their vulnerabilities are and understand the nature of the uncertainties".

Unsurprisingly Driesse senses there's a "keen interest" among instrument manufacturers "to know what I find out". He hopes that rather than serving companies' marketing objectives, this information will be used by them to improve their products and thereby the accuracy of PV yield and performance assessment.

And with investors becoming ever more discerning in the quality of the data they are looking for, that can only be beneficial to the wider solar industry. ■

Irradiance instruments

Thermopile pyranometers These contain an element that warms in response to solar irradiance, producing a proportionate voltage signal. Thermopile pyranometers are sub-divided into different quality classes, with 'secondary standard' offering the best data and fewest imperfections, followed by first or second class.

Reference cell These are essentially photovoltaic cells that are used to measure irradiance. As they are less sensitive to the full spectrum than thermal pyranometers, reference cells are better suited to measuring available irradiance than overall "broadband" meteorological irradiance. This makes them better suited to characterising PV system performance as they behave in a similar way to a PV cell.

Photodiode pyranometer A mix of the two, containing a tiny photocell internally, but designed to behave as much as possible like thermal instruments.

Irradiance sensors being tested in the PV Performance Labs characterisation study.

Manufacturer	Secondary Standard Pyranometer	First or Second Class Pyranometer	Photodiode Pyranometer	Reference Cell
The Eppley Laboratory	PSP SPP GPP			
Hukseflux Thermal Sensors	SR20	LP02 SR03		
Eko Instruments	MS-802	MS-602	ML-01	
Kipp & Zonen	CMP 10	CMP 3	SP Lite2	
Apogee Instruments			SP-110	
LI-COR			LI-200	
Skye Instruments			SKS-1110	
Energy Environmental Technical Services				RC01
Fraunhofer ISE				11311102.00
Ingenieurbüro Mencke & Tegtmeyer				SiS-02-Pt100 Si-02-Pt100 Si-02-Pt100-x
NES - Mess- und Meldesysteme				SOZ-03
Total	**6**	**4**	**5**	**6**

Understanding PID: Improving the performance of large PV systems

Performance | Potential-induced degradation (PID) has emerged as an issue of concern in the last decade because of the increase in the deployment of utility-scale high-voltage PV systems. Rubina Singh, Cordula Schmid and Jacqueline Ashmore of the Fraunhofer Center for Sustainable Energy Systems CSE present an overview of the mechanisms for PID and the impact of degradation, as well as the factors that contribute to its occurrence. They also discuss techniques for the detection, mitigation and predictive testing of PID

PID is a degradation mechanism occurring in high-voltage PV systems because of a large potential relative to ground, and is dependent on the magnitude and polarity of the system. The trend in recent years towards 1000–1500V systems increases the susceptibility of PV modules to PID, as a consequence of the high electric potential. Though degradation caused by high-voltage stress was identified as early as 1978 at JPL [1], PID gained visibility in 2005, when Swanson identified degradation due to polarisation in SunPower modules [2]. The issue, however, has not yet been addressed by qualification standards such as the IEC 61215 and IEC 61646, so a new test method, IEC 62804 TS, is currently being developed.

Cells affected by PID can lose up to 80% power or even more [3]. A power output reduction of over 40% [4] was observed in PV strings of a plant afflicted by PID. This level of power loss adversely affects the operations and financing of PV systems; it is therefore essential to understand and address the issue in its early stages, in order to ensure satisfactory stability and performance of modules over their service life.

PID mechanism

PID is caused by a large electric potential on the module, which in turn results in a leakage current that migrates between the cell and the other components, leading to a reduction in power. As Dr Peter Hacke stated at the 2015 NREL PV Reliability Workshop, leakage current is not a metric for assessing the quality of modules, but a parameter that can be used to detect modules afflicted by PID. Several different mechanisms can lead to PID, but not all of them are fully understood.

“Cells affected by PID can lose up to 80% power or even more”

The field effect model is one of the most common models used by researchers to explain the cause of shunting, which results in PID [5,6]. Bauer et al. [6] found the migration of sodium ions from the front cover to the solar cell, in combination with certain EVAs and a silicon nitride anti-reflective coating (ARC), to be commonly observed in modules affected by PID. One explanation is that during migration, the charged ions accumulate on the cell surface and result in an electric field, which negates the passivation provided by the ARC, thus increasing surface recombination and reducing the power output. The ions can also diffuse into the silicon, causing inversion of the emitter region and resulting in shunting of the cell [7], as shown in Figure 1. Similarly, PID in some thin-film modules has been associated with the migration of metal ions between the frame and the cell, and significant degradation has been observed in modules using sodium-containing substrates [8].

Experiments have been conducted at Fraunhofer ISE to analyse the effect of the inversion layer on the cell, in conjunction with the development of a theoretical model. The results indicated that there was an inversion of the emitter surface but the emitter was not completely inverted; hence, the model was insufficient for totally explaining PID [9]. Further investigations to fully understand all aspects of mechanisms leading to PID are still ongoing.

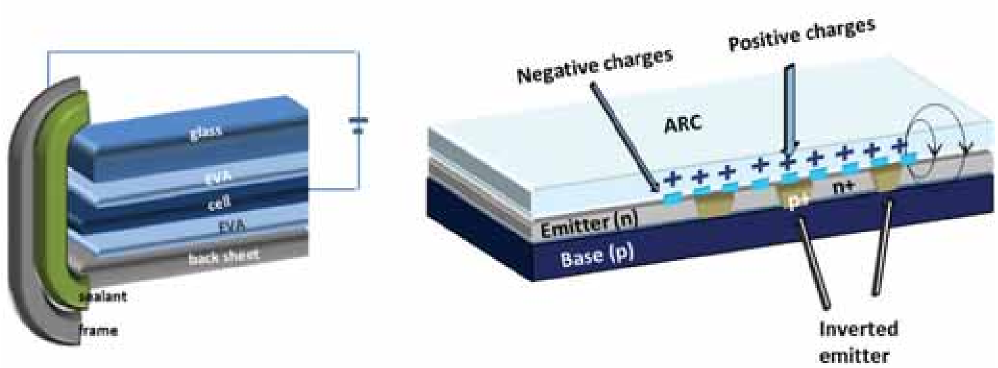

Figure 1. Hypothesised mechanism for PID in crystalline silicon solar cells, based on Bauer et al. [6].

Impact of PID on PV power plants

Numerous cases of yield loss due to PID in PV power plants have been reported in recent years, and this has a detrimental effect on project financing and economics. A survey conducted by PI Berlin [10] reported PID in 20 power plants in Germany; another power plant, comprising 12 strings, showed PID in all the strings, with the majority exhibiting a 10–15% reduction in power output as shown in Fig. 2. In addition, PID affected 41% of the modules in a 10.7MW plant in Spain.

Besides lowering yield, the balance of system (BOS) costs will also be affected. A significant drop in a string voltage will result in a mismatch with the inverter's voltage range, thus increasing inverter losses. Mitigation would require replacement of the affected modules,

> "If PID is undetected and unaddressed, the resulting reduction in yield will result in financial losses for investors"

reconnecting the strings and optimising the inverters to match the string voltages. Such unforeseen mitigation costs would further increase revenue losses [11].

With the significant decrease in capital cost for solar installations, the focus has shifted to the investments over a PV system's lifetime, making it beneficial to demonstrate a system's reliability to stakeholders. If PID is undetected and unaddressed, the resulting reduction in yield will result in financial losses for investors. The financing of future projects would also become more difficult, since stakeholders would lean towards more reliable technologies [12]. The first step towards prevention or mitigation is to understand the various factors causing PID, and the techniques that can be adopted for timely detection.

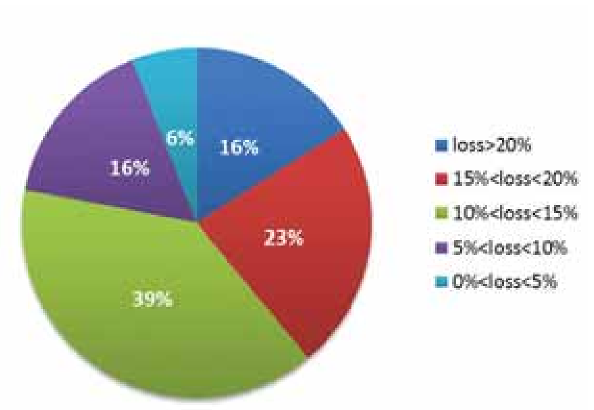

Figure 2. Distribution of power loss at the maximum power point (MPP) for all the strings in a PID-affected PV plant (based on the plot given in Berghold et al. [10]).

Factors contributing to PID

Numerous factors can contribute to PID and can be categorised at the environmental, system, module and cell levels. The occurrence of PID in modules can result from one or a combination of several of these factors, which may be different for different module technologies and climate zones.

Environmental level

High humidity and temperature are the two most significant factors contributing to PID. Various research experiments conducted at, for example, Fraunhofer ISE [13] showed that PID is considerably more likely to occur at high humidity – specifically above 60% relative humidity (RH) – in conjunction with high-temperature conditions.

System level

As mentioned previously, the system voltage with respect to ground and the inverter type significantly influence a system's proneness to PID.

Module level

The module design, glass and backsheet material used can also result in susceptibility to PID. In the past five years several institutes, such as Solon SE and PI Berlin [7], have received a number of modules that were returned because of polarisation; this indicates that recent module designs and technologies may not be immune to PID.

Cell level

The main contributing factors at the cell level are the ARC, base resistivity and emitter sheet resistance [14].

Detection techniques for PID

If left undetected, PID can dramatically reduce a power plant's performance. Some commonly used detection techniques for PID are electroluminescence imaging (EL) and infrared imaging (IR), along with the measurement of I–V curves, which detect any drop in power and operating voltage. Fig. 3 shows EL images for a module, before and after it was tested for PID: the dark regions indicate that the module has degraded as a result of testing. Light and dark I–V can be used for detecting PID, since the cells that are affected will have lower module efficiencies and operating voltages; moreover, those that are severely affected will exhibit reduced open-circuit voltages because of shunting [15].

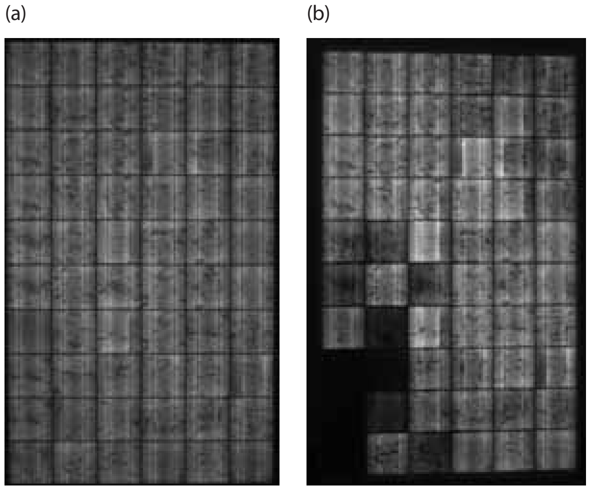

Figure 3. EL images of a module before (a) and after (b) PID testing [16]. Source: Fraunhofer CSE.

Conventionally, the modules would be removed from the field and taken to a lab to conduct EL imaging and I–V curve measurements, but these procedures can now be implemented in the field without uninstalling the modules. EL can be performed on site using a CCD camera while applying a voltage bias to the module at night. IR imaging uses an IR camera while the modules are operating in the field, but might not be an accurate detection method, since PID is not the sole cause of higher temperatures in cells [15]. I–V curve tracers that can be used in the field are also available, but the process of testing each and every module can be time-consuming and expensive. Nevertheless, early detection can help in using appropriate mitigation techniques and prevent further performance and revenue losses over a system's lifetime.

Source: Fraunhofer CSE.

Figure 4. Fraunhofer CSE researcher setting up a module in the environmental chamber for PID testing.

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10%~30% 10%-30% additional conversion efficiency compared to ordinary P-type monocrystalline products

90% Under the same conditions, the reverse side conversion efficiency is 90% of the frontage

22% On snowfield, water surface and white painted rooftop, the additional reverse side conversion efficiency can reach up to 22%

0% Light Induced Degradation

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SUSTAINING INNOVATION SINCE THE 1960s

HT-SAAE's 2015 blockbuster launch Milky Way N-type Pert monocrystalline product

Organisation	PID test [26]
Chemitox	60°C/85%RH/–1000V/96h, module immersed in water
Fraunhofer ISE and CSE	60°C/85%RH/–1000V/(96h) × 3 in environmental chamber
PI Berlin	85°C/ 85%RH/ –1000V/ 48h
TUV Rheinland	25°C/-1000V/168h, aluminium foil method
TUV Sud / IEC 62804	60°C/85%RH/–1000V/96h in environmental chamber

Table 1. PID test protocols typically used by different organisations.

PID mitigation

Conditions of high temperature and humidity occur sporadically in the field, giving the modules time to recover from PID. Besides relying on such favourable environmental conditions, various solutions for mitigating and preventing PID are under development at the system, module and cell levels.

In systems using conventional inverters, grounding the negative pole of the system can help prevent PID. Companies such as SMA have developed the PV offset box [17], which reverses the effect of PID in systems using transformerless inverters. If a voltage of the opposite polarity to that of the system is applied, which can be done by connecting an offset box in parallel to the inverter, the modules will almost completely recover from PID. Furthermore, PID can also be mitigated at the module level by using PID-resistant encapsulants, such as Enlight polyolefin encapsulant film [18], ionomer films and chemically strengthened glass.

Various module manufacturers claim to have developed PID-free modules, which are based on the use of PID-resistant components, anti-PID cells and encapsulant technology. Moreover, frameless and glass–glass modules are also considered to be PID free, since a path for a large potential to be set up is not created; however, the use of metal clips for mounting such modules might negate the anti-PID property. Due diligence is therefore required in order to ensure that the bill of materials and associated processes are all PID free, so that PID can be avoided in a system as a whole [19]. In some cases PID might be irreversible if it is not detected in time or if it is caused by electrochemical reactions. To limit future detection and mitigation costs, it is therefore advisable to test modules for PID resistance, where possible, before field installation.

Predictive tests for susceptibility to PID

The two main testing methods employed in the lab simulate conditions for PID using an environmental chamber and the aluminium foil method. Initially, the test was adapted from the damp-heat test specified in the IEC 61215 standard, with environmental conditions of 85°C and 85% RH. Some organisations are currently using a modified test protocol based on the draft IEC 62804 TS test method.

Tests were conducted over a period of 96 hours in an environmental chamber at 60±2°C and 85±3% RH and with a voltage bias of –1000V or the nameplate-rated system voltage; this standard is based on the findings of round robin tests coordinated by NREL [20]. Hacke et al. [21] have reported corrosion and losses in series resistance caused by a combination of very high RH and temperature of 85°C, which does not simulate PID in the field accurately. Moreover, though a humidity of 100% would be preferable, this setting might also induce stress because of condensation in the environmental chamber, which would otherwise not occur in the field [22]. Testing conditions of 60°C and 85%RH were therefore chosen as the most representative.

In 2014 the aluminium foil test method was added to IEC 62804 TS as a simple and inexpensive alternative to the environmental chamber test [23]. The method consists of covering the module surface with a conductive foil and applying the system rated voltage at conditions of 25°C and less than 60% RH for 168 hours [23]. Experiments conducted at Fraunhofer CSE to compare the different testing methods showed that, compared with the aluminium foil method, the use of an environmental chamber results in more uniformity, control and reproducibility [24]. Fraunhofer CSE therefore conducts PID tests based on the IEC 62804 environmental chamber method, as shown in Fig. 4, and has already tested various modules as part of the PV Durability Initiative (PVDI) [25]. The results from the first round of PVDI revealed that susceptibility to PID for most of the modules was detected within the first 50 hours, which supports the IEC's decision to test for 96 hours. However, in order to increase the severity of the test and detect any late onset of PID in the modules, the testing was continued beyond the 96 hours and repeated twice more with interim characterisations. More rigorous testing will ensure that the modules will work reliably over their lifetime.

