PV TECH POWER

Volume 16 | PV POWER PLANT TECHNOLOGY AND BUSINESS | September 2018

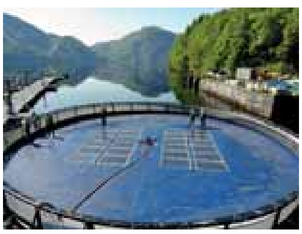
PUZZLING TIMES

Making sense of the turbulent module market

- Technology choices, p.17
- Quality and reliability, pp.22, 25 & 29
- Trade barriers, p.32

DESIGN AND BUILD

Offshore floating solar, a new frontier



STORAGE AND SMART POWER

Managing battery degradation

SYSTEM INTEGRATION

State-of-the-art bifacial technology

About LONGi Solar

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

LONGi Solar is a world leading manufacturer of high-efficiency mono-crystalline solar cells and modules. The Company, wholly owned by the LONGi Group (SH601012), has focused on p-mono for 18 years and is today the largest supplier of mono-crystalline wafers in the world, with total assets above $5.2 billion (2017). It has plans to reach 45 GW mono-crystalline wafer production capacity by 2020.

Enabled and powered by advanced technology and long-standing experience in mono-crystalline silicon, LONGi Solar shipped approximately 4.6GW of products in 2017, which is a 100% growth rate in three consecutive years. The Company has its headquarters in Xi' an, China and branches in Japan, Europe, North America, India, Malaysia, Australia and Africa.

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

Visit us at Solar Power International

Date: Sep 25-27, 2018

Booth: Hall A 528

Venue: Anaheim Convention Center

Visit us at REI 2018

Date: Sep.18-20, 2018

Booth: 9.6

Venue: India Expo Centre,Greater Noida

LONGi Solar

Published by
Solar Media Ltd.
3rd Floor, America House,
2 America Square,
London, EC3N 2LU, UK
Tel: +44 (0) 207 871 0122
www.pv-tech.org

Publisher
David Owen

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

Design & production
Design and production manager:
Sarah-Jane Lee
Production:
Daniel Brown

Advertising
Sales director:
David Evans
Account managers:
Graham Davie, Lili Zhu, Oliver Amos,
Will Swan

Printed by
Buxton Press Ltd., Derbyshire

PV Tech Power Volume 16, 2018
ISSN: 2057-438X

While every effort has been made to ensure the accuracy of the contents of this supplement, the publisher will accept no responsibility for any errors, or opinion expressed, or omissions, or for any loss or damage, consequential or otherwise, suffered as a result of any material here published.

The entire contents of this publication are protected by copyright, full details of which are available from the publisher. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, mechanical, photocopying, recording or otherwise – without the prior permission of the copyright owner.

Brands of Solar Media:

Cover illustration by Adrian Cartwright, Planet illustration

Introduction

Welcome to the sixteenth edition *PV Tech Power*, our fourth year in print and our fourth time at Solar Power International in the US. Four years is an age in the solar industry, the US market knows this as well as most.

Leaving aside trade wars and threats to the investment tax credit, the US has also had to contend with the global shifts in module technology. That's the underlying theme of this issue, summed up nicely in our cover: how to rationalise the puzzle posed by multiple emerging module technologies in an environment of ever changing circumstances.

Our head of market research Finlay Colville and senior news editor Mark Osborne walk through the developments that have led too many plants to underperform and look at the third-party module testing options that could help you avoid making similar mistakes (pp. 17 & 22).

Building on that theme, technical consultancy firm Enertis presents its recommendations for before, during and after the manufacture of your modules to ensure your project does not suffer at the hands of poor module quality (p.25). Should the worst happen you'll want to know that you are suitably protected by a strong warranty. RINA Consulting looks at the value of warranties in an era of aging installed capacity and some advice on the many pitfalls to be avoided (p.29).

We also take a look at several of the market issues facing the industry at present. I speak to some US developers and EPCs about the impact of *those* trade tariffs and the current complicated module market on their work during the past 12 months (p.32). Our Man in Mumbai Tom Kenning sums up all the latest developments in India's huge (and hugely complex) solar sector, from yet more trade duties to cancelled tenders (p.38). Closer to home, we also look at the UK's post-subsidy potential (p.35).

A team from the ZHAW Zurich University of Applied Sciences detail the flood of bifacial products in the market now and crucially the available tracker infrastructure to deliver the best LCOE improvements (p.66). One such tracker manufacturer, Soltec, shares some of the lessons it has learned from its efforts to optimise its technology for bifacial modules (p.81).

We also look at offshore solar, potentially the next frontier for floating solar installations (p.60), and an innovative hybrid project combining solar PV with rice husk-fuelled biomass (p.84).

Our regular Storage and Smart Power section includes the second part of our in-depth look at flow batteries, the long-duration technology increasingly looking like a natural bedfellow for solar (p.111). Meanwhile Andy Colthorpe and David Pratt look at some of the innovative Virtual Power Plant projects up and running in the UK and how they could lower costs for consumers and help integrate renewables and EVs onto the grid (p.102).

As always, thanks for reading and we hope to catch you in Anaheim for SPI, in Delhi for REI or in Taipei for PV Taiwan.

John Parnell
Head of content

Contents

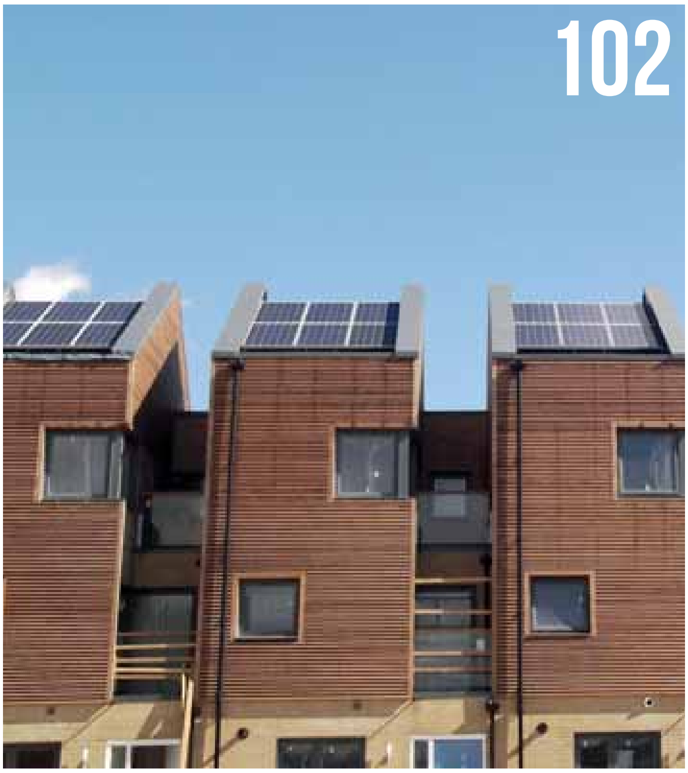
13


Smarter Energy
for a Better Life
Huawei FusionHome Smart Energy Solution,
One-fits-all solution with battery ready
Net-zero energy living is something that we aspire to
and Huawei is leading the way with its FusionHome Energy Solution,
creating new ways for you to connect with and enjoy your home energy.
For more information, please visit: solar.huawei.com
in
You Tube
@ Huawei FusionSolar


84


60


81


102

Smart Solar Solution
Optimized for Great Performance

TrinaPro is a smart PV solution that can significantly reduce the system LCoE by combining premium components, optimized system integration and smart O&M interconnection. TrinaPro features Trina Solar's industry-leading solar modules, state-of-the-art tracker systems and world-class inverters.

TrinaPro

www.trinasolar.com

EUROPE

Tender award

France approves 720MW of solar as price falls another 5%

France has approved 103 large-scale solar projects totalling 720MW in the latest phase of its 3GW deployment plans. The winning bids averaged €58.2/MWh (US$67.5/MWh) a drop of 5% from the previous bidding round. February 2018's capacity was awarded at a price of €61.6. The larger projects (5-30MW) averaged €52/MWh. ENGIE was among the big winners in the auction. More than a third of the awarded capacity is in the northern part of the country. The next two auctions will be for 850MW each.

Credit: Neoen

France's large-scale solar procurement has seen consistently lowering prices.

Policy

Up to 500MW of solar could be ready for Ireland's first renewable electricity auction

Up to 500MW of solar is likely to be able to compete in Ireland's first auction to bring forward new renewable electricity projects when it takes place in 2019. The much delayed scheme was approved by the Irish government and is now awaiting EU state aid approval. The first auction is expected to take place next year aiming to bring forward 'shovel-ready' projects to be completed by the end of 2020. While the total pipeline is in the multi-GW range, just over 270MW of sites have both planning permission and a grid connection; this is made up of around 40 individual sites. There are another 300MW of projects that have contracts with state-owned electricity company ESB that don't yet have planning permission and another 100MW with planning applications submitted that could be approved by the end of this year in time for the first auction.

Turkey studying impact of storage on solar LCOE ahead of gigawatt auctions

Advisory and certification house DNV GL is supporting Turkish plans to source 30% of total electricity generated in the country from renewable sources, carrying out a feasibility study for combinations of solar PV and energy storage. The Ministry of Energy will award 2GW of renewable energy projects this summer. Of this, 1GW is expected to be solar PV, which when completed would contribute significantly to Turkey's target of 5GW of installed solar generation capacity in total by 2023.

BEIS impact assessment lays bare UK government's meagre post-FiT expectations

The UK's Department for Business, Energy and Industrial Strategy (BEIS) expects sub-5MW solar deployment to fall to between 50MW and 100MW each year as a result of its closure of the feed-in tariff (FiT) scheme. BEIS confirmed its intent to press ahead with the closure of the small-scale feed-in tariff on 31 March 2019 as planned, but also stated that it is to close the export tariff to new applicants at the same time. The government's own analysis has forecast that this will have a significant impact on small-scale renewable deployment over the five years following the FiT's closure.

Finance

Big French acquisitions

French energy major Total has completed the acquisition of a 73.04% stake in gas and renewable power provider Direct Energie. The deal is worth in the region of €1.4 billion (US$1.65 billion). Direct Energie has an installed base of 800MW in gas-fired power plants and 550MW of renewable energy. Meanwhile, French power giant ENGIE has acquired Brittany-based renewable energy firm the LANGA Group, which has activity in solar, wind, biogas and biomass.

Big Projects

Scotland's largest solar farm approved in first for government

A 50MW solar farm has been approved at a former RAF airfield, giving UK-based firm Elgin Energy the greenlight to develop Scotland's largest consented solar project in the early 2020s. The development went into planning in August 2017 and is the first solar project to be approved by the Energy Consents Unit (ECU) of the Scottish Government, which rules on projects of 50MW or greater in output. Unlike the majority of subsidy-free solar farms going into the screening process of development, the planning and decision documents for Elgin's project make no mention of energy storage, instead relying on its scale of capacity to be commercially viable.

Ellomay contracts Metka as EPC for 300MW unsubsidised Spanish solar project

Talasol Solar, a subsidiary of Ellomay Capital, has contracted Greek firm Metka, a subsidiary of Mytilineos, to perform EPC services on a 300MW unsubsidised solar PV project in the municipality of Talaván, Cáceres, Spain. The contract, valued at just under €200 million (US$231 million), includes installation of a 400kV step-up substation, a high voltage interconnection line and two years of operation and maintenance (O&M) services.

Iberdrola signs PPA for 391MW Spanish solar project with Kutxabank

Iberdrola has signed a 10-year power purchase agreement (PPA) for a 391MW solar project in Spain with Grupo Kutxabank, in what it claims to be the first contract in the world of this kind to be signed between an energy company and a bank. The Nuñez de Balboa solar facility will provide all the energy under the PPA. The plant will be located in Usagre, Badajoz-Extremadura, and could be Europe's largest PV project once complete. Grupo Kutxabank will use the electricity at all of its banking premises and branches across Spain.

Solarcentury and PowerField partner on Netherlands' largest solar plant

UK-based firm Solarcentury and Dutch company PowerField are partnering to develop a 110MW solar project that will be the largest in the Netherlands. The Vlagtwedde solar farm in Westerwolde, Groningen, is already under construction and will generate enough power for 30,000 homes once operational. PowerField received an operating grant to develop the farm in 2017.

LET'S WRITE SOME **HISTORY**

Top quality modules. Made with intelligence in Europe. Amsterdam actually. Energyra is challenging the PV-industry by building Europe's first operational 'Industry 4.0' module-factory. Producing only the best: innovative, full black, back-contact Mono-PERC modules. Handsfree, fully robotized, multiple HD vision inspection- and quality control systems. A unique, high-tech European partnership with Dutch, Italian and German industry leaders. EU quality, EU materials and 30 years warranty, EU insured. Our 60 cell, 320++ Wp module is available from Q4 2018. The best, made around the corner. Join us!

NEED TO KNOW MORE?

- ✓ Lowest kWh price, lowest cost of energy
- ✓ 100% made in EU, low Carbon footprint
- ✓ Solder-, Lead-, Fluor-, Cadmium- and PID-free
- ✓ Market's highest 30 years warranty; EU insured!
- ✓ Irresistible aesthetics, no busbars: no more microcracks!

www.energyra.com

ENERGYRA® | *all about return*

Seraphim to supply 246MW of modules to Ukraine's largest solar project

China-based manufacturer Seraphim Solar is to supply modules to the largest PV project in Ukraine, a 246MW solar plant being developed by Ukraine's largest energy group, DTEK. CMEC is acting as EPC contractor and Seraphim is the sole module supplier for the PV system in Dnepropetrovsk, central Ukraine. Seraphim's 330W polycrystalline modules will be delivered to the project site before the end of August.

AMERICAS

REC Silicon evaluating suspension of FBR polysilicon production

Polysilicon producer REC Silicon expects its FBR (Fluidized bed reactor) polysilicon production to decline 42% in the third quarter of 2018, after recently announcing further cuts in workforce and production at its Moses Lake facility that would operate at only 25% utilisation rates. The company noted that it was evaluating the possible suspension of all of its solar related materials business in the US. President and CEO, Tore Torvund, said: "Although our semiconductor and silane gas business in Butte remains strong, it is regrettable that we had to reduce our headcount by 85 highly-skilled employees. Despite having the most advanced polysilicon manufacturing technology; REC Silicon has no access to the largest market for polysilicon in China due to the 57% duty imposed by China."

Trump foreign investment stance blocks Recurrent's China deal

The Committee on Foreign Investment in the United States (CFIUS) has blocked the US$232 million investment by Shenzhen Energy in three projects owned by Recurrent. The funds were for stakes in three projects; Mustang, Tranquillity, and Garland, all in California. It would have been Shenzhen's first deal in the US. Recurrent Energy's parent company, Canadian Solar, has sold a number of assets in its native China to Shenzhen Energy. In a statement to the Shenzhen stock exchange, Shenzhen Energy said that despite "repeated communication" with the Committee, the deal could not obtain approval and as a result, Recurrent had issued a letter of termination of the deal on 4 August. The deal was originally struck in October 2017.

New capacity

LG Electronics establishing a 500MW solar module manufacturing plant in US

Major Korean conglomerate LG Electronics will establish a 500MW solar module manufacturing plant in Alabama, US at a cost of around US$28 million. LG Electronics USA said that the facility would be co-located at an existing complex in Huntsville-Madison County, Alabama. LG has had operations in Huntsville since 1981 and became the home of LG's service division in 1987. The company said that PV module production was expected to start at the beginning of 2019, producing its high-efficiency 'NeON' 2 series 60-cell N-type mono modules with 340Wp-plus output, primarily for the US residential rooftop market. The US residential market has been LG's key market and directly competes with SunPower in the high-efficiency residential rooftop market.

Hanwha Q CELLS and Jinko update US factory plans

'Silicon Module Super League' (SMSL) members JinkoSolar and Hanwha Q CELLS have both updated plans to start solar module assembly manufacturing in the US, post the US Section 201 trade case. Jinko said in its latest earnings call that shipments from the plant would be begin in the fourth quarter of 2018. Back in March, the company stated that it would begin operations in October. This keeps in-line with JinkoSolar's key US customer for the Florida-made modules, NextEra Energy, which amended a previously unannounced supply deal with JinkoSolar that increased the deal to 2,750MW over a four year period starting in 2019. Hanwha Q CELLS said in its earnings call that Hanwha Q CELLS (Korea) would begin operations at its 1.6GW-plus module assembly plant in Whitfield County, Georgia in February 2019.

Credit: Hanwha Q CELLS

Hanwha Q CELLS will have 1.6GW of module assembly in place by February 2019.

Series 6 production

First Solar starts Series 6 production in Malaysia but Ohio plant experiences constraints

First Solar has started production of its large-area Series 6 modules at its first manufacturing plant in Malaysia and said it was nearing the start of production at a third facility as new orders in the second quarter almost reached 900MW. In reporting second quarter 2018 financial results, First Solar revealed that it was having Series 6 production issues at its lead Ohio factory. The company took the time in its earnings call with analysts to detail the problems, which centred around a yield issue at a specific tool/process at the upstream cell level, that then impacted downstream assembly throughput, aggravated by insufficient buffer stations.

Credit: Solar Media

Production of the large-format Series 6 module is underway in Malaysia.

Suniva plans partnership to restart manufacturing operations

US-based PV manufacturer Suniva has been released from bankruptcy proceedings and plans to restart manufacturing operations again with a partner, according to SQN Capital Management. SQN Capital Management, was a shareholder in Suniva since its start-up days and post majority sale to China-based Shunfeng International Clean Energy in 2015. SQN Capital said that it was "on the verge of determining which partner will provide the best path to revitalizing the company and meeting the overwhelming demand for Suniva's high-quality, high-efficiency products". It also led the Suniva US Section 201 petition that ended with US President, Donald Trump imposing new import duties on not only Chinese PV manufacturer's imported solar cells and modules but effectively every country with the capability to import solar products into the US.

Mexico

Acciona and Tuto Energy close financing on 404MW Mexico solar plant

Acciona and Tuto Energy, who each own a 50% stake in the 404MW Puerto Libertad solar project in Sonora, Mexico, have signed a financing agreement for the project of up to US$264 million with four banks. The banks, who are financing the project on an equal basis with a repayment term of 18 years, are North American Development Bank (NADB), Banco Nacional de Obras y Servicios of Mexico (BANOBRAS), Instituto de Crédito Oficial of Spain (ICO) and Banco Sabadell. Construction work on the complex, one of the biggest in Latin America, began in February this year and it is expected to be fully operational in the first quarter of 2019. JA Solar was chosen to supply modules which it claimed will have to stand up to extreme climatic conditions presented by the desert and had undergone "drought and sand tests, dry heat and damp heat tests".

MIDDLE EAST & AFRICA

Tunisia tender

Tunisia issues tender for 500MW of PV projects

The Tunisian Ministry of Energy, Mines and Renewable Energy has issued a tender for 500MW of PV projects within the country. It plans to develop five different projects, headlined by a 200MW power station that will be developed in the Tataouine governorate. Other planned projects include 100MW PV projects in the governorates of Kaiouran and Gafsca, along with 50MW projects in Tozeur and Sidi Bouzid governorates. These five projects will all be developed under a build, own and operate (BOO) model, with interested developers now asked to issue pre-qualification applications as part of the tender. Back in April, the Tunisia government announced plans to issue tenders for a total of 1GW of PV and wind projects. The ministry has also issued a call for 70MW of solar PV projects in the second round of its 'authorisation regime'. In the tender, 60MW will be made up of separate projects with maximum capacity of 10MW each. Meanwhile, the remaining 10MW will be made up of separate projects with a maximum size of 1MW. Power from the projects will be sold exclusively to the Tunisian Company of Electricity and Gas (STEG).

Credit: Flickr/Dennis Jarvis

Africa

InfraCo Africa consortium signs PPA for 60MW solar project in Chad

A consortium including InfraCo Africa and Smart Energies International has signed a 25-year power purchase agreement (PPA) with Chad's national utility La Société Nationale d'Electricité (SNE) for a 60MW solar project. Aldwych Africa Development Limited (AADL) is acting as a developer on the project on behalf of InfraCo Africa, which is a majority shareholder in the Djermaya Solar Project.
This will be one of the first large-scale PV projects in Chad.

Zimbabwe mining firm chooses solar over giant coal plans

Zimbabwean firm Karo Mining Holdings plans to build a 300MW solar project close to its new platinum mining operations west of Harare instead of its original plans for a 600MW coal-fired power plant, after discussions with the Zimbabwean government. The operations are at the Mhondoro-Ngezi platinum belt, which includes platinum and coal mining and various refineries.

Progress on big Kenyan solar projects

UK development finance institution CDC and its Africa-focused independent power producer Globeleq are providing US$66 million in debt financing for Malindi Solar Group to build a 52MW solar PV plant in Southeast Kenya. Voltalia has signed a power purchase agreement (PPA) for a 50MW solar project located in Kopere, Nandi county, Kenya, with national utility Kenya Power and Lightning Company (KPLC). The project was initiated by Martifer Solar. Private Kenyan power firm Kenergy Renewables has signed off on a 20-year deal to sell 40MW of PV power to the country's state-run utility at US$0.08/kWh.

GCF and Africa50 join AfDB's Desert to Power programme

The Green Climate Fund, the African Development Bank (ADfB) and Africa50 investment fund are to collaborate on bringing solar energy to the Sahel region in the wake of ADfB launching its 10GW plan. The Desert to Power programme will support grid-connected and off-grid solar initiatives across the belt of countries to the south of the Sahara, aiming to power 250 million people, including 90 million through off-grid solutions.

Middle East

Jordan's solar-plus-storage 'expansion project' reaches financial close

Philadelphia Solar, a vertically-integrated PV company headquartered in Jordan, has reached financial close on a project to bring 12MWh of lithium-ion battery storage to a large-scale solar farm in the Middle East kingdom. It could be the largest energy storage project in the region, with completion and the start of commercial operation expected in the fourth quarter of this year. A 20-year PPA with Irbid District Electricity Company has been signed for the 11MWp extension to Al Badiya's 12MW solar farm in the Jordanian city of Al Mafraq.

ASIA-PACIFIC

India

India imposes 25% safeguard duty on solar imports from developed countries, China and Malaysia

India's Ministry of Finance has imposed a 25% safeguard duty on imports of solar cells and modules from developed countries, Malaysia and China, but on 13 August temporarily deferred the duty imposition due an earlier stay by the High Court of Odisha. The 25% duty will run for one year, then reduce to 20% for a six-month period, and to 15% for the final six months period. Developers Shapoorji Pallonji, Hero Future Energies and Acme Solar as well as domestic PV module manufacturer Vikram Solar had also all filed new petitions at the Odisha High Court against the safeguard duty since its imposition. The Indian solar industry currently sources more than 90% of its cells and modules from China and Malaysia. Module prices in India will remain 14% lower than eight months ago even after the imposition of a 25% safeguard duty on imports, according to analysis by IHS Markit. Meanwhile, India's total PV demand in 2018 will reach just 8.5-9.6GW as a result of the duty, according to EnergyTrend forecasting.

Worrying trend of Indian auction cancellations

Solar Energy Corporation of India (SECI) cancelled 2.4GW of auctioned projects under its 3GW Interstate Transmission System (ISTS)-connected solar tender, accepting only the 600MW won by Acme Solar due to its significantly lower bid of INR2.44/kWh. Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) also annulled a 1GW solar auction citing high prices as the main reason before it retendered just 500MW of PV capacity.

Indian prices match lowest ever then rise again

The lowest bid quoted in Indian state-run utility NTPC's auction for 2GW of interstate transmission system (ISTS)-connected solar was INR2.59/kWh (US$0.037). The L1 bid from Acme Solar for 600MW marked a 15 paisa rise from its previous low bid of 2.44 rupees for the 2GW ISTS auction held by Solar Energy Corporation of India (SECI) on 3 July, where six bidders overall had been happy to bid at 2.54 rupees or lower – before the implementation of the safeguard duty on cell and module imports that has now also been temporarily deferred. Acme had also won 600MW at 2.44 rupees from SECI in its 3GW auction. The remaining 2.4GW from this auction were scrapped by SECI due to high tariffs. Winning bids in the latest solar auction in Andhra Pradesh ranged between INR2.70-2.71/kWh.

Greenko bags approval for 2.75GW solar-wind-storage project in India

Hyderabad-headquartered firm Greenko Energies has received state government approval for a huge renewable energy project involving 1GW of solar, 550MW of wind and 1.2GW of pumped energy storage in the Indian state of Andhra Pradesh. Solar Energy Corporation of India (SECI) also issued a tender for a 160MW hybrid solar and wind project combined with battery energy storage in Andhra Pradesh. SECI has also issued a Request for Selection (RfS) document for 2.5GW of hybrid wind and solar projects to be connected to the Interstate Transmission System (ISTS).

India pondering 100GW ISTS solar tender linked with manufacturing

India is currently mulling over a plan for a 100GW solar tender to be linked with manufacturing, but with no timeframe put down as yet. The announcement came shortly after Solar Energy Corporation of India (SECI) issued a tender for 5GW of PV manufacturing in India to be linked with 10GW of solar project development. The government has also aired plans to link all future solar tenders with manufacturing.

China

China installed 24.3GW of solar power in the first half of 2018

According to China's National Energy Administration (NEA), new solar PV installations in the country reached 24.3GW in the first half of 2018. At the end of June 2018, cumulative PV installations had reached 154.51GW, which included 112.6GW of utility-scale PV power plants and 41.9GW of Distributed Generation (DG) projects, according to the NEA. First half 2018 installations of utility-scale projects was said to have reached 12.06GW, down 30% from the prior year period, while DG installations were reported to have been 12.24GW, a 72% increase year-on-year.

Solar capped

China putting major brakes on solar deployment as new market rules imposed


Credit: United PV

China's PV policy upheaval has huge ramifications for the entire global industry.

China has imposed solar caps and reduced the feed-in tariffs (FiT) mechanism, while setting rules at the central government level for utility-scale projects. In 2017, distributed generation (DG) projects accounted for over 19GW of over 53GW of PV installations in China, a new record high. However, the new 'notice' caps DG solar at 10GW for 2018. The 13.9GW utility-scale target for the year has been abolished, and all regional provinces instructed to impose bans on all entities seeking FiT's under any 2018 mechanism. The impact should not be underestimated on PV deployments in China as almost 34GW of utility-scale projects were deployed in China in 2017. The cancellation of the 2018 FiT for utility-scale projects also pushes support back on local governments to deal with the issue of outstanding payments and grid curtailments. Indeed, local governments were instructed not to approve any utility-scale projects until further notice. The FiT mechanism was also lowered by RMB 0.05/kWh. SolarPower Europe expected global solar deployment to grow despite the China cuts, but GTM Research forecast just 85.2GW for 2018. ROTH Capital expected 34GW of solar production overcapacity in China following the China cuts, with Bloomberg New Energy Finance forecasting a huge 35% drop in module prices.

Australia

Australia's NEG progresses despite widespread criticism

Australia's Coalition Party room has signed off on the controversial National Energy Guarantee (NEG) moving it onto the next stage of consultation. The NEG has been under fire from the renewables industry ever since it was first announced and it is expected to significantly harm the country's large-scale renewables pipeline. However, Coalition MPs and senators signed off on the NEG without any of the changes requested by the various states, including rejecting calls from Victoria for any increase to the emissions reduction target beyond 26% by 2030, as well as three-yearly reviews of the target, among others. Despite news of the NEG, a 280MW solar PV project and a 52MWh battery project are both set to go ahead in South Australia.

South and Southeast Asia

Bangladesh, Vietnam and Pakistan

The Bangladesh Power Development Board (BPDB) has tendered 200MW(AC) of grid-connected solar PV projects to be developed across four locations in the country. Thailand's B.Grimm Power has signed a cooperation agreement with Vietnam's Xuan Cau to develop the largest solar PV project in Southeast Asia, standing at 420MW capacity in Tay Ninh, southwest Vietnam. Meanwhile, the World Bank has committed US$100 million of funding to support 400MW of solar energy projects in the Sindh Province of Pakistan.

Suniva plans partnership to restart manufacturing operations

US-based PV manufacturer Suniva has been released from bankruptcy proceedings and plans to restart manufacturing operations again with a partner, according to SQN Capital Management. SQN Capital Management, was a shareholder in Suniva since its start-up days and post majority sale to China-based Shunfeng International Clean Energy in 2015. SQN Capital said that it was "on the verge of determining which partner will provide the best path to revitalizing the company and meeting the overwhelming demand for Suniva's high-quality, high-efficiency products". It also led the Suniva US Section 201 petition that ended with US President, Donald Trump imposing new import duties on not only Chinese PV manufacturer's imported solar cells and modules but effectively every country with the capability to import solar products into the US.

Mexico

Acciona and Tuto Energy close financing on 404MW Mexico solar plant

Acciona and Tuto Energy, who each own a 50% stake in the 404MW Puerto Libertad solar project in Sonora, Mexico, have signed a financing agreement for the project of up to US$264 million with four banks. The banks, who are financing the project on an equal basis with a repayment term of 18 years, are North American Development Bank (NADB), Banco Nacional de Obras y Servicios of Mexico (BANOBRAS), Instituto de Crédito Oficial of Spain (ICO) and Banco Sabadell. Construction work on the complex, one of the biggest in Latin America, began in February this year and it is expected to be fully operational in the first quarter of 2019. JA Solar was chosen to supply modules which it claimed will have to stand up to extreme climatic conditions presented by the desert and had undergone "drought and sand tests, dry heat and damp heat tests".

MIDDLE EAST & AFRICA

Tunisia tender

Tunisia issues tender for 500MW of PV projects

The Tunisian Ministry of Energy, Mines and Renewable Energy has issued a tender for 500MW of PV projects within the country. It plans to develop five different projects, headlined by a 200MW power station that will be developed in the Tataouine governorate. Other planned projects include 100MW PV projects in the governorates of Kaiouran and Gafsca, along with 50MW projects in Tozeur and Sidi Bouzid governorates. These five projects will all be developed under a build, own and operate (BOO) model, with interested developers now asked to issue pre-qualification applications as part of the tender. Back in April, the Tunisia government announced plans to issue tenders for a total of 1GW of PV and wind projects. The ministry has also issued a call for 70MW of solar PV projects in the second round of its 'authorisation regime'. In the tender, 60MW will be made up of separate projects with maximum capacity of 10MW each. Meanwhile, the remaining 10MW will be made up of separate projects with a maximum size of 1MW. Power from the projects will be sold exclusively to the Tunisian Company of Electricity and Gas (STEG).

Credit: Flickr/Dennis Jarvis

Africa

InfraCo Africa consortium signs PPA for 60MW solar project in Chad

A consortium including InfraCo Africa and Smart Energies International has signed a 25-year power purchase agreement (PPA) with Chad's national utility La Société Nationale d'Electricité (SNE) for a 60MW solar project. Aldwych Africa Development Limited (AADL) is acting as a developer on the project on behalf of InfraCo Africa, which is a majority shareholder in the Djermaya Solar Project.

This will be one of the first large-scale PV projects in Chad.

Zimbabwe mining firm chooses solar over giant coal plans

Zimbabwean firm Karo Mining Holdings plans to build a 300MW solar project close to its new platinum mining operations west of Harare instead of its original plans for a 600MW coal-fired power plant, after discussions with the Zimbabwean government. The operations are at the Mhondoro-Ngezi platinum belt, which includes platinum and coal mining and various refineries.

Progress on big Kenyan solar projects

UK development finance institution CDC and its Africa-focused independent power producer Globeleq are providing US$66 million in debt financing for Malindi Solar Group to build a 52MW solar PV plant in Southeast Kenya. Voltalia has signed a power purchase agreement (PPA) for a 50MW solar project located in Kopere, Nandi county, Kenya, with national utility Kenya Power and Lightning Company (KPLC). The project was initiated by Martifer Solar. Private Kenyan power firm Kenergy Renewables has signed off on a 20-year deal to sell 40MW of PV power to the country's state-run utility at US$0.08/kWh.

GCF and Africa50 join AfDB's Desert to Power programme

The Green Climate Fund, the African Development Bank (ADfB) and Africa50 investment fund are to collaborate on bringing solar energy to the Sahel region in the wake of ADfB launching its 10GW plan. The Desert to Power programme will support grid-connected and off-grid solar initiatives across the belt of countries to the south of the Sahara, aiming to power 250 million people, including 90 million through off-grid solutions.

Middle East

Jordan's solar-plus-storage 'expansion project' reaches financial close

Philadelphia Solar, a vertically-integrated PV company headquartered in Jordan, has reached financial close on a project to bring 12MWh of lithium-ion battery storage to a large-scale solar farm in the Middle East kingdom. It could be the largest energy storage project in the region, with completion and the start of commercial operation expected in the fourth quarter of this year. A 20-year PPA with Irbid District Electricity Company has been signed for the 11MWp extension to Al Badiya's 12MW solar farm in the Jordanian city of Al Mafraq.

ASIA-PACIFIC

India

India imposes 25% safeguard duty on solar imports from developed countries, China and Malaysia

India's Ministry of Finance has imposed a 25% safeguard duty on imports of solar cells and modules from developed countries, Malaysia and China, but on 13 August temporarily deferred the duty imposition due an earlier stay by the High Court of Odisha. The 25% duty will

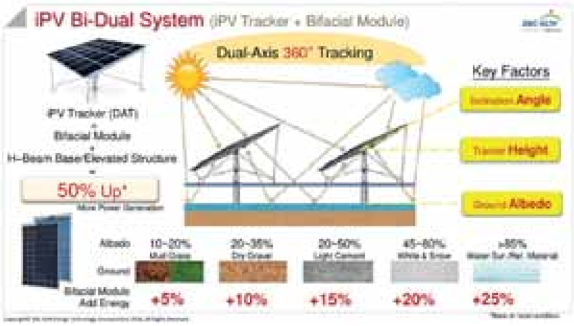
Product reviews

Tracker | BIG SUN launches acquatic tracker system for bifacial modules

Product Outline: BIG SUN Energy has created a new version of its dual-axis iPV tracker for use with bifacial modules or acquatic applications such as fishery ponds, reservoirs and floating solar (FPV) systems.

Problem: Two thirds of the earth is covered by water. Extending the application of iPV Trackers over water surfaces will help increase power generating efficiency without impacting existing land use.

Solution: BIG SUN's iPV Tracker had already been redesigned to maximise the use of bifacial modules. iPV tracker's unique 360 degree, universal axis design with a slim cable drawn driving mechanism, has reduced the shading impact from the sizeable linear actuator and slewing drive employed with the conventional dual-axis trackers. To eliminate



any shading induced from the module mounting frame, BIG SUN has redesigned the rear supporting frame so as to match exactly to the frame dimension of any module. The acquatic version is claimed to harvest 60% of light transmittance and increase power gains by 50%. In shallow waters, the Aqua Solar solution will elevate the light transmittance to 70-80%, according to Big Sun.

Applications: The iPV Trackers can be floating or mounted, when installed at a 3m height with 2.5m spacing in acquatic environments.

Platform: The second-generation iPV Tracker uses a wheel axis structure and spring design. This simplified design has prevented the slipping of the steel cable, resulting in much less noise than before. Also the upgraded design of the spring in parallel connection with steel chains has further reinforced a more robust driving mechanism.

Availability: Available since May 2018.

Module | Energyra launches high-efficiency MWT, back contact mono PERC module

Product Outline: The newly started Netherlands-based PV module manufacturer Energyra B.V is launching its first high-efficiency 60-cell module using p-type mono PERC solar cells with ECN patented metallisation wrap-through (MWT) technology with a back contact conductive backsheet configuration. Energyra modules will have peak power values ranging from 300 to 325Wp and high durability while providing best-in-class aesthetics (all-black) for residential and commercial PV applications.

Problem: In key European solar markets such as The Netherlands, France and Germany, residential customers are increasingly demanding high-performance (kWh), high-quality and PV module aesthetics that are specifically tailored for the European market. Installers and EPC/project developers also demand high

reliability and endurance from proven bill of materials (BOM) that significantly reduce the risk of unexpected power losses and critical failures.

Solution: Energyra's PV modules have been designed from the best-in-class, almost entirely European BOM. ECN's patented cell and MWT technology with p-type monocrystalline PERC solar cells can deliver cell efficiencies in the 21.5% range and peak power values between 300 to 325Wp. Deploying back contacts with EB Foil's patented conductive backsheet almost eliminates cell-to-module losses, while claiming to boost (kWh) power output by 30% and being potential-induced degradation (PID) and micro-crack free.

Applications: European residential and commercial rooftops.

Platform: Energyra's PV modules use EB Foil's patented conductive backsheet, which has proven durability in extended damp-heat and thermal cycle testing. The module comes in an all-black configuration for the best aesthetics.

Availability: First production and sales in The Netherlands starting in November, while full capacity production is expected to be reached in the first quarter of 2019.

Module | GCL-SI Jupiter series 72-cell modules designed for high-efficiency and durability

Product Outline: GCL System Integration Co., (GCL-SI) continues to develop its mainstream high-efficiency and durable Jupiter Series 72-cell (GCL-P6/72) module for utility-scale PV power plants and a core component within its turnkey Super Block 2.5 MW system.

Problem: PV project developers and EPCs require key components such as solar modules to provide the high performance and reliability from high-volume producers to meet up-front cost and LCOE requirements, while providing long-term durability, often in harsh environments.

Solution: The GCL-P6/72 Series polycrystalline module is available in a dual-glass format with maximum power output ranging from 325-360W with maximum module efficiency of 18.4%. A Multi-Busbar Module (MBB) design (12 busbars), improves the current-generating ability of the busbar and decreases the internal losses. It also reduces the shading area on the

cell. This design creates a <5W increase in power output. MBB cell design can also lower residual stress, which can help reduce micro-cracks Moreover, due to the small distance between busbars, losses from micro cracks in a cell are lower, providing security from large losses.

Applications: Utility-scale PV power plants.

Platform: In addition to the regular IEC tests, the GCL-SI MBB module has also been tested in harsh environments, undergoing tests for blowing sand, salt spray and ammonia, and maintains a stable performance under all conditions. The module has been tested twice (100% EL inspection) to ensure the quality and reliability and passed DNV GL's PV Module Reliability Scorecard Report 2017.

Availability: Currently available.

Product reviews

Inverter | GoodWe launches 20 kW SDT series compact three-phase inverter for higher outputs

Product Outline: GoodWe is rolling out its new compact 20kW SDT series inverter for three-phase households. It includes two MPP trackers and a wide input voltage range to ensure design flexibility and compatibility with high-output PV panels.

Problem: As residential rooftop PV projects continue to expand toward larger systems up to 20kW, the use of single-phase inverters in a three-phase environment might cause faults due to unsymmetrical grid issues; many network operators will not allow an imbalance across the phases. Therefore, the only solution is either to install three single-phase inverters for each phase or one three phase inverter that will work across three phases.

Solution: Three-phase feed-in is thought to be the best solution for grid symmetry leading to the highest yields and contributing to a stable grid. Compared with equivalent competitor products, the 20kW SDT series inverter is said to be the most compact and lightweight inverter on the market with the highest capacity density and maximum efficiency of 98.6%. With a weight of just 26kg, the new SDT series is easy to handle and install. Specially designed for three-phase home solar systems, it allows 130% DC oversizing to fully maximise capacity. In addition, with 110% AC overload and a start-up voltage of 180V guarantees an earlier generation of power and a longer working time for maximum energy harvest.

Applications: Three-phase residential and small commercial PV systems.

Platform: The SDT series is designed for today's high-output PV panels, enhanced to meet the latest grid compliance standards while providing unprecedented power and dual, independent MPPT.

Availability: Currently available

Inverter | Growatt's MAX 50-80KTL3-LV/MV series inverters are equipped with 6 MPPTs

Product Outline: Growatt has introduced the MAX 50-80KTL3-LV/MV series string inverters that are equipped with six MPPTs, enabling more flexible string configuration and less string mismatch loss for commercial rooftop installs with shading issues.

Problem: High levels of potential PV module shading on large residential and commercial rooftop applications can either limit the system's intended power capacity or make the project roof unsuitable for solar deployment, due to the imbalance between PV strings. Where the site environment is harsh, such as heavy load or impact load (snow), it is common that inverter will go offline and damage the circuit making the fault hard to find.

Solution: Growatt's MAX50-80KTL3 LV(MV)

inverter's multiple MPPTs and wide voltage range can significantly improve this situation, by reducing the imbalance between strings and also increasing the power generation. Anti-PID is integrated as a standard configuration, so there is no need for any external anti-PID device, increasing system revenue at the same time saves system costs. The inverter has a fault waveform recording function; should the inverter go wrong it will record waveform, voltage, current and power information for trouble shooting purposes.

Applications: Commercial roofs and large distribution projects.

Platform: MAX50-80KTL3 LV(MV) inverters have both lightning protection and fire protection. Low voltage and high voltage models along with sufficient communication methods can match different on-grid scenarios. Growatt service engineers can handle around 60% of the problems by remote configuration and FW update without on-site servicing, saving time and cost for installers and distributors. Smart string monitoring and Smart I-V diagnosis are key features.

Availability: Available since July 2018.

Module | Hanwha Q CELLS Q.PEAK DUO-G5 series module uses half-cut cells with six busbars

Product Outline: Hanwha Q CELLS' new Q.PEAK DUO-G5 series modules are designed for higher efficiency and minimised degradation, with a price to performance ratio designed to target the residential and commercial markets.

Problem: PV installers must meet customer demand for solar module and system durability and higher power requirements, and offer improved shading response performance, while lowering the levelised cost of electricity (LCOE).

Solution: The Q.PEAK DUO-G5 series combines a whole range of technological innovations to reach maximum electricity yields and lowest LCOE. Mono half-cut cells with six busbars,

the company´s proprietary Q.ANTUM (PERC) cell technology for higher efficiency and minimised degradation as well as round wires enable the module to reach power classes of up to 330Wp from 120 half-cells. In Europe, the Q.PEAK DUO-G5 series is now on sale in two versions: the Q.PEAK DUO-G5 with up to 330Wp and Q.PEAK DUO BLK-G5, featuring black back sheet and frame, with power classes up to 320Wp.

Applications: Residential and commercial.

Platform: The Q.ANTUM technology controls the degradation effects of LID (light-induced degradation) and LeTID (light and elevated temperature-induced degradation), which can severely reduce the performance of conventional PERC solar modules throughout their lifetime. The module comes with a 12-year product warranty and performance warranties of 98% in the first year, a minimum of 93% within 10 years and still 85% after 25 years.

Availability: The Q.PEAK DUO-G5 and Q.PEAK DUO BLK-G5are both already available.

Inverter | Hoymiles MI-1200 microinverter is first single-phase microinverter designed for 4 solar panels

Product Outline: Hoymiles 4-in-1 microinverter MI-1200 is the world's first single-phase microinverter designed for four solar panels, with wide DC input operating voltage range (16-60V) & low start-up voltage (22V only).

Problem: Traditional centralised inverters & string-level inverters cannot meet comprehensive demands of 100% safety, affordable cost and installation flexibility while pursuing higher power generation. Concern centres on the potential of electric shock and drawing arc caused by high DC input voltage (600-1500V).

Solution: The MI-1200 offers a module-level in-parallel solution, integrated with extremely low DC input voltage (16-60V, compliant with NEC 2017 for module-level rapid shutdown), module-level monitoring and dual module-

level MPPT, which 100% ensures safety of both installers and end users. Furthermore, 10-30% more power generation is claimed, and much lower LCOE during 25-30 year lifetime of solar system.

Applications: The MI-1200 is adapted to both 60-cell and 72-cell PV modules (200~380Wp) and also works with thin-film PV modules (50-200W) for residential rooftop, commercial rooftop, ground plant and BIPV projects.

Platform: The MI-1200 comes in a light weight 3.75kg configuration, including 2m AC cable (integrated DC & AC cables and three-phase wiring) and up to 60V DC input voltage (natural rapid shutdown) to guarantee no electric shock & fire risk. The MI-1200 comes with a 6000V surge protection, MTBF (mean time between failure) > 550years, yearly failure rate < 0.18%.

Availability: Certified for markets including Europe, North America, South Africa, Turkey, Sri Lanka and China, coming soon for Australia, Brazil, India and California, US (Reactive Power Control version).

Module | JinkoSolar's 72-cell Cheetah module offers 410Wp performance for utility-scale plants

Product Outline: JinkoSolar has launched its 72-cell Cheetah module with peak power outputs of 410W, which is claimed to be highest-performing commercially mass-produced monofacial module on the market.

Problem: Manufacturers face continued pressure to provide PV modules that lower balance of system (BOS) costs and yield better LCOE, while maintaining high durability. The drive towards high performance requires increased focus on solar cell efficiency gains and overall module reliability, resulting in the need for highly automated and quality control checks throughout the manufacturing process.

Solution: All JinkoSolar Cheetah series modules are produced in the company's

next-gen ultra-smart P5 super factory, claimed to represent the most cutting-edge technology in solar module manufacturing. Utilising an all new wafer and cell design, the Cheetah series includes ultra-high performing modules with its industry leading performance in metrics such as output, limited degradation, shade tolerance and durability. The Cheetah 410Wp performance is claimed to be over 30Wp higher than that of comparable products in the industry with a conversion efficiency of 20.38%.

Applications: Large-scale PV projects and projects with ultra-high technical requirements such as those in China's Top Runner programme.

Platform: JinkoSolar's entire portfolio of PV modules has passed the potential-induced degradation resistance test under the conditions of 85 Degrees Celsius/85% relative humidity ("double 85") as required by TÜV Nord's IEC TS 62804-1 standards. UL and IEC 1,500V certified. They are certified to withstand: wind load (2,400 Pascal) and snow load (5400 Pascal). High salt mist and ammonia resistance certified by TUV NORD.

Availability: Since May 2018.

Module | Jolywood debuts range of bifacial module technology developments

Product Outline: Jolywood (Suzhou) Sunwatt Co., (Jolywood) has introduced several new innovations in its n-type monocrystalline bifacial modules that boost cell and module efficiencies, improve durability and lower costs.

Problem: Jolywood has forged a partnership with HuangHe HydroPower Development Co.,Ltd, a subsidiary of SPIC, to develop products for the new energy market in China and overseas, and promote the rapid application of high-efficiency and high-reliability bifacial module technology.

Solution: The mass production efficiency of the n-PERT solar cells used in Jolywood's cooperation project with SPIC has reached

21.7%, while that of the new TOPCON solar cell is up by 0.9% compared with n-PERT. By the end of 2018, further increases are expected in the range of 0.4% to 23%, respectively. The n-type bifacial technology is said to increase overall power generation by more than 17% compared to p-type single-sided technology. Its n-type bifacial glass-transparent backsheet module enjoys a front power of up to 400W, and its maximum comprehensive power of 480W. The module uses a transparent TPT backsheet developed with DuPont. Jolywood has upgraded the transparent backsheet for high-reflection.

Applications: Utility-scale PV power plants.

Platform: Compared with traditional backsheet products, the new transparent backsheet boasts multiple advantages such as light weight, breathability and high gain. The transparent backsheet reduces the weight of the module by 30% compared to the double glass structure, thereby decreasing transportation and installation costs.

Availability: Various product introductions from May 2018 onwards.

Product reviews

Mounting | NEXTracker provides error-roof rail alignment in First Solar Series 6 panel installs

Product Outline: NEXTracker, has collaborated with thin-film module manufacturer, First Solar to provide a patent-pending racking technology for First Solar's Series 6 (large-area) panel rollout this year.

Problem: First Solar Series 6 panel are three times as large as its Series 4 panels. This requires optimised row configurations and unique mounting options for fast track installation, performance and reliability.

Solution: The NEXTracker mounting solution uses a bottom clamp system for installing First Solar Series 6 modules. In this system a shared rail self-locates underneath the frames of two adjacent modules, reducing handling and install times.

A single set of clamps are mounted to this rail, which are used to secure the two modules. During installation, the clamps pass through the module frame mounting slots and are then tightened to the mounting rail. Grounding of the module frame to the tracker structure is built in to the rail system, without the need for additional grounding components. Longer rows improve tracker economics and simplify DC wiring. The high level of diffused light response of First Solar's photovoltaic cells was said to pair perfectly with 'TrueCapture', NEXTracker's proprietary smart control system to increase yields in PV power plants.

Applications: Utility-scale PV power plants

Platform: NEXTracker's mounting solution can be configured to accommodate a wide range of site conditions that may see wind speeds up to 130mph, up to a 15% north-south slope, and also high corrosion environments.

Availability: Available since May 2018.

Inverter | SolarEdge's commercial PV inverter system solutions improve scalability and performance

Product Outline: SolarEdge Technologies has expanded its PV system solutions with the launch of larger-capacity three-phase inverters with synergy technology and a multi-input power optimiser.

Problem: PV installers are still looking for solutions to improve the scalability and economics of commercial PV systems, while still benefiting from optimisation and high-resolution monitoring.

Solution: SolarEdge is increasing the capacity of its three-phase inverters by 20% to now include 33kW and 40kW, while the range of its three-phase inverters with synergy technology will now reach up to 120kW. The new range of inverters adds a number of key features, including the introduction of SolarEdge's new user interface for simplified installation and commissioning. In addition, its PID Guard function mitigates and prevents the build-up of PID and is fully embedded into the inverter.

Applications: Wide-range of commercial/industrial PV power plants.

Platform: The inverter design is based on small, lightweight and easy-to-carry primary and secondary units. They are wall mounted for a minimal footprint, with installation only requiring a one or two-person crew. No crane or special tools are needed when installing the inverter, unlike alternative large capacity inverters on the market today, which are heavy, bulky, and difficult to install. Installing SolarEdge's large capacity inverters instead of using multiple, smaller capacity inverters will further reduce setup times and costs. Integrated DC safety unit with DC safety switch and optional surge protection & DC fuses, eliminating the need for external DC isolators

Availability: SolarEdge three phase inverters are available in 50kW, 55kW, and 82.8kW as well as 66.6kW and 100kW sizes for medium voltage grids.

O&M | UL launches PV power plant certification service to aid quality and safety transparency

Product Outline: UL (Underwriters Laboratories) has launched a new global service, offering a PV Power Plant Certificate to verify the performance of PV systems at several key stages, such as commissioning or during operation, providing greater transparency for all stake holders.

Problem: Grid-connected PV systems are expected to have a lifetime of several decades, with maintenance or modifications likely at some point over this period. The ownership of a system may also change over time, particularly for megawatt-scale ground-mounted PV power plants and systems mounted on commercial buildings. Only adequate documentation, operations and maintenance procedures can help ensure the long-term performance and safety of the PV plant.

Solution: UL's verification and inspection service issues a UL inspection report and UL inspection certificate by assessing PV power plant projects during their commissioning and/or their operation against a set of criteria to demonstrate that the systems are performing at a level based on the IEC 62446-1 Standard and verified by an independent third party. The delivered certificate attests that a PV power plant complies with the criteria outlined in the inspection program at the time of the inspection and will be made publicly available in UL's online database.

Applications: All sizes of PV power plants.

Platform: Based on requirements, UL offers a tiered approach for field inspections based on IEC 62446-1 to offer clients the best certification solution to meet their needs. All category #2 tests in accordance with IEC 62446-1 include; current-voltage curve (IV-curves) measurement of selected strings and thermographic inspection (IR imaging), undertaken while walking/driving/flying through/over the PV power plant.

Availability: Available since July 2018.

New module suppliers and technologies to create more opportunities and risks for developers and EPCs

New tech | Going into 2019 the availability of higher performance, lower cost PV modules will significantly complicate the question of module choice for utility-scale solar projects. Finlay Colville, head of solar intelligence, Solar Media, explores what this will mean for EPCs and developers

Credit: SunPower

Module selection for utility-scale solar sites in 2019 is likely to see the widespread availability of higher performance products with average selling prices significantly lower than witnessed over the past 12-18 months.

While on the surface, this may appear as a dream come true for project developers and EPCs (especially outside China), the challenges in identifying bankable suppliers with quality product offerings are set to increase dramatically, placing far more pressure on making the correct decision to mitigate against risk of plant under-performance over a 20-30 year operating lifetime.

This article explains the background to these imminent changes to module supply, including an outline of the module suppliers' landscape for 2019, while also identifying the most challenging criteria for developers and EPCs in terms of module supplier and technology-type selection.

The discussion below on module technology (and supplier) selection is perhaps the key takeaway for EPCs and developers, providing top-level selection criteria on modules for 2019 and the areas where increased scrutiny will be required.

The choice of what module to use in utility PV projects is set to explode in 2019

Data shown here is taken from PV Tech's Market Research analysis, included in the May 2018 release of the 'PV Manufacturing & Technology Quarterly' report.

Reference is also made to the themes set to be covered in the forthcoming PV ModuleTech 2018 meeting on 23-24 October 2018, in Penang, Malaysia, where module supplier benchmarking is addressed in detail.

72-cell multi modules met utility demand with few questions asked

Until the end of 2017, the PV industry had depended critically on the availability of p-type multi crystalline silicon (p-multi c-Si) modules somewhat as the default go-to choice for utility-scale deployment by many developers and EPCs.

The main exceptions were projects that used First Solar's Series 4 thin-film panels, or SunPower's E-Series c-Si premium (n-type back-contact) panels.

An uptick has been seen in the use of p-type mono c-Si panels over the past few years, with much of the deployment here being within China, using modules where the entire value chain of manufacturing (poly/ingot/wafer/cell/module) has been domestic.

Otherwise, for the (non-China) global developers and EPCs, module selection has been mostly about which supplier of 72-cell p-type multi modules is successful and less so about the technology type. It is this category of developers/EPCs that needs to be most aware of the changes set to unfold regarding module technologies (mono driven) and the new paradigm of ASPs on offer.

Why has multi been so dominant for utility-scale solar?

The answer to the subheading above is not complicated. Utility solar has been the main driver of growth in the solar industry in the past 10 years, and this has been accompanied by limited supply of mono-grown ingots (needed for mono wafers used to make mono cells/modules).

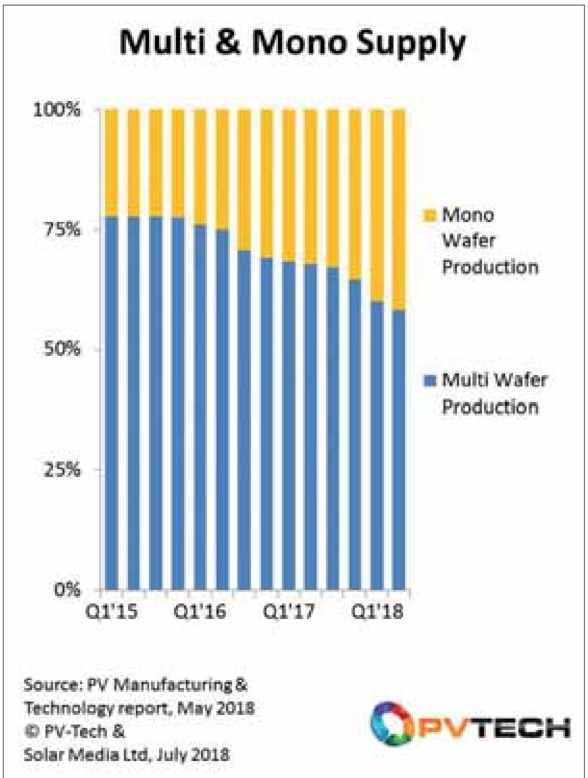


Figure 1. The solar industry is seeing increased supply of mono silicon-based modules, with non-China utility segments set for the greatest shift during 2019 and 2020

In fact, capacity and production levels of multi c-Si wafers and cells mean they have rarely been in short supply, maintaining widespread low-cost product availability for developers and EPCs. Barriers to entry in making multi wafers have been low, and having GCL-Poly setting up tens of gigawatts of low-cost/low-price wafers set the benchmark for every other multi wafer supplier in China/Taiwan.

Had the world decided collectively overnight that the choice of utility-scale solar was to be confined to First Solar, SunPower or p-type mono modules, then it would have seen more than 80% of utility-scale solar being removed, due entirely to lack of module availability from this subset.

Developers and EPCs have needed 72-cell p-type multi modules to exist. And many of them have been largely unconcerned with origin of manufacture, and whether the maker of the product was in Vietnam or Thailand or chosen ad hoc from one of China's many quasi-OEM state-funded institutions.

Pricing was low, often serving the primary goal of lowering site capex and maximising profits when flipping signed-off accredited/PPA-secured plants. Product was available in droves, even during the various trade-related cases in recent memory.

If module suppliers and their respective technologies had been created equal, then this would be the end of the story. However, the raft of underperforming solar plants globally today indicates this is clearly not the case, and anyone thinking that solar modules are a commodity offering needs to spend a few hours with asset owners and O&Ms to get a strong reality check.

For most of last year, for example, looking at many of the 72-cell modules installed globally (or at least reading off the datasheets) showed few if any differences across 50-100 module suppliers, differing only in frame dimensions.

It is therefore little surprise that one of the most frequent questions asked has been: which is the best module supplier – who should I buy from?

If EPCs and developers thought life was tricky in the past few years (having to select which company for 72-cell p-multi modules!), then they are in for a rude awakening by the end of this year, unless they become far more educated in what the GW-scale module supply landscape is set to become shortly. These changes are set to offer major opportunities for plant design, but come with an equal dose of risk should the wrong supplier or technology-type be deployed.

Mono, n-type variants, bifaciality, and Series 6 thin-film panels

Going into 2019, an increasing number of utility solar farms are going to be utilising p-type mono modules (almost all of which will be PERC based), with ASPs largely at parity with p-type multi offerings and at sub 30c/W (EXW) pricing.

While design and operation of solar farms will reflect the higher powers from p-type mono, the main question for module users is likely to come from the increased number of Chinese suppliers, and which company to choose for site deliveries.

By now, it is no great secret that the Chinese market is not going to keep growing exponentially, simply to absorb the collective shipment targets of companies that have added capacity (from polysilicon through to modules) over the past couple of years. This single fact will see approximately 20-30 China-based module suppliers seeking to grow their export business, adding to the 10-20 existing Chinese companies that have appreciable overseas sales revenues today.

Which of the 30-50 Chinese module suppliers are truly bankable? How many of these companies have a level of manufacturing quality control that is low enough risk for external solar farm investors? Are their PERC modules reliable, with a fully audited bill of materials?

But perhaps more pertinent, how many of these companies will be solvent two to three years out and able to honour 20-30-year performance guarantees?

In addition simply to increased p-type mono modules (72-cell PERC), there will be more offers for n-type modules than seen before. Several caveats apply here, as n-type now includes a wide range of company types and performance levels, not to mention strategies.

In theory n-type modules have the capability of higher efficiencies (power ratings) and superior elevated temperature operation, compared to p-type mono and multi modules, as explained below. EPCs and developers should at a minimum absorb these basic facts.

There are three basic types of n-type modules: n-type PERT (using manufacturing processes and equipment closely

Independent Supply Chain Management.

Controlling performance and quality of PV system components.

Why PV Supply Chain Management Services?
You want to mitigate risks and make your PV power plant project attractive for lenders and investors. They want to be sure that the PV modules and PV inverters perform and last as expected. Independent supply chain management services create such certainty for you and your investors, e.g. by carrying out in-line but also pre-shipment inspections, verifying power yields pre and also post shipment and managing risks throughout the supply chain.

Why TÜV Rheinland?
With more than 35 years in Photovoltaics, we provide all-round risk management throughout the supply chain: finding reliable suppliers, conducting tests before and after shipping and monitoring the installation. We offer sound and cost-efficient solution packages worldwide that go hand in hand with our independent engineering services. Take advantage of our global network of PV laboratories and PV experts. Make your PV project a success with TÜV Rheinland.

www.tuv.com/solar

TÜVRheinland®
Precisely Right.

aligned with p-type mono PERC), n-type heterojunction (HJT), and n-type back-contact (or often assigned as interdigitated back-contact or IBC).

Currently, the efficiencies (STC power ratings) from n-type PERT modules are not that different from best-in-class p-type mono PERC variants, suggesting that the value-added proposition for n-type PERT lies mainly in the temperature coefficients.

At the top-end, the LG Electronics version sits as the gold standard today, with several in-house differentiators (front/rear implanting, multi-wire front grid interconnections); however, LG's priority (excluding its domestic market and a few isolated occurrences) is mainly on rooftops, and not mega-solar ground-mount deployment. Therefore, many global utility-based developers and EPCs will remain somewhat excluded from using these panels still.

Other n-type PERT modules are coming now from new Chinese companies, none of which has any strong heritage in solar cell production (aside from Yingli Green's legacy PANDA lines). All of these companies have plans to export in volume to global utility projects in 2019, and this certainly points to a greater awareness of module users when it comes to qualifying these suppliers.

The next n-type architecture seeing increased attention is heterojunction (HJT). For years, HJT modules were synonymous with Sanyo's trademarked 'HIT' modules, simply rebranded as Panasonic following the acquisition phase. HJT production is fundamentally different to all p-type cell/module assembly, and to n-type PERT variants. These lines are process and equipment tool specific and represent a step up in terms of manufacturing complexity.

In the past two to three years, it is mostly HJT that has seen the investment dollars in China across new entrants in cell/module production that needed to select an advanced technology-type to differentiate from the p-type juggernaut that is already in operation. HJT has also been a convenient technology-transfer route for a number of a-Si thin-film fabs (extending outside China also) that had the adaptable deposition equipment and know-how needed to make c-Si HJT cells.

In an ideal world, HJT deployment sits firmly on residential rooftops, commanding ASP premiums that are needed to absorb higher material and production costs compared to the leading multi-GW p-type suppliers today. While LG and Panasonic have been able to manage this mostly during their solar industry participation, these companies benefit from brand association and installer confidence levels built up over many years.

New HJT suppliers are therefore left to focus on ground/utility segments, suggesting again that global EPCs/developers are likely to see new offers from this grouping during 2019, as GW levels of production hit the market with no easy supply channels in China to absorb all produce.

The final n-type (and the most advanced and premium performance) category is based on the back-contact or IBC structure, something that (aside from pilot-line activity in Korea) is the sole domain of SunPower across its Southeast Asia fab operations. There is no indication at all that this will change in 2019 or the foreseeable future, such is the barrier-to-entry level in terms of in-house IP (process and equipment tooling based) that SunPower has meticulously crafted over 20 years of production experience.

This ensures that SunPower's products will remain the highest-performing (STC and elevated temperatures) and with the highest ASPs in the industry, largely without technology-specific competition. This continues to allow SunPower to be selective (for its IBC product lines) in terms of application segments (residential, C&I and utility split), regional deployment, and shipment to in-house or third-party sales. Applying these factors, and given the GW level of IBC product available (compared to the 10GW mark now common to several of the global p-type module leaders), one can conclude that most of the global EPCs/developers will continue to be forced to make choices confined to the other module technology types.

The final technology type to consider of course is thin-film, with this technology belonging to one company today – First Solar. Yes, there are other thin-film companies in the solar sector still, but they are either seeing declining fortunes in terms of product availability and global competitiveness (e.g. Solar Frontier) or have limited if any market credibility or bankability (e.g. almost all China-based thin-film investments going back well over 10 years now).

Manufacturing exclusivity aside however, First Solar's successful roll-out of its Series 6 panels (coupled with multi-GW of new fab builds across three countries now) is set to provide higher performance products in far greater volumes than seen in the past. However, this is not simply confined to product coming off the production lines, but the amount that is now being shipped or sold to third-party developers and EPCs.

To put this into context, during 2019, MW-levels of shipments to third-party developers/EPCs are forecast to increase by approximately one order of magnitude, compared to third-party shipments just 4-5 years ago, and could easily exceed the 4GW mark next year.

Given also that First Solar's product is – for all purposes – utility-segment specific, this effectively propels First Solar to a new place in the PV industry, and will bring a whole bunch of new EPCs/developers into contact with thin-film products for the first time, or simply re-engage those that had been champions of thin-film panels for utility deployment in the past but were forced to rely on p-type multi-modules to fulfil build-out plans over the past few years.

What does this really mean for EPCs and developers?

In short, the companies and product types being considered for utility-scale solar in 2019 will be different to what has been seen for most of the past two to three years (where almost everything was 72-cell p-type multi).

> "The companies and product types being considered for utility-scale solar in 2019 will be different to what has been seen for most of the past two to three years"

Many of these companies have minimal track records in exporting supply out of China, some are new to cell/module production and are trying to ramp up GW levels of new process flows for the first time, while others (JinkoSolar, Canadian Solar, JA Solar, First Solar, for example) are firmly established with global EPCs/developers and will release new module versions with improved performance and reliability.

It is probably fair to say that any developer/EPC currently planning a utility-based solar site for 2019 based on 72-cell p-type multi-modules should pause, and ask whether this is the best option in terms of investment ROI or secondary site valuation figures in three years from now.

While not wanting to complicate the issues, seasoned campaigners may well be asking why there is no talk above of bifacial/half-cut/shingles. The reason for this is relatively simple.

Right now, these are still options, not necessities in the market. The benefits are not in doubt. It is just that they are more additive to existing plans (which are not yet fully implemented and qualified in production).

Bifacial remains a curiosity more than a must-have, with widespread confusion about just what is on offer in terms of yield deltas, and how it is possible at all to predict performance over 20-30 years. While the easy argument is to say that anything extra is always good, this is as dangerous a statement for investors and O&Ms as is anything impacting site under-performance.

How do you value the worth of a site, if you can't forecast yield over 20 years? How can you set performance ratios for O&Ms or even dare to include upside payments based on over-performance relative to a fixed (unknown) reference line?

Either you bite the bullet and have some carefully worded clauses into supply arrangements (power guarantees) or have highly flexible O&M contracts (especially during the first two to three years), while baseline parameters (likely almost all site/environment specific) are established. Or you just wait a few years until the industry has worked out how to deal with double-sided absorption from solar modules.

Half-cut modules are less of an unknown or a differentiation and EPCs/developers have fewer reasons to fear them, other than diving into module supplier selection from an unknown entity. Until now, half-cut cell module design has been a key focus from REC Solar: it is unclear still how much the Chinese sector will fully embrace. Will China solar want to laser cut all its cells in two and re-assemble them all across its various cell/module supply-chains? Taking this one step further to multi-cut – or singulated-cell designs – and potentially we enter more niche-status manufacturing today.

PV ModuleTech 2018 to provide clarity for EPCs and developers

Going into its second year, PV ModuleTech 2018 will focus specifically on utility-scale module supply and demand for the 2019/2020 period, in particular for all countries/regions outside China.

Therefore, this two-day conference should provide EPCs and developers with the tools they need to assess and benchmark module suppliers and product technologies for sites in preparation or going into planning/approval phases over the next 12 months.

The event will include a non-China specific geographic module supply session, where the demand for modules outside China in 2019/2020 will be explained, including company and technology market-shares in key regions globally today and how this may change going forward.

Leading module suppliers will then outline product availability, and what measures are in place to ensure bankability and product quality, and how these companies are placed to honour 20-30 year performance guarantees.

PV ModuleTech 2018 will again hear from leading independent engineers, test and inspection organisations, certification labs, factory auditors, and module assembly materials and equipment suppliers.

Findings from the event will be invaluable to companies (EPCs, investors, developers, O&Ms) whose business models are contingent on the correct module type and supplier being chosen. ■

PV ModuleTech will be held in Panang, Malaysia, on 23-24 October 2018. Further details are available at moduletech.solarenergyevents.com

Author

Finlay Colville joined Solar Media in June 2015 as head of the new Solar Intelligence activities. Until October 2014, he was vice president and head of solar at NPD Solarbuzz. Widely recognised as a leading authority on the solar PV industry, he has presented at almost every solar conference and event worldwide, and has authored hundreds of technical blogs and articles in the past few years. He holds a BSc in Physics and a PhD in nonlinear photonics.

PVMODULETECH CONFERENCE

23 - 24 October 2018

PENANG, MALAYSIA

Going into its second year PV ModuleTech focuses on all technical aspects of PV modules, including manufacturing, equipment, materials, module design, test and inspection and certification.

- Understand key metrics behind module quality, reliability & bankability
- Hear from the key stakeholders in GW module supply, certification, testing & factory auditing
- Determine impact of module technology advances on site yield, monitoring & return-on-investments
- Find out which module suppliers are key to unlocking new end-market growth in utility-scale solar

Sponsors and exhibitors already confirmed:

3M Science. Applied to Life. DUPONT First Solar. JinKO Solar MEYER BURGER MONDRAGON ASSEMBLY risen SUNPOWER TALESUN tt vision

To get involved either as a speaker, partner or attendee please email: marketing@solarmedia.co.uk

moduletech.solarenergyevents.com

PVTECH Photovoltaics International PVTECH RESEARCH SOLAR MEDIA

Getting serious on module underperformance

Module reliability | With so many options open to them, EPCs and developers are faced with confusing choices to make over the right PV module technologies. Finlay Colville and Mark Osborne explore the importance of stringent third-party testing in avoiding asset underperformance

Credit: Suntech

As we have heard on the previous pages, with module supply globally seeing increased contributions now from countries outside China, developers and EPCs across the US, Europe, India, Japan and emerging global markets, are being confronted with greater choice in terms of companies offering modules and technology types that differ from the 72-cell p-type multi products that have dominated utility solar until now.