Some organisations offering PID testing are NREL, Fraunhofer ISE & CSE, Intertek, TUV Rheinland, PI Berlin and PV Evolution Labs; test protocols typically used are given in Table 1.

> "There is a need for a standard method to accurately determine acceleration factors that can be adapted to different locations and technologies"

Future work

Since PID was discovered relatively recently, there is a need for additional reliable and comparable field data in order to better understand the mechanisms and establish more dependable ways to avoid the phenomenon. Canadian Solar [27], REC [28] and SunPower [29] are some of the manufacturers developing PID-free modules, which have been confirmed by independent testing agencies. Although testing the modules indicates their resistance to PID, this cannot be regulated until an international standard and industry-accepted definition of 'PID-free' are developed. Further research is also required to better understand the PID mechanism, since it has been postulated that emitter inversion causes shunting, resulting in PID; experimental results from Fraunhofer ISE, however, have shown the inversion model to be inadequate in explaining PID. Moreover, though the occurrence of PID has been observed in conjunction with the presence of Na^+ ions, their actual role in causing PID is not fully understood.

The time it takes for modules to exhibit PID susceptibility is not totally understood either, since modules in different PV plants have manifested PID at different times. Further research and testing are necessary in order to determine acceleration factors which can correlate the module's time to PID onset in the field with lab tests; some organisations are conducting research in this area [30,31]. There is a need for a standard method to accurately determine acceleration factors that can be adapted to different locations and technologies.

In conclusion, the industry has been proactive in identifying and tackling PID, with extensive research under way to understand various aspects of the phenomenon at the system, module and cell levels. Consequently, the factors causing PID are now being identified, leading to the drafting of a test method for standardising PID testing, and to the development of various mitigation techniques. Additional research, however, is still essential, so that further understanding of the phenomenon can be gained, and to prevent this challenge from being an obstacle in the PV industry's remarkable growth. ■

Authors

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Rise of the machines

Aerial monitoring | With PV projects growing larger and fleets more dispersed, new technologies are emerging to assist plant managers look after their assets. Tom Kenning looks at the growing use of solar drones and robots in plant operations

Despite controversial uses in military actions across the globe, drones have now crossed over into the mainstream commercial sector with a deluge of recent enterprises ranging from Facebook considering solar powered drones to deliver internet access and Amazon testing package delivery via the skies. However, these unmanned aerial vehicles (UAVs) have already become popular with members of the energy industry, who have been using them with thermal imagery to check oil and gas pipelines, wind turbines, construction projects and even to monitor vast PV power plants.

With PV plants and fleets becoming ever larger, the sight of drones flying low over solar installations at speeds of up to 50 miles per hour is becoming increasingly common. Furthermore the necessity to clean PV panels has led to a rise in robot systems used to wipe clean the panels and prevent build up of soiling and dust, which can undermine the optimal operation of a plant.

The global commercial drone market is forecast to grow at a compound annual growth rate of 109% from 2014 to 2020, according to the 'Commercial Drones Market 2013 – 2020' report from MarketsandMarkets, and the energy and infrastructure industries are the cited as main driver for this.

A primary concern in the PV community is quantifying degradation and failure rates of modules and cells in the field. Even though a US National Renewable Energy Laboratory (NREL) study estimates that PV panels suffer a failure rate of less than 1% per year, the effects on energy output builds up over time. Knowing degradation rates and pinpointing faulty cells and modules can help accurate predictions of a plants future output and reduce financial risks.

Timothy Silverman, scientist at NREL National Centre for Photovoltaics, tells *PV Tech Power* that surveyors traditionally perform periodic plant inspections using handheld cameras. In many cases, it is not cost effective to have someone check every single module in the field so they perform spot checks to look for obvious issues. Thus, depending on the size of the plant, using UAVs for flyover inspections may give better, cheaper and more efficient coverage.

Source: Skycatch.

Unmanned aerial vehicles – drones – are becoming a common sight over PV power plants.

PV panels emit a certain amount of heat, and defective panels give off more heat than functioning panels. Therefore the difference in temperature can be easily detected using an infrared thermal imaging camera.

Vigilant Energy Management, for example has used a drone purchased from Canada-based manufacturer Dragonfly on six sites ranging from 1 to 5MW over the last six months. Even for relatively small plants, the drones have the advantage of surveying solar arrays quickly and spotting anomalies using infrared from a long distance, says Jeff Gilbert, Vigilant director of operations and maintenance services.

He says it takes half a day to walk a 1MW site and just 30 minutes to use a drone. "Simply spotting a hot module cell quickly is much more valuable than high resolution images from the ground," he explains.

Historically Gilbert would hire a helicopter or aeroplane to take high resolution pictures for marketing, but now he uses the drone. He concludes: "The prices are coming way down and the uses are going way up. We think it is a good investment."

Products from Google-backed drone manufacturer Skycatch are widely reported to have been tested by industry giants First Solar and SolarCity. Eugene Kwak, Skycatch director of product, hardware platform, told *PV Tech Power* that users can programme in automatic unmanned flight missions for the drone and create maps, while maintaining accurate performance in strong winds. The camera can then spot physical anomalies within a cell, such as physical cracks and cell discoloration, using an RGB sensor.

Meanwhile Italian-based drone developer Panoptes has customised remote controlled drones for thermographic inspections of PV plants. These automatically produce inspection reports using

mT-Panoptes 640 drone:

- Inspects 5-15 MW in one day
- Each day of surveying requires one or two days of post-processing
- Experienced UAV pilot needs five hours training for use
- System weight 700 grams
- Uses HR thermal imager and HD camera

Source: Ecoppia.

Robotic cleaning units save water and labour at large or inaccessible PV sites.

software called 'Solar Inspector', which assist O&M managers in subsequent ground checks.

Silverman says that newer drone applications are emerging with the introduction of electroluminescence (EL) and photoluminescence (PL) imaging. While thermal imagery detects external temperatures, EL and PL techniques take a picture of the emission of the active layer of the material itself.

Meanwhile UAVs can also be used to check cabling, wiring, infrastructure and mounts, or for topographic and feasibility surveys of potential solar plant sites. Drones are even being used to ward off birds and endangered species from functioning PV plants, with bird deaths a politicised issue that can undermine whole projects.

Robotic cleaning

Besides inspection, another concern for PV operators is soiling and the necessity to keep panels clean from thin layers of sand and dust to ensure maximum efficiency in harvesting the sun. Silverman says: "Whether you should clean at all depends on how much soiling you get. In locations like India it is really common to clean twice a month because the plants are so dusty and the lost energy from the soiling would more than pay for the cost of cleaning, but in Colorado, for example, soiling is not too bad and precipitation is just frequent enough to clean off that soiling – so here it doesn't really make sense to do cleaning."

The majority of large-scale installations globally, however, are located in desert areas to get as many sun hours as possible. This not only brings a challenge of dust and soiling but also water scarcity. Anat Cohen Segev, director of product marketing for Israel-based cleaning robot manufacturer, Ecoppia, says this is especially the case in the Middle East, India, Northern China, California, Arizona and South Africa.

"So far the cleaning methods used were primitive – often manual cleaning with squeegees and pouring water," Segev says. "Recently there have been solutions with vehicles driving between the arrays carrying water and that is either being sprayed on the panels or using long brushes, but in any case it is a very costly solution." These techniques using pressure washers and sprayer trucks also have the potential to damage the highly expensive PV equipment while water also requires distillation to avoid panel corrosion.

A vast range of robotic applications have been developed. SunPower acquired Greenbotics and its CleanFleet robots in 2013, which can be configured for use with a variety of solar panels including fixed-tilt arrays and single-axis trackers.

Ecoppia's robot cleaners, on the other hand, are fixed permanently to rails on an array. Powered by their own solar panels, using neither water nor labour, the robots clean automatically each night. Dust sticking to the panel is considerably reduced and output kept high. Automisation also negates problems with predicting dust storms.

Esther Westreich, chief executive of Global Sun Operation and Maintenance at Arava Power Group, which uses Ecoppia robots at its 20-acre Ketura Sun solar farm in Israel, tells *PV Tech Power* that even after a dust storm the Ecoppia robots have the panels clean in an hour. "It has a positive effect on production of a few percent, which is quite significant for this scale of a project," Westreich says.

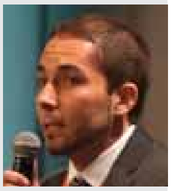
She says the robots do not touch the panel, except for the gentle microfibres that do the cleaning, which minimises any potential for damage. This solution works best on plants with long rows and lots of panels as they can only be fitted to rails.

Ecoppia robots, which are deployed on six plants in Israel and several in India and the Middle East, clean five million panels every month and are expected to be cleaning 10 million a month by 2016.

The case for using drones and robots is clear for large-scale PV plants with high maintenance costs or natural conditions that make traditional cleaning methods difficult and inefficient. Small-scale plants are less likely to require such technologies, but if the prices reduce enough, it may become more widespread.

Looking to the future, Eugene Kwak predicts that drone imagery will be able to monitor individual cells in real time and maybe we will start seeing unmanned drones replacing faulty cells all by themselves. Perhaps by that stage we will be seeing UAVs helping in the most unimaginable of areas of our everyday lives, not just in the energy domain. At the time of writing Skycatch drones were even in the process of helping the Nepal Earthquake rescue missions.

Some of the problems drones can help detect are explored overleaf



Cedric Brehaut, consultant and market analyst at SoliChamba, and author of the GTM Research report, 'Megawatt-Scale PV O&M and Asset Management: Services, Markets and Competitors', gives an overview of drone and robot use in the solar energy market

"Drones are increasingly popular for solar PV maintenance applications, especially for thermal imaging of large PV plants where they can drastically reduce the cost of scanning large-scale photovoltaic arrays for hot spots and other potential issues. But their adoption has been slow due to regulatory constraints and technical limitations.

"In the United States, for example, drones are illegal or restricted in most urban areas so they are only appropriate for plants in certain remote locations. Some PV maintenance providers work around this problem by using tethered drones, but this reduces the productivity benefit.

"A number of technology firms offer robotic solutions for module washing, although few of these solutions have been deployed in scale.

"There is great potential for cost reduction using robots for module washing, but the robots themselves can be prone to failure and can increase maintenance costs. In regions where water is scarce and expensive, dry cleaning solutions have a stronger value proposition since they can reduce labour costs as well as costly and undesirable water usage."

Inspection of PV plants using drone-mounted thermography

Plant inspection | Infrared cameras mounted on drones offer a means of detecting instances of equipment malfunction in PV power plants. Claudia Buerhop-Lutz explains some of the faults such an approach can help reveal

In 2014, worldwide 130GWp photovoltaic power plants had been installed. In the coming years, it is expected that the installed capacity of PV will increase further. Considering the availability and safety aspects of PV electric power, the importance of module quality and functionality increases. The demand for appropriate/suitable methods for controlling the quality and functionality of a solar park grows. The requirements for an almost ideal method can be summarised as following:

- No dismantling and no transport of the modules in order to avoid any stress and harm to the modules
- Measuring during operating conditions in order to avoid power loss and accordingly losses in income
- Money- and time-saving
- Reliable and meaningful, with a known uncertainty of measurement
- Fast, best real-time results and data evaluation
- Plain and understandable presentation of the results

In recent years, investors, proprietors and designers of PV plants have begun to appreciate the benefit of infrared (IR) mapping of PV modules and solar parks. Auxiliary carriers, like piloted and unpiloted aerial vehicles, are convenient as they enable easily the inspection from an optimal observation angle and also the fast execution of the inspection. There are several advantages. One is that the inspection is done during real operating conditions, which means real-time imaging with no service interruption. The method is also contact-free, non-destructive, repeatable and fast. Areas that are difficult to reach become accessible. Due to the two-dimensional images, irregularities, such as hotspots in PV modules, are visualised easily using IR-cameras.

The inspection of PV plants is forced by an interest in the quality control of a system; that means the electric output of the generator as well as safety, warranty and ageing aspects. The first one can be done on a plant or string level whereas the second one must be carried out at a module level. Here, monitoring systems on a string level might not have the accuracy required for measurement to detect individual malfunctioning modules within a string. Monitoring every module in a plant individually is fairly new. Processing and evaluating the huge amount of recorded data in connection with local ambient conditions may indicate positions of malfunctioning modules; however, it carries no information about potential module defects.

Since electric and other defects in PV modules lead to changes in temperature distribution, IR cameras are well-suited for searching for faults in installed PV modules [1]. Departures from normally working PV modules are visible in IR images as irregularities in the temperature distribution. These sites of elevated temperature are a strong indication of module defects.

Solar cells, and by extension PV modules, are electric devices that generate heat as well as electric current under working conditions. They convert only a part of the incident solar radiation into electric power; another part is reflected from the surface and the major remaining part absorbed. Therefore solar cells heat up. Component changes, such as manufacturing defects, maltreatment or degradation, may lead to variations of the (electric) material properties and result in malfunctioning and local temperature change, mainly an increase.

The magnitude of this temperature increase is determined by the module parameters, the specific defect characteristics and the actual operating conditions. Defects that can cause temperature increases include unconnected module strings, open substrings, cell fracture, shunted cells, short circuited modules, solder defects and defective bypass diodes [2]. How the temperature increase differs from that of unaffected, sound components, is described later.

Using IR cameras with a two-dimensional detector such local temperature differences or irregularities can be visualised easily. Different defects can be distinguished by typical temperature patterns. Meaningful images require certain measurement conditions, such as an absence of shading, partial shading and all types of reflections, which could lead to misinterpretation. Therefore, optimal measurement conditions require stable weather and include also incident solar irradiation above 400W/m², cloudless sky, no rain and almost no wind. If these meteorological conditions are fulfilled, quasi-stationary heat transfer conditions are realised and local shading by clouds is avoided.

Since IR imaging displays a temperature distribution by measuring the emitted heat radiation of the investigated object, the optical material properties are of importance and have to be taken into account. Here, the emissivity, the reflectivity of the cover glass of a PV module in the IR spectral range of the camera system, is of importance. The glass emissivity at an observation angle perpendicular to the glass surface has a maximum of 82% and decreases strongly for angles above 40° [3], which affects the temperature measurement significantly.

In practice, mobile platforms and aerial vehicles, unpiloted as well as piloted, are useful camera carriers. Besides emissivity, the flight height – the distance between the IR camera and the PV module surface – and the flight speed gain in importance. Former investigations reveal that the radiometric and geometric resolution decrease with increasing distance. This affects the optically measured temperature, too.

A distinction needs to be drawn between large, extended radiating areas and point-like heat sources. The measured temperature for large areas decreases slightly about -0.05K/m or less due to atmospheric absorption. For small heat sources a more significant temperature drop of about -0.25K/m is typical.

This fact is related to the geometric resolution. When the heat source covers less than 5 x 5 pixels, radiation from cooler surroundings affects the corresponding area. As a result the measured temperature appears too low [4]. Frequently the temperature difference between a heated cell and its surrounding is taken as a measure for the gravity of the defect. However, even the temperature difference depends strongly on the distance between IR camera and solar panel. If the distance is too large, the temperature difference may be underestimated. As a consequence severe faults may not be recognised.

Taking advantage of the mobile, aerial measurement system, IR camera plus drone, the measurement can be accelerated. For imaging with a moving camera, motion blurring is the limiting factor. A measure for motion blur can be either the acutance – or sharpness – of the objects or the dislocation of the pixel due to the movement of the drone, and therefore the IR camera. Thus, the dislocation or motion blurring increases with high flight speed or long exposure times or low frame rates. For minimising the lack of definition of object edges, short times or frame rates

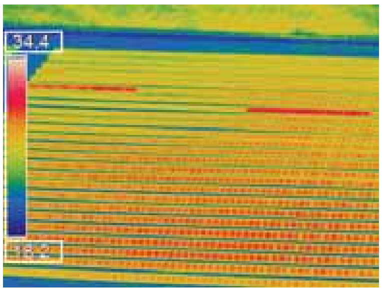


Figure 2: Aerial IR image of an extended solar park, approximately 4MWp, ambient temperature = 15°C, solar irradiance = 420W/m2, showing two irregularly heated module strings that indicates electric disconnection of these strings.

higher than 50-80 Hz are necessary [5].