The preponderance of me-too 72-cell products, from so many channels, may actually be one of the key factors behind the number of solar parks underperforming today.

So many developers and EPCs seemed to be of the opinion that because this module type was in such widespread supply, it implied that the technology was both mature and dependable. In this way, it was much easier to justify driving down site capex, while creating somewhat of an auction across module suppliers when sites approach the build phase.

At the extreme end of this, we have the Indian market, which today epitomises the above narrative. Ultimately, component supply and site capex is of course a trade-off between upfront costs and how much sites can be sold for when it comes to flipping to the institutional investment sector.

Performance over 20-30 years, site yields and ensuing costs to fulfil IRRs sadly have no compromise in this regard; time-and-again, the conversations with asset owners and O&Ms in the past few years have sounded like a broken record when reflecting on module choice enacted prior to their acquisition phase.

Where is the system letting down asset owners, and can it be fixed easily? This would perhaps be the most mature place to start; to identify the gaps in the system that allow multi-MW sites to be populated with modules that can barely perform over 2-3 years, far less 20-30 years.

Plenty want to bury the fact that so many solar plants are underperforming today, as though this would be an indication that the industry was short-changing its funders (government, state or city-based). However, to a man, virtually all of these stakeholders would like nothing more than to know how their future investments can outperform prior rounds of financing, and that the solar industry as a whole recognises that module inspection, certification and testing is not just a bean-counting exercise, but a channel through which everyone can get their act together professionally.

Rigorous testing will help EPCs and developers make the right choices over which PV modules to choose from the many new products emerging

OK, so now we have untried and untested modules coming on the market!

One can sympathise with asset owners today, when they are now starting to see module suppliers offer the next-best-thing after 72-cell utility-based p-type multi modules, to EPCs and developers that are lining up future portfolios of built solar farms.

The manufacturing sector seems to have hit the technology-upgrade button, almost overnight.

For sure, many developers and EPCs are confused. Which of the new product types – and companies supplying them – are actually offering a higher spec product that has inherently lower degradation and lower risk than products of yesterday? And which – despite what it says on the tin – just need to be side-lined until there is field data to show real-world performance?

Knowing the answers to these questions is probably what will differentiate the solar farm builders globally over the next 12-18 months, and right now, everything leading into the PV ModuleTech 2018 event is being configured to have an independent platform to allow rational decisions to be made by EPCs and developers. And not to mention informing the asset owners of today's multi-GW portfolios that can ultimately influence the lenders about component choice they need to pass down to the EPCs on-site.

Within the overall mix of higher performing products (let's classify by stated panel powers at STC here), there are some excellent choices to be made. For example, the move from multi to mono is intrinsically advantageous from a degradation standpoint; and the use of glass-glass modules (mono or bifacial) has many benefits also. And on the thin-film side, moving from a First Solar Series 4 to Series 6 panel size opens up plant capex benefits that are highly positive from a return-on-investment standpoint.

In short, the world is moving inevitably away from me-too 72-cell p-type multi modules to a mix of higher-performing and potentially more-reliable offerings. It is now down to the module suppliers to explain clearly what they are offering, to the third-party testing/auditing/certification labs to undertake the appropriate analysis of the companies/products, and of course to the EPCs/developers/owners to be adequately tooled to make qualified judgements.

Module reliability testing

In making such judgements, basic module certification tests provide EPCs and developers with little 'insurance' against under-performing modules, but accelerated lab tests such as DNV GL's annual 'PV Module Reliability Scorecard' tests do at least provide some transparency and comparative information on module reliability.

The annual PV Module Reliability Scorecard reports the results of DNV GL's PV Module Product Qualification Programme (PQP). The PQP and resulting Scorecard are actually voluntary programmes that enable PV module manufacturers to independently demonstrate the reliability and durability of their products to the global industry, and provide PV equipment buyers and power plant investors with independent and consistent module reliability data.

According to DNV GL, it has lab tested over 300 BOMs (bills of material) for more than 50 module manufacturers since 2014.

The 2018 PV Module Reliability Scorecard summarises the last 18 months of PQP testing results, which included key findings such as:

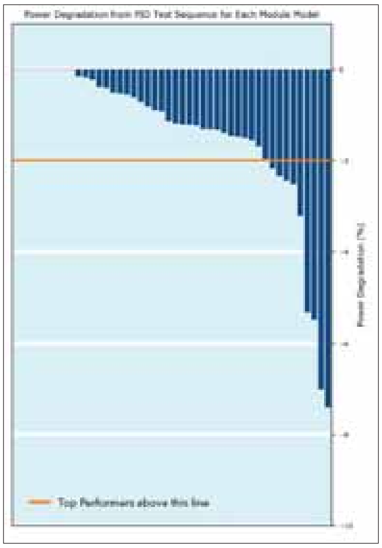
- An overall improvement in test results compared to 2017
- 9% of BOMs submitted failed one or more of the test criteria
- 12% of model types failed one or more of the test criteria
- 22% of manufacturers had at least one failure according to the test criteria
- Failure rates were not linked to the geographic location of the factory or size of the manufacturer

The scorecard has its weaknesses, not least that it is 'voluntary', providing inconsistent data from PV module manufacturers on a year-on-year basis as companies elect to be part of the testing and which specific modules are tested.

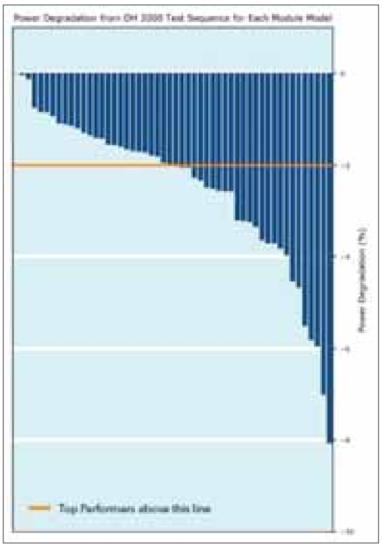
The scorecard also reflects the roller-coaster of an industry, which experiences regular bankruptcies and so companies such as SolarWorld, which had previously participated in the testing, do not appear in the 2018 testing results.

However, the scorecard has become increasingly important, not least due the growing number of PV module manufacturers and the number of modules tested on an annual basis.

We have chosen two of arguably the most import tests undertaken by DNV GL, the damp heat (DH) and the potential-induced degradation (PID) tests and compared the scorecard results from the two most recent test reports.



DNV GL Scorecard 2018, PID test results



DNV GL Scorecard 2018, damp heat test results

With respect to the PID testing, in 2017, 16 PV manufacturers participating achieved 'Top Performer' rankings with 24 modules degrading from zero to a maximum of 2%.

In the 2018 report, Top Performer rankings were given to 20 companies and 32 modules. According to DNV GL, the 2018 median was -1.4%, compared to -0.4%, -2.7%, and -18.4% in 2017, 2016 and 2014 respectively. However, some of the modules tested for PID were said to have not been claimed by the manufacturer to have been PID-resistant.

With respect to the damp heat test, a total of 13 companies attained the Top Performer ranking in 2017 with 19 modules achieving less than a 2% deviation in performance.

However, according to the report, 42 module models with 50 unique BOMs participated in this test, with degradation rates varying from non-measurable degradation to -5.5%.

In 2018, the number of companies with a Top Performer ranking remained unchanged but the number of module models meeting the Top Performer criteria increased to 23.

Yet, according to the report, higher degradation was seen, with the median at -2.5%, compared to -0.9% in both 2014 and 2017 reports. The maximum degradation was -8.8% in 2018, compared to -5.5% in 2017.

Considering that high ambient temperature and humidity can be found in a large number of countries and regions where PV is deployed in significant quantities, the damp heat tests have highlighted that the durability of modules for many markets with such conditions could be compromised.

Scoring manufacturers

We also undertook a sample analysis of module manufacturers that released press releases, specifically highlighting their success in the 2018 DNV GL Scorecard results as Top Performers.

Yingli Green

Yingli Green took a bold stance in the headline: "Yingli is Outstanding in the PV Module Reliability Scorecard of DNV GL for the Fourth Time".

Indeed, Yingli Green was highlighted in 2018 Scorecard by DNV GL to have been rated a Top Performer in at least one test criteria in each of the four annual test so far undertaken. This accolade can also be given to JinkoSolar and Trina Solar.

"The PV Module Reliability Scorecard

report is a voluntary programme initiated by DNV GL, presenting the most complete and transparent comparison of PV module reliability test results. Since 2014, Yingli's PV modules performed at the top level in reliability in the four reports," commented Dr. Dengyuan Song, chief technology officer of Yingli. "The reliability tests covered by the Scorecard include triple IEC thermal cycle, damp heat, humidity freeze, and dynamic mechanical load and PID attenuation. The test results demonstrated the strong reliability of Yingli's PV modules."

In our sample analysis of modules from manufacturers in the DH and PID tests in 2017 and 2018, Yingli's 'robust' YLxxxD-36b module was a Top Performer in three of the five tests in 2017 and in all four tests in 2018.

Yingli modules were not present in the 2017 Scorecard as a Top Performer for the thermal cycling and humidity-freeze test results.

JA Solar

'Silicon Module Super League Member' (SMSL) JA Solar took a more conservative approach with the press release headline "JA Solar Named 'Top Performer' by DNV GL for the Third Time".

However, the company also stated: "In both 2014 and 2016, JA Solar passed the product tests and received the product certification from PVEL (a wholly-owned subsidiary of DNV GL) and won the 'Top Performer'."

JA Solar did not participate in the 2017 report, but was a Top Performer in the PID test in 2016. In the latest report, JA Solar was a Top Performer in the thermal cycling (TC) test with its JAM6(K)(ZEP)-60-xxx/PR module and the dynamic mechanical load (DML) test with its JAM6(K)(ZEP)-60-xxx/PR and AP72S01-xxx/SC modules.

In the PID test, JA Solar had two modules rated as Top Performer, the JAM6(K)(ZEP)-60-xxx/PR and the JAM60S02-xxx/PR module.

Adani (Mundra Solar)

New market entrant, India-based Adani (Mundra Solar), proudly proclaimed it was the only India-based module manufacturer to feature in the report. This was true as Vikram Solar did not participate in the latest testing, although appeared in the 2017 report and had been a Top Performer in the humidity freeze test, dynamic mechaitnical load test and damp heat test.

"Adani Solar gets coveted global recognition on durability and reliability," was the headline but the press release did not specifically use the Top Performer terminology, instead citing that it had been awarded the "top award for three rigorous tests".

Adani appeared as a 2018 Top Performer in three out of the four tests, which include the TC test with its ASP-7-xxx module and well as the DML and PID tests.

Ramesh Nair, chief executive officer of Mundra Solar PV Limited (Adani Solar) said: "Developers/investors should always be aware that not all manufacturers have their modules tested for quality and reliability to vouch for their product lifetime. Procuring unevaluated modules is always a risk that could have major ramifications for their projects. Adani is a committed manufacturer which has implemented state-of-the-art facility with best industry practices ensuring superior performance and reliability of its products."

LONGi Solar

Another recent market entrant was LONGi. Already an SMSL member and the largest monocrystalline wafer producer in the world. Also notable is that in 2017 it had the highest expenditure on R&D in the solar industry at US$175.7 million, up 96.67% from US$89.2 million in 2016 as well as setting a new record for R&D spending in the industry.

Ticking all the boxes, LONGi's press release headline was: "LONGi Solar is "Top Performer" in DNV GL 2018 PV Module Reliability Scorecard"

The company also noted: "LONGi Solar was awarded "Top Performer" for its monocrystalline PERC modules in all four tests categories. This is a validation of the advantages of high efficiency, high reliability and high yield of LONGi Solar's mono-crystalline modules, and an endorsement of the advanced technology, equipment, product testing and R&D capabilities of the company."

LONGi Solar was awarded Top Performer for its mono-crystalline PERC modules in all four tests categories. Indeed, this was achieved for two modules, LR6-72PH-xxxM and LR6-60PB-xxxM. This was also achieved with the LR6-72-xxxM and LR6-72PE-xxxM modules in 2017.

Trina Solar

SMSL member Trina Solar also remained conservative in its press release headline, noting: Trina Solar recognised as "Top Performer" module manufacturer by DNV GL.

The company correctly highlighted that it was the fourth time it has received this award.

Although the company noted the four major tests undertaken, very little else was said about testing specifically in respect to its modules.

Unlike other companies, Trina Solar has put through the testing a notable number of different modules. As the table below shows, in 2017 and 2018 scorecards, a number of Trina Solar modules were awarded Top Performer status in all categories but not all modules in all the categories.

However, it is clear that Trina Solar has extensively used the scorecard since inception, as well as leading SMSL, JinkoSolar.

However, there would seem to be room for improvement in how PV module manufacturers reflect their Top Performer status. ■

Trina Solar's 'top performer' modules in the 2017 and 2018 scorecard

Trina Solar	2017	2018
Thermal cycling	TSM-xxxPD14.18	TSM-xxxDD05A.08(II)
	TSM-xxxPD05.1	TSM-xxxDD05A.18(II)
	DD14A(II)	TSM-xxxPE14A/TSM-xxxPD14
Dynamic mechanical load	TSM-xxxPD14.18	TSM-xxxDD05A.08(II)
	TSM-xxxPD05.1	TSM-xxxDD05A.18(II)
	DD14A(II)	TSM-xxxDD14A.18(II)
		TSM-xxxPD14
		TSM-xxxPE14A
Humidity-freeze	TSM-xxxPD14.18	N/A
	TSM-xxxPD05.1	N/A
	DD14A(II)	N/A
Damp heat test	TSM-xxxPD14.18	TSM-xxxDD05A.18(II)
	TSM-xxxPD05.1	TSM-xxxDD14A.18(II)
	DD14A(II)	TSM-xxxPD14
		TSM-xxxPE14A
PID test	TSM-xxxPD14.18	TSM-xxxDD05A.08(II)
	TSM-xxxPD05.1	TSM-xxxPE14A/TSM-xxxPD14
	DD14A(II)	

Implementing risk mitigation strategies through module factory and production inspections

Quality | Developers and investors must be proactive to ensure the quality of modules they purchase is as high as possible. Vicente Parra and Ruperto Gomez detail some of the practices they can follow to mitigate module quality risks during the manufacturing process

Credit: Hanwha Q CELLS

Today, every player involved in the development of a large-scale solar PV project is aware of novel PV module concepts like half-cut cell, double-glass, mono/multi-PERC, black silicon or bifacial technologies, among many others. All of them are innovations or upgrades to the common crystalline silicon technology that has been used for many years, the well-known glass/back-sheet Al-BSF design. Each year, module manufacturers announce their brand-new, high-efficiency and cost-optimised PV modules in vast exhibition events worldwide. This systematic tendency has probably been the main driving force for the present, 'here-to-stay' deployment of the PV industry and market, globally. While this is good news for the PV technology evolution, all innovation is usually inferred by investors as a potential risk, in the sense that the long-term behaviour of these new devices is not properly known and tested yet. Indeed, the abovementioned classical Al-BSF module still suffers from outdoor failures and underperformance issues, notwithstanding its well-studied device structure and performance.

Therefore, the main concerns for PV investors and developers continue to be the quality and reliability of the modules, very complex concepts that must be duly scrutinised and warranted, usually in close cooperation with independent PV consultants, such as Enertis Solar.

Quality control

In the last 10 years, the expenditures related to PV plant construction and operation have been reduced considerably. CAPEX reduction accounts for approximately 85% and OPEX has dropped by more than 50%. Cost reduction has also been a key cause for the global market growth that is currently being experienced. For instance, the public renewable energy auctions for large-scale power projects that are being implemented worldwide today are leading to unprecedented low solar energy prices, such as those of Mexico, Chile or Saudi Arabia, as important examples. Nowadays, no one is especially surprised to find press releases covering new PV project developments with 150MW, 200MW or even larger capacities, as standard figures. As a comparative reference, in 2008, the largest PV plants in Spain (leading market at that time) hardly exceeded 15-20MW of installed power, using nearly 50% less powerful PV modules than today.

This 'big-size/lower-cost' scenario is definitely changing the development of a PV project. This is especially significant with regard to the acquisition of large PV module orders from Asian manufacturers, which need a very carefully planned process by the buyers.

Thorough inspections of modules prior to shipping is a key part of the quality control process

A 150MWp supply comprises around 450,000 individual PV modules. These are made of approximately 20 different materials of varying structures, purpose and composition (e.g. PV cells devices, glass, polymer encapsulants and back-sheet, metal ribbon connectors, adhesives and potting material, junction box, cable, by-pass diodes, etc.). These materials, in turn, can come from many different suppliers, which are able to produce diverse models based on individual features and performances. Altogether, the final list of materials comprising the PV module is the so-called 'bill of materials' (BOM), a major concept related to quality that will be revisited later in this article. Likewise, the manufacturing of large supplies of PV modules will usually encompass the use of more than one factory location (a factory usually contains one or more workshops; a workshop is based on one or more production lines) during several uninterrupted months.

Consequently, there are many variables (different materials and factories, extended time, etc.) to be carefully set up by a manufacturer before undertaking the production of a MWp-based supply of PV modules. Therefore, the implementation of consistent, traceable and stable manufacturing processes all over the production period becomes mandatory to safeguard and ensure the quality of the PV modules, which are the energy generator, and thus the core of the power plant.

In this regard, mitigation practices for quality risks during manufacturing are being increasingly demanded by any sophisticated PV developer and investor, by implementing third-party inspection activities throughout the production period (including on a 24/7 basis). They are understood as customised ways to mitigate risks at early stages of the PV project development. As evidenced by Enertis experience, many PV module failures and underperformance issues arising at a PV plant during its lifetime can be directly associated with the implementation of low-quality production processes or the use of non-certified BOM lists and materials.

Frequently, when a PV developer or EPC contractor ask for quotations for a, e.g. 150MWp PV project to five different Asian PV module suppliers (let's consider the so-called Tier-1 manufacturers), the respective commercial proposals are based on different module technologies among suppliers, with diverse power distributions. Occasionally, the manufacturer suggests several manufacturing workshops, some of them OEM-based (modules produced by a third-party manufacturer), to be potentially involved in the production of the supply (commonly in China or Southeast Asia countries). If, just a few weeks later, a new buyer replicates this request, for an equivalent project site, it will most likely receive (very) different technical proposals from these same five suppliers. Therefore, the PV module market depends upon the existing availability at the time of request, the estimated production capacities in the short/mid-term and the specific market goals and strategies that each supplier seeks to develop. However, the level of adequacy of the PV device (including constructive materials to be used) for the specific environments and conditions of the PV plant (high irradiances, desert locations, shore environments, windy sites, etc.), are scarcely considered as major variables when the supplier submits the quotation.

In any case, by default, the maximum product quality is assumed and confirmed by the manufacturers via IEC and ISO standard certificates, including BOM and factories/workshops to be eventually used in production. Unfortunately, according to Enertis Solar's experience, the assurance of the quality and reliability of the eventual supply needs further verifications, at various levels. In theory, Tier-1 suppliers are a trustworthy choice for any stakeholder involved in the development of a PV project, even though the commercial-based metric for the company, which is somewhat clichéd these days, should not be automatically associated with "Quality-1". Also, as per Enertis Solar experience over recent years, with more than a 40GW track record as a PV consultant and independent engineer, a PV module is still far from being considered a commodity, precisely because of the dozens of variables that influence its performance, quality and reliability, not to mention the new device concepts steadily coming to the market.

It is known that many Chinese Tier-1 suppliers suffered from financial problems in the recent past. Their operations are typically based on debt, in an industry that does not favour positive cash flows. Furthermore, most of these manufacturers are systematically undertaking huge capacity expansion plans, in order to satisfy the increasing PV market demands in China and the rest of the world, in a continuous context of price fluctuations and tight delivery schedules.

In summary, notwithstanding the accredited and well-proven technological/R&D know-how and supply capacity of the PV manufacturing industry over the years, this market scenario creates a risky cocktail for PV developers, investors and lenders.

A quality risk mitigation strategy

Therefore, it is highly recommended for PV module buyers (either PV plant owners or EPC contractors) to design a Quality Assurance and Quality Control (QAQC) strategy before tackling the purchase of thousands or millions of PV modules for their utility-scale PV projects.

This strategy should be based on the three main aspects below:

i) The determination of a detailed module technical specification sheet, to be included in the corresponding request for proposal process, indicating any specific need to be fulfilled by the supplier, addressing the special environmental conditions of the PV site, if any. These needs are usually covered by, but not limited to, the IEC standard certificates.
ii) A shortlisting process via technical due diligence or supplier assessment.
iii) The establishment of a suitable 'module supply agreement' (MSA) with the manufacturer that accurately stipulates every aspect related to module quality requirements and batch acceptance before shipment from the factory and after delivery at the site.

This MSA should collect all certification quality requirements for both modules and factory capabilities, the protocols for production inspection, a clear definition and requisites for the BOM, and the sampling and module testing procedures to be implemented to regulate the pass or fail condition of a batch prior to shipment.

As mentioned before, solar PV technology has experienced a tremendous evolution in the last few years. In contrast with this optimistic evidence, there is a consensus among PV developers and independent consultants regarding the certain obsolescence of the module warranties still offered by the suppliers (the so-called Product and Performance Warranties). Therefore, as part of the risk mitigation strategy, in Enertis Solar's opinion, these standard warranties should also be subject to revision and updates in the MSA, redefining the concept of defect, together with the valid protocols to control and confirm any module failure event in a practical and undeniable way.

A highly recommended practice, to be also stated in the MSA, is what Enertis calls a Pre-Production Factory Audit. This audit process seeks to detect any potential quality risk associated to the Standard Operational Procedures (SOP) and Quality Management System (QMS) of the manufacturer. This is especially important when the supplier proposes several workshops from different locations, even countries, sometimes even based on OEM factories, as the respective SOP, QMS and BOM management can diverge more than expected. Additionally, other key aspects under evaluation are the in-house PV laboratory capacities, the traceability system and the training level of the operators (these factories often experience high rotations of personnel over short periods of time). The audit outcome, per production workshop, is its 'pass' or 'fail' condition to guarantee a minimum level of quality in the modules. Even if the result is a pass, a corrective or improvement action plan is usually triggered, which should be addressed and completed by the manufacturer prior to the official commencement of the production plan. This task is carried out by the auditors in close collaboration with the manufacturers, which, indirectly, helps them improve their processes and protocols.

During the audit, it is also recommended to select some module samples with an equivalent BOM (at least the PV cell device) to the one included in the supply, and then produce calibrated modules in an external and independent PV test laboratory. These modules will be used as standard references for the maximum power measurements, via I-V flash testers, during the inline production period and laboratory retesting for individual batch acceptance purposes. These reference modules will help guarantee the measurement of accurate maximum peak power values of the modules under production. Moreover, these added-value modules should be carefully handled and stored in the workshops, then shipped to the PV site, as their role can be very useful in subsequent testing activities upon delivery at the PV site and any time during the lifespan of the PV modules (warranty claims, for example).

For the batch acceptance testing, it is worth defining the size of the individual *manufacturing batch*, which should correlate, preferably, with the *delivery batch*, so that the sampling and quality criteria stipulated in the MSA can be directly ascribed to a well-defined module population.

Ideally, a batch should be based on only one BOM, defined as a closed list of construction materials, limited by one model per each material. Usually, most module manufacturers propose BOM lists that imply hundreds of potential material combinations, with the use of, for example, 10 PV cell providers, six glass models, four polymer encapsulants and back-sheets and three different junction box/connector suppliers. The final BOM list/s should be duly certified according to the individual IEC certificates requested for every project, going beyond the basic IEC 61215 and 61730 standards. By 'duly certified', we mean updated certificates associated with the selected workshops, coupled with the corresponding test reports per IEC certificate, including the BOM used to pass the respective test or test sequence. The well-known Constructional Data Forms (CDF) are typically considered as proof of BOM compliance versus IEC requirements, although these documents do not actually constitute irrefutable evidences of such technical agreement.

Additional inspection procedures related to the quality control of modules can also be proposed, in a different context than that of an MSA, extending the responsibility in the event of module underperformance to other project stakeholders beyond the PV module supplier. This topic is out of the scope of the present communication and is worthy of an entire article in itself.

Overseeing module production

As mentioned before, the manufacturing of a large supply of PV modules needs to be consistent and reliable over the entire production period, and in every workshop eventually implemented by the supplier and previously accepted by the independent auditor.

> "The implementation of consistent, traceable and stable manufacturing processes becomes mandatory to safeguard and ensure the quality of the PV modules"

For this purpose, current market practices are the use of third-party inspector companies that verify that the MSA requirements are strictly followed during production and oversee the previously audited SOP and QMS procedures of the manufacturer. This basically covers control points such as: warehouse conditions, production orders (BOM verification), incoming material quality controls and every production step involved in the process (tabbing/stringing, lay-up, lamination, framing, junction box adhesion, curing, flash test process, etc.).

As it happens in any inline manufacturing process, not only in the PV industry, a series of defects (either of random or systematic nature) and non-conformities may arise during production, affecting the materials condition, the adequacy of the equipment maintenance and adjustment, the process traceability, etc. In consequence, a detailed third-party inspection is really useful for monitoring and correcting any potential deviation encountered during production, and especially in critical production steps like soldering, lamination, flash testing and packaging.

This inspection should be thoroughly coordinated with the manufacturer, in order to assist the operators and production engineers with the identification and fulfilment of the specific quality criteria and features of the supply under production, which might evidently differ from others simultaneously running, based on different MSA conditions.

An essential part of this oversight process is the so-called Pre-Shipment Inspection (PSI) testing, which aims at the determination of the pass or fail condition of the previously defined batch of modules. This has to be performed before shipment to the PV site, either at the manufacturer's facilities or in an ISO/IEC 17025 accredited laboratory managed by the inspector (both laboratories can even be involved). This testing task needs to be swiftly completed, almost in real time during production. For this purpose, the PSI must be based on a well-established module sampling, selecting a limited quantity of modules that represent the respective batch (the BOM is usually a variable included in the sampling equation).

The idea behind this key exercise is to get rapid and reliable knowledge about the main quality condition of the batches under production. The type and quantity of tests is not standardised by any international body and so it will always depend on the specific MSA conditions and PV project features. Therefore, the PSI testing is usually accomplished via straightforward measurements like visual and electroluminescence inspections, hotspot checking, electrical insulation-based tests or maximum power retest, as simple and fast methods to diagnose any major defect in a PV module. Moreover, if a sampling and testing plan is properly coordinated with the respective shipment dates, per batch, extended tests that address the propensity of the modules to certain degradation phenomena can be also conducted, even within a PSI batch context.

Especially valuable are tests for light-induced degradation (LID), applying short light soaking periods, and potential-induced degradation (PID), following, but not restricted to, the somewhat limited IEC TS 62804 guidelines. These tests, in spite of their inherent time-consuming nature, have been systematically implemented by Enertis Solar in many PSI procedures, leading to batch acceptance/

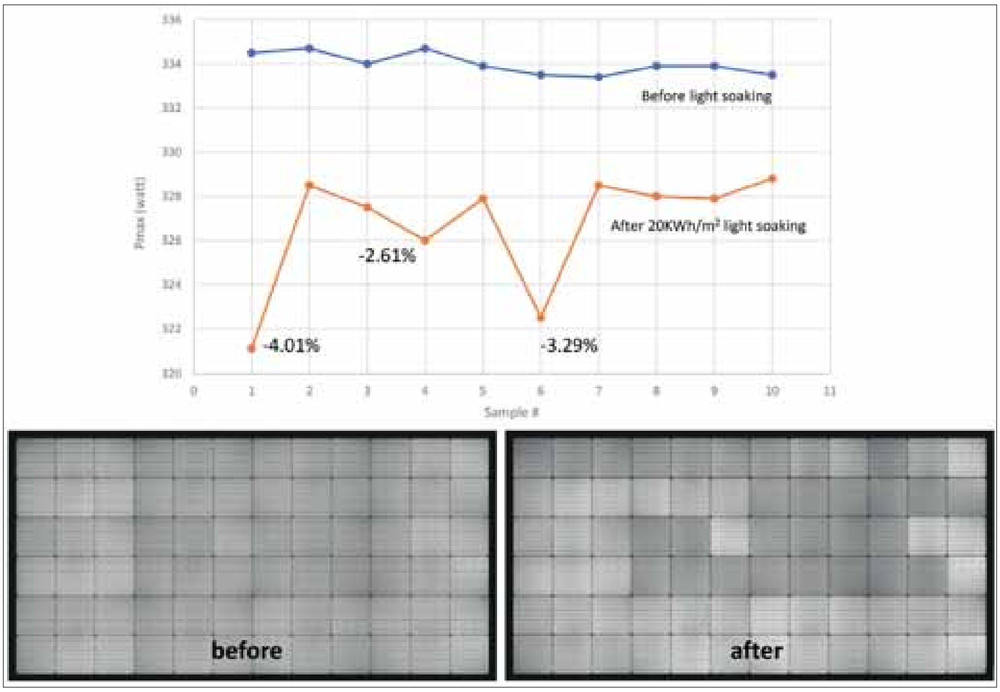


Figure 1. a) Maximum power flash test results before and after 20KWh/m², for a small sample of 72-cell multi-crystalline silicon PV modules from the same production batch. Up to 4% degradation can be evidenced, despite the short light soak period applied; b) electroluminescence images of a mono-PERC based module after an equivalent outdoor exposure period, resulting in 3.3% maximum power degradation. The images show a lower cell activity behaviour in some of the cells because of transient LID effects

rejection outcomes and/or change of BOM materials. LID behaviour, even after short outdoor exposures (20KWh/m2) in open circuit conditions, is quite variable, as it depends upon the individual characteristics of the solar wafers and cells forming the module, and so it is worth checking (Figure 1).

Regarding PID, as per Enertis Solar's experience, it is nowadays much better controlled by PV module and solar material suppliers. Still, many PV investors and developers consider PID as one of the most harmful degradation effects that a PV power plant can be affected by, and so they continue to request maximum warranties against it. In fact, the tacit 'PID-free' condition usually claimed in module datasheets is not well proven yet. Figure 2 collects a box-plot analysis with a series of PID stress tests involving new and randomly selected crystalline silicon PV modules, from several suppliers (BOM variable was not controlled, purposefully), all of them claimed to be PID-free. From the plot, it seems evident that, notwithstanding the promising low degradation values shown by most of the manufacturers (medians well below 5% degradation), the technical risk does remain latent, with severe outlier module degradations found in some cases (from 10 to 35+% degradations).

Many other testing approaches may be proposed and agreed with a manufacturer, with no necessary correlation to individual batch acceptance/rejection purposes, per se. Common examples are the temperature coefficients crosschecks, maximum power behaviour at various temperature-irradiance conditions or extended UV-resistance tests.

In conclusion, despite the unquestionably elevated know-how of most PV manufacturers worldwide, the current PV module market status is opening the way to the implementation of QAQC risk mitigation strategies at earlier phases of project development, so that maximum returns on investment can be ensured, especially when large-scale PV power plants are involved. ■

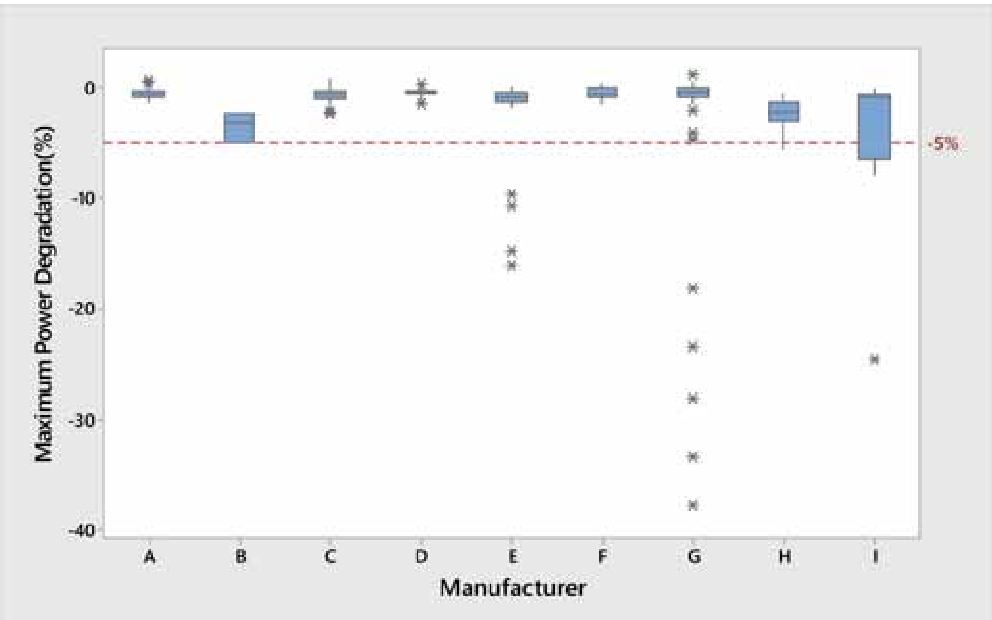
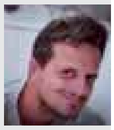


Figure 2. Box-plot analysis showing PID degradation results from some randomly selected PID-free modules manufactured by several Tier-1 suppliers. The basic IEC TS 62804 guidelines were applied, as a simple method to check the general propensity of a module to be affected by PID phenomenon

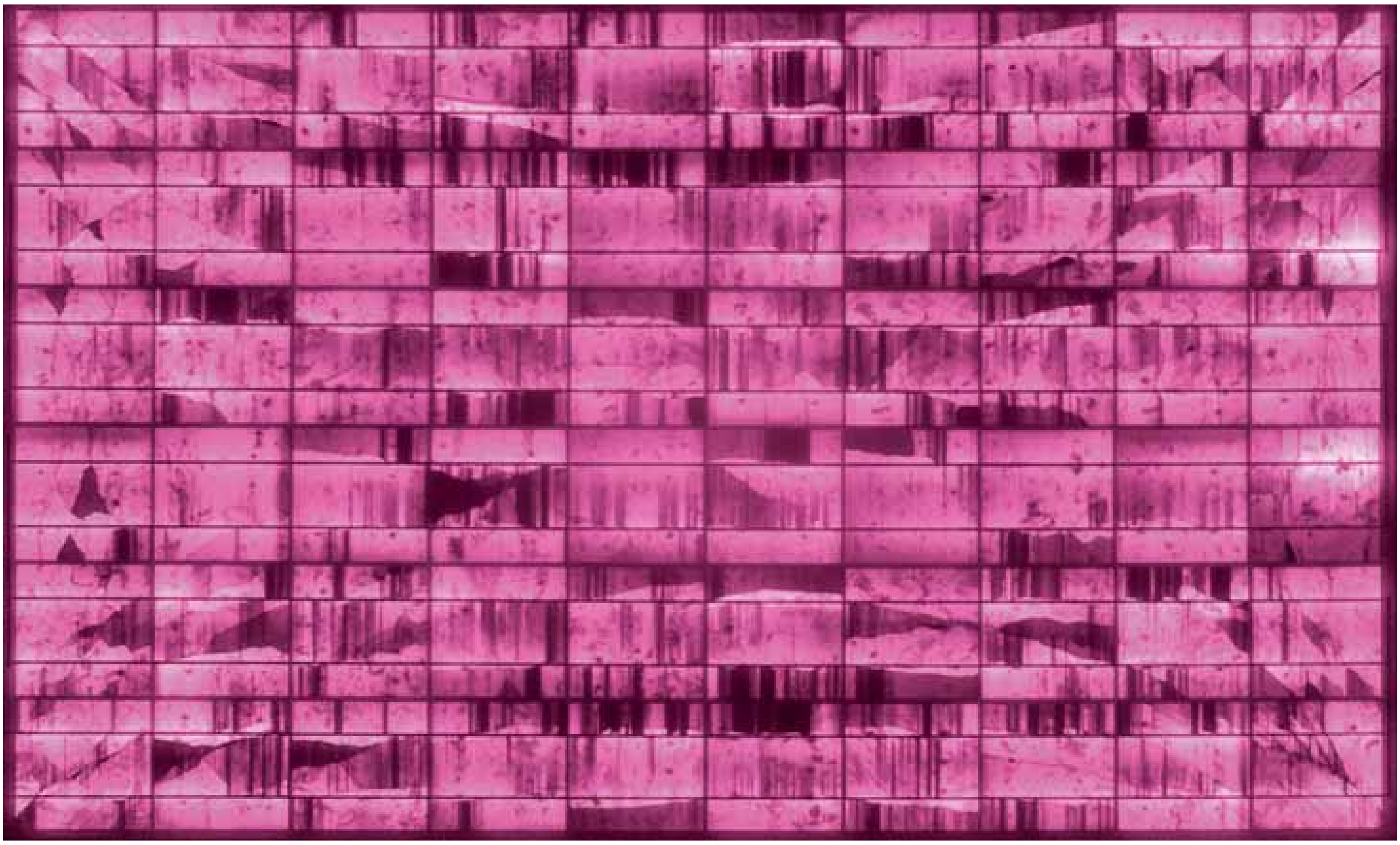
Authors



Dr Vicente Parra is the head of quality, innovation and technology at Enertis Solar. He has a 10-year track record in the PV industry, as technology manager in solar companies devoted to silicon ingots, wafers, cells and modules manufacturing. Vicente has managed testing projects dealing with 15,000+ PV modules, from nearly 50 suppliers and 200+ PV plants worldwide. Also, he has led many factory/production inspection and supply agreement advisory activities, totalling more than 3GWp so far.