For inspecting installed PV modules or PV plants aerially, drone-mounted IR imaging systems are used. The measurement system, as shown in Figure 1, consists of an unpiloted drone, a lightweight IR camera, a visible camera and equipment for navigating. For efficient, fast and informative imaging the IR camera needs a high-resolving detector array, a focusing optic (telephoto lens or wide-angle lens) and additionally a high frame rate. A high geometric resolution enhances the ability to visualise temperature differences and therefore the detection of module defects. Various sensors to measure solar irradiation, ambient temperature, wind speed and so on, record conditions for post-processing data evaluation. Navigation systems allow waypoint navigation. That means that the GPS data of the borders of the PV plants are used to mark the routing of the flight across the PV plant. This is a valuable tool to inspect extended solar parks systematically, efficiently, quickly and reliably, so that outstanding modules can be located easily.

Figure 2 shows a typical IR overview of a PV plant. Temperature gradients across a larger area of the PV plant due to inhomogeneous irradiation or locally differing heat transfer become visible. These phenomena have to be carefully distinguished from optical effects. Singular spots, cells, substrings or module strings with elevated temperatures are a strong indication of faults. This temperature rise is linked on the one hand with heat generation on the other hand with electric losses.

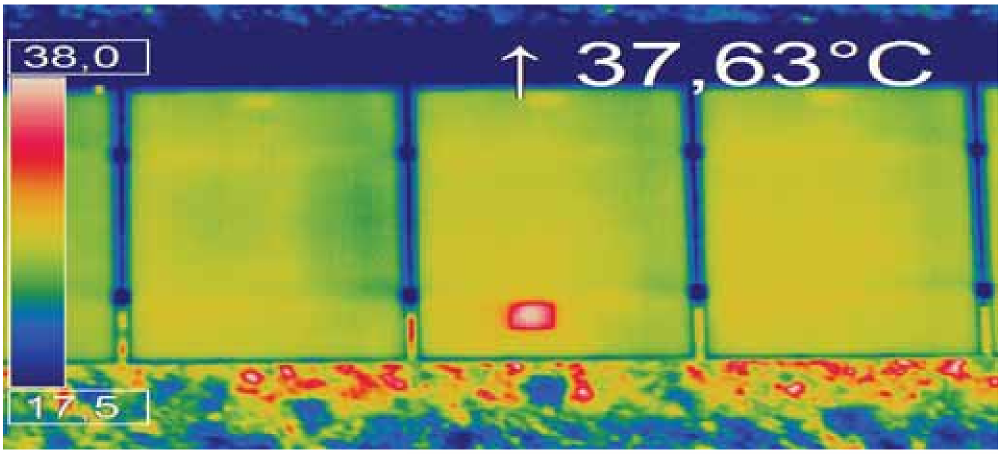
Nevertheless, the solar park of Figure 2 has two irregularly heated, outstanding module strings, marked in the IR image. Presumably, these two module strings are not electrically connected to the inverter. In this case the absorbed solar energy is only converted to heat. For this reason these strings have a higher temperature than their neighbouring modules and are visible in the IR image. Typical temperature differences are 4 to 6K. The most reasonable explanation is that this module string is not connected to the converter or the electric connection is lost. The electric power output is zero. The consequence is a significant power loss.

In the following some module defects and their impact on the module performance are described in detail. Close-ups show more details and enable a deeper investigation of the modules. Different defect types can be distinguished [2]. Figure 3 shows typical examples of two different module defects, but of the defects described below, various types can be distinguished by their characteristic appearance in IR images.

Bypassed module substrings are visible when module failures with a strong impact on the output power are present in PV modules. It is typical for the cells of such a substring to have a homogeneous, elevated temperature of about 4 to 6K above the neighbouring cells and additionally that the corresponding bypass diode is operating and has a higher temperature (approximately 6K). The consequence for the power output of such a module, in the case that one out of four substrings is bypassed, is that the resulting output power is reduced to three-quarters compared to the nominal power of the module.

Cell fracture is one of the most common faults in PV modules. The origins can

Figure 1. Inspection of an installed PV plant using an aerial, unpiloted IR-measurement system consisting of an octocopter with control unit, a fast and high-resolving IR camera and a visual camera for orientation.



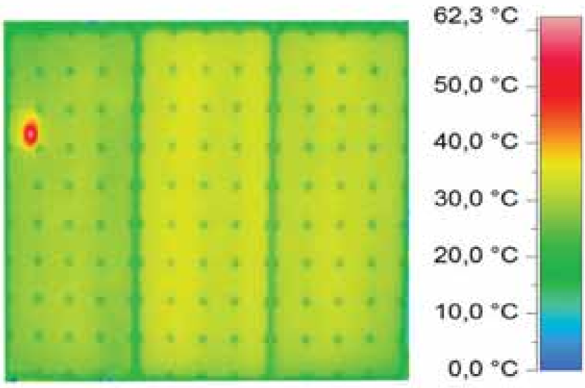


Figure 3: IR images (close-ups) of two typical module defects.
▲Cell defect with homogeneously elevated cell temperature. Temperature = 37.6°C, temperature of good neighbouring cells = 27.5°C, ambient temperature = 14°C, solar irradiance = 410 W/m².
▶Point defect (defective solder joint) with locally raised temperature. T = 62.3°C, temperature of good neighbouring cells = 29.3°C, ambient temperature = 9.3°C, solar irradiance = 760 W/m².

be manifold: manufacturing, transport, installation damage as well as natural lifetime degradation. Fractured cells in PV modules are visible in IR images (see Figure 3, upper image). The temperature difference to the neighbour cells can be high depending on the fracture characteristics, the operating point and the measurement conditions. (For example, we found sample module with ΔT > 100K for distinct cells.) Normally, just the cell with the largest cell fracture shows the temperature increase. Therefore, the resulting module power is determined by the failure characteristics.

Faulty soldering is another frequent failure. Typically, the temperature rises locally at the sites of open or bad solder joints (see Figure 3, lower image). The area is much smaller than the area of a cell and therefore called hotspot. The spot can be at fairly high temperatures. A temperature difference of ΔT > 33K is measured for the example in Figure 3. At higher irradiance on a summer day even higher local temperatures may be reached. This can harm the module, accelerate ageing and reduce the power output because of material degradation. The number of such defects visible depends on the amount of bad solder joints. The impact of defective solder joints on the power output is determined by the number of defects and their electric properties.

Shunted cells result if the front and back contacts of a solar cell are connected electrically. Then the current flows through the low-resistant contact and does not pass the cell. Therefore, the affected solar cell is essentially short-circuited. Since the absorbed energy is not useable, the cell heats up. These shunted cells have a slightly increased temperature, roughly ΔT > 1.5K. In one module several cells can be affected. The influence on the output power is negligible for one shunted cell but for an increasing number of cells the output power can be decreased significantly.

Bypass diodes should prevent modules with defects from damage and excessive power loss. In cases of strong failures, which can reduce the output power drastically and harm or even destroy the module, the bypass diode becomes active. Then, the current flows over the diode and the cells are bypassed. If the bypass diode is stressed too much, it can be damaged too, becoming visible in the IR image.

Quality control benefits

The benefits of IR inspection with unpiloted aerial vehicles for the quality control of PV plants are manifold. Using IR imaging module failures can be differentiated through the visualisation of their typical temperature pattern. It is non-destructive and works without contacting the modules. Thus, the measurements are repeatable. Because they are carried out during normal operating conditions, under solar irradiation, neither energy input for activating the modules externally is necessary, nor are energy and income losses due to service interruptions incurred.

With the drone, optimal measurement parameters are realised. The routing system enables the systematic, fast and reliable examination of a solar park. Short temporal measurement periods can be used efficiently. Outstanding modules are located easily within a solar park taking advantage of the navigation and the two-dimensional IR-imaging. Thus, a 100% check rather than a sample study is possible.

IR imaging with drones is a time-saving inspection method with the potential of giving laypersons an impressive overview of the quality of a solar park as well as experts the data for further analysis and measures. ■

Author

Dr. Claudia Buerhop-Lutz studied material science at the Friedrich-Alexander University of Erlangen-Nürnberg in Germany. Since 2006 she has worked at the Bavarian Center for Applied Energy Research (ZAE Bayern) in Erlangen, Germany, where she is responsible for the outdoor analysis of photovoltaics, pioneering the use of infrared thermography for outdoor analysis of PV modules.

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Minimising risk from plant performance defects

Plant defects | To ensure profitability in PV power plant investments it is crucial to minimise operation risks in the early stages of project development and during planning, installation and commissioning. Potential performance losses and the economic risks due to failures in plant design, employed components and construction must be considered, as Willi Vaaßen of TÜV Rheinland explains

Credit: TÜV Rheinland.

Declining costs, a growing energy demand in many countries and government incentives have diversified the worldwide solar investment landscape. Every few weeks a new potential solar hotspot shows up on the global solar map, attracting investors and project developers of PV power plants. Particularly in countries with little experience in large-scale installations, it can be quite risky to count on a quick return on investment if quality is not ensured, however. Indeed, the golden days of double-digit returns on equity are gone for most projects in the solar industry. Small losses in performance can already lead to drastic cuts in profit.

Given a calculated return of (e.g.) 5%, a slight loss in performance of (e.g.) 1% will already lead to a 20% loss in the planned return. In terms of absolute numbers, a power loss of 1% in a 100 MW PV power plant can result in a loss of earnings of more than 3 million euros over 20 years.

Causes of faults and performance losses

To avoid faults, their potential causes must be analysed. Here it is important to consider the project phases during which the faults arise, the affected components, the effects these faults can have and how they can be prevented.

The minimisation of operational risk of a PV power plant begins during the planning phases.

A recent analysis of PV power plants globally inspected during commissioning and after a few years of operation by TÜV Rheinland during 2014 and the first quarter of 2015 (see figure 1) revealed 40% of the detected defects to be installation faults. Thirty-two percent were planning and documentation errors, 17% product defects or performance deviations and 8% environmental effects, such as sand or dust pollution as well as shading.

Given these causes of faults, we see that quality assurance measures for fault avoidance must be implemented in the early beginning stages of project development and system planning. The concrete

> "Small performance losses can already lead to drastic cuts in profit"

reality of new subcontractors often being employed who in turn outsource partial tasks can lead to an unmanageable flood of faults even for established EPCs.

The rectification of these defects, which often involve safety issues and can therefore threaten the life and limb of the operations and maintenance (O&M) personnel or which may be revealed only in the medium term through fast wear, early part failure or higher maintenance costs, can prove very labour-consuming and costly later on. Severe weather conditions (e.g. hail, lightning, storms, etc.) can also cause damage to unprofessionally planned and installed systems. If redress can then no longer be taken against participating companies because they have since become insolvent or because the warranty has expired, the costs will generally hit the investor or owner of the facility.

Loss of revenue factors

Risk factors for PV power plant investments can be roughly categorised according to technical, financial and legal and tax-related aspects. Of course, all risk areas are affected by the technical risks, since the object of investment is a technical facility that can be operated economically only if it delivers the predicted yield in the long term. To this end it must be optimally planned and implemented. The selected components must of course also meet this requirement.

Although the photovoltaic industry is no longer in its fledgling stages, the quality available on the market is far from meeting this requirement, for a variety of reasons. In part, module and other component production has grown too fast and has suffered substantial financial losses in past years. The boundary conditions do not obtain for complying with the utmost quality demands, should this even be attempted. This fact is also evident from the failure of a few quality providers in this market situation. Dubious vendors and practices make quality assessment difficult.

On paper, module and component quality has changed for the better over the last years because the results of type tests have improved. However, as previously mentioned, many manufacturers are suffer-

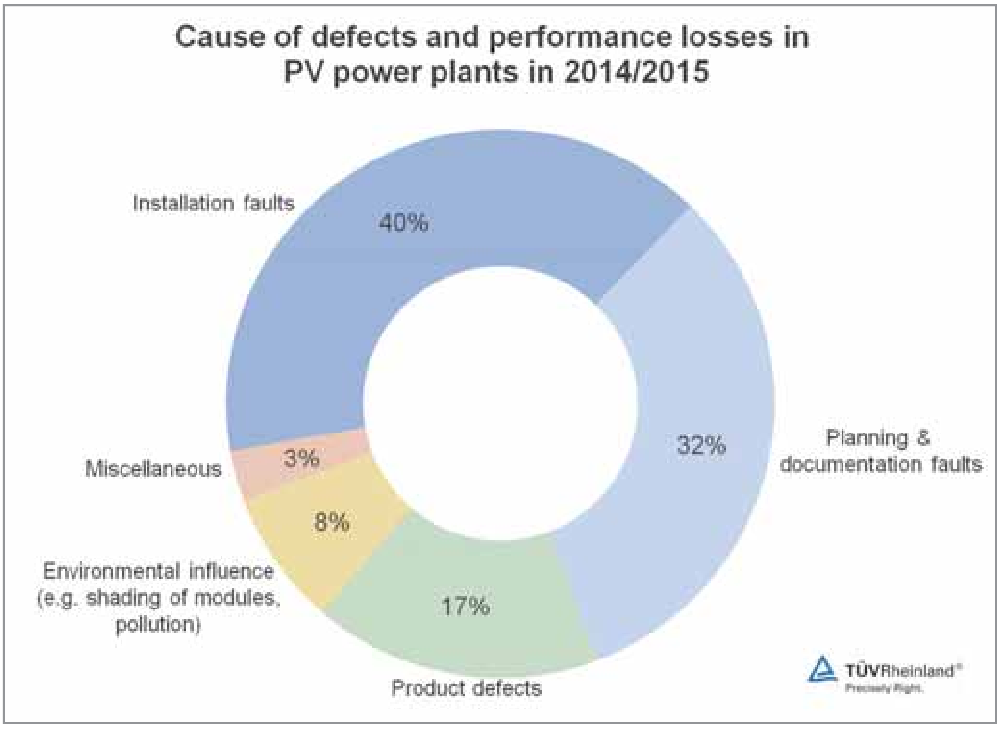

Figure 1: Causes of faults and performance losses in PV power plants during 2014/Q1 2015

Figure 2: Categorisation of risk factors for PV power plant investments

> "IEC certification is only an imperative for market entry and is unsuitable as proof of quality"

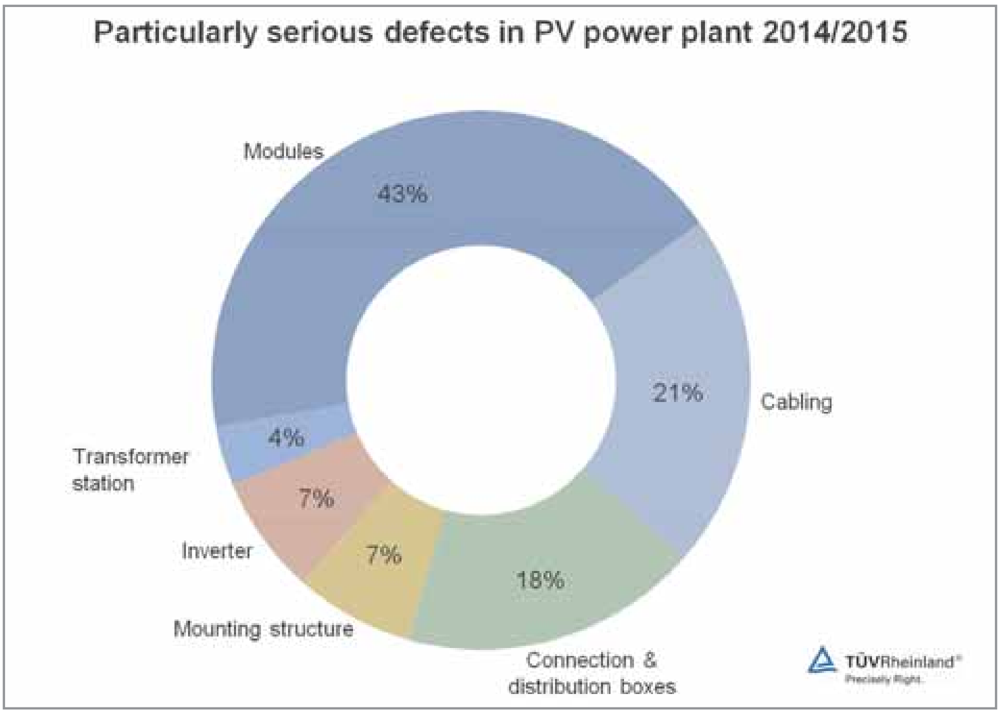

Figure 3: Particularly serious defects in PV power plants 2014 - Q1/2015

ing from heavy cost pressure due to worldwide competition and organising their market entry with minimal effort. Continual quality assurance of processes, materials or qualified staff is often lacking. IEC certification is consequently only a minimum requirement and is unsuitable as proof of continuous quality. Adequate factory inspections or the sufficient quality of the materials used is not always secured.

The quality of the installed PV modules in the field has therefore even decreased over the last few years, as TÜV Rheinland inspection reports indicate. The share of modules with particularly serious or serious defects rose from 25% in the years 2012-2013 to 34% in the years 2014-2015.

Quality – and primarily technical quality is at issue – must therefore be rethought and put into practice by the users (investors, banks, operators, insurance companies). It is certainly helpful to employ institutions, like TÜV Rheinland, which know the risks through many years of international field experience and laboratory testing and are therefore able to prevent faults.

The following fault analyses and technical risks should provide the requisite information to this end. For its studies TÜV Rheinland employs the FMEA (failure and mode effect analysis), which affords a representation of the effects of faults on performance and therefore on the economic success of the plant.

Particularly serious defects, serious defects and less serious defects

The fault analysis distinguishes between three categories of defects: particularly serious defects, serious defects and less serious defects. Particularly serious defects require immediate action to prevent the breakdown of the overall PV plant. In case of serious defects, plant operation is possible but the defects must be rectified. In the case of less serious defects, there is no compelling need for action but observation is recommended. In total, over 30% of the inspected PV power plants showed particularly serious or serious defects.

The especially serious defects of modules identified, such as glass breakage, burnt junction boxes or defective back sheets, are caused by either product defects or by inappropriate installation. Delamination and potential-induced degradation comes from product deficiencies. Other frequently occurring cases are missing covers of connection and junction boxes (no protection against electric shock), damaged cables, burnt-down connectors, transformer stations with blocked panic locks, inverters out of operation or mechanically damaged mounting structures. Instant countermeasures had to been taken when modules with glass breakage or burnt junction boxes were found.

With a share of 43%, modules were by far the items most affected by particularly serious defects in PV power plants in the years 2014 to Q1 2015 (see figure 3). As shown in Figure 1, the causes were product failures as well as a high rate of installation errors. These factors are followed by cabling (21%) faults and defects in connection and distribution boxes (18%).

Figure 4 shows the distribution of serious and less serious defects. Here the preponderance of fault occurrences shifts. Besides the PV modules, faults in cables and lines, connectors, connection & distribution boxes and in mounting systems occur to an increasing extent. Installation and mounting faults are often concerned here. Unfortunately, however, the number of product faults in so-called Balance of System (BOS) components is also increasing.

The selection and purchase of these components is the responsibility of the EPC, which has the overall responsibility for planning, selecting components and constructing the plant. The EPC must be urgently advised to make a careful selection of components. The choice of certified products is certainly an important criterion here. Unfortunately, the quality of the actual plants often differs from the tested quality in the

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A global leader in renewable energy solutions, APS ranked No. 2 among top microinverter suppliers worldwide by shipments in 2013 according to GTM Research. APS remains committed to innovation, keeping microinverter technology at the forefront of the industry and putting more power and efficiency into your solar array.

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Now APS offers another industry first, the YC1000, a true three-phase microinverter that handles an unprecedented four modules per unit. It's purpose-designed and built for demanding large-scale applications, bringing all the advantages of microinverter technology for the first time to the commercial segment.

APS's advanced microinverter products and installations have earned recognition in leading solar journals. And with distribution through top-tier international channels, APS microinverters are now available on four continents.

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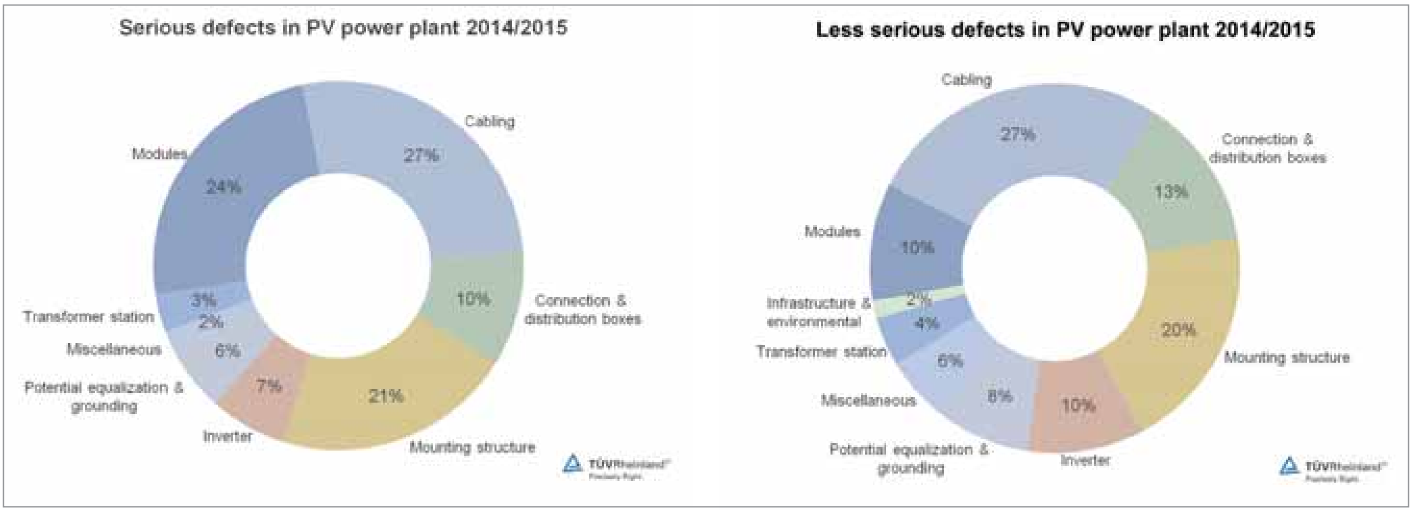
APS knows what the future looks like. We design it.

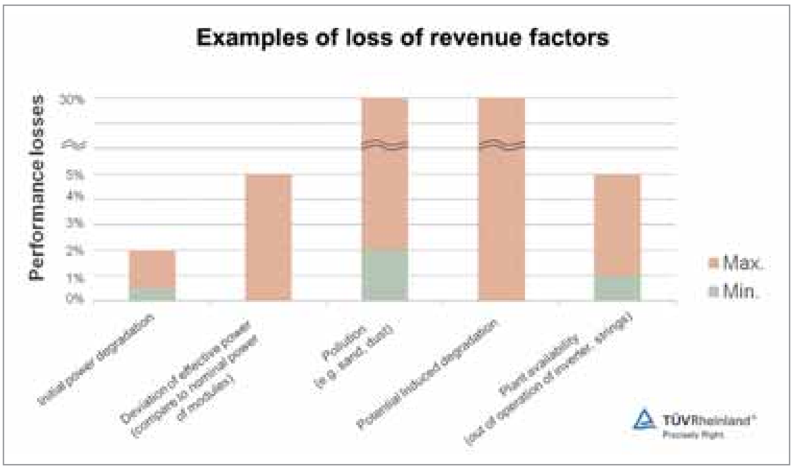
APS is a worldwide leader in the development, manufacturing and marketing of microinverters based on our proven, leading-edge solar technology. APS is headquartered in Seattle, USA, and Jiaxing, China, with regional offices in Europe and Australia.

APS

Components	Category	Defects (examples)	Example
Modules	PSD	• PID • Undervalued power, glass breakage, delamination • Burnt junction box	Delamination 
	SD	• Defective backsheet • Browning, serious microcracks	
	LSD	• Module frame damaged • Snail tracks	
Inverters	PSD	• Out of operation	
	SD	• Insulation faults • Not suitable for local environmental conditions	
	LSD	• Inverter door without filter	
Connection & distribution boxes	PSD	• Missing cover	Burnt cable terminals 
	SD	• Burnt connection, surge protector out of operation • Water in distribution box • Wrong fuse rating	
	LSD	• Missing labels • Dirt inside	
Mounting structures	PSD	• Unstable, damaged • Weak anchorage	Poor foundation 
	SD	• Missing edge protection • Screw not fixed in place • Module clamp not tightened	
	LSD	• Corrosion	
Cabling	PSD	• Connector charred/burned • Damaged cable	Corroded socket/plug 
	SD	• Different connector type • Not UV resistant • Improper insulation • Wrong dimensioning	
	LSD	• Not fixed (loose) routing	
Potential equalisation & earthing	SD	• Missing or improperly secured potential equalisation	
	LSD	• No corrosion protection	
Weather station	LSD	• No maintenance or calibration logs • Wrong location or orientation of sensors	
Infrastructure, environmental influence	SD	• Shading • Land slide due to bad drainage system	Shading by vegetation 
	LSD	• Fence damaged • Refuse at the plant	
Communication & monitoring	SD	• No communication link to inverter	
	LSD	• Incorrect data transmission	
Transformer station	PSD	• Panic lock blocked	
	SD	• Insecure access • Improper cooling system	
	LSD	• Refuse in station	

Table 1: Examples of particularly serious defects (PSD), serious defects (SD) and less serious defects (LSD).





▲Figure 4: Serious defects and less serious defects in PV power plants, 2014 to Q1 2015

◄Figure 5: Risks of performance losses, loss of revenue

certification. Longitudinal water damage to cables or contact problems in the use of connectors from various manufacturers (to mention only two issues) can result. In very large plants more than 100 kilometres of cable or million connectors are installed, for example. This shows the risk that exists with systematic defects in the components. Additional spot checking in the laboratory would afford assurances that the applied product corresponds to the certified product.

Examples of serious defects, where operation was still possible but repair was necessary, were modules with defective backsheets, inverters with insulation faults or missing communication links, water in distribution boxes, missing edge protections on mounting structures or improper insulation of cabling. Moreover, repair was necessary for improperly secured potential equalisation, module shading or insecure access to the transformer station.

Effects of typical defects on the energy yield

Figure 5 illustrates some typical defects that can lead in part to considerable performance losses and consequently to financial losses of (e.g.) up to 30%. These defects can be prevented in part with low expenditures in quality assurance.

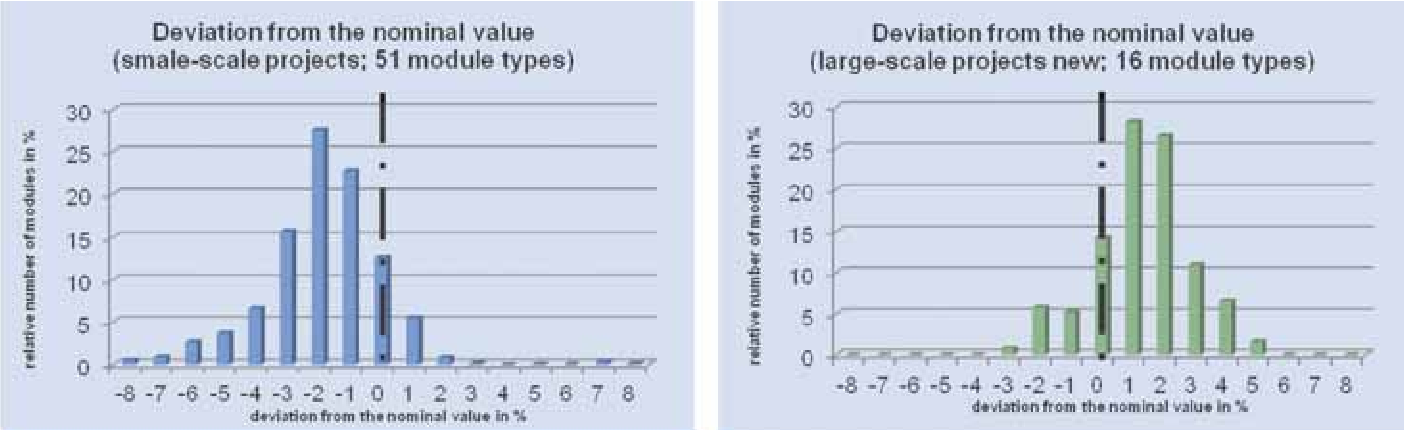
Measurement experiences at the laboratories of TÜV Rheinland show that light-induced degradation (initial degradation) occurring during the first few days of outdoor exposure in PV modules can amount up to 2%; in exceptional cases even higher levels are possible. These losses should be taken into account by the manufacturer when specifying performance, which actually occurs only seldom, however. If the manufacturer supplies flash lists, the flash data likely will not include any initial degradation, since the latter will occur only following installation under constant light conditions. It may therefore happen that following the initial degradation, after a few days of operation the modules will deliver up to 2% less power than indicated in the flash lists. Whether the selected module type undergoes initial degradation can be verified by a corresponding measurement on individual modules of a type series. It must then be clarified with the manufacturer how this can be taken into account in determining the installed performance to be charged.

Another risk factor is that the actual performance of the delivered PV modules will not correspond to the specified performance and the performance to be charged – often documented by the manufacturer's flash data. Figure 5 shows a possible deviation of up to 5%. The deviations lie within the low percentage range, but in exceptional cases are higher. Actual measurement values from the laboratory appear in Figures 6a and b. The various causes may lie in the labelling or in the flash measurement of the PV modules at the manufacturer's plant. A simple control measure and remedy can lie in generally recognised and representative random measurements, which should be contractually agreed upon prior to delivery. If a representative sample seems too large for economic reasons, the parties may agree on a smaller sample size.

A major risk factor is pollution, which can cause revenue losses of up to 30% in very dusty or sandy surroundings. During project development, energy yield predictions must therefore always consider such losses and a reasonable cleaning concept must be implemented and/or more dirt-resistant modules chosen.

Potential-induced degradation (PID) can be the number one performance killer. Here it is important to determine in an early phase of the project whether modules exhibit this effect. If so, it must then also be determined whether appropriate countermeasures are to be implemented during installation or whether PID-free modules are required, and these requirements must be documented in the laboratory through the corresponding measurements for the material combinations used in the project for the given module types.

During plant operation the goal should



▲ **Figure 6: Project-related and precise module performance measurement, a: retroactive, b: contractually foreseen prior to installation**

be pursued of attaining 99% plant availability. This level is possible only with a high-quality plant and only if an O&M concept with short detection and reaction times in case of faults is available. Maintenance agreements with the appropriate content must be concluded.

The challenge in general is to minimise these technical risks and ensure a return on investment through an integrated approach and independent technical consulting throughout the entire project implementation and operation period. It is advantageous to tackle problems in the early stage of project development, however, including module and product testing.

Importance of project-related module testing

The results underscore the importance of the precise laboratory testing of modules, careful product sourcing and diligent planning as essential to the risk minimisation for PV power plant investments.

Example 1: Project-related and precise performance measurements are essential

Precise performance measurement of modules is essential for protecting the return on investment, as measurements by TÜV Rheinland demonstrate (see Figure 6). Over 65% of 51 tested module types (in small-scale projects) showed a deviation from the nominal value of -3% to -1%. The measurements were carried out in part after installation following doubts about the performance of the modules. The modules were new or in mint condition with an operating period of less than one year. In most cases their actual power was lower than that listed by the manufacturer at the outset.