Dr Ruperto Gómez is a process, manufacturing and technology senior engineer with a 16 years' experience in the PV and semiconductor industries. Ruperto has led several projects with international partnerships such as the start-up of new PV manufacturing lines in China, India, Mexico and Poland. With Enertis Solar, he has coordinated numerous on-site module testing projects using mobile laboratories. He is currently the operations manager of the quality and inspection activities developed by Enertis in Asia factories (over 3GWp track record).

Negotiating the pitfalls of PV warranties



Credit: PI Berlin

Module performance | The value of warranties attached to PV modules is coming under increasing scrutiny as plants age and more is understood about the degradation of modules in the field. Gustaf Schuler discusses the ins and outs of PV warranties and the best methods for mitigating risks

There has been much discussion in the solar industry about PV module warranties and their worth; certainly it is not simple to make a claim. Firstly it must be proved that the modules are not performing to their detailed specification, which involves myriad tests all with varying levels of accuracy. Armed with that information, the next hurdle is to decide against which company to make the claim: the manufacturer themselves, assuming that they are still in business, a third-part insurer or even the engineering, procurement and construction (EPC) contractor.

The basics of warranties

The modules themselves are certified, as are the inverters. The modules have quality standards and certificates that are supplied by the manufacturer, with every supplier having their own warranties consisting of two parts. One part is the material or product warranty pertaining to the module itself, typically valid for 10 years. This states that the module will be generally free from any material defect that might impact on its functionality. Then there is the performance warranty, which defines the maximum foreseen rate at which the module performance will degrade over time.

This performance warranty is in effect the supplier defining the potential maximum loss of power; it is usually not higher than 0.7% of nameplate power per year, plus up to 3.0% initial degradation over the first year. This would equate to a value of approximately 80% after 25 years, with a linear degradation from the end of year one up to that point. If a client were to approach RINA after 10 years in the belief that any given modules were not performing to the expected levels, these parameters would be used to calculate the minimum expected power, taking into account the initial degradation and subsequent year-to-year linear degradation. If the results were to support the client's belief of underperformance, then a warranty claim could be valid.

Identifying faulty or underperforming modules and seeking suitable recourse is a complex process

Aside from the manufacturer's warranty, there will also be a warranty from the EPC contractor, who is responsible for the design, purchasing, installation and commissioning of the facility. The EPC warranty covers the entire system for the first two years of operation, and during this time the EPC contractor should be the first point of contact for any warranty claims to be processed.

Maintenance

Although important to overall performance, regular maintenance is not a typical warranty requirement. From a purely technical perspective, modules should operate normally and achieve the expected levels of performance without the need for further maintenance. Most operators do, however, perform a certain degree of maintenance as the warranty would be invalidated in the case of improper handling and/or operation. For example, modules can develop hot spots as a direct cause of bird droppings, which could make it difficult to claim against the warranty.

Disappearing manufacturers

In terms of assessing a PV plant and its modules, it is very important to audit the module manufacturer and its level of market acceptance. Every three months Bloomberg release a list of 'Tier 1' module manufacturers based on module sales and financial stability. Whilst not taking technical parameters into consideration, modules on this list are being used for large, bank-financed PV projects, and should therefore offer some degree of reassurance. On the other hand, should a module not be included within this list, it may be an indication that further investigation and testing are required.

A major consideration is often the 'status' of the manufacturer. In recent years many suppliers have ceased operations, and this must be a concern. The market has consolidated, mainly due to tough competition from China, where the entire PV industry is heavily supported by the Chinese government, and such competition has forced other manufacturers from Europe and the United States out of the market.

Another common reason why some manufacturers have closed their doors is the decline in the price of the modules, which has led to them being unable to compete on the market. This industry-wide issue is not unusual and RINA does sometimes become involved in PV projects where the module supplier has exited the market.

As an operator or any other company looking to purchase an existing PV farm, there are several options to consider. Some, but not all manufacturers have a backup warranty meaning a third-party insurer may be willing to take on this risk, although claiming against third-party insurance is often an arduous task. It is therefore necessary to study each individual policy in detail, remembering that it has been specifically tailored to the client or project. In the event of a claim, the insurance company will consider the condition of the modules and make a decision based on this assessment. Even in the event of a successful claim, one issue often cited is the limited liability against a manufacturer. If a client is one of several claiming against the manufacturer, it is possible that the policy limit (for example US$10 million out of US$100 million) may have already been reached and the claim, whilst valid, will not be satisfied.

Flash and EL testing can be used to identify damaged or underperforming modules

Credit: Suncycle

Testing

To help mitigate this risk, RINA recommends undertaking a range of tests on a sample of modules from the farm. The first is a simple visual and thermal inspection of the modules in order to determine their condition. Although not definitive, such inspections can confirm the presence or otherwise of 'snail trails', eventual delamination of the layers and any discoloration or hot spots. Following this initial inspection there are various other tests that can usually be undertaken on site with a mobile testing laboratory. Flash testing and electroluminescence (EL) tests are the most common and, together with the visual and thermal inspection, will give a reasonably clear indication of the modules' condition.

For more sophisticated tests, or in areas where on site testing is not possible, a sample of modules can be sent to specialist testing facilities such as TÜV Rheinland, TÜV Sud or PI Berlin, able to perform further tests to simulate the ageing process of the modules. Test results can be compared to the modules' expected performance, and from that comparison a profile can be developed which will help assess the level of risk.

Flash tests

A flash tester is used to measure the output performance of a solar PV module, with results compared to the power output specifications of the module. During a flash test, the module is exposed to a short, bright flash of light from a solar simulator – a xenon-filled arc lamp with an irradiation of 1,000 W/m^2, as close as possible to the spectrum of the sun – at a temperature of 25°C and an air mass of 1.5. These parameters are referred to as Standard Test Conditions (STC). The testing parameters of the module are voltage and current at maximum power point (VMPP, IMPP), open circuit voltage (VOC), short circuit current (ISC) and the module maximum power output (PMAX).

Electroluminescence analysis

Electroluminescence testing will determine whether a module has microcracks or other defects which can lead to increased rates of degradation and are undetectable through a simple visual inspection. To carry out an EL analysis, current is fed into the solar cells and an electroluminescence image is captured by an infrared camera. In a fully functioning cell, current, and therefore light distribution, will be homogenous, so defects captured by the EL test show up as dark areas on the cells. The main advantage of this method is that it is quick and non-invasive, giving prominence to defects that would otherwise have gone unnoticed.

Testing in action

RINA was recently approached by a client interested in acquiring a solar plant within the UK. As some modules were showing significant levels of delamination and discolouration, the EPC contractor had approached TÜV to carry out an independent assessment of the modules' present operating performance and predict future degradation.

Considering the visual evidence of delamination and discoloration, test results were expected to confirm a drop in performance and/or increased degradation, but in fact showed performance levels to be in line with the module performance warranty.

The industry recognises the difficulties in measuring degradation, but small errors create doubt. A figure of 0.7% per year represents standard degradation, but flash tests allow for tolerances of ±3.0%. If testing measures the level of degradation at 0.8%, or even 1.0%, it will be difficult to make a claim for underperformance due to the accepted tolerances of the tests. In reality therefore, a significant level of underperformance is necessary before a claim on the warranty is considered, and such claims are rarely straightforward.

Ultimately the individual operator must take a view balancing the complexity and uncertainty of the warranties against the risk of module underperformance. In this case, RINA was not given a mandate to carry out further due diligence and testing to support the client with a potential claim either against the EPC contractor (as module supplier), or directly against the module manufacturer.

Snail trails and microcracks

The snail trail phenomenon drew the considerable attention of the industry, and scientists and researchers considered it a potential topic for research. A series of experiments including EL analysis and infrared measurements were conducted using EL cameras, optical and field-emission scanning electron microscopy and various other instruments. They compared the performance of defective PV modules with those performing according to expectations, and presented a completely new picture to the market. According to the results, snail trails were in fact a symptom rather than the disease itself, and do not directly affect the performance of the plant, but rather are evidence of underlying microcracks.

Microcracks can lead to higher degradation and a consequent reduction in performance. Such microcracks cannot be detected with the naked eye, however at times they do lead to snail trails which appear when moisture and other compounds gain access to the front of the module through cracks and cell edges, passing through the de-bonded areas between the encapsulation layer and the Si substrates to interact with the silver gridlines.

For this reason snail trails are usually not covered by the manufacturer's warranty. It is, however, recommended that their presence be reported to the module manufacturer and written confirmation be obtained ensuring that any microcracks the trails reveal will not have a negative impact on the module performance, and that all warranties will remain valid.

The value of warranties

Warranties may be significant when it comes to the perspective of a bank or financial institution, which require a reasonable amount of certainty and securities in place before it can grant the necessary funds to invest in a project, but from a technical perspective they hold little value. Of far greater importance would be a thorough plant or module inspection with comprehensive tests carried out on a representative sample of modules as defined by the ISO 2859-1 standard.

When our clients obtain a warranty RINA always recommends that it is site-specific, to ensure that the warranty is valid. Site-specific conditions such as proximity to the sea and the subsequent risk of salt corrosion, or the particular risks of floating PV installations, should be clearly covered to avoid unwanted surprises in case of warranty claims. It is also important that the warranty is properly transferred from the EPC contractor (who in most cases is procuring the modules for the project) to the owner or special purpose vehicle (SPV – a company specifically created to manage and build a given project).

In the example mentioned previously, the testing process was driven by the EPC contractor who, as the supplier of the modules, has the overall responsibility for the works until Final Acceptance, i.e. two years after Provisional Acceptance, and as such has every interest in demonstrating that the farm is fully operational. It is always advisable to engage an independent consultancy to lead this process, select the modules for testing (ensuring this is not limited to a specific batch), interpret results and write an unbiased assessment with further recommendations on how to proceed. In case of any warranty disputes, they can check on a claim, support setting it up and make sure the right documentation is in place.

Where to claim

In the case of microcracks, it is believed that the majority develop in cells due to poor handling, but they can be caused by a number of different factors and occur during production, transportation, or installation. It is important to know where the problems lie as these phases are covered by different entities. If the fault is found to originate during production or transportation, it will be the responsibility of the manufacturer, whereas a fault caused by the installation process is the responsibility of the EPC contractor.

Sometimes installers or plant operators walk on the modules and, whilst not causing any immediate visible damage to the glass (the modules are stable, and can support a person's weight), this can crack the underlying cells which are very thin and very fragile. If over time the modules develop cracks or snail trails, the operator would need to decide whether the claim should be made against the manufacturer or the EPC contractor, and it can often be difficult to prove that defects are attributable to one or the other.

Trying to ascertain the best approach to PV warranties can be a problematic process, but what is important is to fully understand the benefits and limitations of each individual policy while having a firm grasp on the physical condition of the PV plant itself. Armed with that information it is possible to define a strategy to fit any specific requirements. ■

Author

Gustaf Schuler is a senior consultant at RINA with 10 years' experience in project management and consultancy for energy projects. Over the last five years he has specialised in technical due diligence services for multi-MW solar PV projects, advising developers, EPC contractors and financing entities during development, construction and operation of projects in Europe, Australia and Africa. He has a German diploma in electrical engineering and a masters in renewable energy systems technology.

Back to the drawing board: US utility market rides the wave of change

Policy | Trade tariffs, technology changes, new suppliers and shifting timelines. US developers and EPCs are riding out challenging times. John Parnell looks at the scale of the upheaval and how module pricing and module technology changes are feeding into the day-to-day work of deploying megawatts

Credit: Conti Solar

The more things change, the more they stay the same. This works on a few different levels for the solar industry. The industry does tend to land back on its feet after the now routine rounds of subsidy cuts, regulatory hurdles and trade disputes come to an end, just in time for the next round. The state of constant flux does seem to feel like the modus operandi.

President Trump has proven to be an agent for change for the solar industry. Concerns over the future of the investment tax credit (ITC), the section 201 trade tariffs, steel tariffs, duties now being mulled on inverters, slashed corporation tax rates taking the wind out the sails of the tax credit market, foreign investment rules scuppering project sales…and we're only half-way through his first term.

The 30% safeguard tariffs on modules and cells started in February 2018 offering a degree of the certainty that was missing while the spectre of even harsher duties lingered.

Despite this, major developers were announcing projects delays and cancellations within months of the tariffs starting. GTM Research put the number at over 3GW. Cypress Creek alone said the tariffs had impacted 1.5GW of projects.

In May, China's authorities surprised most in the industry and moved to cap deployment triggering speculation over a period of oversupply. With a near endless string of capacity expansions announced in China some kind of intervention was perhaps less than surprising. Major Chinese manufacturers were bullish, happy that the resulting drop in price would grease the wheels of demand in other markets and make up for the shortfall at home. In the US, there was hope the price reductions would be passed along and offset the Section 201 tariffs.

"I read some articles where people were predicting that in the US you'd be seeing 30 cents a watt modules and it is nowhere near that but it has certainly come down," says Eric Millard, chef commercial officer at Conti Solar. "We saw a very big bump in pricing running up to the tariff and right after the tariff was announced, and that bump has been softening over the last several months. But we haven't seen a major reduction like I saw folks predicting."

The industry is continuing to install multi-GW levels of solar but the margins for some developers have been trimmed

Installation figures have suggested that the tariffs are having less of an impact on deployment than many feared but when you look deeper, even deployed MWs can create headaches for developers.

"We're still seeing a lot of projects getting built like they tend to be in states that have more attractive incentives," explains Millard. "But we're also seeing projects that are getting built with the developers still making money but taking a big haircut in order to get the project done. That's because they have certain deadlines they need to hit and if they miss those deadlines the project is worth substantially less, so it wouldn't be worth it for them to do that."

Many companies responded to the looming trade tariffs by stockpiling what equipment they could. Others moved project timelines. As an unintended consequence, those who acted on the Section 201 tariffs now can't benefit from the softening prices.

"With Chinese demand lessening we have seen the market price come down," says George Hershman, general manager for renewable energy at Swinerton. "It's been difficult to fully take advantage of it because projects had been delayed or scheduled to use other product. We'd already started making changes around

NORTH AMERICA SMART ENERGY WEEK

North America's premier gathering of energy professionals

More than 20,000 attendees and 750 exhibitors from 120 countries gather to discuss the future of energy - from policy, technology, business and more - to help transform the region's future. This is your opportunity network with key players in the North American market. Mark your calendars and join us at North America Smart Energy Week 2018.

POWERED BY

SEIA Solar Energy Industries Association®

Smart Electric Power Alliance

LEARN MORE at www.events.solar/smart-energy-week

SOLAR® POWER INTERNATIONAL

ES® ENERGY STORAGE INTERNATIONAL

SMART ENERGY MICROGRID MARKETPLACE

THE TECHNICAL SYMPOSIUM

module efficiencies and other things and it's tough for some of these utility segments to react fast enough. It's been a good sign but it hasn't been as immediate as we had hoped. We weren't able to suddenly turn projects back on."

Dan Yonkin, VP of asset and fund management at developer Sol Systems, says schedules are still shifting. Just a few days before participating in this article, Sol Systems was asked by an EPC partner to shift a project timeline further into 2019 so that modules could be imported after the tariffs had drop from 30 to 25% on 7 February 2019. He is sceptical about the driver of that module stockpiling.

"My impression was that it was being used as a sales technique by the sellers," suggests Yonkin. "Fast forward a year and you have to question whether that was actually the optimal strategy from the buyers' perspective to accumulate these modules at a higher cost than they are today. How are they going to burn through that capacity while maintaining a competitive advantage in their cost structure?"

High and low

While everyone is getting on with those issues, there's another change in terms of module procurement that is creating challenges – and opportunities – for EPCs in particular.

"We can now get high-efficiency modules for what we might have paid for low efficiency," says Swinerton's Hershman. "Everybody is looking at higher efficiency modules because we are seeing the delta between poly and mono or mono PERC close."

Conti's Millard says assessing the benefits of adding in that price premium for higher performing modules is something that needs to be done on a project by project basis but in states with a sufficiently high level of support or when the negotiated PPA price can support it, then the swap makes sense. A trend established in 2017.

"Last year we ended up using a lot of higher efficiency stuff and particularly in the first half of this year we're seeing lower wattage stuff went out on the economics. We'll see what happens in the next six months," says Millard.

Other variables are shifting in a direction that makes the numbers behind higher performing modules stack up. Hershman lists all the balance of plant costs that are on the rise – steel, fuel and labour chief among them.

"It's about getting more kWh on a smaller footprint," says Hershman. "For every module you don't install, you make a saving. You don't have the copper wire associated to that module, you don't have the labour cost associated to that module. Because that gap is getting closer between high and low-efficiency modules it becomes about land value savings. [Should] project sites get smaller so that you have less grading, for example, all those things come into play. They are coming down to commodity cost too, the glass and the aluminium, all that costs the same for either module. You're not really seeing the big, significant cost increase between the high and low."

"In the utility sector right now, over the last year, almost 100% of our work has been redesigned multiple times because of equipment challenges as we continue to chase what module type is best"

Back to the drawing board

Between the schedule of stepped tariff reductions introduced by the Section 201 tariffs and the shift in global module prices, developers and EPCs are having to be increasingly flexible. Often, this means overhauling planning and design work.

"I would say there have been a dozen smaller utility projects this year that we have had to go through a design review on with our contractors," says Yonkin. "Module availability has an immediate implication on the system. We've been on top of it since last year and we've been proactive about ensuring we didn't create issues for ourselves."

For Swinerton, one of the largest EPCs in the US market, that willingness to adapt to the seemingly ever-changing circumstances has become the new normal.

"In the utility sector right now, over the last year, almost 100% of our work has been redesigned multiple times because of equipment challenges as we continue to chase what module type [is best]. More now than ever we're redesigning on a fairly constant basis. It is taxing on project delivery and being able to get schedule certainty," says Hershman.

With the redesigning and the changing shape of the module pricing landscape, the door is opening for new suppliers and new technologies.

"The price drop is opening up the market for new players that are exploring different technologies with higher efficiencies. So yes, we've opened up our list of vendors and suppliers to bridge that gap for sure. I'm looking at more mono PERC and potentially more bifacial as we see that move into the market," says Hershman, noting that for now there remain issues about capturing the value of the additional yield.

"We have a lot of projects in the test phase and test data but we have got to turn that into a bankable return so that we can offset the cost of doing it. If you're not able to bank the return then it's going to be difficult. I think there will be a lot of projects that move forward next year that will start to build, because of players in the industry that are able to finance differently, and that will drive up bankability," he adds.

Domesticated

Announcements of impending capacity in the US itself, while welcome, won't contribute to the first 12 month period of the tariffs with the strongest 30% rates in play. Hanwha Q CELLS will start operation at its 1.6GW module assembly plant in Georgia in February 2019. In total, more than 2GW of new capacity should come online. The section 201 tariffs are not applied to the first 2.5GW of cell imports and this quota was used up very quickly this year. US import data seen by PV Tech shows imports of cells (not made up into modules) from China shot up by 400% in Q1 2018. The same figure for Vietnam was 1,200%. Malaysia was the biggest source (US$33 million) just ahead of the Philippines on US$22 million.

Millard, Yonkin and Hershman all said they had talked to the vendors involved in developing new US capacity but it was too early to discuss orders at this stage. In the case of Hanwha Q CELLS, the utility market needs to know what if anything will be produced for them.

The tariffs might look like they've been a success on paper, with GWs deployed and new factories announced, but the reality is that the industry is working harder than ever to juggle the changes and account for global technology and pricing trends at the same time. A less agile, resilient and resourceful industry might not have coped as well. Further evidence, if any were needed, of why the US administration should consider its solar sector to be an enormous asset. ■

The 'coming of age' of UK Solar

Post-subsidy solar | UK solar has defied a retraction of subsidies by finding ever more innovate routes to market. Liam Stoker analyses some of the most interesting business models to take hold as the UK emerges as a post-subsidy solar destination


Credit: Anesco

Subsidy-free solar projects such as Anesco's Clay Hill are becoming a more common phenomenon in the UK

The UK government's retraction and removal of solar subsidies has been a process now more than three years in the making. The Renewables Obligation, the UK's subsidy support for large-scale solar farms, was slammed shut and the technology remains locked out of competitive auctions. The small-scale feed-in tariff has been slowly wound down and will close in March 2019. And in a further blow, in mid-July 2018 the government confirmed its intent to shutter its export tariff for new renewables too.

There is also increasing uncertainty in the UK's legislative framework. Documents released by the government in mid-July outline a future vision of small-scale renewable generation in the country, but these have been derided as "frighteningly vague" and an 18-month delay in their publication, alongside a government fully bogged down in the quagmire of Brexit, mean that there is almost certainly going to be a post-subsidy policy gap.

All that could lead outsiders to conclude that the market was entering a dim hiatus.

But a picture of the UK solar market is emerging that proves that not to be the case. Trade associations in the country talk of a "coming of age" of UK solar, buoyed by continuing reductions in component prices of course, but more so through the emergence and adoption of business models that exemplify a level of maturity beyond the market's years.

And what's promising for the UK market is that this innovation is not limited to just one sub-sector. There is activity across both residential and commercial and industrial rooftops, and the multiple gigawatts of solar planning applications sitting not just with local councils, but with the country's national Planning Inspectorate (designated to handle applications for projects in excess of 50MW in size) indicate an appetite to get stuff done.

Council adoption

The reduction, and removal, of subsidies has undoubtedly made project economics harder to work, but solar in the UK has found potentially an ideal partner in councils and local authorities.

Whereas home owners have grumbled at IRRs below 8 or 9% and institutional investors are not exactly keen on fluctuating revenue streams that aren't backed by government-endorsed subsidies, other public bodies are able to be a little more lax in what they deem to be a financeable project. Coupled with a post-Paris desire to clean their act up, so to speak, and council leaders are looking with increasing interest at solar PV.

A prime example of this can be found in the Welsh capital of Cardiff. In June 2018 Cardiff City Council rubber stamped proposals to turn an old landfill site into a 7.5MW ground-mount solar farm at a cost of around £14.9 million (US$19.4 million).

The scheme itself is essentially split in half. The council has negotiated a power purchase agreement with a business located a stone's throw from the site which will see it procure power generated from 4.5MW of the project's capacity for a period of 20 years. The remaining 3MW worth of generated power will be exported to the national grid.

Once the PPA expires, and unless it is renewed, every last kWh of power will be exported for the remaining 15 years of the project's forecasted lifetime.

Cardiff councillor and cabinet member for clean streets and recycling Michael Michael explained that the projected income from the site could be "in excess of £21 million" over the 35 years, effectively securing more than £6 million of profit to bolster stretched council coffers.

Furthermore, the council has also opened up the possibility of installing electric vehicle chargers at the site to provide clean power for its fleet of EVs when they are brought into operation over the coming years. Whilst that hasn't been factored in to the business case just yet, Michael said it could potentially make the scheme "even more attractive to the council".

"In this instance, the business case shows that the council can reduce our carbon emissions and increase the production of renewable energy in Wales in line with Welsh government's requirements. It could also generate an income for the council from an otherwise difficult site to develop," Michael said.

The council had initially sought to turn the landfill site into a solar farm in 2010, leasing the land to a private developer. But the early closure of the country's Renewables Obligation programme kneecapped those plans in their infancy. Now, falling component prices and a more mature understanding of the business models that can be built around solar have breathed fresh life into public body appetite for PV.

The post-subsidy PPA

With the feed-in tariff (FiT) regime coming to an end in March 2019, concern may be rife within the UK solar industry as to whether or not the bankability of new installations will take a fatal hit once all subsidy is removed.

It should offer some reassurance then that Eden Sustainable, working alongside developer Oakapple Renewable Energy, has funded and completed what could be one of the first subsidy-free, high-profile commercial & industrial (C&I) installs, for League One football club, Doncaster Rovers.

Completed at the end of May, the install – adding to a 50kW FiT-supported array already in place – was intended to add 450kW to the stadium. However, after the grid offer was reduced, a new 177kWp solar array was settled on, taking the total solar capacity to 228kW on the south facing side of the roof.

Offering 100% self-consumption, the new array is predicated on a power purchase agreement with the football club, which will now pay a unit price of £0.085 (US$0.11) compared to the almost £0.11 (US$0.14) it was paying previously.

This was made possible by the low technology costs now prevalent in the market, according to Scott Burrows, director of Eden Group, who says systems could be installed for as little as £500 per kW.

The project was also made possible by the strength of the counterparties involved in the project. While Doncaster Rovers offered a stable off-taker for the PPA, as freeholder for the stadium Doncaster Borough Council provided exceptional covenant strength to support the project.

"The fact that the council is standing behind the lease with Doncaster Rovers is clearly fantastically bankable," Burrows says.

"That is going to be the focus for subsidy-free projects in the first instance from Q2 next year. We will have to revert back to where bankability is particularly important again for a period of time.

"I don't think it will be all that long but you will need to have a public sector counterparty, or effectively underwritten by a public sector organisation such as in education."

Even with these circumstances, in which blue chip companies are also a target despite bringing "their own challenges for C&I developers", Burrows remains confident that the post-subsidy world for solar is already here and, more importantly, can be a success.

"We want the investment community to look at this and see that it works," he says. "Our debt providers Close Brothers are happy with it, we're happy, and our equity backers are happy with it. We want other potential PPA off-takers to look at this and see that they can still save.

"Doncaster Rovers is going to save £1 million with some pretty standard assumptions of RPI and electricity price rises. That's £1 million at no capital cost for a League One football club, and that's really exciting. It works; take note."

Burrows also believes the success of this project, and those to come, offers a moment of reflection for the FiT regime. Despite the "political palavers" that have made up the subsidy's history, Burrows says the completion of subsidy-free projects like that for Doncaster Rovers shows FiTs have, all things considered, been a success.

"In the end we are getting to where we were always supposed to be and that gives me a real sense of warmth as an industry stalwart that it's worked. This really is proof of concept, [we can] replicate this and the reason why is the financial model works.

And so the message to industry that Burrows says should be taken from the project is simple: "Get out there and find some more installations."

Credit: Eden Sustainable

The new array on the Doncaster Rovers stadium is one of the first subsidy-free C&I arrays in the UK

The power of the collective

Another business model to have found success in other markets before resonating in the UK is the group-purchasing or reverse-auction model.

In essence, it's a relatively simple prospect. An entity sources a group of prospective customers before inviting installers to essentially bid for that business on an estimated cost-per-install basis. Through economies of scale and by all but removing the cost of sale, installation businesses can deliver quotes far cheaper than the market average.

Having witnessed success in the Netherlands, group purchasing scheme specialist iChoosr brought the concept to the UK market via the Mayor of London and the Greater London Authority. The maiden 'Solar Together London' scheme was launched in five of the capital's boroughs and received expressions of interest from some 4,000 households.

UK industry stalwart Solarcentury won the tender in partnership with retail giant IKEA, providing significant discounts in the process. By sourcing those efficiencies, a 10-panel rooftop solar system was offered to registered participants at an average cost of £3,210 (US$4,172), nearly £1,400 cheaper than the market average. Savings under the scheme ranged from 10-41%, with an average of 35%.

iChoosr has since taken the concept into some of London's neighbouring counties – Essex in particular, which has a population of more than 1.4 million people – and so taken with the scheme was the Mayor of London, Sadiq Khan, that a second round has been scheduled for later in 2018, taking in 12 of London's boroughs.

But Ruud Frijstein, solar project manager at iChoosr, says that the group purchasing schemes are a "completely different ball game" for installers and

The no-money-down storage offer

No-money-down offers for energy storage in the commercial & industrial (C&I) sector are nothing new globally, with solution providers tapping into the 'energy as a service' trend to provide and manage batteries on C&I premises.

But for the nascent market in the UK, this has only recently begun to move to the fore as technology costs decrease and the range of business models increases.

Take Omnio Energy, a spin-off from solar and storage developer British Solar Renewables (BSR), which offers 50kW storage installs free of charge to the "overlooked" SME sector.

No-money-down storage is a new prospect for UK C&I customers

Credit: Thrive Renewables

Meanwhile, others are thinking bigger, with the likes of Siemens Financial Services and partner GBSL offering larger behind-the-meter (BTM) solutions to manage and accrue revenue.

Such a model is proving to be too much to resist for a number of similar partnerships, such as that between investor Thrive Renewables and project developer Aura Power, which recently launched their own no-money-down offer for C&I customers.

The partnership targets businesses spending £500,000 a year or more on electricity with an offer to install batteries on site for free, ranging from 500kW up to potentially around 5MW.

Once installed, savings accrued from premium-cost peak energy charges will be combined with revenues from local and national grid services into a single pot to be shared between the joint venture – split equally between the companies – and the host business.

Aura Power director Simon Coulson explains: "Our approach is to maximise revenues, be it from savings or services… and because everyone is sharing from the same pot everyone's aligned."

Matthew Clayton, managing director of Thrive Renewables, adds: "We're showing commitment by making the capital expenditure but further than that we're demonstrating that we're all in this together by using that model."

The pair estimates that customers with a mid-range 2MW battery could save more than £1 million over a 15-year standard contract.

"We take the investment risk, manage the development and operate the battery to maximise mutual returns. We agree a contract with the customer, they can get on with their core business and save tens of thousands from year one," Coulson says.

Having previously funded or developed renewable generation sites, the two have made the move to behind-the-meter storage in the wake of subsidy cuts, but also to access the growing opportunities for revenue in this space from savings and grid services.

Clayton adds: "The attractive element of the business model is that it can be dynamic with those revenue streams and depending on which way policy goes and the frequency incentives go, we aim to be able to work with our hosts to make the best of the situation."

The partnership says it is already in advanced talks with several clients including a large dairy, a food processor and a tile manufacturer, and at the time of writing was nearing agreement with an aggregator to take on the grid services responsibilities of the portfolio.

They expect to make a 'modest' start over the next 18 months, deploying around 40MW of new BTM energy storage at up to 30 sites, depending on the scale of each project, which are expected to range from £1 million to £3 million investments.

as a result, require far more proficient business operations. For that reason, iChoosr conducts a range of due diligence processes and assesses all potential bidders on their financial health and their so-called 'method of approach' – a document submitted by the bidder describing in detail how exactly it would go about facilitating so many installs.

"To handle volume, your operations should be able to support that from every aspect, from consumer contact, to supply chains, survey procedures, IT... what we try to do is make installers aware of what they need to make this a success. That's one of the first steps, and if they become aware of that some might say it's not their key [skill set]," Frijstein says.

iChoosr's selection team awards points to each bidder at various stages of the process and each bidder must receive a certain number of points to qualify for the process. After the vetting process, companies submit their bids in a blind auction process and a winner is chosen – or winners, if the auction is suitably large and requires more than one company to complete the work.

Then it is very much down to the installer to convert the interested participants into solar home owners. "The success rate [of installers] depends upon the effort put into it and where the company is at the moment, because you could have a very solid company but if you don't put effort into the method of approach you won't get access to the auction," Frijstein adds.

Previous auctions have seen conversion rates of around 25%, however iChoosr expects London – with its difficult rooftops – to bring forward somewhere between 600 and 700 completed installs from its first round. If forthcoming schemes can produce similar results, they could provide much sought-after lifelines for residential installers beleaguered by what's left of the country's feed-in tariff.

Indian solar policy clear-up muddled by safeguard saga

Policy | The Indian solar juggernaut shows few signs of slowing down en route to its huge target of 100GW by 2022. But, as Tom Kenning, recent policy developments could create a few bumps in the road along the way

At the end of 2017, India announced plans to tender out 20-30GW of large-scale solar energy capacity every year, with its eyes firmly on Prime Minister Narendra Modi's 100GW by 2022 target. The idea was to blast away the cobwebs of stagnation through sheer ambition, regardless of any major issues plaguing the sector at that point in time. Indeed, tenders came out thick and fast, perfectly in line with government timelines in early 2018, but it took until the summer for the auctions to really start rolling. This was because there were still issues with a new countrywide sales tax and confusion at ports where PV modules from foreign suppliers were entering India, along with complete uncertainty over an anti-dumping investigation that had been dragging on for some time. The auction bonanza then hit its own, far larger snag when the Ministry of Finance suddenly announced a safeguard duty against cell and module imports from China, Malaysia and developed countries on 30 July 2018 (see boxout). The duty is sure to cause more confusion and debate over the coming weeks and months, particularly with a worrying trend of auction cancellations rearing its head.

This article seeks to clarify where India stands with each of these hindering laws and regulations at present, while also highlighting more progressive introductions such as the National Solar and Wind Hybrid Policy and their efficacy.

Goods and Services Tax

The industry was pained for several months by the Goods and Services Tax Bill (GST), introduced on 1 July 2017, as it awaited clarity on tax levels for different equipment. Eventually, modules would be taxed at 5%, while certain other equipment would be hit with levies of 18% or higher.

"Now, by and large there is clarity in terms of what is the level of GST applicable on individual pieces of equipment, modules, inverters, cables etc.," says Vinay Rustagi, managing director of consultancy firm Bridge to India. "The big issue is the lump-sum EPC contracts – do they qualify under the 5% GST regime or are they taxed at higher rates? And many different states are interpreting the GST order very differently and levying full GST of 18% on the lump-sum contracts, as against an expectation that the lump-sum contracts will attract a GST of only 5%."

For months, goods were also being held up at ports all over India due to confusion over a customs duty, however, the issue has now been resolved and Bridge to India has not heard of any related issues in the last month.

With GST and customs duty cleared in the spring, the solar sector looked forward to unfettered auctioning, only with the threat of a safeguard duty imposition lurking in the background.

Tender opportunities

Whatever short-term moments of stasis or confusion arise in the industry, there is a general sense that Modi and his government's vision of solar is so robust in the long term that players can step in for the long game with confidence. For example, Leandro Leviste, CEO of developer and manufacturer Solar Philippines, a company that plans to enter India by signing 500MW of solar PPAs this year, says that his company is willing to accept initially lower returns since it believes in India's massive long-term potential.

"The investment interest in the sector is very, very strong," adds Rustagi. "There are still many players both domestic and international who've got a very strong appetite for bidding large numbers for these projects."

This manifested itself in heavy oversubscription for tenders in the state of Odisha, and NTPC and SECI's multi-gigawatt, pan-India auctions prior to the safeguard duty imposition.

Credit: Government of Karnataka

The Pavagada solar park in Karnataka is expected to become the world's largest single PV project at an eventual 2GW

"Also bear in mind that while land acquisition, transmission and even fundraising is going to become more challenging given the increasing scale of these projects," says Rustagi. "Now the developers have got a much larger time period for implementation of 21-24 months as against 12 months. So, on the whole we don't see any cutback in developer interest. What we do see is the level of aggression in terms of tariffs to come down a little bit and we think it has already come down somewhat because module costs are now back to their historic lows or where they were about 1-1.5 year ago and the tariffs are still in the INR2.50-2.80 category and it's pretty unlikely that the tariffs will go down beyond these levels."

The Power Ministry recently amended solar power procurement rules, giving the likes of procurers SECI and NTPC the option to extend:

- land acquisition periods from seven to 12 months;
- financial closure periods from seven to 12 months from the date of execution of the PPA;
- project commissioning timeframes from 13 months to 21 months, from the date of execution of the PPA;

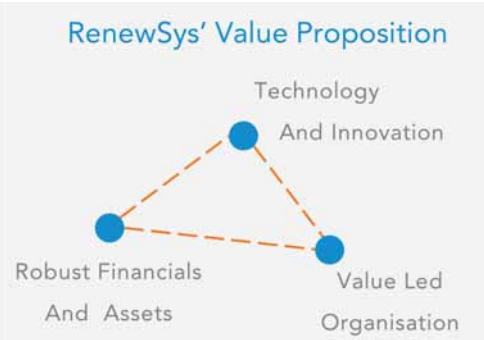
Our PV product quality is winning us partners for life...

380 Wp giving up to 500 Wp @32% Albedo

Mr. Avinash Hiranandani, Managing Director, RenewSys - India's leading solar PV manufacturer, shares his insights on the dynamic PV market and their strategic approach for sustained growth.

Module manufacturing is a competitive space right now. Why pick RenewSys?

RenewSys is the first integrated manufacturer of Solar PV Modules and its key components - Encapsulants, Backsheets and PV Cells. What sets us apart is our team and a vision - of being the first choice for quality PV Modules and its components worldwide.



We realise this on three fronts: -

1. **Technical Prowess** - RenewSys has set up dedicated Product Excellence Centres at our manufacturing facilities. These are the hubs of research, reliability testing, and new product development. **Two revolutionary new products are - India's only UL certified POE Encapsulant, Finalist - InterSolar PV Awards 2018 and DESERV Extreme - India's most efficient Solar PV Module.**

2. **ENPEE Group** - RenewSys is part of a 55+ year old, global conglomerate - ENPEE Group that has established a legacy of manufacturing excellence in fields as diverse as crown - caps, construction chemicals, and FMCG products. It lends **financial support and stability** to RenewSys.

3. **Value Led Organisation** - Most importantly, we are led by values that ensure fair, honest and reliable partnerships. These support the holistic growth of all our partners. This is secret of our sustained growth.

You mentioned DESERV Extreme, could you tell us about this in detail?

DESERV Extreme heralds a revolution as India's most efficient Solar PV Module. Engineered at our Hyderabad facility, it delivers a front face output of 380 Wp and total output as high as 500+ Wp when the Albedo is above 30%.

The Bi - Facial nature of this PV Module enables it to generate power from both sides/ faces. This increases its efficiency. Land is a limited, scarce resource and hence efficiency will be a crucial determinant for the growth of the solar.

DESERV Extreme combines Bi - Facial, Mono PERC and Cut Cell technologies with India's only Transparent Fluoro Backsheet, developed especially for use in this Glass - Backsheet PV Module. It is IEC compliant and has undergone the same rigorous testing that all our modules undergo.

Innovations are great to hear about, but reliability is a key concern. What are you doing to ensure that your solar panels last for 25 years?

Our PV product quality is winning us partners for life. Innovation is certainly at its heart. Replicability of performance and reliability are equally important. These hinge on PV component calibre, manufacturing equipment quality, & systems and processes.

We leverage our expertise in **PV component manufacturing** to develop Encapsulants, Backsheets and PV Cells that suit the demands of varied, extreme environments. These components are tested both independently and after incorporating them in PV Modules, at the Reliability Testing labs, and finally at the captive solar power plants, located at our facilities.

Our manufacturing 'systems and processes' create a symphony between best in class machinery, components and a robust talent pool to deliver world - class PV Modules. To doubly ascertain consistent quality, PV Modules are subjected to routine, random sampling from each batch.

With offices across India, Mauritius, Nigeria, South Africa, Singapore, UAE, UK, representative offices in USA and countries in Europe, our customer base is truly global.

An in-house 'Reliability Lab' - at par with global third party certifying labs - tests modules for 2 - 2.5 times IEC Certification requirements. It consists of 7 climate chambers, that test for varying and extreme conditions like prolonged dry heat, and cold. These measures in tandem ensure that our PV Modules exceed expectations.

What are your expansion plans for RenewSys?

We had doubled our module manufacturing capacity from 150 MW to 300 MW last year. Based on demand and a growing customer base we are expanding to 700 MW this year and to 1+ GW immediately thereafter.

We manufacture and export our range of our Encapsulants (EVA and POE) (1.2 GW), Backsheets (3 GW) and PV Cells (130 MW). Consistent, reliable product performance and a host of future ready products like POE Encapsulant, PID Resistant Encapsulant and 1500 Vdc and Metallic Backsheets have helped us cement our position despite fierce competition and price volatility.

RenewSys India Pvt. Ltd. is the first integrated manufacturer of Solar PV Modules (300 MW; expanding to 700 MW by Dec. 2018), and its key components - Encapsulants - EVA and POE (1.2 GW), Backsheets (3 GW), and Solar PV Cells (130 MW). **www.renewsysworld.com | renewsys@renewsysindia.com**

RenewSys®
let there be light

- projects of >250MW capacity commissioning timeframes from 15 months to 24 months, from the date of execution of the PPA.

The sheer number of tenders also means that developers who don't win projects one day can be sure to have a crack at another auction after only a short wait, adds Rustagi.

Developers had lobbied NTPC to change the rules of its 2GW auction as they claimed the maximum allocation available to any single player was so big that it favoured the biggest and most financially powerful bidders who could take the risk of economies of scale and bid for the whole amount. It was somewhat surprising to the industry then that NTPC's 2GW auction saw Japanese giant Softbank walk away with just 600MW having bid at 2.60 rupees per unit, just higher than the three other winners Acme Solar, Azure Power and Shapoorji Pallonji who bid at 2.59 rupees.

When asked if there is now room for smaller developers to come back into the market, Rustagi says that the ever increasing project sizes are seeing some consolidation within the industry and it's only the larger developers with the experience, the funding capability etc. who will play the lead role going forward.

"So we do expect that the smaller developers will continue to be edged out of the market because they simply can't compete versus the bigger developers, and the project sizes are getting larger as well," he adds.

There were some worrying signs even before the safeguard duty came in, however, with SECI cancelling 2.4GW out of its 3GW auction citing the tariffs as being too high, while Uttar Pradesh (1GW) and Gujarat (500MW) cancelled their auctions of late for the same reason.

Credit: Indosolar

The Indian government has sought to link project tendering with manufacturing capabilities

Tying up with down

One of the most impactful ideas touted by the Indian government is its unusual plan to link all future tenders for solar deployment with manufacturing capacity. It would mean all developers would no longer be able to think exclusively in downstream terms and would have to either start upstream manufacturing operations or – more likely – enter a joint venture with an established manufacturer, whether a foreign or domestic firm.

There are two issues with this plan that have already surfaced in the first attempt at such a tender. A 5GW manufacturing/10GW solar deployment tender (minimum project bid for 1GW manufacturing/2GW solar) was floated in late spring 2018.

In a briefing note, Bridge to India stated: "We believe that few players have the willingness and capacity to participate in a tender of this scale/complexity. Combined capital cost of a 1GW manufacturing line and 2GW projects is estimated in excess of INR110 billion (US$1.6 billion). Minimum net worth requirement for bidders is INR20.4 billion (US$300 million). Our list of potential candidates is limited to ReNew, Adani, Softbank and Tata Power."

Secondly, SECI is reported to have toyed with the idea of reducing the manufacturing component back down to 3GW instead of 5GW to make the proposition more attractive. It may come as some comfort to developers that most analysts believe that the 10GW solar was there to be tendered in any case – whether tied to manufacturing or not – so the amount of solar being tendered should not to be critically affected by the success or failure of any attempts to tie in manufacturing.

Solar parks

Aside from the odd state tender, the bulk of tendered capacity in 2018 and for the coming year will be for projects outside solar parks. Even though MNRE sanctioned the Solar Parks scheme to be increased from 20GW to 40GW, it has now extended the implementation period from 2019-20 to 2021-22. This is partly due to land acquisition issues and an overall lack of power demand compared to expectations in certain states. Developers must now focus on pan-India tenders with PV to be connected to the Interstate transmission system (ISTS).

O&M/EPC opportunities

New opportunities on the engineering, procurement and construction (EPC) side are also narrowed by the fact that larger India-based firms are increasingly bringing all the EPC work in house and Rustagi thinks this a trend that is unlikely to change. However, there is one caveat in that there has already been a bunching up of tenders, and developers that win large amounts of capacity may simply not have enough capacity for execution. This would then open the doors for outsiders to come in and perform EPC services. Acme Solar for example has racked up more than 2GW worth of capacity awards in the last two months, although, when asked, Shashi Shekhar, vice chairman, Acme Group, does not say whether his company will need outside help.

Hybrid push

In May, MNRE released its 'National Wind-Solar Hybrid Policy' seeking to encourage hybridisation of projects due to the benefits they offer for grid integration. Hybrid systems involve solar PV systems and wind turbine generators being configured at the same point of connection. In order to be classed as 'hybrid', the rated power capacity of one source of energy must be at least 25% of the rated power capacity of the other resource.

Supported by

Valued Partner

NEDO

UBM

Renewable Energy India Expo

A UBM Event

18-20 SEPTEMBER, 2018
India Expo Centre, Greater Noida

Your most powerful source of limitless energy.

Solar | Wind | Energy Storage | E-Mobility | Bio Energy

12th REI EXPO

The forthcoming edition of REI Expo is expected to attract over 800 Exhibitors, 35000+ Trade Visitors, 1200 Delegates and 10 Country Pavilions from across the globe.

Pavilions by:- EU| IGCC-IGEF | NEDO | TAITRA | BASQUE PROVINCE | ISA | IBA

KEY FEATURES

- Conference Sessions
- Business Matching
- Skill Competition
- CEO Conclave
- SERIS Industry Day
- Bio Energy Pavilion
- Pavilion for Sunrisers
- Workshop by TFE Consulting GmbH
- Matchmaking Pavilion & Technical Seminar by European Union
- Indo-German Energy Symposium
- Finance Leadership Forum
- Quality Roundtable by pv magazine
- Future PV Roundtable by pv magazine
- World of Innovation
- Participation by International Solar Alliance (ISA)
- 20,000+ sq. mtrs. Net display area
- Participation from 40+ Countries
- 35,000+ Trade Visitors
- 800+ Exhibitors
- Multiple Workshops
- Master class by WBCSD

PARTNERS 2018

Solar Turnkey Solutions Partner: RAYS POWER INFRA
Badge Partner: WAAREE One with the Sun
Lanyard Partner: vikramsolar
Silver Partner: sunsure
Techwall Partner: adani
Industry Networking Partner (Day 1): ZNSHINESOLAR
Premier Solar Partner: orb energy
Site Plan Partner & Mascot Partner: SUNGROW
Inverter Partner: HUAWEI
Premium Solar Module Partner: EMMVEE
Solar Module Partner: JinKO Solar
Module Technology Partner: swelect
VIP Lounge Partner: DSM
Conference Delegate Bag partner: 中来股份 JOLYWOOD
Solar Equipment Partner: APPLIED MATERIALS
OOH Partner: CanadianSolar
VIP Invite Partner: RADITE GROUP
Lucky Draw Partner: KOSOL ENERGIE, SOLEX, phocos, SUNTER ZHONGHUAN SUNTER
Water Bottle Partner and Mascot Partner: solis inverters
Roadshow Partner: HERO FUTURE ENERGIES planet positive power
Province Partner: EUSKADI BASQUE COUNTRY
Conference Session Partner: DNV·GL, PREMIER SOLAR
Shuttle Partner: MERSEN Expertise, our source of energy
REmobility Partner: wbcsd
Solar Partner: BRIDGE TO INDIA

Onsite Branding Partners: JA SOLAR, Oriano Your Solar EPC Partner, JinKO Solar, Arctech Solar, SUNGROW, LONGi Solar, DELTA, HUAWEI, SERAPHIM, MERSEN, KEHUA TECH, TW SOLAR, harsha abakus solar, TAIYANGNEWS

TO KNOW MORE, CONTACT

ATTEND CONFERENCE | BOOK YOUR SPACE NOW! | VISIT THE SHOW

Media Partner: PVTECH

Bhagwan Dhuldhule
M: +91 99307 78254
E: reconference-India@ubm.com

Julian Thomas
M: +91 9940459444
E: julian.thomas@ubm.com

Pankaj Sharma
M: +91 99713 65776
E: pankaj.sharma@ubm.com

www.renewableenergyindiaexpo.com

Moreover, any form of energy storage can be added to such projects.

Hyderabad-headquartered firm Greenko Energies has received state government approval for a huge renewable energy project involving 1GW of solar, 550MW of wind and 1.2GW of pumped energy storage in the Indian state of Andhra Pradesh, while SECI has a tender out for a 160MW solar-wind-battery project in the same state and a 2.5GW tender out for hybrid projects across India.

Testing standards

While India's attempts to bring in new quality standards came under fire for not being any more stringent than already well-recognised global standards, they are also burdensome for developers, not just manufacturers.

"Obviously they affect everybody because all modules sold need to reach the specifications of the standard, and even today there are not enough testing labs in India and MNRE has been extending the deadlines on a piecemeal basis," says Rustagi. "That again doesn't give any clarity to the market, so the issue is not just for the module makers, it is for all equipment makers and it is for developers who are hoping to buy this equipment. It's hard to see how the situation will improve even in the next one year."

Conclusion

When India announced its 100GW by 2022 target, many laughed at the idea, but its progress has astonished bystanders. The market – now settled in the top three of the world – is close to full maturation. The safeguard duty saga will certainly make further progress bumpy, but most consider it a short-term challenge. Utility-scale solar is here to stay, in any case, but its trajectory hinges on how the government goes about trying to appease both the solar developers and its domestic manufacturing lobby, and whether that materialises in several manufacturing-linked solar tenders or even a future anti-dumping duty.

India's National Energy Storage Mission (NESM) sadly focuses almost entirely on batteries for electric vehicles (EVs) but the hybrid solar and wind opportunities could be a strong outlet for this fledgling sector.

With all this in mind, the issue of quality still has to be raised when discussing India. Has the frenzy to drive down costs and get a foot in the market with little or no margin created a sustainable industry?

After visiting six solar projects in various Indian states, PV consultancy PI Berlin, which has opened a subsidiary based in Delhi, issued a report highlighting serious safety concerns, poor installation practices and system output monitoring as well as a worrying lack of warranties. It found faulty electrical joints, delamination and cracked cells, much of this stemming from the installation process. Ultimately, to draw suitable rates of return from PV projects, the focus must not only be on navigating the minefield of policy changes, but also on taking steps to ensure the use of high-quality components with proper assurance processes in place. ■

Safeguard duty

At the time of writing, India's Ministry of Finance had tried to impose a 25% safeguard duty on imports of solar cells and modules from Malaysia, China and developed countries starting on 30 July, but it has now temporarily deferred the duty.

The backtracking came following direction from the Odisha High Court, which had issued a stay on the safeguard duty imposition prior to the ministry's announcement. While uncertainty on the issue is likely to remain for some time, it can be assumed that the duty will come fully into force again in the near future.

Once imposed, the 25% duty will run for one year, then reduce to 20% for a six-month period and to 15% for the final six-month period.

The Indian solar industry currently sources more than 90% of its cells and modules from China and Malaysia, so the duty has major ramifications for the sector.

Concerns include the threat of rising tariffs, the appetite of utilities to buy more expensive power (there is already a trend of auction cancellations due to high tariffs), the possibility of circumvention of the tariffs though other Southeast Asian countries (Vietnam, Thailand, the Philippines and Indonesia) and the duties not being high or long enough to actually support domestic manufacturing.

"We are pleased that something at last has been done and uncertainty has been removed," says Rakesh Tiwari, CFO, Mundra Solar, a unit of Indian conglomerate Adani, and a member of the Indian Solar Manufacturing Association (ISMA). "Now solar manufacturers and developers can both go back to their drawing board and work accordingly."

However, given a Parliamentary Committee report revealing that 200,000 jobs in India had been lost as a result of the country's reliance on cheaper solar imports from China and other countries, Adani had been expecting a higher tariff imposition.

For developers, the greatest concern is the effect of the duty on projects that are already under construction or bid out.

Indeed Sunil Jain, CEO of Indian developer Hero Future Energies, says that developers had met with the MNRE secretary Anand Kumar, who had said ongoing projects would be given a pass-through option to avoid bearing the costs of the duty. However, there is still uncertainty and Jain says that even with a pass-through, how to implement it will be another problem. For example, many companies are still waiting for a pass-through on the Goods and Services Tax (GST) more than a year after its implementation.

"Obviously this has put a number of projects which are half constructed or 75% constructed into a situation of uncertainty," says Shashi Shekhar, vice chairman, Acme Group.

Acme expects its 2.44 rupee solar tariffs to go up to 3.01 rupees (up 60-70 paisa) as a result of the safeguard duty, while Bridge to India has itself estimated a 25% duty is equal to around a 40-50 paisa impact on tariffs.

A safeguard duty on certain cell and module imports into India has been temporarily deferred

ENERGY TAIWAN

台湾国际智慧能源周

19-21 SEPT. 2018

2018年9月19日至21日

The most competent procurement platform for renewable energy in Taiwan!

全台湾最专业的可再生能源盛会

Taipei Nangang Exhibition Center, Hall 1

台北南港展览馆1馆

Feature Exhibition
展览规划

PV Taiwan
台湾国际太阳光电展

Wind Energy Taiwan
台湾国际风力能源展

HFC Taiwan
台湾国际氢能与燃料电池展

Smart Storage Taiwan
台湾国际智慧储能应用展

Visit us at
展会网站 www.pvtaiwan.com

Contact:
展商及观众服务窗口
energy@taitra.org.tw
gwu@semi.org

TAITRA semi

Emerging market briefing

Ben Willis look at the latest developments in some of the most promising emerging PV markets worldwide. This issue features Ukraine, Zambia and Ethiopia

Zambia looks to fulfil solar potential

On paper, Zambia is sub-Saharan Africa's most promising solar market-in-waiting. The southern African nation has become the de facto test-bed for Scaling Solar, the flagship PV support programme of the International Finance Corporation, part of the World Bank group.

Scaling Solar is an initiative designed to help governments, initially in Africa, quickly procure lagre-scale solar projects using private finance. So far, it has made a notable impact on the pipeline of utility solar projects lining up in the region, without, as yet, any megawatts actually being installed.

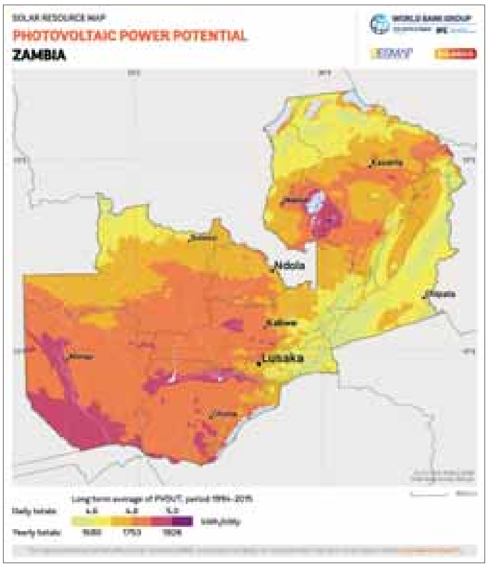
In Zambia, an initial round of Scaling Solar tendering in 2016 resulted in contracts being awarded to two projects of 47.5MW and 28MW, both at record low prices for the region.

This year, those projects edged nearer to hitting the ground. In February Neoen, the French developer spearheading the larger of the two projects, hired Indian EPC firm Sterling & Wilson as its EPC contractor, having reached financial close on it at the end of 2017. Local media recently reported that the project is due for completion this September.

Italian developer Enel's project, Ngonye, has been slower to get to the spade-ready stage, with the company still in the process of lining up finance for the plant. In June this year it announced a financing deal totalling US$34 million with the IFC, Canadian government and European Investment Bank.

Meanwhile, a second procurement round under the Zambian Scaling Solar programme is moving ahead. This will be worth a larger 500MW, with the first 200MW of this already out to tender.

Separately, the Zambian government in association with German development bank KfW earlier this year launched the pre-qualification process for a 100MW tender under its 'GET FiT' programme. In December 2017, GET FiT Zambia became the official implementation programme for the Zambian Renewable Energy Feed-in Tariff (REFiT) Strategy, which was formally launched by the Ministry of Energy in October 2017. The GET FiT model has been applied successfully in Uganda, delivering around 170MW of projects.



Credit: Solargis

Zambia looks set to see its first utility solar projects reach completion

Proposals for some 41 projects from 24 individual developers were submitted in response to the Zambia programme. A shortlist of bidders was revealed in June, featuring some of the big international names such as Scatec Solar, Enel Green Power, EDF Energies Nouvelles and Engie Afrique. The process will now move to a 'request for proposals' phase, with shortlisted companies invited to submit proposals for up to two projects of <20MW each. From this, at least five projects will be selected for implementation.

Ethiopia eyes solar to plug energy gap

Another country benefiting from the Scaling Solar programme is Ethiopia. The East African nation has been associated with a number of large solar project proposals over the years but has little by way of installed capacity to show for the hype. Hydro currently serves around 70% of Ethiopia's needs, but the country still has a generation shortfall of around 500MW, according to the IFC.

Solar looks set to play a key role in plugging that gap, and a several large projects from serious players are now in the works.

Two of these will come from the 250MW first round of Ethiopia's Scaling Solar programme. This took its first big step forward earlier this year when the state-run utility Ethiopian Electric Power (EEP) announced a list of pre-qualified bidders to submit formal proposals for the two 125MWAC projects planned under the venture. The winning projects will be chosen largely on the on the basis of the lowest proposed tariff.

The 12 shortlisted developers are: Access Power/Total Eren Consortium, Acciona/Swicorp Consortium, Actis/Mulilo Consortium, Acwa Power, Al-Nowais/Aldwych/Alten Consortium, EDF/Masdar Consortium, Enel Green Power, FRV/Globeleq/Belayab Consortium, KoSPCo/KEPCO Consortium, Mitsui, Nareva/Adani Consortium and Scatec Solar.

Overall, the IFC is advising Ethiopia on the development of up to 500MW of solar, suggesting a second Scaling Solar procurement round is likely.

Separate to this, EEP is running a tender for another 100MWAC utility solar plant and earlier this year selected a consortium including Italy's Enel Green Power and Ethiopian infrastructure company Orchid Business Group to take the project forward.

The firms, which will invest around US$120 million in the project, will develop, build and operate the PV capacity in Metehara, in the Oromia region, nearly 200 kilometres east of Addis Ababa.

Multiconsult, the firm responsible for the environmental and social impact assessment for the Metahara PV power plant, has said that it will be spread across 250 hectares of undeveloped land beside the main road between Addis Ababa and neighbouring Djibouti.

EEP invited proposals in May 2016, before five firms were shortlisted for the technical and financial proposal stage. These included Fotowatio Renewable Ventures (FRV), Meridiam-Solairedirect Consortium, Enel Green Power, The Building Energy Consortium, and CCE Oasis Technology Corporation.

The Metehara plant is expected to enter into operation in 2019 in order to generate roughly 280GWh of electricity per year. The solar park has a 20-year power purchase agreement (PPA) with EEP for all of the energy generated.


GCL
Bringing Green Power to Life
GCL ALL-STAR FAMILIES
-Jupiter- | -Saturn- | -Mars- | -Mercury-
en.gclsi.com
GCL S.I. is part of GCL Group. Based on a fully-integrated Vertical PV industrial chain capacity operation, GCL S.I. delivers a one stop, cutting-edge, integrated energy system solution package which incorporates DESIGN-PRODUCT-SERVICE.
E-mail:gcisisales@gclsi.com

Ukraine's second coming

Ukraine could be more accurately described as a 're-emerging' than an 'emerging' solar market. Until political turmoil engulfed the country in late 2013, Ukraine was one of Eastern Europe's most promising new solar markets, with a generous feed-in tariff driving a healthy development pipeline and some significant projects reaching completion. Then crisis struck – president Viktor Yanukovych was ousted, unrest enveloped the country and Russia annexed the Crimea region, home to many of the country's largest operation PV power plants.

The succession of crises all but brought the country's PV industry grinding to a halt. One developer, Activ Solar, was particularly badly hit, ultimately losing the multiple hundreds of megawatts it had built in the Crimea and later filing for insolvency. But recent months have seen the green shoots of recovery, with a string of announcements suggesting that Ukraine is on the up again.

The torch-bearer has been Norway's Scatec Solar, a specialist in developing projects in new or emerging markets. In July the company announced a partnership with local firm Rengy Development to build three projects in Ukraine totalling 47MW.

These came hot on the heels of two other Ukraine projects the company announced earlier in the year of 33 and 50MW. These will be built in the country's Cherkassy region and have qualified for financial support from the European Bank of Reconstruction and Development. All five projects Scatec Solar is developing in Ukraine fall under the country's feed-in tariff, and CEO Raymond Carlsen said the company was looking to build a sizeable portfolio in the Eastern European nation.

Aside from Scatec's efforts, Ukraine continues to see activity on a number of other fronts. Earlier this year, Chinese PV manufacturer Seraphim Solar revealed that it had won a deal to supply modules to what it billed as Ukraine's largest PV project to date, a 246MW plant being developed by Ukrainian energy group, DTEK. The project will be built in Dnepropetrovsk, central Ukraine. Meanwhile, a steady trickle of project announcements have come out of Ukraine this year, including a 19MW project by Danish developer Better Energy and Nordic finance corporation NEFCO.

However, on one of the more eye-catching project stories of the past couple of years there appears to have been little further progress. In 2016, GCL System Integration, a subsidiary of the eponymous Chinese polysilicon giant, announced plans to build a vast 1GW project on land inside the exclusion zone around the erstwhile Chernobyl nuclear power station, the site of the notorious 1986 disaster. Despite a flurry of headlines at the time, there has been little evidence since of further progress on the project.

However, earlier this year Germany's Enerparc and local firm Rodina Energy Group succeeded in commissioning a 1MW PV power plant next to the defunct reactor, the first of up to 100MW the two partners hope to build in the area. The plan forms part of a wider objective by Ukrainian authorities to bring back into productive use the contaminated land around the old nuclear plant, which cannot be farmed or inhabited.

One of the utility solar plants built in Crimea before its annexation by Russia

Credit: Activ Solar

Inside community solar, America's star performer

Finance and regulation | Community solar is the fastest growing segment in the US. Ben Willis looks at some of the legal and financing drivers helping propel the sector forward, and the ongoing challenges it faces in fulfilling its potential

Credit: William Byers/USDOE

Community solar is rapidly becoming a serious player in the United States. Until comparatively recently, community or 'shared' solar, which allows residential and business customers unable to install solar on-site to access its benefits, was little more than a bit player – a nice idea that had yet to fully catch fire. According to the latest figures from the Smart Electric Power Association (SEPA), the spark now appears to have been well and truly ignited, with community solar reckoned to be the fastest growing solar segment in 2017, outstripping the overall growth rate of the US solar market nearly twofold at 112%. Estimates put the total installed capacity of community solar in the US now at a little over 1GW.

Many factors feed into community solar's recent advances, but at a fundamental level, the key driver is simply a growing market demand for the benefits solar offer among groups previously unable to access them.

"Clean generation, no-carbon electricity – that's the number one driver," says Dan Chwastyk, SEPA's community solar programme manager. "People are concerned about the environment, concerned about future generations and want to do the most they can to reduce the carbon emissions in their area.

"Secondly, solar because the sun doesn't cost anything: it offers the potential for there to be some kind of long-term financial savings, and so for people who want to potentially hedge against the chance that traditional energy generation [prices] will increase, solar provides an interesting opportunity for them to lock in a price right away and not worry about fluctuations in gas or oil markets."

Many shapes and sizes

Against this backdrop of growing public appetite for solar and its many advantages, state legislators appear to be increasingly willing to respond by implementing legislation that provides the regulatory framework for community solar to flourish. Not all community solar projects in the US are happening in the context of state-level community solar policies, but the fact that some of the most of the most active community solar states also have shared solar policies (currently 19 states plus Washington DC) is a good indication that this is proving to be an important stimulus for the sector.

According to Jeff Cramer, executive director of the Coalition for Community Solar Access (CCSA), the legislation being passed to help community solar flourish varies widely.

"Sometimes these pieces of legislation are highly prescriptive, sometimes they're very basic and sometimes they're in between," Cramer explains. "So for example the Minnesota programme legislation, I think the bill is one page and it just basically says any customer should be able to buy community solar, anyone should be able to develop community solar and there shouldn't' be a cap on the amount of community solar that should be built. And then it puts it up to the commission to figure out how that actually works. And then in other states you have highly prescriptive programmes – such as Maryland, where the legislation was very specific on a number of features. So it really varies state by state."

Community solar is currently the fastest growing segment in the US

Another area where community solar is proving highly variable is in the nature of individual programmes, their design and the particular business models they follow. According to Cramer, a key differentiator is geography, with the rules and market conditions in one area likely to be very different to another.

"Developing a community solar project in somewhere like Nevada versus somewhere like Connecticut is going to be very different, and the rules are going

Credit: William Byers/USDOE

State-level policy is proving to be an important stimulus behind the growth of community solar

to have to be different," he explains. "In a place like Connecticut you're going to have smaller parcels of land and in a place like Nevada you're going to have larger parcels of land. So perhaps in Nevada they may put geographical constraints on how far the project may be located from the customer – a little further away, but make the projects a little bit bigger – and vice versa in Connecticut. And Connecticut may allow for co-location of projects because there is a benefit to one tie-in to the distribution grid versus multiple."

SEPA's Chwastyk concurs with this analysis and highlights how important this variability of design is to the success of individual programmes. From his research, Chwastyk says a standout finding has been the very high subscription rates among customers.

"That suggests two things," he says: "One is that community solar is just an interesting product to customers. And two, because different designs are working in different areas, there needs to be recognition that there's not a one-size-fits-all programme; you really have to be able to design a programme for your local customers, and what folks in Florida may be interested in is probably going to be very different from the Minnesota market. So, local designs resulting in different programmes, but still high subscription rates, is evidence of that."

CCSA and SEPA publish respectively a 'community solar policy decision matrix' [1] and a 'community solar decision tree' [2]. These documents are both intended to help guide policy makers and utilities or developers in designing either state-level community solar programmes or individual projects. By posing certain questions and providing various options and recommendations in response to those questions, the two pieces of guidance aim to streamline the process of arriving at the most appropriate solution for a specific area.

Finance and investment

But despite the many positive steps forward taken by community solar in recent years, an area that continues to cause headaches for the sector is finance and investment. Jared Leader, the author of a SEPA report 'Financing Community-Based Solar Projects' published earlier this year, says that the finance community is "lagging" where community solar is concerned, with funding opportunities for projects still limited.

This is partly a consequence of the unfamiliarity of community solar to many in financial institutions, even those that in principle seem well suited to be geared to supporting endeavours such as community solar projects (see box, next page). Another factor preventing the flow of capital into the solar sector, says Leader, is simply that the scale of most projects on the table puts them below the radar of most investors.