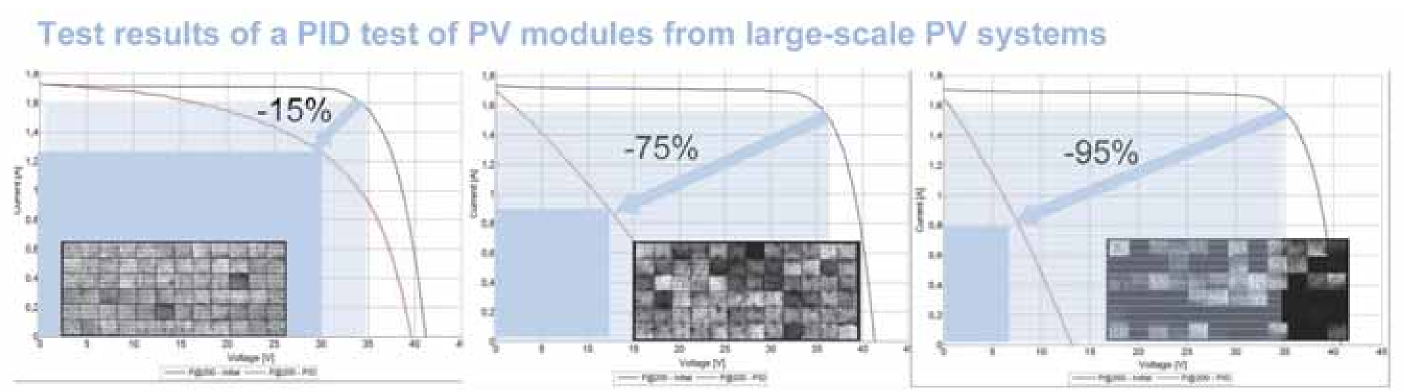
> "Performance killer number one is PID"

Compared are the performance results of 16 module types with contractually agreed precise measurements prior to installation (in large-scale projects). Over 60% of such module types showed a deviation from their nominal value of +1% to +3%, a difference of up to +6% in performance compared with the retroactive measurements. Apparently manufacturers had begun concluding contractual agreements on measurements during the PV power plant planning phases and delivered better modules. Even if we deduct the possible initial degradation occurring within a few days during outdoor exposure at a level of up to 2%, most of the contractually agreed measurements (figure 6b) will attain or exceed the nominal power.

Another important aspect is that a high level of measurement accuracy is required for a high level of acceptance at the manufacturer's site or for use of the measurement results in judicial proceedings. Measurements in the field are rarely helpful in the verification of performance, since the measurement uncertainty even of many mobile systems is greater than 5% and because critical measurement results are generally questioned by manufacturers.

Example 2: Special risk of potential-induced degradation (PID)

Performance killer number one is the potential-induced degradation (PID) of modules, however. It occurs in cases of high voltage, sensitive module material combinations and moist environments due to (e.g.) condensation and high humidity, and leads to gradual losses in performance. PID is often underestimated and its results are



▲ **Figure 7: Special risk: potential-induced degradation (PID)**

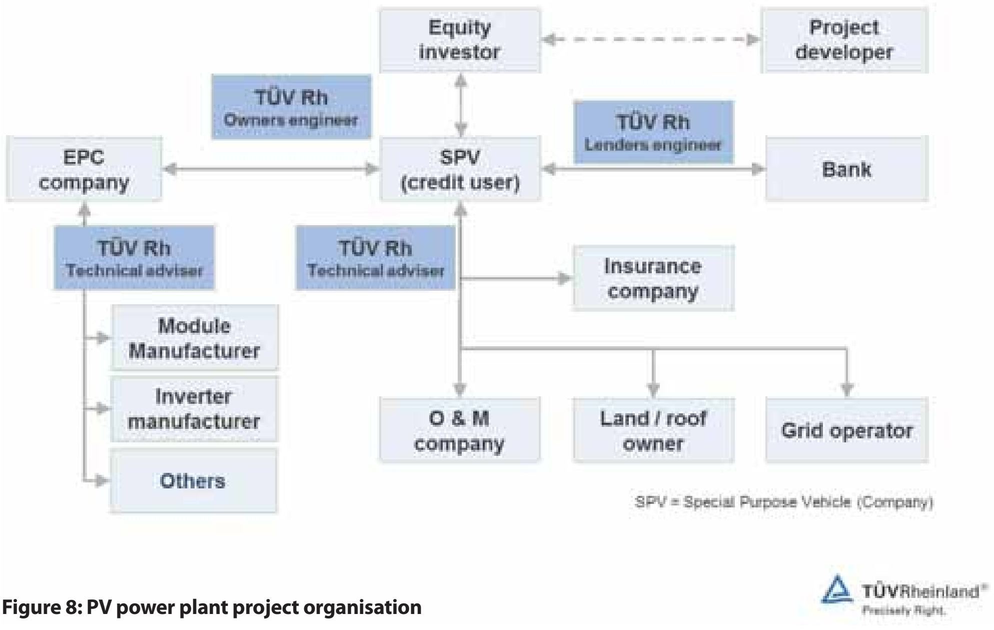


Figure 8: PV power plant project organisation

disastrous. Power plant performance losses of 10% to 30% or more are not infrequent. Fortunately, the effect is mostly reversible; the implementation of suitable measures in the plant, which require in part higher investments can regenerate the modules.

For preventing such losses, the knowledge of the PID sensitivity of modules is essential. All possible material combinations for a given module type (different cells, glass, EVA, backsheet) must be considered before declaring it PID-resistant. The supposedly PID-free PV modules offered with various certificates therefore cannot be fully trusted. In many cases this certification will apply only to a single material combination and not to all different combinations falling under a type designation.

Figure 7 shows the deformation of the characteristic curves of the solar modules depending on the severity of the damage and the related reductions in performance (-15%, -75%, -95%), represented by the reductions in area from the given light performance rectangle of the undamaged characteristic curve to the dark rectangle of the damaged characteristic curve. The effect is also discernible at the electroluminescence images. The greater the number of dark or black cells, the larger is the inactive or less active sector of the modules.

All the more important is the testing and manufacturer-independent consulting that TÜV Rheinland can provide. For finding worthwhile solutions, the bill of materials (BOM) for the modules to be produced for a given power plant must be defined and the correspondingly designed module tested in the laboratory to ensure PID-resistance and sustained revenue. Useful design optimisations of the modules include (e.g.) the use of denser silicon nitride layers for cells, high resistant EVA for module encapsulation and PID-inhibiting coatings for the glass or increasing the current leakage paths by use of frameless modules. The goal is to inhibit ion current to the PN junction.

Importance of independent advice

The risk distribution in large projects depends on the project structure. Very often a structure will be selected like the one in Figure 8. The investors establish an SPV (special purpose vehicle) for implementing the project. For the investors in this construct it is important that the SPV not enter into incalculable risks and that a corresponding position be assumed towards the EPC and other parties.

For controlling the risks, ensuring quality and preventing profit loss, the integration of neutral technical advice in PV power plant project organisation is crucial. One possibility is for the third party to act as an owner's engineer in this case. Another way is to act as a lender's engineer for the bank, with a strong focus on neutral technical consulting within the scope of the bankability inquiry.

At all interfaces in the project, neutral consulting provided by a technical advisor is possible and useful. This neutrality is based on the fact that no product recommendations are made, but rather that the protective aims, requirements and criteria to be fulfilled are defined and laid down on the basis of many years of field experience and product testing. The services include consulting on all technical aspects of site evaluation, energy yield prediction, planning, design, contracts, qualification of components and approvals.

Risk mitigation through quality assurance

There are substantial risks for PV power plant investments. The experience already existing in different markets with the many implemented projects over the last few years has unfortunately not led to a reduction in risks and in defects. Besides the many installation errors, grave product weaknesses repeatedly occur in (e.g.) the PV modules that significantly can diminish plant performance from the outset or lead to an increasing loss in the overall return on investment during operation.

Only comprehensive quality assurance during all project phases provided by qualified and neutral technical adviser can prevent serious defects. If this technical consultant has many years of experience with PV plant inspections, is active in standardisation and in applied research and knows the potential product weaknesses from the many product tests, risks can be significantly reduced.

Author

Willi Vaaßen has several decades of experience in the field of PV plant qualification and monitoring, laboratory module and component testing, performance measurement and failure analysis. He is an active participant in several applied research projects. Holder of a university degree in engineering, Mr Vaaßen serves as director of the Global Competence Centre for PV Power Plants (globally, over 12 GWp are inspected) and is head of the Business Field Solar Energy and authorised officer at TÜV Rheinland, Cologne (Germany).

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Storage and the rise of the virtual power plant

Aggregation | Tesla's much-hyped battery announcement in April raised important questions over what business models will drive the deployment of stationary battery storage. As Andy Colthorpe reports, one answer is the virtual power plant, in which residential and commercial battery systems are aggregated to provide grid services

At the end of April, Tesla officially launched its range of energy storage batteries, for homes, businesses, off-grid and utility-scale applications. Energy storage landed on the mainstream news agenda, as newspapers around the world joined tech blogs in watching CEO Elon Musk's tweets drip-feed hints until the big night.

There was undoubtedly great satisfaction in both the storage and solar industries that Tesla's calculated publicity drive and its tie-ins with solar companies including installers SolarCity and Sunrun, power electronics makers SolarEdge and Fronius, and others, brought the technologies into greater public visibility.

Yet Tesla's dramatic entrance into the space does not in itself fill in the most important piece of the puzzle, namely to create a market for energy storage. While it is big news, too, that SolarCity as well as some of its big residential PV rivals like Sunrun will be marketing Tesla batteries, that alone will not yet convince the public to buy them in huge numbers.

An aggregate victory

The question mark hanging over the Tesla announcement, as it does over all discussions of battery storage deployment, is one of business models. The Tesla/Panasonic units may well be cheaper than their rivals', but the same familiar questions of who owns, deploys and operates energy storage within the structures of regulated electricity markets remain.

It seems that much of the mainstream media misunderstood, dismissed or skipped over the possible significance of what SolarCity – and others – intend to do with Tesla's residential Powerwall storage products. Some focused on the fact that

Source: SolarCity.

at present, even in Tesla's home state of California, the majority of residential storage systems are sold to provide backup power, something that is hard to put a price on. Tesla and its partners will be trialling various business models in different regions, including direct electricity sales from individual storage boxes in Australia. However, with net metering in place in most of the US, storing solar power to use cheaply at night or to reduce time of use charges simply is not a compelling economic driver for storage at home as it is for commercial customers.

While energy storage is often said to be analogous to solar in terms of its development and deployment, one obvious but crucial difference is the bi-directional power flow of storage resources. Long term, SolarCity and others are interested in harnessing the bi-directional capabilities of batteries in several ways. One is aggregation – in essence using residential and commercial batteries as interconnected building blocks of much larger storage systems.

The aggregation of stationary residential and commercial storage units offers a promising business model to propel forward deployment of the technology.

As Chris Edgette, a consultant and director of the California Energy Storage Alliance (CESA) explains, aggregating storage systems can enable them to provide the same benefits to the electricity network that large-scale storage can offer, such as providing grid balancing services and preventing the need for expensive infrastructure upgrades.

The systems can be operated as a 'virtual power plant', even acting like generators and selling electricity in bulk at meaningful volumes. According to Edgette, while Tesla's residential systems will only be sold in its home state of California to provide backup from outages initially, successful aggregation trials might allow distributed systems to play a greater role in the network.

"Reliability for customers is a good selling point, but key to this market in the long term is in grid services," Edgette says. CESA and others are working to enable this at a widespread level in California, with Edgette optimistically projecting that regulations will be in place by the end of this year.

"An aggregated fleet of distributed energy storage resources can provide huge value to the distribution system, while providing flexible capacity to the grid. You can bet that Tesla has not overlooked this in their business model," Edgette says.

From blue sky to real world

It's not just in the US that the broad scope of value energy storage can provide, both at system and network level, is finally starting to be tapped. In Germany's maturing solar market, where residential storage systems have seen a significant upturn in sales, adoption has been largely driven by feed-in tariffs (FiTs) now expiring and it is now making better economic sense to self-consume solar than export it. Storage systems have also been subsidised, albeit modestly, to encourage uptake. Yet asking for further direct financial support at government level is one thing the energy storage and solar industries are wary of and companies are rapidly finding new ways to make storage pay.

Sonnenbatterie sells its lithium-ion battery systems into Germany's self-consumption market for residential and commercial PV, as well as recently opening sales channels into the US. In two separate programmes, the company's CEO Christoph Ostermann says, connected Sonnenbatterie systems will join the commercial frequency regulation market, as well as trading electricity in bulk to match supply and demand.

In the first of those projects, the company has partnered with Lichtblick, a utility company which operates 100% renewable energy assets. Sonnenbatterie is supplying its units to a pool of devices Lichtblick is using to provide 5MW of flexible capacity for the frequency regulation market. There are high technical barriers to entering the frequency response market, which is why Sonnenbatterie is only one of a number of contributors to Lichtblick's pool – or "swarm" – of devices, which also includes CHP and EV chargers. What's more, Ostermann estimates that it would take around 2,000 Sonnenbatterie units to build up to this required threshold, so while it would be possible for the battery company to do it alone, for now it seems more sensible to join Lichtblick's existing swarm.

In this example, Sonnenbatterie doesn't own the batteries once on a customer site; the utility controls the batteries, making direct payments to the end customer. At the moment the battery system maker is using the scheme as a value add-on to market batteries to potential customers, but the company's head of business development, Benjamin Schott, says that if it goes well, a profit sharing model with customers and the utility would be the next step.

The second of Sonnenbatterie's aggregation ventures will start small, with a few hundred systems operating in Germany's energy market on a peer-to-peer (P2P) trading basis, essentially using the virtual power plant concept to balance production and consumption of electricity regionally. Eventually, CEO Ostermann says, the same batteries that trade electricity could also be utilising spare capacity in the grid services and demand response markets.

While the P2P demonstration will use generated power to balance supply, other trials around the world, such as that by Germany's Next Kraftwerke and the UK's Open Utility, are also showing that storage system owners can become independent power producers (IPPs), selling electricity into the retail market. Together, these different applications could be a powerful hand for residential storage to be able to play.

Smoothing the disruption

It has often been said that solar poses a disruptive threat to utility business models, much the same way that Tesla hopes its electric cars will displace gas guzzlers from the roads one day. Solar-plus-storage goes even further, with Morgan Stanley and Barclays among others recognising its potential to eat into utility revenues like no other technological advancement before.

Aggregated storage assets could help utilities keep existing transmission and distribution (T&D) networks in the loop, even as we move towards ever-greater levels of distributed generation. Indeed, SolarCity chief technical officer Peter Rive has written in the company's blog that SolarCity has never targeted cutting out the grid entirely. On the contrary, Rive wrote, grid operators and utilities may be in the best position to manage batteries effectively. SunPower CEO Tom Werner has gone one step further, telling *PV Tech Power* in the journal's first volume that "grid independence" is a "naive", unrealistic and fallible scenario.

Utilities in the US are already starting to deploy energy storage, driven not only by California's famous mandate, AB2514, but also to protect grids, prevent the need for infrastructure upgrades and provide capacity lost with the decommissioning of ageing nuclear plants.

Southern California Edison (SCE), one of California's three main utilities, is also one of Tesla's partners on energy storage, trialling the deployment of Powerwalls to existing rooftop solar customers. SCE says it wants to "help create a market" for energy storage, demonstrating the use of customer-sited batteries in providing demand response. Customers who participate in the SCE demonstration may be given rebates on their electricity bills, while the trial's findings may help bring down costs and open new revenue streams. Details of the demonstration have not yet been given, but this is likely to be an extension of the type of 'virtual power plant' being deployed in the commercial space for SCE by Stem

Case study 1

Stem Inc for Southern California Edison

Residential aggregation trials in the US could build on examples from recent work in related fields. The 'virtual power plant' has been an established term for some time in managing demand response, where an aggregator will contract heavy industrial users of electricity to lower consumption to manage supply and demand balances.