"A 1MW project with a US$2 per watt installation is US$2 million and for some investors that is a very small investment," Leader says. "And to get the institutional money behind something that is still a small investment, relative to a tax equity investor that would be able to take advantage of the ITC as it lasts, it's a barrier to entry, for sure."

Keith Martin, a project finance lawyer with international law firm Norton Rose Fulbright, which has advised on a number of community solar financing deals, adds to this a long list of other reasons why investors still regard community solar as a risky proposition.

"One is that most of these [community

RISEN ENERGY CO.,LTD
Add:Tashan Industry Zone, Ninghai, Ningbo, China
(Tel): 400 8291 000
(Fax): +86 574 59953599
(E-mail): marketing@risenenergy.com
(Web): www.risenenergy.com

solar] developers are small, they don't have a track record of showing they have staying power or the ability to be around long enough to service these customers for the term of the debt or tax equity. A second big risk is customer attrition; the residential customers could walk away at any moment. The third one is the early community solar projects that were financed had geographic diversity; the portfolios might be a mix of projects in multiple states. And that's not the easiest to finance, the market has decided; the transactions costs are too high, the rules vary by state and so financiers are trending towards wanting to do a single state at a time.

"Another risk is the net metering debate: utilities have been pushing back on legal obligations to buy electricity from solar panels because particularly at retail rates they say they can buy the same electricity in the wholesale market for less. So as state policies change on NEM that creates risk for community solar, it goes directly to the viability of the model. And I think the last risk is just if you're losing customers because residential customers walk away the customer acquisition costs are high, they remain in the order of 15-20% of the cost of a project and so that has to come down."

This may all sound like a lot for the community solar sector to put right, but the upside, according to Martin, is that there is a "wall of money" looking for projects. "There are 70-90 project finance banks chasing projects," Martin says. "In such a market people find a way to cut through the issues and get the deal done."

For example, one approach being taken by developers to appear more attractive to financers is to bundle up projects in a way that both offers the sort of scale investors are looking for and helps to diversify the risk associated with investing in just a single project. "In Massachusetts, where many of the recent financings have been, developers have portfolios of projects, so there's risk diversification – you're dealing with 15 to 20 projects at a time," Martin explains.

Developers are also developing solutions to the 'easy-come, easy-go' nature of residential community solar projects, where customers can walk away from subscriptions as they choose without fear of any financial penalty.

"Many of the investors want to see 100% subscription by the time the first funding occurs, or 95%," Martin says. "Sometimes the developers are over-subscribing – they start with a waiting list to try to address the concern that residential customers might disappear during the financing. And there are termination payments for non-residential customers; if you're relying on a commercial customer for a large share of the revenue those contracts might have a termination payment to ensure that financing can be paid down if that customer stops buying."

Beyond these practical steps, Leader says there is a task for community solar advocates generally to be more effective at educating investors about exactly what community solar is. "Some think of it as just a small-scale solar project, but there's much more than goes into a community solar project than just the size," he says. "And where the risk falls is all determined based on how the community solar programme is designed, how the PPA is structured, the contract between the developer and the utility and the customer, is all the basis of a contractual agreement based on the community solar design itself. Educating the finance community and potential investors is number one."

The winding path to financing community solar

When the city of Fremont in Nebraska decided to pursue a 1.55MW community solar farm as part of a plan to hedge against future increases in fossil-fuel generation costs, it found its financing options to be highly limited. After first being knocked back by various financial institutions supposedly geared towards funding community-based projects, the municipality then approached local lending banks but found the cost of loans on offer from them to be less than favourable.

With these options exhausted Fremont looked to itself, in the end opting to self-finance the US$2 million project from its own internal reserves. The project sold out in just seven weeks, and city officials are looking at launching a second project and exploring new options for financing it.

The unwillingness of the various agencies and banks approached by the municipality to put any money up for the project highlights the general lack of familiarity within the finance world around community solar and thus the need for the sector to do more to educate would-be lenders or investors about what community solar actually is.

SEPA's Jared Leader says: "If I were a developer and I wanted to build a park in my community with tennis courts and so forth I could go to specific financial institutions and apply for specific community-style loans and grants. In Nebraska, Fremont, before they came up with this innovative programme design to deal with how they would finance the project they first looked to one of these financial institutions that generally give grants for community-style projects.

"And thinking that community solar had an element of community for sure, they applied to get certain favourable loans based on the status of community solar. The Nebraska Investment Finance authority declined; they were not able to give that kind of loan to Fremont. And that I think is education as the starting point; you can educate not only the investor on not only what CS is so they can feel good about it, you can also educate these financial institutions that would perhaps consider community solar along with the likes of a community basketball court or tennis court."

The community solar vision

Despite what may seem like a long list of challenges the community solar sector must overcome in order to cement its place more firmly as a safe bet for investors, optimism nonetheless seems to be high for the sector. A report in late July prepared for campaign group Vote Solar by GTM Research outlined various scenarios for the future growth of community, the highest of which predicted up to 84GW of operational community solar assets by 2030.

Such a scenario would require many more states than have currently done so to "open their doors" to community solar and put in place active policies to encourage community solar programmes and projects, the report said. Indeed, for Cramer, aside from the ongoing challenges with the investment community, "regulatory atrophy" whereby the current momentum behind community solar generated by the emergence of state-level enabling legislation abates, remains the single biggest risk to the sector's future growth.

"That's really it," Cramer adds. "All the other pieces are there: the businesses are ready to innovate, the financiers are ready to sponsor and customers are ready to buy. So the question is: are policy makers willing to enable the development of these programmes?" ■

References

[1] Coalition for Community Solar Access, 2017, "Community Solar Poliy Decision Matrix", http://www.communitysolaraccess.org/community-solar-policy-decision-matrix-2017/
[2] SEPA, 2018, "Community Solar Program Design Models", https://sepapower.org/resource/value-stacking-in-minster-a-rural-village-leverages-solar-storage-and-4-revenue-streams/

Global standardisation: cutting red tape and slashing LCOE

Soft costs | A global effort to standardise solar contracts by IRENA, the Terrawatt Initiative and a staggering 15 giant law firms, has made great strides. A first glimpse at the template's content was offered at Intersolar Europe ahead of the new templates being put out to the industry for feedback. John Parnell reports

Standardisation of the bureaucratic processes involved in PV development is regarded as vital to opening up opportunities in emerging solar regions such as Africa

There has been a body of work going on, collaborative, innovative work that could lower the barrier to entry for smaller plants in emerging economies and drive down costs for all involved globally. It hasn't been taking place in a lab or a pilot module facility; it has been the combined effort of 15 of the world's largest law firms coordinated by the Terrawatt Initiative and International Renewable Energy Agency (IRENA), and the focus has been the multitude of contracts, from PPA through to O&M, involved in a typical solar project.

PV Tech has been covering the solar industry for 10 years and our sister journal to this publication, *Photovoltaics International*, has been detailing the multitude of technical advances that have been slashing costs right through the manufacturing process. I'm going to posit something a little controversial in this piece that I suspect some of my colleagues would baulk at: the successful adoption of standardised solar contracts, from PPAs to O&M and finance facility agreements, will be the single largest contribution to lowering project costs. There, I've said it.

The first templates for these new standardised contracts are scheduled to begin the review process later this year, offering anyone in the industry the chance to contribute. At Intersolar Europe this year, many of those who have been painstakingly whittling these contracts down to their shortest practical forms discussed the challenges and the opportunity presented by the Global Solar Energy Standardisation Initiative (SESI).

Format

The challenge of compressing contracts

while building up enough functionality to make them universal is clearly going to be complicated. The result is contracts that are "simpler not simple". Daniel Kaufman of law firm Norton Rose Fulbright summarised the guiding principles for the project.

"There are three core objectives that have impacted on every decision that we have made. The first is to lower the cost of energy, reduce capex, opex and remove any inappropriate risk. Secondly, to reduce development and negotiation costs. And, thirdly to scale up the volume of investment; that is really important," he stressed.

"What is important is not for the country to get money because you didn't perform, what is important is for the community to get kWh"

"These contracts are shorter than the ones you will be familiar with. We've stripped back the contracts to match the needs of the solar PV industry today, not 30 years ago. It's now well understood and simple technology with a very experienced market and the contracts should reflect that."

The other crucial point that Kaufman explained is the process by which the contracts should be used. These are not prescriptive documents chiselled into tablets of stone.

"These are templates, they're starting positions and we'll be absolutely encouraging the market to review, engage, comment, amend us and abuse them and provide us with all of this feedback," said Kaufman, "and as we move from the first version to the second and third they can evolve in a collaborative way with the whole industry behind them. The more feedback we get the better these contracts are going to be for the whole industry to take forward into the solar market."

What's the problem?

Anne Lapierre, global head of energy at Norton Rose Fulbright, leads the power purchase agreement (PPA) working group. With the example of one wind power project, she summed up the precise kind of situation the new standardised contracts could mitigate.

"In 2008 I started to develop and assist on a 150MW wind project in Senegal called Taiba Ndiaye. At the time Senegal had 450MW of spinning power for the whole country," said Lapierre. The project's finance closed on 30 July, a few weeks after Intersolar Europe and after practically a decade of negotiating.

"The lesson is that bearing the cost of development for 10 years is a massive expense. Only a big project can support that kind of cost. The other lesson is that when you have only 450MW of spinning reserve in a country, you also have a very weak grid. There are 1.3 billion people in the world with no access to power and the only way to get access to power is to develop small size distributed PV power projects near where they live. In Africa and non-OECD countries, the price of power can be 2-3 times higher than in OECD countries because of the risk, the problem of development costs. Standardisation and disruption is the key.

"That's why I strongly believe in this project and was so keen to lead the PPA group because that's the only way in my view, in terms of the global need, electrification and access to power will be achieved."

Limiting the number of projects that can support and survive the initial development costs is also hamstringing the ability to deliver new capacity where it is needed most.

"In Africa, you have more money to build power projects than you have projects," said Lapierre, "because you have only got the big projects that can attract the finance. You have an enormous amount of need in terms of MW, but a very limited number of big projects that can be developed, that are bankable because their scale is enough to bear all the transaction cost."

Lapierre describes the draft PPA contract in strong terms ("not innovative – disruptive"). It has looked at the situation with the Taiba Ndiaye project, with the status quo, and started over.

"There are no delay damages in the PPA contract: you build it or you do not; if you don't do it, you lose the right to do it. What is important is not for the country to get money because you didn't perform, what is important is for the community to get kWh. We're keen to have the cheapest project built in the shortest period of time, we don't want to sue people if they do not deliver, we just take the land and we give it to someone else who will actually deliver," she stated with no shortage of passion. "If you're a lawyer and you look at what we've drafted, you will see it's very disruptive. I've contributed to the draft PPA and it doesn't cover the same standard clauses that we negotiate. That's the point. What is the cost of negotiating my Taiba Ndiaye project for 10 years? What is the cost to the population to do that?"

Daniel Kaufman: SESI programme is about scaling up the volume of solar investment

Operations

Lapierre's example and visible frustration with the conditions as they are, demonstrates ably how SESI's work can get more projects, especially smaller ones, up and running. The suite of contracts being standardised extends into operations as well. Work on a template for an O&M contract has been led by Bird & Bird's Elizabeth Reid. The need for such a template was best put by BayWa r.e.'s Paolo Chiantore, MD of the company's O&M division.

"I'm really looking forward to the finalisation of these contracts," said Chiantore. "Each client has a different idea about what should be in a contract. With an active secondary market, a contract could be in place for a site and then the owner changes and they have their own ideas. In the last year I've spent 30-40% of my time negotiating O&M contracts and why this clause should go there and that one should go here."

Reid explained that the contract had to allocate the risk and responsibility for a project's long-term future, and reward that, in a way that doesn't burden additional costs onto the plant owner. Essentially, it's a balancing act.

"Sometimes it isn't the most cost-

Anne Lapierre: Standardisation and disruption are the key to opening up energy access worldwide

effective thing to do to transfer all the risk to the O&M contractor and sometimes the project company might be better placed to take the risk than it might first think," said Reid.

For the corrective maintenance element of the contract, a compromise was found with all repairs covered by a flat fee, with the exception of select components that the project company commits to purchase. This removes the need for the O&M company to ensure its fee covers the possibility of any particularly extensive and expensive work. Similarly, the group found it was more cost effective for the project company to use its insurance to protect it against hurricane or other *force majeure* damages, rather than having that priced into the O&M contract from the outset.

Each workstream, including the O&M group, consulted with a number of industry figures including banks and technical advisories. In the case of O&M, the draft proposals have been confirmed as perfectly bankable. The templates might be contrary to current widespread practice, but they are being designed with approval of their harshest eventual critics once they move into the real world – the banks.

The O&M template has also removed performance-liquidated damages. Reid described it as one the more controversial elements of the work.

"We decided that actually, and on feedback from a number of technical advisors and O&M contractors themselves, ultimately the performance and efficiency of the plant is down to things like the modules, the materials that have been selected and the design of the plant. It isn't something that the O&M contractor can control so it's more effective not to have a performance ratio in there but to have a sensible lifecycle plan instead on issues like module replacement and so on," she explained.

"What we did do is ensure that the project company has very adequate remedies for things that the O&M contractor can control such as availability. So we have availability liquidated damages, a service credit regime to make sure they respond on time and come to the plant on time, with a simple and easy reduction mechanism if they don't. There is an optional availability bonus as well."

Interestingly, the initial contract template also puts the onus on the O&M firm to pitch new technical upgrades.

"They're also obliged to proactively seek to optimise plant performance over the long term, so to actively come forward with change requests and say 'there is this new technology coming out, I think you should consider it, here is why'," added Reid.

The Turkeys are voting for Christmas

It's a fair question: why would the world's largest law firms contribute to a project that will ultimately trim the amount of hours they can bill individual projects for lengthy negotiations?

There are at least two good reasons, one practical and one more human. Unlocking greater deployment will generate plenty of work for these law firms and their competitors, even if the amount of work on each is greatly reduced. Secondly, in any profession, would you rather be working on the same frustrating project for several years or spending the same time processing a volume of more diverse projects delivering greater tangible benefits across the board? Either way, you're billing for the same number of hours.

"I have to say, before I joined SESI, if you had told me that you could get all those law firms working harmoniously together, hand in hand, towards a common objective, I genuinely would have said I think you're mad," said Kaufman. "Not only has it been possible, it's been a really incredible exercise. Rather than the normal approach where you see the lawyers on either side of the table and always acting in their clients' interest, far from the interests of the solar industry as a whole, the process we have been through has been very open, very collaborative and with engagement across different perspectives." That engagement has included regional legal expertise from across the globe and a steady stream of input from the solar industry itself.

It's fitting to end at the beginning with a final word from the Terrawatt Initiative's general secretary, Jean-Pascal Pham-Ba.

"Yes it's a dry topic, it's about drafting contracts but at the beginning of the story, it is about 2015, the Sustainable Development Goals, it's about the Paris [climate change] Agreement and other international agreements to bring energy to more people and reduce emissions.

"One of the key things to accelerate the penetration of renewable energy, which is absolutely crucial and essential, is just the price. Why is it so expensive today? A lot of people thought it was only about the price of the equipment. When you break down the LCOE you realise the cost of financing and the cost of transactions is absolutely enormous and it is a major factor in the cost of this energy, especially in developing countries," said Pham-Ba.

"Business as usual was created for a different industry, oil and gas, with very large assets, it doesn't work any longer. If we want to achieve the objectives set in 2015, we don't have to change the technology, or the capital or the people, we need to change the way we do things and we need to accelerate."

On that point, there can be little disagreement. ■

Standardisation nothing new

The remarkable thing about the SESI project is the scale and the reach of the contracts. Development banks, notably the IFC's Scaling Solar programme, are built on standardisation and ensuring that work does not have to be repeated. But as Norton Rose Fulbright's Lapierre noted, the Scaling Solar contracts have been written with one bank in mind, the IFC itself. Dubai's gigawatt-scale solar park has reissued tweaked versions of the same contract in each of its four phases and it has eventually generated an eye-wateringly low PPA price. From a bank's perspective, a clutch of smaller projects using the same contract could be aggregated with little fuss driving down the cost of finance further in a similar way to that perfected by SolarCity in its heyday for residential leases.

Seraphim Carves Out Innovative Path for Shingled-Cell Modules

Largest Global Rooftop Project Using Shingled-Cell Modules Changzhou, China | 1.5MW

Global Largest Ground-mounted Power Plant Using Shingled-cell Modules. Henan, China | 5MW

Since its founding in 2011, *Seraphim* has executed significant achievements in innovation. The company's core mission is to focus on innovation as the key driver for growth.

First-Class R&D Center

To produce innovative and reliable solar modules, *Seraphim* set up an in-house world-class R&D center several years ago.

Seraphim was recently certified as only the third IEC CTF (Customer Testing Facility) by TUV SUD. Becoming a recognized CTF laboratory means *Seraphim* will now be listed directly on IEC's website, and its testing results can be officially used in CB (Certification Body) reports issued by *TUV SUD*. Furthermore, *Seraphim* can now internally generate CB testing reports for new products and materials from its own lab, reducing the time and energy used on transporting samples. This capability alone will accelerate new product releases by several weeks or months. The CTF qualification is acknowledgement of *Seraphim's* superior capabilities in quality control and testing. In the meantime, it offers immediate benefits to our worldwide customer base.

This is the fifth world-class lab certification awarded to *Seraphim*, after already receiving similar authorizations as a *CSA Witness Laboratory, TUV TMP Laboratory, CTC*-authorized lab qualification and *CNAS* certified in-house laboratory.

Out of this accomplished laboratory, the company developed the first high-efficiency shingled-cell solar module in the world that passed *TUV SUD* tests in 2016.

Shingled-cell Technology Is Trending

By eliminating busbars, the active working area of the shingled-cell module is enhanced, enabling more sunlight to reach cell surfaces. At the same time, these modules create 50% less thermal energy, minimizing hot spots and guaranteeing continuous electricity generation.

In 2016, possessing the most mature shingled-cell process in the industry, *Seraphim* became the first company to produce laminated components at commercial scale—and was the first to successfully integrate them in large-scale photovoltaic power stations. So far, more than 100MW of shingled cell modules, also known as *"Eclipse"*, have been installed globally.

Compatible with Diverse Cell Types

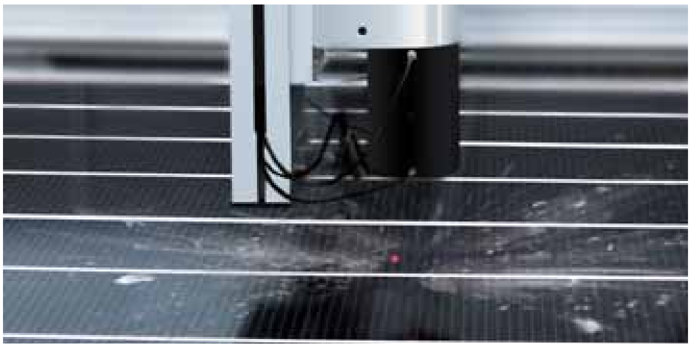
The shingled-cell manufacturing process accomodates other mainstream high-efficiency cell technologies, such as PERC, Black Silicon and HIT, creating the possibility of a wide-variety of finished modules.

Thanks to these cell compatibilities, the *Eclipse* will continue to upgrade to higher wattage modules. During *SNEC 2018* in Shanghai, *Seraphim* introduced impressive additions to the Eclipse family - Bifacial *Eclipse* and Mini *Eclipse*, offering further flexibility for system designers.

Cutting Cost with 100μm-cells

Wafers are typically engineered to a minimum thickness of 160μm to avoid breakage; however, when wafers are reduced to less than 100μm, they actually gain elasticity. Shingled-cell modules are able to accommodate these thinner components and thus drive down LCOE.

For more information please visit **www.seraphim-energy.com**
Media contact: **Shirley.wang@seraphim-energy.com +86 25 8536 0181**



SERAPHIM®

Tier 1 by BNEF
Top Performer by DNV GL

BLADE™

Half-cell module, higher output, less mis-match, power loss, shadow effect

Eclipse™

FIRST high-efficiency modules that use shingled-cell technology certified by TÜV SÜD in the world

SHIFTING · THE FUTURE

www.seraphim-energy.com / info@seraphim-energy.com

A tipping point for financing large-scale storage?

Storage finance | Storage has an important role to play in the UK's future energy system, but the challenge for investors and developers is to select the right business models and combination of technologies. Maria Connolly and Stuart Urquhart at UK law firm TLT look at how some of the new regulatory and policy developments are helping enhance the bankability of storage

Credit: Renewable Energy Systems

The UK energy sector is undergoing huge transformation and disruption, with the way electricity is produced, distributed, sold and consumed changing rapidly. Global demand for energy is rising and in order to provide low carbon, affordable and secure supplies, the settled order needs to change to a flexible energy system.

New markets, new routes to market, new entrants to markets, technological innovation across the energy value chain and innovative new business models are emerging as the sector makes this transition. The conundrum facing markets, investors and governments alike is which models and combination of technologies will succeed and become the new norm. Which of these are able to meet rising demand, serve our smart homes and smart cities and deliver an acceptable return on investment at an affordable price for consumers?

Energy storage is a key component of the flexible energy system that is needed to meet increasing demand. This includes storage deployed as a stand-alone, grid-connected asset, storage deployed "behind the meter" at a particular source of demand and storage that is co-located with a particular source of electricity generation, such as a solar farm.

Future energy scenarios

In the latest scenarios modelled by National Grid in its Future Energy Scenarios report (FES) [1] , it highlights the fact that demand for electricity is expected to increase significantly by 2050, driven by increased electrification of transport and heating. The report suggests that there could be as many as 11 million electric vehicles (EVs) by 2030 and 36 million by 2040. If the UK Government's target of 34 million EVs on the road by 2040 is met, it is estimated that an additional 60TWh of electricity every year will be needed. The FES report also estimates that 65% of generation could be local by 2050.

In scenarios of this kind, National Grid and other local system operators will face a huge challenge in ensuring electricity can be made available at the right places and at the right times to meet demand. While Vehicle to Grid (V2G) and other smart grid technologies will likely play a crucial role in meeting this challenge, there is also likely to be a significantly increased requirement for dedicated storage capacity.

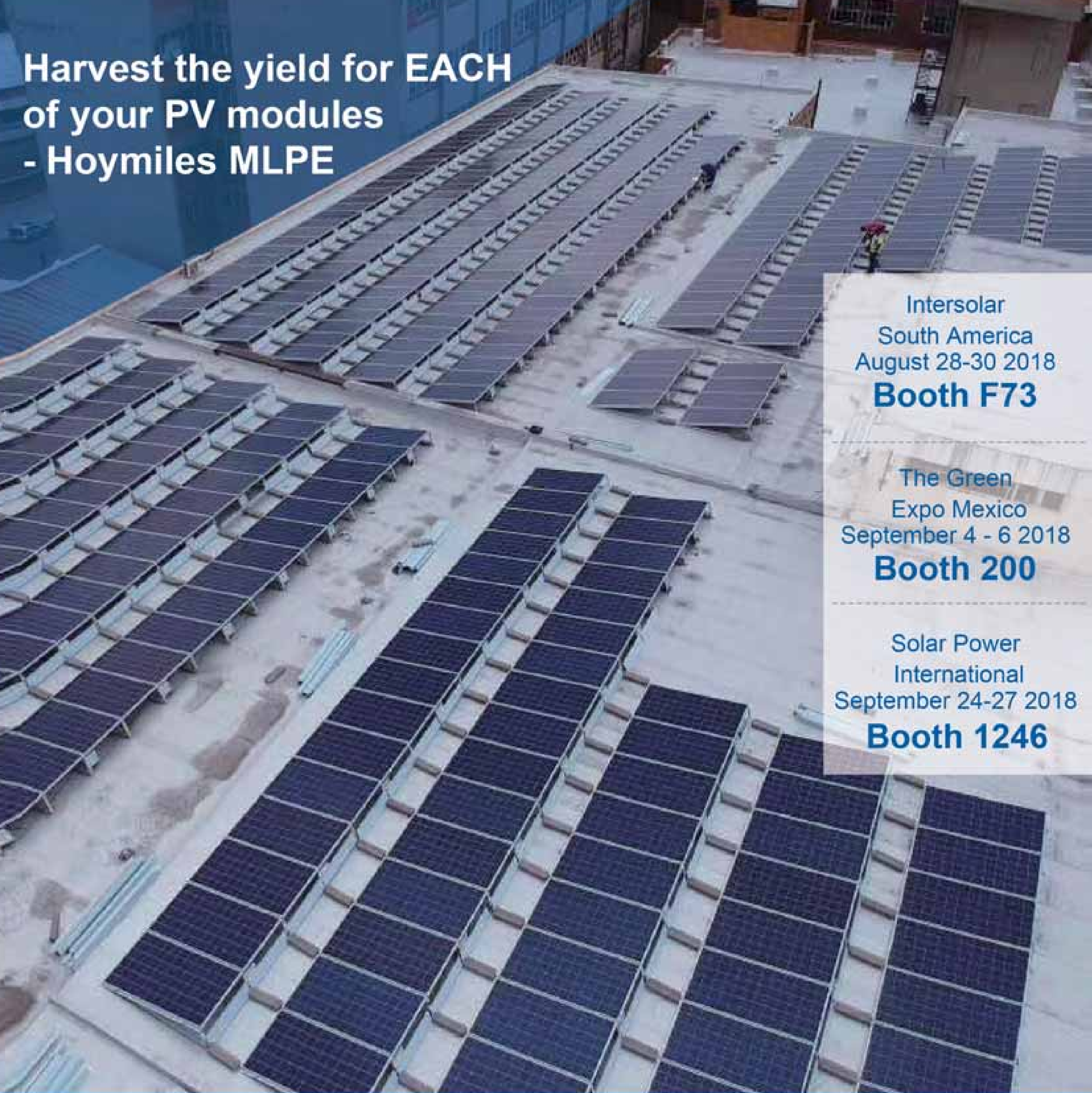
Large-scale storage presents opportunities but also bankability challenges for investors

EVs are expected to massively increase demand for electricity by the middle of the century

Globally, the energy storage market is expected to double six times in the years to 2030 rising to a total of 125 GW of capacity, according to Bloomberg New Energy Finance (BNEF) [2]. It predicts significant growth in energy storage investments of up to US$103 billion and forecasts that eight countries will lead the market, with 70% of capacity to be installed in the US, China, Japan, India, Germany, the UK, Australia and South Korea.

Energy storage, unlike other grid infrastructure, provides the unique ability to store excess electricity and deliver it when and where it is needed to utilities, industrial and commercial customers, independent power producers and power system operators. In addition, BNEF predicts the cost of utility-scale battery systems will likely decline significantly by 2040, falling from around US$700 per KWh of storage capacity in 2016 to less than US$300 per KWh. This presents opportunities for the storage and EV market and makes energy

Source: National Grid, Future Energy Scenarios Report 2018



Safer
100% safe with up to 60V DC input voltage (natural rapid shutdown); IP67

Smarter
Smarter monitoring for remote Module-level troubleshooting & maintenance

More Powerful
Module-level MPPT & unique parallel design ensuring 10-30% higher yield than series-wound PV system

More Reliable
6000V surge protection, MTBF (mean time between failure) > 550 years, yearly failure rate < 0.18%

hoymiles

www.hoymiles.com

sales@hzconverter.com

storage and co-location of energy storage combined with other technologies increasingly attractive to investors.

The increasing bankability of energy storage

The business model for a storage project is likely to be significantly more complicated and less certain than for the kind of feed-in tariff (FiT) or renewable obligation (RO) subsidised solar farm that many investors will have become familiar with over the last six or seven years. In particular, there is no potential revenue stream that can be compared to the index-linked 20-year subsidy available under the FiT and RO schemes.

In principle, Capacity Market agreements can provide up to 15 years of index-linked revenue. However, even based on 2016 values, Capacity Market revenues would not have been sufficient on their own to underpin an investment in a storage asset. Since then, the introduction of de-rating factors for shorter duration storage combined with a significant reduction in auction clearing prices has further reduced the amount of long-term "contracted" revenue that a storage project could look to secure.

The primary revenue stream that many storage developers will likely be focussing on will be revenue payments from National Grid for provision of balancing services, in particular frequency response services. But there is only a finite amount of frequency response capacity that National Grid will require and contracts have relatively short duration; storage developers therefore need to factor into their model the likelihood of having to participate, either directly or through aggregators, in multiple competitive tender exercises over the life of the project.

Other revenue streams may also be factored into the equation, depending on the configuration of the project. For a number of early projects, revenue from triad-related embedded benefits will likely have been important (see box, below left). For other projects located "behind the meter" with a source of demand, the ability to shift the time of demand away from peak (both triad and red band) periods will likely be a significant source of value. In both cases though, as illustrated by the changes now introduced by Ofgem to triad embedded benefits and, looking ahead, to other changes potentially following on the back of Ofgem's Targeted Charging Review, there is no guarantee that these revenue streams will continue to be available on a long-term basis.

Set against this backdrop, it is perhaps inevitable that there have been some challenges in devising "bankable" storage models that will appeal even to cautious investors. However, there have been a number of interesting developments over the last 12 months that we would treat as being positive in terms of future investment for storage projects:

- Established funders, with a long track record of investment in renewables projects, have closed deals involving storage projects. This includes Santander's financing of a portfolio of battery storage projects developed by Battery Energy Storage Systems and The Renewable Infrastructure Group's acquisition of the Broxburn facility.
- Major solar asset owners, such as Next Energy, have acquired storage projects co-located with solar farms. Even though the size of some of these early acquisitions may not be large, they may lay the foundations for future acquisitions and new developments, in support of new build, subsidy-free projects, by enabling asset managers to become more familiar with the way that storage can be utilised.
- Established players from both the aggregator and renewables PPA markets are working on new products to provide value for operators of storage assets, especially where they are co-located with renewable generation. Alongside revenue from frequency response or other balancing services, project owners may increasingly have the opportunity to secure value through participation in the balancing mechanism and/or through electricity price arbitrage.
- There now seems to be real momentum behind the roll-out of EV charging infrastructure to support the dramatic increase in EV use that is being projected. This points not only to an increased need for storage capability in the system generally, but also more specifically to opportunities for storage to be co-located either with charging infrastructure (to manage periods of peak charging demand) or with generation assets which are contracted to supply EV charging stations.

Even without the potential to lock-in to long-term contracted revenues, the combination of increased demand for flexibility in the system (and so potentially greater confidence in the need for storage as one class of flexibility provider), increased, on-the-ground experience of how storage assets can successfully be operated and an increasing penetration of trusted service providers (whether O&M/asset management or aggregator/PPA providers) may collectively help to unlock investment even from some of the more cautious investors.

Good commercial sense

For early movers, a key benefit of co-locating storage with an existing, grid-connected solar generation asset will have been the opportunity to benefit – through shifting of the time of export to grid – from triad embedded benefit revenue. As noted earlier though, this particular revenue stream is now being effectively phased out as a result of changes introduced by Ofgem.

If the solar asset in question is itself located behind the meter (for example, a rooftop array on a commercial building or, in the future perhaps, a solar farm with a private wire connection to a nearby electric vehicle charging station), there is likely to be scope to generate value through avoidance of peak grid import charges, by allowing the solar generation to be shifted to, say, the early evening period and off-set grid demand at the commercial building or EV charging station during that period. This should be the case for at least for the next couple of years, pending the outcome of Ofgem's Targeted Charging Review. Even if existing network charges are restructured so they are no longer calculated by reference to volumes of demand at peak periods, there may still be potential for using behind-the-meter generation and

Embedded benefits explained

Embedded benefits are savings or payments available to generating stations that are directly connected to distribution networks (commonly referred to as embedded generation or distributed generation). Historically, one of the key embedded benefits has been the benefit associated with the avoidance by licensed electricity suppliers of Transmission Network Use of System (TNUoS) charges. The TNUoS charges are designed to cover certain costs related to the operation of the high voltage transmission system in the UK. In broad terms, licensed electricity suppliers have to pay these charges by reference to the amount of electricity they are treated as supplying during the three peak half hourly periods of electricity demand each winter i.e. the "triad" periods. Electricity that is exported to the grid during triad periods can be netted-off against a supplier's demand for these purposes, resulting in a reduced exposure for the supplier to the relevant TNUoS charges. The value of these avoided costs can then be shared, as an "embedded benefit" payable under a power purchase agreement or similar contract, with the generator (or storage provider) that provided the exported electricity.

Co-location of storage and solar is likely to provide a key source of revenue in the future

storage to reduce a demand customer's peak grid capacity requirements and so reduce its exposure to any future capacity based network charges.

Looking to the future, wholesale electricity prices and in particular balancing system cash-out prices may become increasingly volatile. Having the means through co-location of storage with a solar asset to shift the time of export to (or where co-located with demand, shift the time of import away from) higher price periods is likely to be a further source of value. Unlike the current, passive model of operating a solar farm, new, more active approaches to the management of the solar asset may become the norm and the availability of co-located storage may prove key to maximising the value that can be secured under future "smart" PPAs.

Key considerations for investors

For any storage which is to be co-located with an existing solar asset, the headline consideration is likely to be the impact on the existing solar asset's ongoing eligibility for subsidy support under the FiT or RO schemes.

Uncertainty on this issue has undoubtedly been one of the barriers to investment in projects of this kind to date. However, much of that uncertainty has now been removed through the publication by Ofgem of specific guidance on the issue. This guidance, which was only issued formally a few weeks ago following an earlier consultation, confirms that in principle storage can be added to an existing solar asset without affecting its accreditation under the FiT or RO schemes.

The key practical requirement will be to have the right metering in place, so that FiT payments or ROCs are only claimed on electricity which can be shown to have been generated by the solar asset, as opposed to electricity which may have been imported from the grid by the co-located storage and then subsequently exported. For FiT projects specifically, the addition of co-located storage may – unavoidably – mean a loss of entitlement to claim FiT export tariff payments, but this is unlikely to be viewed as critical for most investors.

More generally, wherever any storage is to be co-located with an existing solar asset, some or all of the following may need to be reviewed and potentially amended, depending on the specific arrangements for the project:

- Lease – does the lease for the existing solar asset allow for the installation and operation of a storage asset?
- Planning – what additional or varied planning permissions will be required?
- Grid connection – will additional grid import or export capacity need to be obtained in order for the storage to work alongside the existing asset? If the storage asset is to be owned/operated by a separate project company, will there be a need for a grid sharing arrangement to be put in place with the solar asset owner?
- PPA/revenue sharing – will any existing PPA in place for the solar asset need to be revised to reflect the operation of the storage asset, including (for example) in relation to forecasting of output? If the storage asset is to be owned by a separate project company, what commercial arrangements will be in place between this company and the solar asset owner for sharing of the value derived from operation of the storage (e.g. frequency response revenues secured by the storage owner or PPA benefits secured by the solar asset owner)?