Another recent example where cues could be found is with Stem, another company that, like Tesla, is working with Southern California Edison (SCE) on deploying storage. Stem operates in the commercial segment and last November was awarded a whopping 85MW contract by SCE to use customer-sited storage in the Western Los Angeles Basin to act as "dispatchable capacity to enhance the local reliability of the region".

Stem vice president Ben Kearns explains some of the advantages offered by a number aggregated small-scale storage plants.

"[One of] the pros for a large-scale system is that you have a single point of communication to it [but] you have a single point of failure as well. One of the challenges that the utilities have is they're not really used to dealing with power in very large chunks, like 100GW, 200GW, 400GW.

"So their systems are designed to dispatch power in a very large manner. Through aggregation you can make small assets look like large assets but it requires a coordinator in order to do that. That's what distributed energy storage is good for."

Source: Stem.

Stem is installing commercial-scale battery storage units under a contract with Southern California Edison.

(see Case study 1).

Chris Edgette of CESA says the best practice principles of aggregation would allow utilities to retain a stake in future distributed network models. Edgette says that among the leading lights in this area is New York's Reforming the Energy Vision (REV) programme, currently adapting that state's T&D networks for distributed generation (DG), while determining who can own what and who can get paid for what. The danger is to avoid giving utilities a reason to stifle progress in the interests of the incumbent energy industry or to exploit the unique monopoly position conferred on them as guardians of the network, Edgette says.

"That's the balance in every given region: how to understand what the utilities or system operators should be incentivised to do, what they should be allowed to earn a rate of return on," Edgette says, giving the example of EV charging networks in California, where utilities have asked for the right to rate-base an asset by levying fixed fees to all ratepayers.

"Which sounds great, more EV charging stations," Edgette says, "but it means that any other companies doing EV charging and market participation are competitors to the utility and the utility has the monopoly power…Meanwhile the utility customers are all paying five bucks extra a month for this charging infrastructure that isn't providing them with any value."

Building scale

Aside too, from the pitfalls of equating scale with monopoly power, not everyone is convinced that aggregation is a realistic near-future prospect as a business model for solar storage. Logan Goldie-Scot, energy storage analyst with Bloomberg New Energy Finance (BNEF), believes that while it remains a possibility, it is still early days.

First, he says, while some of the more forward-thinking parts of the US may act out of pragmatic concerns for the reliability of the grid, this is not yet the case in many regions of the world.

"There is less of an incentive to change systems which are currently meeting [required] criteria in providing some reliable balancing. Grid operators often in many markets do not have an incentive to overhaul the existing market structure," Goldie-Scot says.

"Having said that, the early indications suggest that deploying storage or other fast-responding regulation can reduce the amount of regulation required in a market and also lead to fewer emissions. There you start seeing incentives for grid operators to at least look at this."

While grid networks could ultimately benefit, for the time being the onus is on storage providers to prove a compelling case for the storage-led virtual power plant, Goldie-Scot says: "If you can reduce the payback for one of these residential storage systems by adding in additional revenue streams such as the revenue for balancing then that will create a bigger market for residential energy storage systems because they will be more attractive."

It is true also that building scale will be difficult to achieve for some time without the support of network operators and regulators with the jurisdiction and resources to oversee meaningful pilots, with the data these pilot programmes collect essential at this stage. Additionally, as we have seen for some time, technologies to enable so-called 'Smart Homes' and 'Smart Communities' exist, but so far have not been supported by the kind of widespread storage and solar deployment to live up to their promise.

Another analyst, Cosmin Laslau of Lux Research, says aggregation is already a "legitimate business model" but agrees with Goldie-Scot that scale is a pre-requisite.

"Critical mass will be key in making these aggregates large and more useful, so the more sales Tesla and SolarCity can generate for stationary energy storage, the better its chances to make a difference with this business model."

In an article which began with mention of Tesla we have not even touched on what it means for the growth of grid-connected electric vehicles. Adoption of one technology at home may yet spur on the adoption of the other.

Although for now it remains the realm of those that can afford it, the interest of third-party leasing companies from solar, other innovative financing models to get the kit deployed and new business models to open up revenue streams mean we could really start to see the dots begin to join up on a distributed generation-powered future network. With solar, storage and an EV in the garage, the average residence could become a critical component that benefits the individual, the grid and the economy. ■

Case study 2

Moixa Technology for the UK Department of Energy and Climate Change

Stem is focusing for the most part on commercial customers because demand charges applied to their bills make energy storage economically viable already. It is on the shoulders of Tesla and its partners, and other aggregation frontrunners like Moixa and Sonnenbatterie, to prove the case for scaling up its residential counterpart. Meanwhile, third-party management of a distributed resource as seen in demand response could be an interesting way to finance an aggregated storage virtual power plant, especially with companies like SolarCity that are already familiar with leasing models for solar.

A trial to aggregate 250 mainly residential storage systems is underway in the UK.

Source: Moixa Technology.

Among the other trials aggregating customer-sited storage is one by UK company, Moixa, in which 250 systems are being deployed across houses and a few community buildings and businesses. Totalling around 0.5MWh of storage, the company was awarded the contract by the UK Department for Energy and Climate Change. The pilot project, awarded in late 2013 and currently ongoing, will demonstrate residential peak shifting, solar self-consumption and back-up, together with "aggregate storage as service for network and grid benefits", according to the original description of the project.

According to Simon Daniel, Moixa's CEO, the government department has "seen the international examples, but they need some examples of what could work in the UK in order to create evidence for policy". Part of the reason for needing a UK-specific example is again in market design. The UK's electricity infrastructure is overseen by a number of distribution network operators, which manage networks separately from utilities, which are primarily responsible for electricity sales.

The project was awarded in late 2013 and is currently in a "data phase", Daniel says. The trial tests the capabilities of connected storage to mitigate solar and wind and other network constraints. Ultimately, Daniel says, Moixa aims to prove that "if you aggregate lots of storage it can make available that storage to other participants in the system for when the location doesn't need it, or for when the other locations have greater economic value from that asset".

Battery technology for PV storage and system services

Battery technologies | The development of battery storage is seen as vital in the grid integration of increasing amounts of renewable power, but the various technologies present different advantages and limitations. Stephan Lux of Fraunhofer ISE weighs up the pros and cons of the main battery technologies in a range of applications

The increasing share of renewable energy sources, such as solar and wind, requires storage systems in order to preserve the quality and the power of the grid. On the other hand, for the private user, especially in Germany, the increase in self-consumption is a very important factor. There are certain requirements from an application point of view, as well as some restrictions related to the available technology, that have to be considered. This paper will focus on the question of how to determine the best battery technology for a given application.

Applications and requirements

Home storage systems

The changes to the German Renewable Energy Act (EEG) are resulting in a growing market for home storage systems. End user prices for electricity of up to €0.28/kWh are common, with feed-in tariffs of around €0.12/kWh. With the price for electricity from PV around €0.12/kWh, increasing self-consumption is the more interesting option for private households at the moment. The typical size of a home storage system is 3–6kWh usable energy, with a nominal power of 2–4.6kW (Fig. 1). Depending on the installed PV power and the corresponding load profile, a typical home storage undergoes between 200 and 350 full cycles per year.

Small-business and industrial appliances

For small-business users and industry, the focus lies on the integration of different energy sources, for example solar power, diesel, and combined heat and power technology. These users will benefit not only from cutting down on their maximum power consumption from the grid to reduce the cost of electricity, but also from increasing their self-consumption and keeping production operational during power cut-offs by using the battery system as emergency power.

Source: Fraunhofer ISE.

Figure 1. A 5kWh home storage system offering grid services.

Grid stability

For power distributors and the operators of heavy-usage systems, such as quay cranes and rail lines, grid stabilisation and the recovery of energy are important. For these types of application the storage has to be operated for several seconds at a time, with a high power demand in the megawatt range; in this case the storage might be cycled several thousand times a day. Supercapacitors are favoured for these applications – for example, the Yangshan Deep Water Port, with an energy storage capacity of 17.2kWh, is able to deliver 3MW reserve power for 20 seconds.

Primary reserve

The primary reserve market is of particular interest – here the requirement is a minimum power of 1MW, which is usually only feasible with very large storage units. In Germany some operators, such as Deutsche Energieversorgung (DEV), are coupling a large number (3,500) of home storage systems to act as a virtual battery. For this kind of service almost any type of battery technology is suitable.

Battery technologies

Lead–acid batteries

As compared to other cell technologies, lead–acid batteries are very low cost, with prices in the range €50/kWh to €90/kWh, and hold a market share of approximately 90%. Because of their simple construction and worldwide availability, a variety of designs are currently used in many applications, such as starter batteries in vehicles, non-interruptible power supplies in telecommunication institutions, transaction batteries in fork-lift trucks, and autonomous island systems with regenerative power supplies. Depending on the application, lead–acid batteries are differently optimised with respect to performance density, cycle lifetime and calendar lifetime when being discharged.

Designs

In the case of lead–acid accumulators there are flooded and maintenance-free designs. Flooded batteries contain plugs, which can be opened to control and refill the electrolytes. Maintenance-free batteries are an enhancement, with immobile electrolytes in the form of a glass mat or gel; they also have valves instead of plugs.

Properties

Typical values of the characteristics for lead–acid batteries are shown in Table 1. The specific energy of this type of battery drops to 40Wh/kg in practice. The performance is very dependent on the battery construction and varies from typically 100–200W/kg to 1,000W/kg in high-current batteries. The self-discharge rate at 20°C is approximately 3% per month, but a 10°C temperature increase leads to a doubling of the rate. The cycle lifetime ranges from 200 to 2,000 full cycles, depending on temperature and usage.

Ageing mechanisms

The main ageing processes are acid stratification, grid corrosion and sulphation. The calendar and cycle lifetimes decrease with high depth of discharge (DOD) and high operating temperatures. To enhance the lifetime, the amount of discharge is usually limited to 50% in the cycle application.

Lithium-ion batteries

The term *lithium-ion battery* applies to a number of different lithium-ion cells with very different features. The various lithium-ion technologies are categorised according to the electrodes' materials, which not only yield different characteristics but also affect the price of the cells. On the other hand, the battery quality varies between different suppliers and different production lines (e.g. consumer cells and car batteries for OEMs); this means product quality must be checked thoroughly.

Materials for lithium-ion batteries

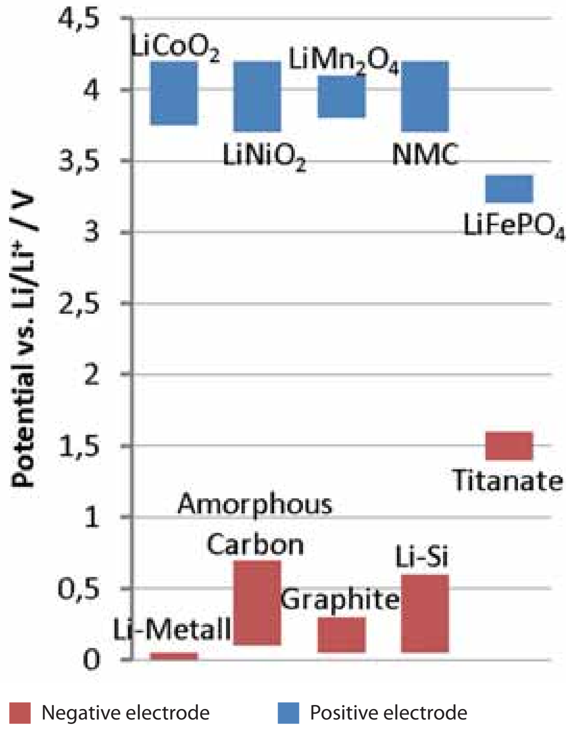
Although a wide variety of materials can be used today as the active material for the electrodes of a lithium-ion cell, the fundamental principle – intercalation of lithium atoms into a grid – remains the same. As Fig. 2 shows, these different active materials have different potentials at which they store lithium. Generally speaking, the image illustrates that, for the negative electrode, materials with potentials slightly above the potential of metallic lithium are suitable, whereas for the positive electrode, materials preferably with high potentials are suitable.

The combination of graphite for the negative and $LiCoO_2$ or MNC (manganese nickel cobalt) for the positive electrode is nowadays a common standard solution and is used in mobile phones, electric cars and stationary storage. For stationary storage, $LiFePO_4$ is common for the positive electrode. Titanate might be used to replace graphite on the negative electrode; this leads to a very stable cell with an excellent temperature behaviour and a low energy density.

While the electrolytes are usually stable on the cathode side, side reactions between the negative graphite electrode and the electrolyte always occur, forming the solid electrolyte interface (SEI). The formation of the SEI layer takes place in the first charging process and can be influenced by the usage of additives. After its formation, the SEI layer remains quite stable and prevents a fast reaction between the electrolyte and the electrode.

Properties

The development of material for lithium-ion cells is still a work in progress, but the characteristics of some important material combinations for lithium-ion cells are summarised in Table 2. The main advantages of the lithium-ion battery compared with other battery technologies are the high nominal voltage, the high energy density, a long storage ability with low self-discharge, and a wider operating temperature range.



▲Figure 2. Potentials of several active materials that can be used for lithium-ion cells. Metallic lithium is chosen as the reference potential.

Ageing mechanisms

Lithium-ion cells gradually lose capacity, but this can be reversed to some extent by recharging the cell. There is some loss of capacity that is irreversible, however, which limits the maximum calendar lifetime. Ageing is accelerated by frequent cycling of the cell, resulting in a gradual decrease in capacity, energy and power rating; this is mainly a result of the growth of the SEI, which increases the internal resistance of the cell and leads to loss of active material.

"Lead–acid batteries are very low cost and hold a market share of approximately 90%"

Energy density [Wh/kg]	40
Power density [W/kg]	350
Cycle lifetime	200–2,000
Calendar lifetime [years]	7
Costs [€/kWh]	150
Efficiency [%]	80
Self-discharge [%/month]	3
Operating temperature [°C]	–15 to +50

◀Table 1. Properties of a high-quality lead–acid battery.

Vanadium redox flow batteries

Vanadium redox flow batteries (VRFB) differ fundamentally from conventional batteries in their design and operation. In this system the energy storage is a solution (electrolyte), which is stored in external tanks (Fig. 3). To charge the battery, the energy storing solution is pumped through the stack; this performs the electrochemical transformation of electrical energy into chemical energy, or vice versa in the case of discharge. Because the tank size and the size of the stack are independent quantities, the

Cathode/anode	Li (NCM) / graphite	LiMn$_2$O$_4$ / graphite	LiFePO$_4$ / graphite	LiCoO$_2$ / LiTi$_5$O$_{12}$
Energy density [Wh/kg]	160–200	130	110	65
Power density [W/kg]	700	1,500	3,000	3,000
Cycle lifetime [years]	2,500–5,000	3,000	5,000	8,000
Calendar lifetime	8	8	12	15
Costs [€/kWh]	140–400	400	120–400	600
Efficiency [%]	93	94	94	94
Self-discharge [%/month]	3	2	3	2
Operating temperature [°C]	0 to +50	0 to +50	0 to +50	–20 to +70

Energy density [Wh/kg]	45
Power density [W/kg]	120
Cycle lifetime	12,000
Calendar lifetime [years]	15
Costs [€/kWh]	350
Efficiency [%]	80
Self-discharge [%/month]	5
Operating temperature [°C]	–20 to +80

▲Table 2. Comparison of the properties of lithium-ion cells with different material combinations.

◄Table 3. Properties of a vanadium redox flow battery.

ratio of power to capacity can be chosen independently.

Properties

Table 3 summarises the features of a vanadium redox flow battery. A big advantage of the VRFB is the system's long lifetime of approximately 15 years. The internal consumption of the electrolyte pump leads to an electrical efficiency of the system of approximately 80%. The possibility of physically separating the tanks from the transformer can be used to avoid internal losses during longer rest phases.

The cost of VRFB does not increase linearly with its capacity and strongly depends on the size of the storage capacity or the corresponding electrolyte tanks. Large systems are proportionally much cheaper than small ones, because the costs of the transformer unit are very high. The determination of the lifetime is more complicated, however, since certain system parts, such as the stack, have to be exchanged after 5–10 years, whereas the electrolyte can be used for up to 25 years.

VRFB differs from conventional systems in its construction, which gives rise to several advantages and disadvantages.

Advantages

- Electrical power rating and capacity are independently scalable.
- Isolation of the unit for electrochemical conversion can be used in order to prevent internal consumption.
- Complete discharge of the solution without capacity loss is possible.
- Electrolyte is easily replaced manually and does not change its aggregate state (fluid).
- Relative costs are low for larger systems with high capacities.
- High level of safety and long lifetime are assured.

Disadvantages

- Capacity is reduced as a result of insufficient mixture of electrolyte in the storage tank.
- Resistant materials must be used for the components because of sulphuric acid in the electrolyte acid.
- Energy density is low.

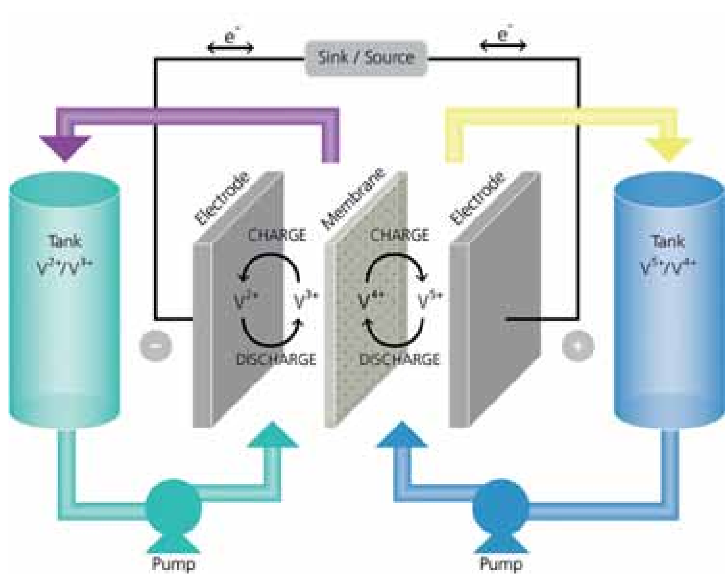
High-temperature batteries

High-temperature batteries (NaNiCl and NaS) are currently used in stationary and mobile systems, but the high operating temperatures of up to 350°C cause significant challenges in relation to thermal isolation and correct tempering. Specially developed covers keep the exchange of heat with the surrounding area as low as possible.

ZEBRA batteries (NaNiCl) differ from most other battery systems because the electrodes are in a fluid aggregation state during operation. The current collector is surrounded by fluid electrodes during operation and is found in the middle of the cell. The positive electrode is surrounded by a ceramic electrolyte, namely β''-aluminium oxide. In the outer area the similarly fluid negative electrode is surrounded by the cell wall, which also operates as the negative pole. In the completely discharged state, the ZEBRA battery consists of sodium chloride (common salt) and nickel. In the charged state, both nickel chloride and sodium emerge. The ceramic electrolyte β''-aluminium oxide is an isomorphic form of aluminium oxide (Al_2O_3) – a solid polycrystalline ceramic – through which only natrium ions (and no electrons) can diffuse.

Sodium sulphur batteries have an anode consisting of melted natrium, and a cathode of a solid graphite material soaked with fluid sulphur. The solid electrolyte β''-aluminium oxide is used as the electrolyte, which

▼Figure 3. Functional principle of a vanadium redox flow battery.



becomes Na-ion-conductive at a temperature above 300°C. During discharge, the positive-charged natrium ions split from the natrium polysulphide and diffuse through the electrolyte to the negative electrode, where they receive an electron and form metallic natrium. During the charging phase, this process is reversed.

NaS batteries are as yet only used in stationary systems as temporary storage for grid support and are offered (from Japan only) with system performances ranging from 500kW to several megawatts by the producers NGK Insulators, GS Yuasa and Hitachi. Because of the high internal consumption necessary for maintaining the operational temperature, these batteries are only practical for charge and discharge cycles during the daytime and are not suitable for long-term storage.

Properties

Table 4 summarises the characteristics of a high-temperature batteries; high energy densities and long cycle and calendar lifetimes are demonstrated. The high operational temperature, however, leads to internal consumption, which is why the comparatively small self-discharge is negligible. Natrium strongly reacts exothermically with water, which results in an increased emphasis on ensuring safety. The internal resistance is virtually independent of the charge state, and only towards the end of charge does it increase dramatically. The required operational temperature is obtained by an electrical heater.

The disadvantages of high-temperature batteries are the low power density and the dependence on temperature. If a grid connection, to keep the battery at a constant temperature, is not possible, the energy to heat it must be taken from the battery itself.

Ageing mechanisms

The ageing of the electrodes and the electrolyte in a ZEBRA battery is minimal. Cells and batteries can be used for several thousand cycles, which equates to an operational lifetime of 12 years, but even after that, they are still capable of storing the nominal capacity. The disadvantage of this technology is the operational temperature: repeated cooling and reheating leads to mechanical stress of the ceramic electrolyte, which in turn leads to fracturing of the ceramic layer.

	NaNiCl	NaS
Energy density [Wh/kg]	110	100
Power density [W/kg]	120	100
Cycle lifetime	2,500	4,500
Calendar lifetime [years]	15	15
Costs [€/kWh]	450	300
Efficiency [%]	85	85
Self-discharge [%/day]	10	12
Operating temperature [°C]	270 to 350	310 to 350

▲Table 4. Properties of high-temperature batteries.

Double-layer capacitors

A double-layer capacitor, or more specifically a supercapacitor (also 'ultracapacitor'), is not a battery, but a special type of capacitor that stores energy by shifting charge at the interface of the electrolyte and the electrode. Just as in standard capacitors, the storage is based on the electrostatic principle and not on the electrochemical one. A double-layer capacitor has a performance density comparable to that of high-performance batteries and is therefore mainly suitable for use in applications requiring high performance and low amounts of energy. Basically, the construction of a double-layer capacitor is similar to that of an accumulator; in terms of their characteristics, the gap between capacitors and conventional batteries is closing. Supercapacitors yield a power density of more than 10,000W/kg, with an estimated lifetime of 1,000,000 duty cycles.

Construction and operation

When a voltage is applied, the ions from the electrolyte attach to the interface of the two carbon electrodes and charge them. The storable energy of this system depends on, among other things, the surface of the electrode and the decomposition voltage of the electrolyte.

Properties

Table 5 summarises the characteristics of double-layer capacitors; these types of energy storage system show barely any conversion losses and thus have a very high degree of efficiency, a high power density, and an almost unlimited number of cycles. Since the level of voltage on the accumulator side, in contrast to electrochemical energy accumulators, is linearly dependent on the charge state, an elaborate power controller is necessary. The low energy density of double layer capacitors leads to relatively high specific costs per energy unit.

"A double-layer capacitor stores energy by shifting charge at the interface of the electrolyte and the electrode"

Energy density [Wh/kg]	15
Power density [W/kg]	10,000
Cycle lifetime	100,000
Calendar lifetime [years]	20
Costs [€/kWh]	2,250
Efficiency [%]	96
Self-discharge [%/month]	60
Operating temperature [°C]	–25 to +80

◄Table 5. Properties of double-layer capacitors.

Sodium-ion batteries

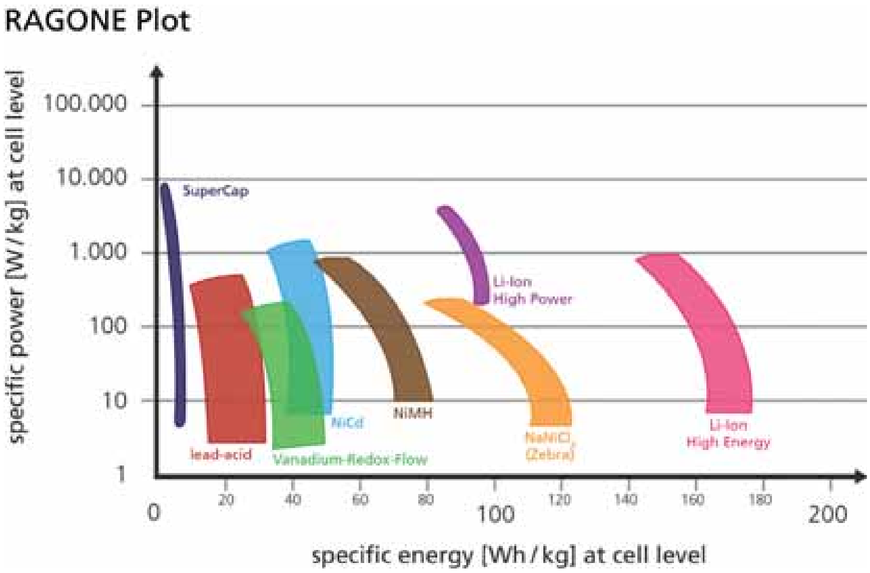
Commercially, sodium-ion technology is very new on the market and production has been driven by Aquion in the USA. The structure of these batteries consists of non-hazardous materials, such as manganese oxide on the cathode, activated carbon on the anode, and a seawater-like electrolyte. Sodium-ion batteries provide a long cycle lifetime, together with a low energy density of 40Wh/kg; in terms of price, they can compete with lithium-ion batteries on a mass-production basis. A drawback, however, might be their low efficiency at high current flows.

Future technologies

Intensive research work is currently under way with the aim of improving electrochemical storage as a result of developments in electric mobility and renewable energies. Alongside the improvements in lithium-ion batteries, there are also many new technologies emerging, such as Li–air, Li-S and Zn–air.

Lithium–air (Li–air)

The most attractive of the new technologies from the point of view of energy density is lithium–air, with a remarkable specific capacity of 3,842mAh/g. The lithium–air system also offers a theoretical potential of 3.72V (in the case of an acidic electrolyte), though in practice only 2.9V is achievable [1]. The approach is still far from being technically usable in any application; moreover, the power density is also much smaller than in commercial lithium-ion cells. If lithium–air batteries are successfully implemented in a working system with reasonable efficiencies and lifetimes, the low power density will be one of the main hurdles to overcome in a real application. Entry into the market for this system is expected in 2030.



▲Figure 4. Specific energy and power densities at the cell level.

> "The most attractive of the new technologies from the point of view of energy density is lithium-air"

Lithium–sulphur (Li–S)

Another very promising battery, partly because of both the abundance and the cheapness of raw materials, is the lithium–sulphur system, with a theoretical specific capacity as high as 1,600mAh/g. In a best-case scenario, in which the complete formation of Li_2S from lithium and sulphur is assumed, a specific energy of 500Wh/kg might be achieved [2]. The low charge and discharge efficiency at the end of charge and discharge, respectively, are still making it difficult to obtain a good cycling behaviour of Li–S cells, and only about 50% of the maximum capacity potential, equating to ~800mAh/g, can be achieved so far.

Two companies – Sion Power Corporation and Oxis Energy – are just entering the market with Li–S products, but in the literature it is not expected that marketable, mass-produced Li–S batteries with long lifetimes will be seen in the next five years.

Zinc–air

Zinc–air batteries are commercially used today as primary batteries. Electrically rechargeable zinc–air batteries include a bifunctional oxygen electrode, so that the charge and discharge processes take place within the battery. The negative electrode consists of zinc particles, and the bifunctional air electrode comprises a plastic membrane and carbon with suitable catalysts. The NaOH electrolyte contains gel-forming additives and fibrous absorbent materials.

With such a structure, specific energy densities of 180–200Wh/kg are possible at an operating voltage of 1.2V. Additionally, zinc–air batteries not only achieve low costs, but also have another advantage over lithium batteries, namely improved safety properties. It remains unclear, however, whether this technology can become established on the market, particularly since the cycle lifetime and energy efficiency are poor at high power [3].

Conclusion

Each battery technology has its pros and cons; for special applications, therefore, it is always useful to have a look at what the technologies offer in terms of energy and power densities (Fig. 4).

The market for home storage options is currently dominated by lithium-ion systems: compared with lead–acid systems, they are small, lightweight and maintenance free, with a higher efficiency and longer lifetime, but suffer the drawback of higher cost. If Tesla delivers its systems with a price of $350/kWh and 10 years' warranty, then lithium-ion will be the winner.

As regards small-business and industrial appliances, all the above-mentioned technologies might be appropriate. For smaller appliances, lithium-ion and lead–acid batteries are mostly employed, whereas for large installations and longer storage times, high-temperature batteries and redox flow batteries are used, as they deliver a high energy content at a reasonable price.

For grid stabilisation, most technologies are suitable; however, high currents are needed, and it is useful to pick a technology with a high energy density, such as supercapacitors or high-power lithium-ion cells. If other technologies are used, for example lead–acid batteries, it is necessary to upsize the energy content of the storage system, even in the case of advanced technologies. ■

Author

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Off-grid: When hybrid plus storage makes sense

Off grid | Reducing the reliance on costly diesel-based power generation is high on the list of priorities for off-grid operators around the world. PV-hybrid systems alone can only go so far in meeting this need. The addition of storage can significantly alter this picture by increasing fuel savings and offsetting additional investment. Increasingly sound economics are already convincing circumspect off-grid operators such as mine owners who are starting to build the first large installations.

Diesel-based power generation is widely used around the world. Alone, for capacities above 0.5MW, there is a large global installed base of more than 110GW, with the overall market growing by >15GW annually. Diesel fuel-based plants are used mainly by off-takers to compensate for inadequate power supply from centralised generation, such as in weak grids, or in remote areas not connected to a large grid at all (e.g., mining sites, islands).

Energy intensive off-grid sectors such as mining have been following the rapidly declining cost of PV-based power generation in recent times with great interest, as they have a clear motivation to offset their diesel consumption. Diesel fuel is not just subject to volatile prices in most parts of the world, it is often expensive to transport to remote sites, supply can be unreliable and bottlenecks are common in certain countries due to insufficient infrastructure such as refining capacities or political conflict and regional instability.

The advantages of renewables are well known and the economics are attractive. Generation costs for PV and wind power have never been lower. The price of large PV systems has dropped by more than half in the last five years resulting in a LCOE as low as US$0.07-0.09/kWh in locations with good solar irradiance. In contrast, despite the current slump in oil prices, the LCOE for diesel-based generation in many locations still stands at ~US$0.29/kWh, as the costs of oil only account for ~40% of the overall diesel price. Consequently, renewable energy is increasingly considered as a strong alternative by off-takers who currently rely on diesel-based power generation.

Bolivia's Cobija project, one of world's largest storage-equipped PV-diesel hybrid systems. The plant is independent of Bolivia's main grid.

Source: SMA Solar.

Overcoming intermittency

For off-grid or mini-grid applications, however, the intermittent character of solar power imposes a significant entry barrier to renewable energy. The availability of sun and wind often does not match the full load profiles of off-takers, for example, during the night; in fact many need a constant supply around the clock, such as mining sites with 24/7 operations. Furthermore, in contrast to applications in large and stable grids, it is typically not possible to compensate for fluctuations in renewable energy by dispatching other flexible power plants.

By hybridising diesel-based generation with PV power directly at the site, the intermittency issue can be solved and the supply of uninterrupted, high quality power ensured.

Various customer groups have already started meeting their power generation needs with hybrid-PV solutions, e.g., tourist resorts, cement plants and mines. For example in 2012, Cronimet hybridised their diesel generators at one of their off-grid South African mining sites with a 1MW photovoltaic system. The recent end of the commodities boom has further increased mine owners' sensitivity to energy costs, with the first mines closing as fuel expenses take their toll e.g., Rio Tinto's Groote Eylandt mine in Australia. Consequently, solar and other technologies are now emerging as viable alternatives.