Other key considerations that will be relevant to any project involving the co-location of storage with a solar asset, whether existing or new include:

- The robustness of the EPC and O&M arrangements, including whether there will be an overall "wrapping" of these arrangements and reduction in the risk of interface issues between different component parts of the project.
- The contractual route to relevant project revenues, including in particular whether the project company will be seeking to participate directly in relevant tender or auction exercises (e.g. a National Grid frequency response tender) or via a third-party aggregator. If the latter, then depending on the size of the project and the identity of the aggregator counterparty, there may need to be some form of security put in place to mitigate the risk of the aggregator counterparty becoming insolvent.

Conclusion

Despite some initial uncertainty, the last 12 months have brought about a steady stream of changes and developments that indicate battery storage and co-location with another renewable energy source has an increasing role to play in the UK energy mix. As the industry continues to develop and demand for flexibility and new technologies grows, this is only going to gather pace. It will be important for investors to understand how these opportunities are changing and, crucially, to position themselves appropriately when they do. ■

Authors

Maria Connolly is a partner and head of the real estate group and leads TLT's cross-discipline clean energy team. She has worked on several hundred wind, solar, biomass, hydro and energy storage projects and advises on a wide spectrum of property matters. She is a frequent commentator on clean energy and a regular speaker at industry events.

Stuart Urquhart is a legal director at TLT specialising in the commercial and regulatory issues surrounding clean energy projects, including PPAs, FiT agreements and the rules governing subsidy schemes.

References

[1] http://fes.nationalgrid.com/fes-document/

[2] https://about.bnef.com/blog/global-storage-market-double-six-times-2030/

Offshore floating solar – a technical perspective

Offshore PV | With floating solar on lakes and reservoirs well on the way to becoming a mainstream concept, attention is now turning to the possibilities offered by offshore systems. Børge Bjørneklett describes some of the pioneering R&D work being undertaken in the race to take solar to the open seas

Over recent years floating solar has rapidly emerged as a new frontier for photovoltaic systems. In areas with limited space on land, the possibility of floating solar on lakes and reservoirs opens up vast possibilities. The use of floating solar on hydro power reservoirs is particularly interesting. Here the grid infrastructure is readily available and facilitates an inter-play between solar and hydro power. The potential energy in the reservoir can be utilised much better. The predictable output from the water turbine fits well with the inherent intermittency of solar power. A floating solar system will also limit evaporation from the reservoir. Although this new hydro power and solar hybrid market is huge by itself, the application area is still limited on a global basis, restricted to regions with favourable topology and water catchment.

In large power consumer areas as in the big cities, rooftop solar is an attractive solution. The technique is well established over decades. The drawbacks are more related to limited surface for large installations, ownership and competition with other good initiatives such as rooftop gardens or terraces. Rooftop PV installations are also sometimes subject to poor airflow, which causes relatively high operating temperatures in the modules and subsequently low yield. Soiling by smog is another potential problem in cities with high pollution.

Ocean Sun pilot system in the fjord next to the Osterøy island, Norway. Offshore PV offers further opportunities in the floating solar segment

Most of the world's mega cities are located along the coast lines. Historically they evolved at trading centres with good harbour conditions, in bays, river deltas or in between archipelagos offering sheltered waters for the trading ships. Despite today's busy ship lanes, recreation areas, aquaculture and fisheries, huge surface areas in coastal regions are virtually unused. If this space can be exploited for floating solar power, transmission of power to major consumer groups is shorter than for most land-based installations.

Arguably, the most attractive sites for utility-sized PV plants have already been taken. Ground-mount PV installations on farmable land are controversial and banned in many countries. Consequently, the search is widened to more desolate areas further from the grid. The penalty for remote power plants is poor transmission infrastructure and consequent high costs for power delivery over long distances. Hence, with the ever-increasing manufacturing capacity and high output of solar modules, installers need to find new surfaces. A cost effective and reliable method for installing PV on water bodies will create a new era for solar power. Potentially, huge population groups can be given access to abundant renewable energy.

Offshore solar is in many ways different from offshore wind power. The best conditions for wind power are found some distance offshore in regions with steady winds. The visual impact is strong with turbines towering up to 200 meters high, potentially interrupting scenic ocean views. On the other hand, floating solar is essentially flat and less invasive since systems would drop below the horizon at relatively shorter distances. With near proximity to consumers the transmission cost for solar power is a lot cheaper than offshore wind power.

If various floating PV designs struggle to achieve necessary bankability and conformance to established standards, the notion of offshore floating solar is even more challenging. The larger waves and saltwater add considerable technical difficulties. Albeit the sound scepticism, Ocean Sun has tested prototypes in Norway and Singapore with satisfactory results. It is absolutely within reach to install large floating PV plants on seawater. The practical results from Ocean Sun's testing of the new patented concept look promising.

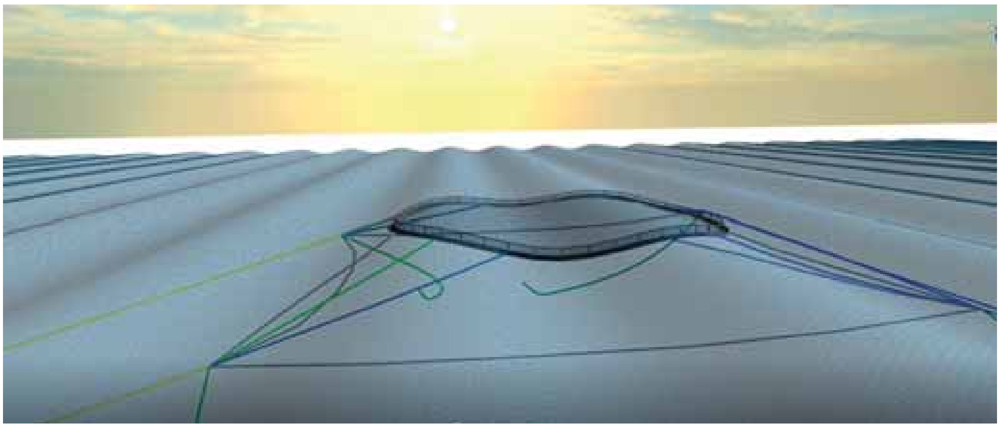


Figure 1. Computer model of floating torus with surface membrane

The floater architecture

The PV industry is notoriously driven by cost. Hence, to move to the water surface, a successful floater design must use minimal amount of material, have good robustness and offer a protective environment for the solar modules.

Attempting to address all parameters, Ocean Sun designs floaters consisting of thin reinforced membranes suspended in a buoyant double torus structure. The membrane is fully hydroelastic and prevents breaking of waves underneath the structure. The effect is not unlike the well-known phenomenon of oil on troubled water. Historically, the method was widely used among seafarers to dampen rough waves during rescue operations, or when navigating treacherous straits in severe weather. A reinforced polymer membrane spread out on the water can achieve much of the same effect. The sea is calmed and only the regular waves, typically with longer wavelengths travel across the membrane. Such hydroelastic membranes can be made large and can serve as an ideal surface area for solar modules. Practical experience has shown that the floating membrane offers a good and safe working environment for installers and the modules can be securely attached at high speed. The hydroelastic design is also found in nature among aquatic plants relying on photosynthesis. The giant water lily, Victoria Amazonica, is a good example.

For most floating PV systems, the buoyancy is distributed uniformly, supporting one or several PV modules, typically by using individual polymer buoys that are interconnected, either directly linked or via rails. This design is flexible, but the motions are concentrated to the connections between the individual buoys, making these points vulnerable to stress, wear and fatigue.

When dealing with strong current, at sea, on rivers or on hydroelectric reservoirs, it is favourable to position the buoyancy at the perimeter of the floater. Otherwise, the system is more easily dragged under by the mooring arrangement in strong currents. In the Ocean Sun design, the dual torus provides buoyancy and the interior membrane serves as the installation surface for the modules.

The principle has been tested in the basin laboratory at the Marine Technology Centre in Trondheim, Norway. The sea-keeping capabilities were tested for a range of wave conditions using a 1:16 model of a 2,000 sqm membrane. Due to the high flexibility, the membrane easily follows even several meters high waves and dampens out irregular wave motion. The design limitations for the model were found at the freeboard, which must prevent intrusion of irregular waves washing over the system. A relatively large freeboard is necessary in big waves and a porous structure must be designed to prevent high slamming forces. However, without further design modification, the model worked well for a significant wave height up to 1.5 meters. Statistically, in this sea state individual waves may reach a height of about 3 meters.

The mooring system is derived from fish farming and follows the rather stringent NS9415 standard. This standard has been developed to prevent ecological disasters following mechanical failure and the potential escape of up to 200,000 salmon from a single fish cage. For a floating torus with a fish cage, the mass and particularly the drag forces are significantly higher than for the floating solar installation with only the surface membrane. In a hydrodynamic analysis of the floating solar installation, the mooring forces were found to be only a fraction of the forces acting on a torus equipped with a fish cage. Further work on hydrodynamic modelling, using the finite element method, has been initiated to downsize the system optimally for FPV in more benign waters. Careful material selection of durable polymers with good UV and hydrolysis resistance is crucial for the robustness and longevity.

In many regions, strong winds represent a major challenge for floating solar, particularly in the typhoon belt where wind speeds can approach 300km/h. Cases have been reported where floating solar arrays have been partially damaged in typhoons, e.g. at the Umenoki Furugori Water Reservoir, Japan, where 152 modules were damaged in 2016.

In a computational fluid dynamic model, the Ocean Sun design was simulated with a wind speed of 275km/h. At a strong wind force, the leading edge of the floater experiences uplift while the trailing edge is pressed downwards. The forces are primarily generated by the wind load on the freeboard and the exposed torus over the waterline. It is, however, relatively easy to account for the uplift in the ballast and mooring arrangement. A certain draft must be maintained at the rim of the floater to prevent air from entering under the membrane. Due to the rotational behaviour of typhoons, the wind successively attacks from all directions and the circular floater geometry is then ideal with no weak broadsides or vulnerable corners.

Figure 2: Laboratory basin model

Figure 3. Fish farm outside Singapore with floating solar installations

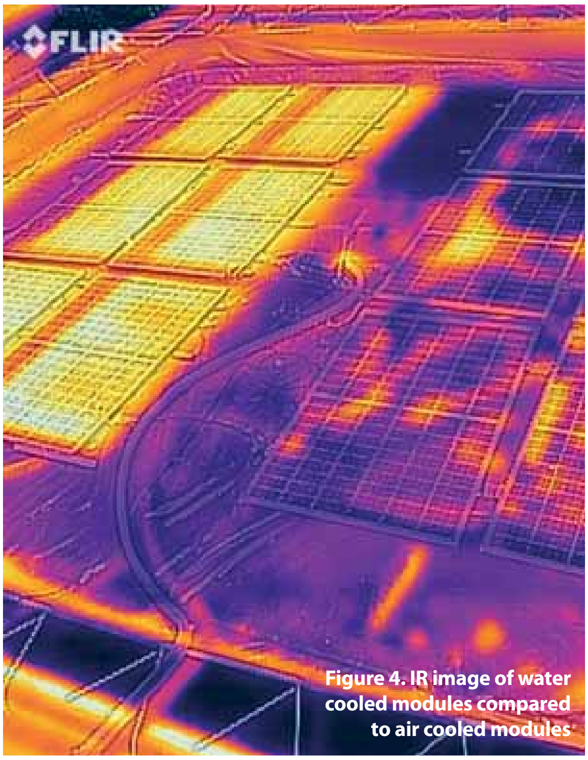


Figure 4. IR image of water cooled modules compared to air cooled modules

Module integrity

In the basin test (Figure 2), the membrane was equipped with 740 modules modelled to scale in the form of thin aluminium shims. Several modules were instrumented with strain gauges to measure the deflection. The stiffness of the modules was scaled to match the stiffness of the common dual-glass 60-cell utility module. The degree of deflection is important for the mechanical integrity of the modules and the potential hazard of micro-fracturing of solar cells. The micro-cracking phenomenon is typically characterised under electroluminescence of solar modules and can be a major contributor to reduced power output over time, as fractions of cells eventually become isolated. Micro-cracking of cells may occur due to strong wind, snow load or e.g. careless stepping on the front glass on frame mounted modules. In the basin laboratory tests, the modules showed small deflections on the floating membrane and significantly less than the deflection that can be observed during e.g. wind load testing according to IEC 61215. The maximum up-scaled stress value in the modules for the steepest wave travelling across the membrane was much less than the bending stress limit calculated from the standard wind load test. The stress distribution in modules lying flat on the flexible membrane is fundamentally different, and less critical than the stress concentrations that can occur with typical four-point clamping fixation on conventional rails.

Another degradation mechanism in solar modules is the thermally induced stress caused by temperature fluctuations between day and night. The metallic busbars soldered onto the solar cells have a high coefficient of linear thermal expansion while the silicon material itself is more thermally stable. When subjected to high temperature differences this cause a sheer force between busbar and the cell, potentially adding to the micro-cracking. This problem is avoided in the Ocean Sun design since the solar modules are thermally connected to the membrane and the water body itself, resulting in small temperature variation between day and night in the module.

Water will accumulate on the surface of the membrane during rain. The water is removed by small bilge pumps that are placed in shallow recesses, evenly distributed around the surface of the membrane. In very heavy rain the modules can be partially submerged for short periods and the dual glass type module offers good resistance to water ingress. Additional water ingress protection and measures against PID can be achieved with e.g. butyl rubber lining or other sealants along the module edges protecting the exposed EVA. The environment is not necessarily more challenging than for example rooftop modules covered by ice and snow. Junction boxes should be IP68.

Module performance

An important aspect of the Ocean Sun concept is the thermal coupling to the water that gives a significant contribution to the electrical performance of the modules. The floating membrane acts as

Ciel & Terre

THE FLOATING SOLAR EXPERT

300+ MWp
120+ Projects
WITH HYDRELIO® TECHNOLOGY
In 25+ Countries

Yamakura Dam, Japan - 13,7 MWp
©Kyocera TCL Solar LCC

LET'S MEET UP!

- RENEWABLE ENERGY INDIA EXPO (REI)
  September 18-20 | Greater Noida, India
- PV TAIWAN
  September 19-21 | Taipei, Taiwan
- Solar Power International (SPI)
  September 24-27 | Anaheim, California (U.S.A.)
- World Lake Conference
  October 15-19 | Tsukuba, Japan
- Japan solar + energy storage congress & expo
  October 29-30 | Osaka, Japan
- ASIA CLEAN ENERGY SUMMIT (ACES)
  & INTERNATIONAL FLOATING SOLAR SYMPOSIUM (IFSS)
  October 31-November 1 | Singapore
- SOLAR AND OFF GRID RENEWABLES: SOUTH EAST ASIA
  November 26-27 | Bangkok, Thailand

MORE INFORMATION:

contact@cieletterre.net
+33 (0)3 20 01 05 65
www.cieletterre.net

FOLLOW US:

an efficient heat sink and several tests have shown that the module operating temperature only reaches a few degrees Celsius higher than the water temperature. For crystalline silicon solar modules, the temperature coefficient is typically around 0.4% per degree Celsius. In a pilot installation outside Singapore, the air-cooled modules reach well over 600C on an average day, while the direct water-cooled modules sitting on the membrane operate at 35⁰C, only a few degrees over the water temperature of 32⁰C. See Figures 3 and 4. The difference of around 25 degrees means that direct cooling gives roughly 10% higher output compared to modules in conventional air-cooled floating PV systems.

In the lower latitudes, the effect of the direct water-cooling contributes more than having the perfect module inclination. At higher latitudes, the loss caused by the horizontal orientation becomes more pronounced. The pivot-point is not simply given by latitude but also involves insolation, water temperature, wind speed, ambient air temperature and to some extent water current. In practice, floating solar installations with steep module inclination face other problems with expensive structural design, limited wind resistance and shading effects between modules causing inefficient utilisation of the floater space.

Pilot installations

Ocean Sun has tested the concept of floating membranes in several installations. System size has ranged from a few modules tested in swimming pools and up to a 100kWp installation in the sea outside Bergen, Norway. The first moored installation was positioned in the fjord next to Osterøy island in Norway (see main image). The floater has been in operation for 1.5 years and has been subjected to several storms, precipitation of up to 110mm in one day, minus 10⁰C with ice on the fjord and heavy snow fall.

While Norway offers varied conditions for testing the seaworthiness and mechanical integrity of floating solar system designs the insolation is moderate and very limited during the winter. To better demonstrate the cooling effect through the membrane, a system was installed close to equator in Singapore.

Several large fish farms in Norway obtain power from diesel generators. Energy consumption is mainly driven by pneumatic feeding systems delivering pellets for salmon or trout. The fish only eat during daylight and consequently the energy demand fits well with solar power. An off-grid 2,000sqm floater was installed next to the main barge (see Figure 5).

Figure 5. Off-grid installation powering a large fish farm at the west coast of Norway

Commercialisation

Ocean Sun has plans for even larger units in the MW range (see Figure 6), and multiple units will form large solar power plants. However, floating solar power has a long way to go before reaching the technical maturity of the ground mount installation. Competing floater designs make standardisation and certification more complex and the marine environment places new demands on the solar modules.

Introducing the flexible membrane as a mounting surface for the standard dual- glass module is highly unconventional. Still, the principle offers a sound thermal and mechanical environment which in many aspects is better than traditional installations. The low cost of the floater combined with the increased yield obtained by stable and effective cooling is difficult to ignore.

New floating solutions will rock the boat in the established PV industry, and the prospect of supplying cheap renewable energy to coastal regions will drive development of new standards and certificates, eventually creating a fundament for bankable systems. Meanwhile, the pioneers in the FPV industry are prepared to take initial higher risk.

Figure 6. Illustration of a 1MW floater with a diameter of 100 meters

Author

Børge Bjørneklett is co-founder of Ocean Sun and the inventor of a new floating solar concept. Børge has experience with R&D from the automotive (Norsk Hydro), solar (REC Solar) and offshore O&G (Aker) industries. Børge has a doctorate degree in materials science from NTNU. He has authored 10 patents.

Anchoring innovative **floating applications is our passion!**

SEAFLEX is the flexible mooring solution that has been securing floating applica - tions world-wide since 1981. The system can be used regardless of water depth, while handling large water level variations, strong currents and storm conditions.

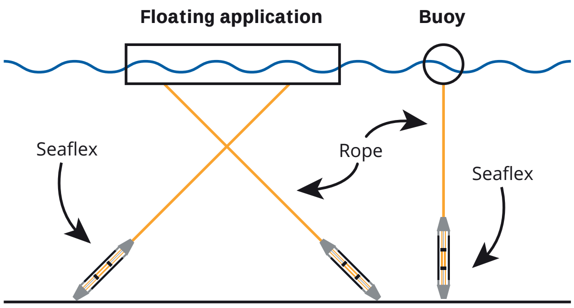
We are thrilled to follow the development in the groundbreaking floating renewable energy sector. Anchoring such innovative applications couldn't be a better fit for us, since achieving longevity while taking environmental responsibility have always been cornerstones in the creation and development of the SEAFLEX mooring system.

GEUMJEON, KOREA, Nemoeng Co.

This pictured 2MW floating solar power plant produces electricity that can be used by 660 households at the same time. SEAFLEX is used to secure both 110 x 100 m platforms.

KERALA, INDIA
Adtech Systems Limited
Shown above is a 0.5 MW floating solar park in India, the SEAFLEX holding it in place manages their 20+ meter water level variation.

How Seaflex mooring works



SEAFLEX is used whenever there is a need to anchor something floating, such as commercial marinas, wave attenuators, floating solar parks or wave energy converters. The system expands and retracts with each tide and wave, taking on and dampening the forces year after year.

Contact us
info@seaflex.net

See more at
www.seaflex.net

State-of-the-art bifacial module technology

Bifacial | Bifacial technology promises significant reductions in the levelised cost of electricity for PV systems, and almost all major PV suppliers are already producing or planning bifacial modules. Hartmut Nussbaumer, Markus Klenk, Andreas Halm & Andreas Schneider give an overview of the currently available bifacial modules and cell technologies and adapted mounting solutions

Bifacial solar cells go as far back as the 60s [1–3] and were first used in satellites [4–6] and for niche applications, such as sound barriers [7], and for shading elements [8]. The production volume remained low at the semi-industrial fabrication level [4,9], but has increased with the introduction of the Sanyo HIT Double and later the Panda [10] and EarthOn [11] modules from Yingli and PVGS. Since about 2012, interest in bifacial PV has been constantly increasing, which is reflected by the installed capacity [12], the number of available products [13] and the number of publications. As a result of technical progress, such as improved bifacial cell concepts and the availability of thin solar glass, this technology has become increasingly attractive. Furthermore, some of the new solar cell technologies, which are currently being implemented in industrial production, allow a comparatively simple adaptation to a bifacial layout. The general trend towards glass/glass modules with superior reliability, as well as the interest in 'peak shaving' and customised solutions for specific applications, further supports the development path towards bifacial technology.

In spite of the advantages, the installed capacity of bifacial systems is still small compared with monofacial mainstream systems. A major issue is the uncertainty regarding the additional 'bifacial' yield, which is due to the more complicated irradiation conditions and the power rating of bifacial modules.

It is still common to regard bifaciality as an add-on and to base the power rating/pricing on the front-side measurement under standard test conditions (STC). The effect of this is that embedding bifacial solar cells in a monofacial module structure with a reflective backsheet may allow a higher price on the market than if they were embedded in a real bifacial module version [14,15]. This is also a reasonable procedure if the cell type used is bifacial, but the modules are mounted in locations with unattractive albedos, such as shingled roofs. Panasonic offers specific modules [16] to exploit the advantages of their bifacial HIT cell technology in 'non-bifacial' modules.

> "It is still common to regard bifaciality as an add-on and to base the power rating/pricing on the front-side measurement under STC."

While it is comparatively simple to define standardised indoor measurement conditions for a monofacial module, the measurement of a bifacial module must also include the power generated by the rear side. Standardised measurement conditions for bifacial modules are still under discussion but close to finalisation [17,18].

Even if a standardised indoor measurement procedure for bifacial modules is defined, the actual yield of a bifacial PV field will always be extremely dependent on the installation conditions. For free-standing bifacial modules, the optimum orientation is a trade-off between the front- and rear-side outputs, and the efficiency is dependent on factors such as the ground reflectance, tilt angle and installation height. In extended arrays, additional factors, such as direct shading and reduced ground albedo due to adjacent rows, have to be considered. Because of the sensitivity to multiple additional factors, compared with monofacial standard installations, an accurate prediction of the yield of a bifacial PV array is, by far, more complicated. At present there are still only limited simulation tools available for bifacial arrays; however, the number of software suppliers is increasing [19–21], and there is considerable effort being devoted to improving the models and to appraising the prediction reliability [22,23].

While the improvements with regard to the simulation and measurement are important, the increasing installed capacity [12] will in itself promote the future growth of this technology. The estimates concerning the bifacial market share for the coming years vary but are most promising (Fig. 1); indeed, starting from

(a) (b)

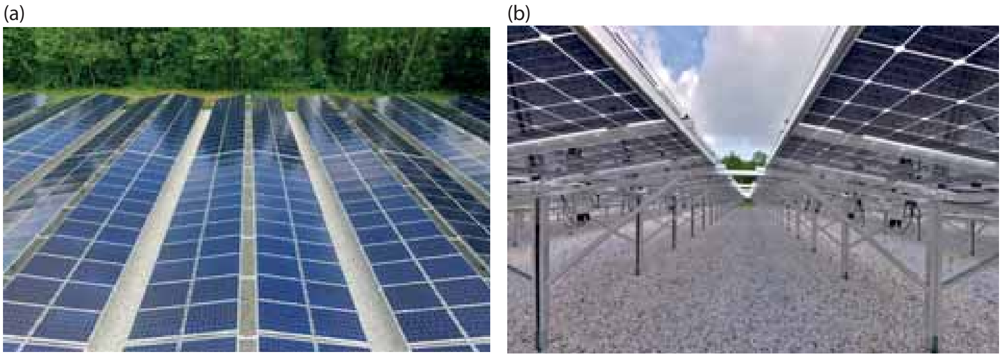


Figure 1. A bifacial 400kWp system from Tempress with an east–west orientation [26], which is indicative of the expected significant rise in the market share of bifacial PV: (a) view from above, and (b) view of the rear of the bifacial modules. The white gravel results in an albedo of 40%. Source: Tempress, Amtech Group

today's 3% bifacial market share the ITRPV roadmap 2017 predicts an increase to around 30% by 2027 [24], while Bloomberg even anticipates 40% by as early as 2025 [25]. Accordingly, more and more adapted components for bifacial technology will become available. In addition, the bifacial module design, which is still very similar to the standard monofacial one, may reflect specific conditions, such as increased currents or more inhomogeneous irradiation uniformity. This paper presents a comprehensive overview of the state-of-the-art technology for bifacial PV modules and of the potential trends concerning future developments.

Solar cells

Bifacial solar cells were first proposed in the 1960s [1]. Even though cells of various types were produced on a very limited scale to cover the demand (e.g. for satellite applications [6,9]), such cells were not produced in large volumes. The industrial production of bifacial cells began in 2007 with Sanyo implementing an open Ag grid for their proprietary HIT cell technology [27]. Yingli Green Energy was the first company to launch an n-PERT (passivated emitter, rear totally diffused) cell [28] in 2010; this was followed about four years later by announcements of the industrial production of bifacial p-PERC (passivated emitter and rear cell) cells and modules [29,30] by companies such as SolarWorld and NSP/ET Solar. Since then the interest in bifacial systems has been on the increase, with reports of many different technical solutions; these differ in detail but can be assigned to a limited number of technologies, which will be discussed below (HJT, PERC, PERT, IBC). More detailed comparative information concerning the technologies can be found elsewhere in the literature [2,31–33]. The technologies in question are predominantly linked to a preferred type of wafer doping: PERC is mostly related to p-type wafers, while heterojunction technology (HJT) and the PERT concept are typically linked to n-type wafer material.

Cells based on HJT were the first commercially produced bifacial solar cells. On the front and rear sides of such cells, a material other than c-Si (amorphous silicon) is deposited in order to passivate the surface and to form a second p-n junction. After Sanyo's patent on this technology expired in 2010, several module manufacturers and equipment suppliers offered comparable products based on HJT, with some differences in the processes, often using their own naming conventions, such as HCT technology from Sunpreme [34].

Today, among other companies, Panasonic, Hevel [35], 3Sun [36], Hanergy and Jinergy [37] are producing, or ramping up their production of, silicon heterojunction cells. Manufacturers, institutes (such as CSEM [38] and CEA INES [39]) and equipment providers (such as Meyer Burger [40]) are constantly working on improvements to increase efficiency and obtain more cost-effective processes. HJT cells achieve superior efficiencies of up to 23.4% on a pilot scale [39], with high bifaciality (> 0.95) as well. While the technology is attractive in many regards, cell fabrication is very different from that of homojunction c-Si cells. Existing cell manufacturers cannot therefore simply adapt the technology in an evolutionary process, like an upgrade. Nevertheless, some companies, such as Jinergy, which are already producing PERC cells have also announced the fabrication of HJT cells [37]. It is also an option for some companies to start up production, such as Sunpreme [34,41], and in particular it offers opportunities for companies which have a background in thin-film deposition, such as Hanergy [42] and 3Sun [36].

In contrast to HJT technology, the well-known PERC concept has been (or currently is being) implemented by many mainstream p-type c-Si cell producers (p-PERC) in terms of an upgrade. Basically, the former standard Al-BSF (back surface field) type of cell is changed in such a way that the full-area rear-side aluminium layer is replaced by a passivating layer and the rear-side metallisation process is correspondingly adapted. To obtain a bifacial PERC cell, which is often termed *PERC+* [43], the rear-side metallisation is realised by a grid, as on the front side. SolarWorld started to produce bifacial modules in 2015 [44]. Today, the PERC+ concept is mainly implemented by Chinese and Taiwanese tier one manufacturers, such as Longi [45,46], Trina [47,48], JA Solar [49,50], NSP [51,52], EGing [53] and Jinko [54]. Because of degradation issues on multicrystalline (mc) material [55], however, all the above-mentioned PERC+ concepts are realised on p-type Cz wafers. At the PV Cell Tech conference, Canadian Solar announced it was switching all its P4 mc PERC cell production to PERC+ in 2018 [47].

> "A disadvantage of bifacial PERC is the comparatively low bifaciality."

A disadvantage of bifacial PERC is the comparatively low bifaciality, although Longi recently announced a significant improvement [46], with a bifaciality factor of 0.82% (at the R&D level) and reports of front efficiencies of 21.2% and higher in production. Because of the large PERC production capacity installed worldwide, the growing interest in bifacial technology, and the comparatively easy implementation of PERC+ in an existing PERC line, it is not surprising that bifacial PERC modules are increasingly becoming available.

A higher bifaciality factor is made possible by PERT technology [4], which is in principle quite similar to PERC technology. The 'T' in PERT stands for 'totally diffused' and indicates that the doping and passivation layers on both sides of the wafers are applied by diffusion. PERT is suitable for p- and n-type wafers (p-PERT; n-PERT) and also applicable to mc wafer material, as demonstrated by RCT Solutions and Shanxi Lu'An [56]. The technology has the potential for higher efficiencies than those possible with PERC, but is more complex and based on more expensive components (boron deposition, n-type wafers, silver paste consumption, etc.). In the case of p-type wafers, the rear side is exposed to boron diffusion instead of the deposition of an aluminium oxide layer in the PERC process. It should be pointed out that p-PERT has a very low market share. It has to be mentioned, though, that p-PERT was already used in the first bifacial cells for the Russian space programme; additionally, PERT is also still subject to recent research [4]. Examples of technology providers for p-PERT are RCT Solutions [57] and Schmid [58].

The implementation of n-PERT technology is more common than p-PERT, with PERT being the standard technology on n-type wafers. Since both n-type and bifacial technology have increasingly attracted interest in the PV community, it is not surprising that numerous bifacial n-PERT processes and module types are on offer today [32], aiming at cost-effective solutions. A description of all the different processes would be beyond the scope of this paper, but suffice it to say that the aim of several processes is to introduce simplifications in order to make them more cost-effective.

All of the major suppliers of diffusion furnaces – centrotherm, Tempress, Schmid and others – offer process technology and adapted equipment. Some processes also use quite different process equipment: the diffusion process, for example, can be replaced by ion implantation [32] (Yingli [59], Jolywood [60]).

Bifacial n-PERT modules are offered, for instance, by Yingli [61–63], Jolywood [60,64], LG [65,66], Prism Solar [67], HT-SAAE [68], Linyang [69], Trina [70], Adani [71], REC [72], Jinko [73,74] and Valoe [75], with some of those mentioned being in the launch phase.

The highest lab efficiency reported so far is 22.8%, achieved by imec [38] and featuring a bifacial factor of 97% [39]. In future, the introduction of passivated contacts [60] with high-temperature firing through metallisation might increase the efficiency level of industrial n-type-based solar cells to a value of 23% or higher [76].

Bifacial IBC cells are another promising option to obtain high-efficiency solar cells. 'IBC' stands for *interdigitated back contact*, which means that the contacts are solely on the rear side of the solar cell; this approach requires other fabrication procedures, while the core process equipment of n-PERT may also be used for IBC [77]. Bifacial IBC is still in its infancy, but corresponding modules have already been fabricated [78] and are even on the verge of entering industrial production [75].

Table 1 lists the most common bifacial cell architectures, including the main technological features.

Cell interconnection

The key requirement for interconnecting bifacial solar cells in terms of an optimised power output is the application of a module interconnection technique with the lowest ohmic losses. This is essential because bifacial modules experience far higher current generation because of the rear-side contribution which is added directly to the front generation. The above requirement becomes even more important in locations with increased albedo, for cells with higher bifaciality factor or for larger output currents in general (e.g. tracked modules). While most commercial PV modules based on commercially available bifacial solar cells currently utilise all the same 'standard' soldering interconnection technology, alternative technologies exist with greater benefits in terms of quality and reduced ohmic losses.

"The key requirement for interconnecting bifacial solar cells in terms of an optimised power output is the application of a module interconnection technique with the lowest ohmic losses."

Nowadays, the interconnection standard still relies mainly on an H-pattern metal grid on the front and rear sides of the cells, as applied to the very first cells decades ago. So-called *conductive fingers* collect the silicon-bulk-generated photocurrent and transfer the current to busbars (BBs), thereby creating the H pattern of the metallisation. Coated (usually containing Sn and Pb) Cu ribbons are soldered to the busbars; this way a serial interconnection between the front of one solar cell and the rear of the adjacent cell is formed and so on, typically creating a string of up to 10 or 12 series-connected cells. Soldering is a mainstream interconnection technique in electronics but not necessarily the favoured process for novel high-efficiency solar cells. The applied temperature of up to 250°C jeopardises the cells' mechanical integrity and is not suitable for all metallisation schemes and materials. In addition, the resistive losses in the cell–cell interconnections usually dominate all other resistive losses in a solar panel compared with a bare solar cell.