Variable savings

The overall economics of a PV-hybrid system depend heavily on how much of the diesel-based generation can be replaced by PV power, or in other words, how much fuel can be saved. As adding PV requires an upfront investment that is amortised through reduced operation costs, a low PV yield leads to unfavourable IRR and payback periods that will make a hybrid solution economically unviable in many cases.

However, hybrid systems are often limited in the fuel savings they can deliver due to certain characteristics of both diesel gensets and PV plants.

For a diesel genset to function efficiently, it needs to operate above 40% utilisation. This naturally limits the PV penetration – the ratio between nominal PV power and nominal genset power (of gensets running at the same time) – to 60%. Due to PV's intermittent nature, a spinning reserve is required in case a drop in output is experienced (e.g., due to cloud cover), enabling online diesel capacity to take over the load immediately. Hence multiple diesel gensets often run jointly at low utilisation rates, which limits overall PV penetration, reduces generation efficiency and therefore impacts achievable fuel savings.

Adding storage

The need for a spinning reserve can be reduced with the addition of energy storage to the hybrid system, thereby mitigating the drop in efficiency and fuel savings.

If PV output falls, storage is immediately available and extends the time required for the diesel genset to start up. This provides the benefit of needing fewer diesel gensets to run while allowing the remaining units to operate more efficiently at a higher utilisation rate. As some of the diesel gensets can be switched off completely, they can be fully replaced by PV capacity, increasing the PV penetration of the overall hybrid system setup.

In fact, this ability to switch off one or more generators for a defined time, or to run generators at an almost fixed operational point for a long period of time, is a key requirement for adding storage. The switching off of generators due to the inclusion of storage, however, requires the storage to have the power rating of the running generator and sufficient energy storage capacity to supply electricity demand until a black start of a generator could be performed. This prevents potential outages. Furthermore, meeting the necessary n-1 safety standard may still require another generator to remain operational, although in theory it would not be needed directly.

Hence, adding storage to a PV-hybrid system can significantly increase fuel savings and largely offset the impact of the increased investment.

According to analysis by Apricum, a 24/7 operation in a sunny region with 2,000 full irradiation hours could double its fuel savings from around 10% to 20% by adding storage, thanks to the higher operation efficiencies of the diesel gensets and more PV power replacing fossil fuel-based generation. Because of this, both the project IRR and payback period remain largely unaffected despite the additional capex.

Storage does not, however, make sense in every situation. Careful assessment of a number of factors is required such as operational parameters, PV system size, cost and efficiency of the energy storage applied, as well as genset performance at different utilisation rates. Load profile is another important factor requiring thorough evaluation, which significantly affects the viability of storage.

Spinning reserve

Spinning reserve is defined as all (spinning) generation capacity (i.e. generators with inertia) that is already connected to the grid, but not used by the electrical demand. A simple example would be two 1MW diesel generators with a current load of 600kW each – this would leave an 800kW spinning reserve in total.

In a PV-diesel hybrid system, spinning reserve also takes the following factors into account:

- Step loads (e.g., sudden increase in demand caused by the activation of heavy machinery)
- Loss in PV production (e.g., due to cloud cover)

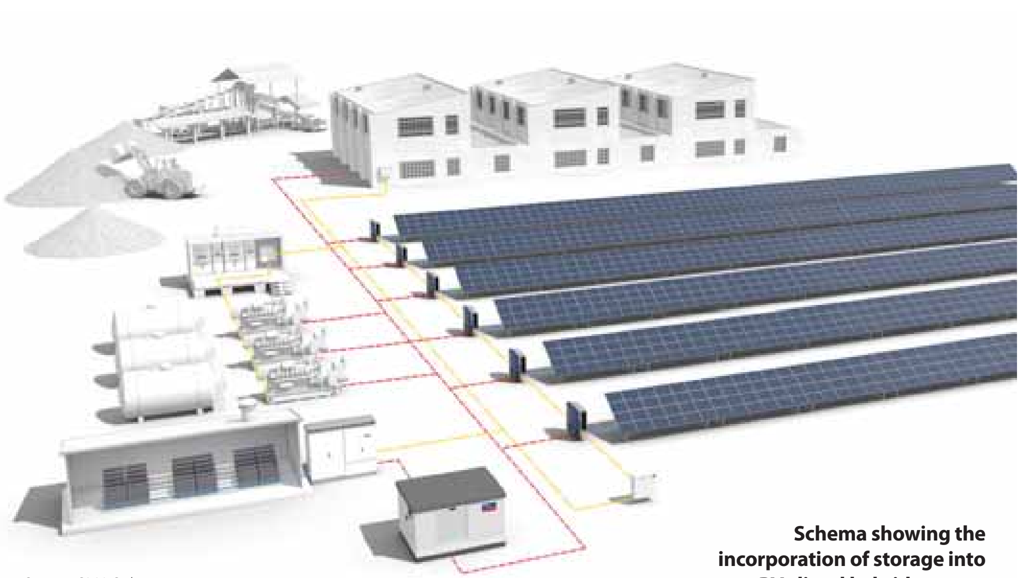
The resulting spinning reserve factor can be a simple combination of the above factors or a more complex calculation factoring in the time of day. The spinning reserve factor can be understood as a set point, which is maintained by the hybrid controller through adjustments of the PV output power and the loading of the generators.

Load profile assessment

Assumptions versus measurement

The main difference between grid-connected systems and mini-grid systems is that the generation system covers the local loads that arise at any one time, but that there is no "endless" pool of demand, as there is in a large grid system. Hence, it is critical to fully understand the demand that the system will be serving.

The demand of different types of mini-grids or industrial customers is still one of the big unknowns as very little data has been gathered or is publicly available. In the real world, demand is often analysed by collecting existing information on the mini-grid, for example diesel fuel usage levels as well as the operating schedules of generators and their main loads. This is complicated by the fact that this information is often not or only partially available or even false. Gaining a detailed and solid understanding of the electrical demand is even more valuable when energy storage



Source: SMA Solar.

Schema showing the incorporation of storage into a PV-diesel hybrid system.

components are included in the system, as these add substantially to the overall cost.

On-site measurements are the best way to gain a more solid understanding of the electricity requirements of a specific mini-grid or customer. In some cases, developers of mini-grid systems measure load data for a very limited time, often only for a couple of hours or one day. It is strongly recommended to measure data for a longer period of time. Collecting three months of data coupled with other locally collected monthly costs and usage data significantly improves the understanding of the needs. Gaining access to larger pools of data for one or several years of course would be ideal to better understand the implications of seasonal variations and longer term developments.

Implications of inaccuracy

Inaccuracies from assumed data, or data measured at a poor resolution, have a negative impact on all further simulation and directly affect the size of a potential PV plant and the energy storage device. Determining these major elements is highly dependent on factors such as the demand profile and total energy consumption. An error of 5-10% on these assumptions will result in a significantly oversized renewable system with associated increased costs.

In addition, the usage of an energy storage system, the number of cycles and well as the depth of discharge depend strongly on the actual energy usage. An oversized system might last longer but would have an unutilised capacity – which is also an unused investment. An undersized system might empty quickly, resulting in a shortened lifetime due to increased times at a low depth of discharge.

Certified process of data measurement and interpolation

In order to fully establish the market segment of hybrid generation systems with investors, it is critical to have a fully transparent and standardised approach to load measurement, extrapolation and system design. This will over time become a vital step during the due diligence phase of any investment decision regarding hybrid generation systems. For that reason the German Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, OneShore Energy GmbH and the Verband der Elektrotechnik und Elektronik (VDE), which is one of the main organisations establishing global standards for electrical systems, have teamed up to establish a relevant standard. During the process most of the leading companies in the hybrid market segment provided valuable input. The procedure for load measurements and projections and minimum technical requirements to determine the simulation input parameters for hybrid-power generation systems will be made publicly available in summer 2015.

Storage + hybrid in action

There are already several examples of PV-hybrid systems including storage projects in development with more being planned. In particular, mining companies are starting to see the economic advantages. Renewable-hybrid systems with energy storage tick the boxes in terms of delivering significant economic savings along with a reliable, high quality power supply, which for mine owners is non-negotiable.

It should be said that initial hesitation from some mine owners is still to be overcome, as renewable energy and storage technologies represent unfamiliar territory. Bankability is also getting more difficult compared to PV-only hybrid solutions but can be improved through validated savings simulations based on real load measurements as described above. Also, government support in strong mining countries such as Australia has already sparked the first projects, which are currently being implemented.

For example, in Western Australia, Sandfire Resource's DeGrussa Copper Mine has announced the installation of 6MW/1.5 MWh of storage capacity along with 10.6MW PV to hybridise its existing 20MW diesel system, which is expected to generate more than US$7 million in annual savings. The project will be built, owned and operated by juwi Renewable Energy.

Also in Australia, the mining giant Rio Tinto Alcan is hosting a US$23.4 million thin-film PV-plus-storage facility at its bauxite mine in Weipa on the Cape York Peninsula. In the first phase, a 1.7MW PV plant will be built and later extended to 6.7MW by 2017, including battery storage for total coverage of the demand. The diesel-PV hybrid project is supported by US company First Solar and Australian solar company Ingenero and is expected to reduce daytime diesel demand from the mine's 26MW diesel generator by up to 20% already in the first phase. By adding more solar and storage later, these savings will increase significantly. Rio Tinto Alcan will buy the electricity under a 15 year power purchase agreement.

It is very likely that these initiatives will help mine owners to better understand the technology, recognise its reliability and identify where further savings can be made. These learnings will further reduce costs in future projects, and eventually eliminate any need for government support.

Source: SMA Solar.

Mining is one sector that particularly stands to benefit from hybrid systems fitted with storage.

Key technical requirements for a hybrid-renewable energy system

Control system

When connected to the grid, a PV plant can always produce as much energy as the solar irradiation allows, as the grid under normal circumstances absorbs all produced energy. In off-grid hybrid systems this is different. In a hybrid system the PV power that can be fed into the local grid (or mini-grid) has to be curtailed in some situations in order to avoid blackouts and maintain the stable operation of the mini-grid. Here a control system is mandatory to ensure safe operation by monitoring important values such as the current loading of diesel generators, the electrical demand and current PV plant production. Based on this input, the control system defines a power set point for the PV plant to ensure all electrical demand is met with appropriate production capacity at all times, and secondly that thermal generators (e.g. diesel generators) operate within safe parameters and are not damaged due to increased PV production.

N-1 criteria

The overall hybrid power station should be capable of operating with the loss of a single generator without any problems. The PV plant can be seen as a single generator when it has a single point of AC coupling. When it is a decentralised plant with multiple AC connections, the loss of a single inverter should be covered by other generation assets. Usually in the diesel plant, there are sufficient generators, to cover the loss of one generator during normal operation.

Careful design and individual assessment

Energy storage can help to increase the fuel savings of a renewable hybrid system significantly. However, whether these savings are sufficient to justify the additional costs depends on the individual project specifics, as there is no general rule on when storage makes sense. Economic aspects play a major role, such as the costs of financing, local diesel costs and operational expenses of the diesel generators. The demand profile and potential renewable production also have an impact.

All in all, each project requires an intensive study to reach a sound technical decision regarding the inclusion of energy storage solutions. Since both the photovoltaic and the energy storage system require a large upfront investment and operations cost are negligible, the financing cost is probably the single largest factor driving the overall decision on the financial side. Making investors and financial institutions more comfortable is one of the key prerequisites for the adoption of more PV-hybrid systems with energy storage. It is therefore critical that all industry participants ensure that systems are carefully and transparently designed to deliver the promised savings in order to increase the confidence of both clients and the financial community.

Authors

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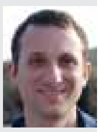

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A softer solar landing after 2016

An extension and gradual phase out of the investment tax credit would help the US solar industry on to a more sustainable footing in the long term, argues James A. Mueller


Source: Wikimedia Commons.

As the solar investment tax credit (ITC) steps down at the end of 2016 under current US law, the solar PV industry faces an uncertain future. Projections for 2017 span every possible scenario with extremely different outlooks.

Projections from leading energy models forecast a coming solar cliff due to the ITC step down that will depress solar installations for many years to come. For example, the Annual Energy Outlook 2014 from the US Energy Information Agency (EIA) and its 2015 update found an 80-97% decrease in utility-scale PV from 2016 to 2017 and an 88-94% decrease in distributed PV. Recently, the Solar Energy Industries Association (SEIA) refuted these projections but agreed with the spectre of a coming cliff.

A new policy brief from the George Washington University Solar Institute (GWSI), which analyses several options for the ITC beyond 2016, estimates that the ITC step down would increase the costs of PV electricity by roughly 10%. This price spike, mitigated in part through assumed installation cost reductions and a lower cost of capital in 2017, induces less severe but still significant deployment reductions: a 42% decrease in utility-scale PV and a 15% decrease in distributed PV. These projections are more in line with the recent SEIA/GTM Research US Solar Market Insight report that anticipates a 57% drop in total PV, the vast majority from the utility-scale market.

Extension and gradual reduction of the ITC

According to GWSI analysis, utility-scale PV deployment will become much less sensitive to the ITC level by 2022 than it will be in 2017. This increasing independence of ITC support, if realised, would allow Congress to reduce the permanent 10% ITC level over the long term with only minimal impacts on solar deployment. Such a long-term phase out could offset the government's outlays from raising the ITC level in the near term when the solar industry really needs it.

In 2017, even a step down to a 20% ITC level would reduce utility-scale PV deployment by over 30%. In contrast, a full step down to the permanent 10% ITC level in 2022 would only reduce utility-scale PV deployment by about 10%.

To avert the cliff in 2017, Congress could offer a softer landing by extending the ITC at the current 30% level through to 2018 and changing the qualifying criteria to include projects that "commence construction" rather than only those that are "placed in service".

The prudence and optimal timing of an ITC phase out beyond 2018 are unsettled. If Congress were to provide long-term certainty for the solar industry with a prescribed phase out, the ITC level could decrease by 5% each year starting in 2019. Following this path, the ITC would be at the 10% level in 2022 and go to zero in 2024. GWSI's analysis suggests that solar deployments would be impacted by, at most, 10% under this plan.

Legislation that follows this phase-out plan would unlikely be "scored" as a revenue raiser or even deficit neutral within the official 10-year "budget window" that the Joint Committee on Taxation (JCT) uses to evaluate tax proposals. JCT would likely score the plan to be a revenue raiser, however, if the budget window were just a few years longer. Nevertheless, temporary tax provisions are commonly extended *en masse* but only occasionally offset with revenue increases elsewhere.

Of course, these impacts on the US Treasury are the difference between two modelled futures: one under current law and the other with the plan enacted into law. In reality, economic growth and associated tax receipts from a booming solar industry may offset the government's investment either in part or in full.

Energy innovation and diffusion insulated from the political process

Seven years ago the ITC extension passed the US Senate with near unanimous support, but political winds can change abruptly. Today the ITC faces an uncertain future, generating the current industry dynamic in which some companies are planning for the ITC to expire, others are planning for an extension and others yet are hedging between the two. This illustrates why the political process is not apt for bringing a technology like PV to full maturity and scale.

A permanent technology-neutral ITC, which includes an automatic phase-out provision for fully competitive technologies, would eliminate the market guessing game and insulate innovation from the political process. Along with other complementary innovation policies, it would incentivise the innovation and diffusion of new energy technologies and help to finance and bring them to scale.

Regardless of what Congress decides to do with clean energy incentives, it should work to ensure that electricity markets accurately capture the full costs and benefits of each generating technology, create policies with parity across energy technologies (e.g. providing clean energy access to master limited partnerships) and modernise the electric grid to support both centralised and decentralised power sources as recommended in the Department of Energy's recently released Quadrennial Energy Review.

This is an edited version of a blog post that first appeared on www.pv-tech.org ■

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James A. Mueller is the director of research at the George Washington University Solar Institute, which generates and shares pragmatic policy solutions to catalyse the adoption and scale of solar energy.


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