Solar module concepts are rare and only a few have been developed over the last 12 years to specifically pass the required IEC and UL certification standards to enter the mass-production process. Several hurdles have to be overcome for any new technology in order to finally prove its superiority over soldering, which is such a simple technology that has remained virtually unchanged over the years. The easiest way to reduce ohmic losses is to instead make modifications at the cell level, specifically by increasing the number of busbars. For more than 10 years, the standard number of busbars has been three, but there are now solar cells available with four, five or six busbars. By adding more busbars, the effective transfer length for charge carriers in the emitter is significantly reduced, with the additional benefit of redundancy in case of cracks or similar flaws. The interconnection still typically relies on soldering but causes less damage to the mechanical integrity because of the much-reduced ribbon thickness. Beside this, the modifications required for mass-production equipment, such as stringers and cell flashers, are relatively minor. Ohmic losses are reduced for each busbar added, but the positive effect in terms of series resistance reduction gradually gets smaller and smaller. An optimum is typically reached somewhere between five and six busbars

Cell concept	Bifaciality factor	Si base material	Junction and BSF doping method	Contacts	(Front) Efficiency potential	Industry
Heterojunction	>0.95	n-mono	a-Si:H p- and n-type doped	TCO / Ag TCO / Cu plated	22–25%	3Sun, Hanergy, Hevel, Jinergy, Panasonic, Sunpreme, etc.
PERT	>0.90	n-mono p-mono p-multi	B and P tube diffusion n-doped poly-Si rear side possible	Ag and Ag/Al printed	21–23%	Adani, Jinko, Jolywood, LG, Linyang, REC, Trina, Yingli, etc.
PERC+	>70%	p-mono p- multi n-mono	B and P tube diffusion, local Al BSF	Ag and Al printed	21–23%	Eging, JA Solar, Jinko, Longi, NSP, SolarWorld, Trina, etc.
IBC	>70%	n-mono	B and P tube diffusion APCVD doped oxides	Ag and Ag/Al printed	22–25%	Valoe

Table 1. Bifacial solar cells, main parameters and manufacturers (some products in the launch phase)

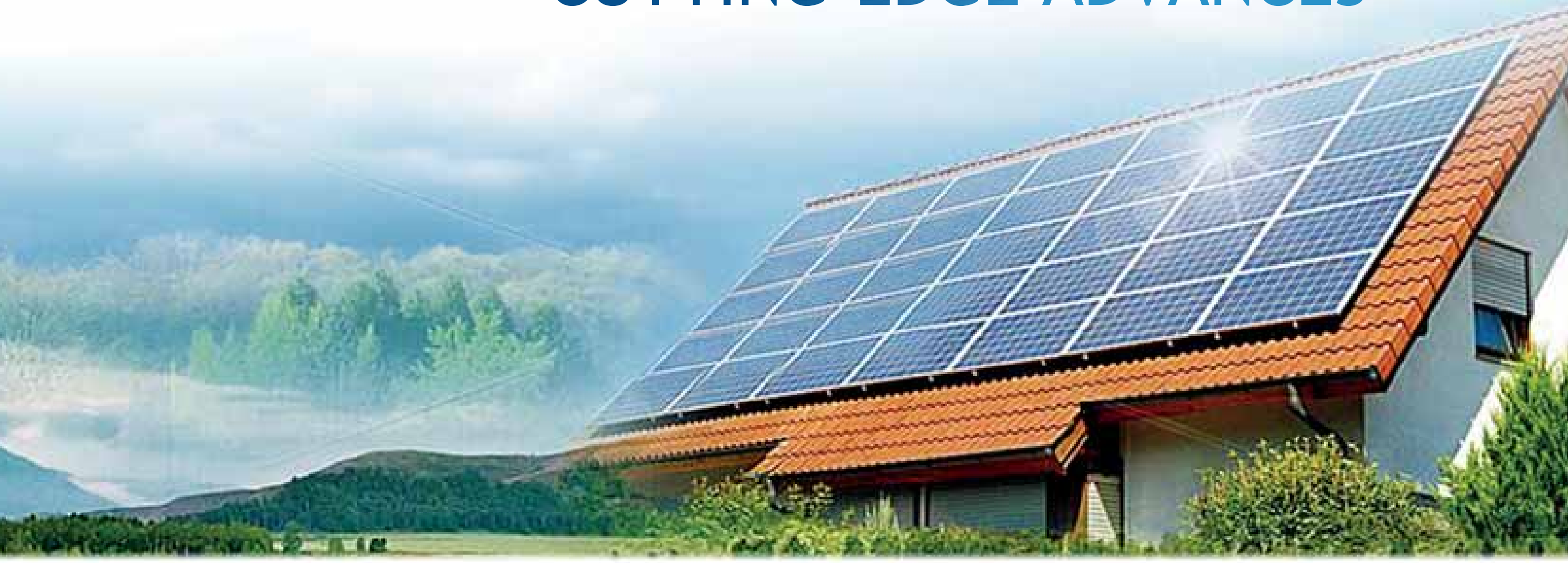
REI EXPO 2018 INDIA
BOOTH NO. 9.102
ALL ENERGY 2018
BOOTH NO. 1934
High Quality Module Manufacturer

航天机电 HT-SAAE

1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

20th ANNIVERSARY

DEDICATED TO OUR ORIGINAL AIMS AND TO STRIVING FOR NEW CUTTING-EDGE ADVANCES



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

in terms of technological, process and financial aspects, also for bifacial cells, with 10–30% higher output current. A logical continuation of this approach would be to further reduce the diameter of the ribbon, now referred to as *connecting wire*, as the number of wires increases significantly, to far more than 10. Two mass-production techniques based on this principle are the multi-busbar technique from Schmid [79], employing typically 12 wires with a core diameter of 360µm, and the Day4Energy [80] interconnection scheme, in which 36 wires of 150µm diameter are used. The latter method was purchased and further developed by Meyer Burger and is now called *SmartWire Technology* [81]. Both technologies allow the omission of cell busbars completely, thereby significantly reducing the number of cell metallisations, emitter recombination and direct light shading. Because of the very small nature of the series resistance in both technologies, the merits for interconnecting bifacial cells are evident. In addition, because of the unique solder coating in the Day4Energy concept, the cell aluminium layer can be contacted directly, paving the way for interconnecting cells with modified metallisation layouts and materials.

Ohmic losses can be attributed to two sources: the series resistance, as established by the above-mentioned three technologies, and the cell current. Reduction of the latter is addressed by a module concept based on half cells [82] or by the so-called *shingling technology* [83]. Both of these concepts are very well suited to interconnecting bifacial solar cells: the standard soldering technique is used for half cells, whereas typically electrically conductive adhesive (ECA) or solder paste is applied for shingling. Half cells require only minor modifications to the cell and module process; however, shingling technology can really be regarded as a different (though not necessarily novel) approach, which is based on a different module process with significant modifications at the cell level. Although the origin of the shingling approach goes back decades, it had never been used in mass production until just recently, when its implementation was driven mainly by the need to interconnect cells with the highest output currents and the lowest ohmic losses. In fact, fill factor values at the module level exceeding 80% can be achieved, demonstrating the benefits of shingling technology [84]. Besides this, the necessity of applying an ECA also allows cell interconnection concepts which are not suitable for soldering, for example because they cannot withstand the high soldering temperatures. Currently, bifacial modules with shingled cells are also being tested at the R&D level [84,85], and the first bifacial products have even already been launched [45]. The use of conductive adhesives in combination with a structured ribbon for HJT cells was announced by Teamtechnik [86].

A technology for simplifying the interconnection and for reducing the mechanical load at the cell edges is the *flip-flop* design of bifacial solar cells [87], in which the p and n sides are respectively alternated for adjacent cells in a string. This is only possible with reasonable mismatch losses if the cells with p and n sides have a very similar power rating, which means a high bifaciality factor.

An alternative solar cell interconnection approach is the *conductive backsheet* method, invented by Eurotron and ECN [88]; this concept is based on a PCB (printed circuit board) design, typically used in electronics. All the contacts are formed inside the copper layer, which itself is integrated into the backsheet; the solar cells are interconnected on the conductive backsheet layer by either ECAs or soldering pastes. The conductive backsheet technology overcomes cell bowing issues and is therefore a perfect match for interconnecting rear-contact solar cells. The electrical polarities of the solar cell are separated by isolating trenches which form continuous circuit tracks to establish the current transport. Usually this technology results in monofacial modules; however, if a large part of the conductive backsheet layer is removed, thereby creating conductive circuit tracks with a well-defined aspect ratio, a ribbon-like interconnection can be created, allowing bifacial operation.

Finally, the NICE module concept from Apollon [89] can be mentioned as one technology that is very well suited to the interconnection of bifacial solar cells for several technological reasons. Cell interconnection is based on a pressure contact rather than soldering, allowing the use of a greater amount of ribbon to interconnect the solar cells without the detrimental effects of the soldering process. Furthermore, NICE technology is by nature a glass/glass technology, which makes it perfectly suited to bifacial application. Table 2 shows a rating for the discussed module technologies, and indicates how well the specific module technology is matched with the various bifacial solar cell types available on the market.

The light-trapping properties of the cell interconnection are discussed in a later section dedicated to optical confinement and light management.

Encapsulants

A state-of-the-art solar module contains various components, all designed and developed with specific functions for increasing longevity and for optimising the potential to harness sunlight and convert it into electricity. The key to longevity of solar modules is the selection of the right material, which is indeed even more important for bifacial products. One of the key materials is the encapsulation film, which protects the solar cell and guarantees reliability and performance by protecting it against water vapour and aggressive chemical substances, as well as partly against mechanical shock and other disturbances. Its role is to provide the highest possible optical transmissivity, hinder moisture from entering the module interior, deliver a very high and durable adhesion to the adjacent materials, and guarantee a capacity to withstand high voltage.

The material of choice for many decades

Cell concept	5BB	5BB HC	Conductive BS	Multi-busbar	Day4Energy / SmartWire	NICE	Shingled
PERC, PERT	+	++	In comb. with MWT	++	++	Combined with 5BB / HC ++	++
HJT	0	0	In comb. with MWT or IBC	0	++	++	++
IBC (Zebra, Mercury,…)	(√)	(√)	++ (bifacial?)	(√)	(√)	(√)	-

0 = suitable, + good fit, ++ special advantages, (√) suitable, but adaptations necessary (isolating layers…)

Table 2. Ratings of interconnection technologies suited to bifacial modules.

has been ethylene vinyl acetate (EVA), which now comes with a long track record of almost 40 years in terms of field experience and successive developments. Even today, EVA is still the most commonly used solar module encapsulation material, and dozens of experienced suppliers exist worldwide. On the negative side, three disadvantages can be listed for EVA: 1) the relatively high UV cut-off wavelength; 2) the high moisture vapour transmission rate; and 3) the materials added to improve EVA's crosslinking and adhesion properties, which generate free radicals (such as acetic acid), contributing to physical deterioration and degradation of the material properties [90]. Typical field failures here can be corrosion, yellowing or discoloration.

With all its advantages for bifacial solar modules, glass is currently the best choice for the front- and rear-side superstrates [91]. No other material delivers the same mechanical stability, transmission rate and water transmission rate of practically zero. The last of these properties also means that free radicals stemming from the encapsulation material are trapped inside the module interior, and can only be released in the limited regions of the module edges [92]. Acetic acid – in combination with photons of higher energy (meaning those in the lower visible light spectrum), heat and the time factor – acts in a deteriorative way on the module materials and can significantly reduce the module lifetime. This is particularly true for bifacial modules, given the higher operating temperature because of the significantly increased irradiation levels to which the materials are exposed. Alternatively, transparent backsheet materials can be combined with front glass, thus eliminating the above-mentioned risks but also resulting in a much-reduced mechanical strength compared with glass.

Decreasing the module temperature to a minimum is key to reducing the chemical reaction rate inside the encapsulation film [93]. For a typical glass/glass bifacial solar panel, the main chemical reaction is related to a degradation of the chemical stability of the encapsulation film, which will result in delamination or discoloration over time. Besides degradation, corrosion is aggravated by increased temperatures: the coated copper ribbon and the solar cell metallisation can both suffer corrosion. The water ingress rate is significantly reduced in the case of glass/glass bifacial modules, and is therefore one of the promoting factors for degradation and corrosion that is taken out of the equation. As long as chemical by-products exist inside the encapsulation film, however, any degradation will inevitably occur over time. Therefore, there has been (and still is) an urgent need to develop new encapsulation materials.

Nowadays, various encapsulation materials – besides standard EVA – are available on the market: new EVA material developments with a lower UV cut-off (⊠320nm), polyolefin (POE), thermoplastic polyurethane (TPU), polyvinyl butyral (PVB) and silicone-based products. Each of these materials has its advantages, and in all cases unfortunately also inevitable disadvantages, even if these (in some cases) are only related to the pricing. In terms of energy production, most of the various encapsulation materials with UV cut-off wavelengths of approximately 320nm will perform alike. Since the degradation effects of the encapsulation material are more pronounced and accelerated in bifacial modules, leading to an early material degeneration and hence a loss in transmissivity, the choice of the best materials is key to longevity. This means that module manufacturers must carefully evaluate the encapsulation material for overall long-term durability.

Junction box

The junction box electrically connects the embedded solar cells within the module with the outside world; it houses the bypass diodes and protects them, as well as the sensitive interconnections, from the environment. Overheating of bypass diodes or increased contact resistances of the clamped or soldered interconnections, caused (for example) by corrosion or faulty clamping, may lead to hazardous situations. Such defects pose a real threat and, as repeatedly reported, have caused considerable economic damage to manufacturers [94–96] and are a long-term burden [97,98]. The junction box is therefore a crucial part of the module with regard to reliability and safety.

On monofacial modules, the junction box can be placed on the module rear side without causing a detrimental shading effect. Accordingly, the size of the box is not a relevant factor, allowing sufficient volume for a thorough interconnection and enabling options which permit sufficient heat transfer, such as potting. For bifacial solar modules, however, this is obviously not the case, since any shading of the light-sensitive sections on the rear side should be avoided. Because an increase in the module dimension is also undesirable, the junction box has to be reduced in size and should preferably be placed on the rim of the module. At the same time, smaller junction boxes need to handle high currents because of the extra current generated by the module rear side; moreover, the heat generated by the bypass current has to be taken into consideration.

Because of the risks described above, it is not surprising that, in spite of the considerable rear-side shading, numerous manufacturers of bifacial modules have relied, or still rely, on conventional junction box types. Another factor favouring the use of conventional junction box types is the lower cost associated with standard components.

There are, however, also junction boxes available (or in development) which are explicitly designated for use on bifacial modules by TE Connectivity [99], Stäubli/multicontact [100,101], Leoni [102], Changzhou Almaden [103] and Amphenol [104]. These junction boxes are far smaller and are placed at the edge of the laminate [100] or at the rim of the laminate rear surface [102–104]; some are appropriate for both placements [99]. Typically, these boxes also address the market of glass/glass modules in general, which is not limited to bifacial devices, because a low visibility of the junction box is desirable for this module type.

Positioning the junction box at the edge of the module is an attractive option, because the laborious handling of the cross-connectors and the related opening of the rear-side cover are avoided and the non-productive glass area is minimised. On the other hand, this type of fixture may be more vulnerable to mechanical damage or to moisture ingress as a result of the more

"With all its advantages for bifacial solar modules, glass is currently the best choice for the front- and rear-side superstrates."

irregularly formed and smaller contact surface.

Another option for bifacial modules is the use of multiple junction boxes, which are generally smaller in size than the typical standard devices. While two of the already mentioned boxes for bifacial modules are of this type [99,103], there are numerous other examples which may also be suitable for bifacial modules, provided that the electrical parameters are within the specified range [105,106]. The decentralised design enables a simpler layout of the cross-connectors and attracts related material savings; it should also result in lower series resistance and improved heat transfer. Triple-pole junction boxes are used in several bifacial modules from, for example, Yingli [107], Ningbo [108], Trina [109], JA Solar [49], Jolywood [110] and Meyer Burger [111], among others. It must be mentioned, however, that the rear-side glass needs to have additional feedthroughs.

Multiple-pole junction boxes are also found on bifacial modules which are based on the half-cell approach and on the innovative interconnection scheme as presented by REC [112] in the form of a split module concept. In these cases, the splitting of the junction box into several units is adapted to the new layout; the same concept is also realised in similar modules incorporating monofacial solar cells. The half-cell approach is interesting for bifacial modules [62,113] because the impact of the increased additional current from the rear side is reduced. Such new module architectures with combined parallel and serial electrical layouts may also be a means of addressing inhomogeneous irradiation effects. With regard to the irradiation inhomogeneity, the use of integrated optimisers is also of interest for bifacial applications and has reportedly been implemented [114]. Furthermore, other developments – such as the replacement of bypass diodes by active elements [101] – may be particularly useful for bifacial modules in coping with the higher current rating of these types of module.

> "For bifacial solar modules, any shading of the light-sensitive sections on the rear side should be avoided."

Optical confinement/light management

In monofacial modules, an optimised absorption of light in the cell is typically realised by using a front glass, covered with an anti-reflection coating (ARC), an encapsulant with a refractive index close to that of glass, and a highly reflective backsheet.

In the case of a bifacial module structure, the rear side needs to be transparent in order to utilise the irradiation which is usually reflected from the ground (albedo). It should be mentioned, however, that white, full-area backsheets are also used in modules with bifacial solar cells. This can be advantageous when the pricing is based on STC measurement results alone, or if the modules are intended for use in locations with low albedo. For these measurement conditions, the contribution of the bifacial module rear side due to the albedo in real installations is not taken into account. With a white, full-area backsheet, light passing through the bifacial cells or the spacing between the cells is reflected by the backsheet, and also utilised to a certain extent [14,15,115]. The specific gains and losses are dependent on the cell spacing, the spectral properties of the solar cell, and the reflectivity of the backsheet. Panasonic [16] offers modules which utilise this effect, and Dunmore [116] promotes a highly reflective backsheet particularly for this purpose. Related concepts are the structuring of the backsheet or the application of IR-reflecting coatings on the rear side [14]. Even though these measures are applied to transparent module structures to utilise the albedo, they also aim to use the reflected light from the rear side.

Light passing through the spaces between the cells of the module area contributes, after reflection from the ground, to the rear-side illumination only to a small extent. Several approaches have been proposed for reducing these power losses. One way that is effective is the use of white reflecting foil stripes in the areas between the cells [115,117]; this has now been rolled out as a commercial product (or it has been announced that it will be marketed), for example by SolarWorld [118] and Trina. These highly reflective stripes are advantageous compared with the transmission of light through the cell spacing and subsequent reflection on the ground described earlier, while leaving the electrically active rear side of the bifacial solar cells open.

Another approach aims at increasing the portion of collected light on the rear side by using a specially designed light-trapping foil (LTF) on the back of the module [119]. This specific light-trapping layer for bifacial modules was designed by the manufacturer DSM to fulfil two functions: 1) to enhance the back reflection of light coming from the front side towards the cells; and 2) to reduce the reflection of diffuse reflected light from the ground. The LTF has not yet been launched as a commercial product.

Other efforts to increase the light management are the use of structured ribbons or light-directing films which are positioned on top of the soldered ribbons, as offered, for example, by Ulbrich [120,121] and 3M [122]. The use of conductive adhesives in combination with a structured ribbon for HJT cells was announced by Teamtechnik [86]. In addition, multiwire approaches, such as the SWCT smart-wire technology from Meyer Burger, promote light-trapping properties [123].

Several years ago, the company Prism Solar developed an interesting module concept [124,125]. In this layout, a wide spacing between the cells results in a module area coverage by solar cells of around 50%. An optical film called *holographic planar concentrator (HPC)* is embedded between the solar cells; this layer guides the incoming light via total internal reflection at the glass–air interface to the strings of solar cells, resulting in a concentration of energy per unit area of PV material. This low-concentration design is especially suited to a bifacial module structure. Other low-concentration concepts have been proposed but have not yet been integrated into the module structure [126–130].

Modules

As with monofacial modules, a common attribute of bifacial modules is the cell technology used; often the module names do not directly refer to the underlying technology, such as n-PERT, HJT or p-PERC+, but are instead chosen by the manufacturer for their specific process. As shown in the solar cell section of this paper, there is a wide range of different technologies that allow a differentiation of cell types. Apart from the cell technology, the layout of bifacial modules is still quite homogeneous.

Aside from some products which use bifacial cells in a monofacial module with a white reflective backsheet (as offered, for example, by Panasonic [16]), the rear side of a bifacial module has to be transparent in at least in one direction. In addition, modules which partly utilise internal reflection, by covering the cell spacing with a white reflective material [115], have a transparent rear side, as implemented in some commercial modules (e.g. SolarWorld [118], Trina or Linyang). For details of both of these approaches, see also the internal reflection section of this paper.

To obtain a transparent rear side, there are two options available on the market: laminates with a transparent backsheet or a glass/glass layout. By far, most of the suppliers choose a double glass design, which promises better reliability and is also being increasingly used for monofacial modules; on the other hand, some very large bifacial manufacturers, such as LG and Jolywood (which is also a leading producer of backsheets), offer transparent backsheet modules. (Jolywood offers bifacial modules with glass/glass and glass/transparent backsheet structures [110].) Interestingly, modules with the highest STC efficiency (Jolywood: 20% [110]) and the highest overall front power (LG: 395W [66]), which were discovered during the authors' market screening, are those assembled using a transparent backsheet. DuPont recently announced its release of a transparent Tedlar backsheet [131], whereas manufacturers such as Krempel [132], Dunmore [116], Coveme [133] and Isovoltaic among others offer a transparent backsheet or are currently working on its development. SolarWorld changed the module layout and replaced the version with a transparent backsheet [134] by a glass/glass version [135].

> "Modules with the highest STC efficiency and the highest overall front power are those assembled using a transparent backsheet."

The advantages and disadvantages of both layouts are widely discussed in the PV community. Glass/glass has obvious advantages concerning the mechanical stability and shielding capability of the inner components. In a symmetrical structure, the cell matrix is also located along the neutral fibre, which means that any bending of the laminate does not result in tensile or compressive stresses to the cells. On the other hand, a backsheet allows undesirable chemicals, such as acetic acid (which is a result of EVA degradation), to diffuse out of the laminate [92], as described earlier in more detail in the encapsulant section. A backsheet also promises a lower cell operating temperature, may result in a lighter module and allows a faster lamination process.

While glass/backsheet modules almost always have a circumferential frame, with glass/glass modules (dependent on glass thickness, size and the intended mechanical load resistance) frameless configurations are also standard. In the case of monofacial modules, most are currently 156mm × 156mm in size and incorporate 60 cells, but the share of 72-cell modules is increasing. The number of cells also defines the module size and is therefore often dependent on the application.

Other trends, such as half cells and shingle cells, are relevant to bifacial modules as well as to monofacial ones. With regard to half cells, the lower current is particularly interesting; because of the additional rear-side contribution, bifacial modules have higher currents and consequently greater ohmic losses than monofacial modules. Accordingly, the highest promoted module efficiency has also been demonstrated with a half-cell module [110]. Innovative layouts for half-cell modules [72,136,137] with non-standard interconnection schemes may be advantageous for bifacial modules in other respects too, because the performance in shaded conditions could be improved.

Measures, particularly the multi-busbar

	STC front [W]	Eta front [%]	Cell	No. of busbars	No. of cells	Cover	Frame	Junction box	Remarks
JA	370	18.6	p-PERC	5	72 full	GG	yes	3 edge	short frame optional
Jinko	310	18.7	n-PERT	5	60 full	GG 2x2.5mm	no	edge	
Jolywood	325	19.8	n-PERT	4	60 full	GG 2x2.5mm	no	3 edge	
Jolywood	330	20	n-PERT	4	120 half	G/BS 3.2mm	yes	edge	high voltage
LG	395	18.7	n-PERT	12 round wires	72 full	G/BS	yes	edge	large cell size
Longi	310	18.7	p-PERC	5	60 full	GG	yes	3 edge	
Megacell	280	16.9	n-PERT	3	60	GG 2x2mm	yes	rear	~2015
Ningbo	340	17.1	n-PERT	4	72 full	GG	yes	3 edge	
NSP	310	18.5	p-PERC	5	60 full	GG 2x2.5mm	yes	3 edge	POE
Prism	295	17.7	n-PERT	3	60 full	GG 2x3.2mm	no	edge	
Panasonic	225	15.7	HJT	3	72 full	GG	yes	edge	~2014 small cell size
SolarWorld	290	17.3	p-PERC	5	60 full	GG	yes	edge	white cell spacing
Sunpreme	410	19.5	HCT (HJT)	5	150 half	GG 2x2.8mm	yes	2 edge	
Sunpreme	380	19.5	HCT (HJT)	3	72 full	GG 2x2.9mm	no	edge	Tigo optimizer
Trina	310	18.6	p-PERC	5 (12)	60 full	GG 2x2.5mm	no & yes	3 edge	POE
Yingli	295	17.8	n-PERT	5	60 full	GG 2x2.5mm	no	3 edge	
Yingli	360	17.8	n-PERT	5	144 half	GG 2x2.5mm	no	3 edge	

Table 3. A selection of bifacial modules implementing different technologies.

Source: Trina Solar

Figure 2. The DUOMAX Twin bifacial module from Trina, featuring a frameless glass/glass configuration with 60 monocrystalline cells (5BB) and p-type PERC cell technology; the reported bifaciality factor is greater than 70%. The module incorporates split junction boxes at the edge with three bypass diodes. The standard glass thickness is 2.5mm on both sides. The module efficiency ranges from 17.6 to 18.9% under STC conditions.

approach, to reduce the series resistance affect bifacial modules even more than monofacial ones because of the higher currents. Currently, bifacial modules with shingled cells are also undergoing testing at the R&D level [84,85], and the first bifacial products have even already been launched [45].

Another trend, which is also implemented in monofacial devices, is the use of optimisers [138]; because of the more inhomogeneous irradiation conditions, the technique might even be more relevant to bifacial installations or at the bifacial module level, as implemented by Sunpreme [114].

Today, bifacial state-of-the-art modules are framed glass/glass modules with 2.5mm sheet thickness, POE encapsulation, 60 or 72 full-size n-SHJ, n-PERT or p-PERC+ five-busbar ribbon-connected cells, three separate junction boxes and an Al frame. The most common module variations are a transparent backsheet, cells with three or four busbars, half-cut cells, interconnections based on round wires (multi-busbar, SWCT or similar), single junction boxes or single module power optimisers, and a frameless structure. Efficiencies range between 17 and 20% at STC for front illumination. Not all companies state the bifacial factor of their products, nor is it yet common practice to give a quantitative statement on the bifacial energy gain under specific irradiation conditions. For double-glass modules, the thickness of the glass could be reduced to 2mm or below, from a technical point of view. There is no real cost-reduction potential, however, since a thickness reduction of hardened solar glass to under 2mm is complicated and at present only feasible using expensive techniques, such as chemical treatment. In addition, the module layout would need a redesign, with supporting structures located on the rear [139], since the mechanical stiffness of such thin laminates would not be adequate.

Table 3 is an attempt to summarise bifacial modules of different types, without claiming to be complete. It also has to be mentioned that manufacturers usually promote several types with different properties; in the list, however, typically only one product has been arbitrarily chosen as an example, except where there are striking differences, such as half-cell and full-cell versions, which are interesting for comparison. Generally, the version with the highest power output has been selected. Note also that the products are subject to change, and the data shown may differ from information found on the manufacturers' websites.

A bifacial module which matches the typical description above is the DUOMAX Twin from Trina, as shown in Fig. 2. This is a frameless glass/glass module with 60 monocrystalline cells (5BB) and p-type PERC technology, with a bifaciality factor of greater than 70%. It is constructed with split junction boxes on the edge with three bypass diodes. The standard glass thickness is 2.5mm on both sides. The module efficiency ranges from 17.6 to 18.9% under STC conditions.

Modules with various modifications may be acquired from other manufacturers. According to Trina, their bifacial modules are also available with white reflective covering in the spaces between the cells, with an alternative glass thickness of 2mm, and also in a framed version. Trina also offers modules with 12 busbars. On the Trina website, a 72-cell DUOMAX Twin version is promoted [140].

Another non-standard feature is the use of POE instead of EVA as the encapsulant for bifacial modules.

Module mounts and single-axis trackers

In contrast to standard monofacial PV modules, the output performance of bifacial module installations is much more dependent on the mounting and on the condition of the ground. Four installation configurations exist, namely fixed-tilt and vertical, along with one-axis and two-axis tracking. In all cases, the rear-side irradiation reaching the bifacial cells needs to be maximised, the rear-side light has to be uniformity optimised, and the portion of rear-side shading must be prevented. All the parameters mentioned earlier have an impact on the energy yield of bifacial module plants; they therefore have to be taken into account and if relevant will need to be optimised. This also applies to the cable guiding and the junction box, which must be installed outside the active area of the cells.

Since bifacial solar modules are categorised either as *framed* (typically glass on the front and transparent backsheet foil on the rear) or as *frameless* (typically glass on the front and rear) products, depending on the mounting structure, it is essential that the right module type be carefully chosen. For framed bifacial modules, the solar cells adjacent to the frame parts (i.e. the cells located directly beside the frame) are specifically subject to excessive shading under certain light conditions (usually in the early morning and late afternoon) [141]. Consequently, frameless bifacial modules are favoured over framed ones. Nevertheless, this is only a valid assumption if the mounting structure itself is arranged in such a way as to prevent any additional shading on the rear side. In other words, the uniformity of the indirect irradiation (the diffuse and reflected portion) over the entire

"The output performance of bifacial module installations is much more dependent on the mounting and on the condition of the ground."

AUSTRALIA
EXHIBITION & CONFERENCE
ALL-ENERGY 2018®
IN PARTNERSHIP WITH
CLEAN ENERGY COUNCIL
CELEBRATING 10 YEARS
3 – 4 October 2018 | Melbourne Convention & Exhibition Centre
Australia's most comprehensive
CLEAN AND RENEWABLE
ENERGY EVENT
6,700+
ATTENDEES AT LAST EVENT*
180+
INDUSTRY SPEAKERS
6x
CONFERENCE STREAMS
200+
EXHIBITORS
*6,772 attendees at All-Energy Australia 2017.
CAB Audited by AMAA.
FREE-TO-ATTEND
EXPO & CONFERENCE
Register now at: all-energy.com.au
Organised by
Reed Exhibitions
Supporters
Platinum Sponsor
Gold Sponsors
Silver Sponsors

module rear side is a key parameter to be optimised. The rear-side light uniformity is significantly improved with increasing module height above ground, affecting the rear-side irradiance level as well [142]. SolarWorld, for example, recommends an installation height of at least 1m for their current fixed-tilt-installed bifacial products [143]. This parameter, in combination with the ground reflectivity (typically called the *ground albedo value*), defines the amount of light reaching the rear side of the bifacial solar module. These two parameters play no role in monofacial PV plants but require a careful pre-evaluation to be performed by the installers/planners in order to squeeze the maximum energy yield out of a bifacial installation. For tilted bifacial installations, the preferred mounting concept is based on landscape-mounted modules with a tilt angle of 30°, installed at a height of 1m or above and a ground albedo of greater than 50%.

Solar trackers are a highly efficient way to mount PV modules: the sun's position in the sky is tracked, which maximises the energy yield throughout the day, and indeed throughout the year. Since the sun's position constantly changes, it is impossible to achieve optimal energy production with fixed-tilt or vertical PV installations. The use of tracking systems entails higher installation and maintenance costs than for fixed systems but ensures a higher energy output during the whole year. Single-axis trackers have only one axis of movement, allowing the installed panels to move from east to west, thereby tracking the sun as it rises, moves across the sky and finally sets. On the other hand, dual-axis trackers possess two axes of movement, allowing the tracking to also take into account the change in seasons. The major advantages of dual-axis tracking are evident during the winter months, when the angle of incidence of the sun is not optimised for modules with a fixed 30° tilt.

The yield gain for tracked PV installations finally depends on the geographic location, the type of module tracker used and the module temperature coefficients, since the module operating temperature increases with the light level and exposure time.

According to new data from GTM Research, global solar tracker shipments hit a record of 14.5GW in 2017 [144]. With the significant benefits associated with tracked solar modules, the tracker market is now also adapting to bifacial module technology. The necessary adaptations, however,

Source: Arctech Solar

Figure 3. Independent horizontal single-axis tracker from Arctech Solar, designed for bifacial modules [145]. The modules are fixed using aluminium elements at the module edges, overlapping with the long purlins to avoid covering the back of the bifacial modules. Junction boxes at the module edges in such a system, as shown, can be integrated without shading caused by cables.

mean a redesign of existing trackers. The mounting structure must not cause shading of the rear side of the module; this argument is also valid for any driving and actuator units, and the cabling needs to be arranged accordingly. With such specifically designed tracking devices, suppliers such as Arctech Solar promise energy yield gains ranging from 15 to 50%; if the tracker system using bifacial modules is installed over a water surface, the achieved increase in yield can approach 60%, compared with a fixed-tilt system utilising monofacial modules, as reported by Big Sun Energy.

Fig. 3 shows a specifically designed single-axis tracking system for PV systems which avoids shading of the rear side of the modules.

Outlook

At the moment, it is impossible to predict which cell technology will be superior for bifacial applications. HJT and IBC, both with more complex processes and more expensive n-type wafers, promise the highest efficiencies in bifacial systems, although HJT is superior with regard to the bifaciality factor. Bifacial IBC is the most complex but least investigated technology. The most common bifacial cell types today are n-PERT and PERC+, with n-PERT yielding a higher bifaciality and higher efficiency potential, but at a higher cost. There are a large number of n-type manufacturers, but there are also a steadily growing number of p-type PERC+ competitors.

PERC+ has the advantage that the current switch from Al-BSF as a mainstream cell technology to PERC, combined with the growing interest in bifacial and the comparatively simple implementation

> "HJT and IBC promise the highest efficiencies in bifacial systems, although HJT is superior with regard to the bifaciality factor."

of the bifacial PERC+ layout, will lead to increased efforts in this direction. Considering the historical development and the focus on mainstream technology in the PV industry that has repeatedly been demonstrated, this is an impressive argument. On the basis of these observations, it may be reasonable to assume that PERC+ will increasingly dominate in the short to mid term, while the improvements in n-type processing will make this technology superior in the mid to long term.

Besides cell selection, the module layout is of great interest. While there is a lot of activity in backsheet manufacturing, there is a general trend towards glass/glass modules (also true for monofacial modules) in order to improve durability and reliability. Since glass/glass is adaptable to bifacial demands, it is also very likely that this approach will dominate in the future. Glass thicknesses below 2mm will not be standard in the mid term. If modules are available as a framed or unframed product, the choice will mostly depend on the size and the application. Some developments which are innovative today show a lot of promise concerning their application to bifacial systems. In particular, the more inhomogeneous irradiation conditions over the module area make corresponding techniques that have been developed for monofacial modules (such as innovative interconnection schemes or optimisers at the module level) even more attractive for bifacial modules. The use of innovative interconnection schemes, especially the split module type, is often linked to half cells, which, because of the lower current, are an obvious alternative for bifacial devices anyway. Ultimately, the price–performance ratio and the observed reliability will, as always, be the decisive factor for the success of all innovative approaches. ■

References

[1] Mori, H. 1960, "Radiation energy transducing device", U.S. Patent 3.278.811.

[2] Cuevas, A. 2005, "The early history of bifacial solar cells", *Proc. 20th EU PVSEC*, Barcelona, Spain.

[3] Romijn, I. 2016, "Bifacial modules – Review", bifi PV Workshop, Miyazaki, Japan [http://bifipv-workshop.com/index.php?id=myazaki-program].

[4] Kreinin, L. & Eisenberg, N. 2017, "P-PERT bifacial solar cell technology past and future", bifi PV Workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[5] Letin, V.A. et al. 2000, "Bifacial solar arrays of Russian space crafts", *Proc. 28th IEEE PVSC*, Anchorage, USA, pp. 1067–1070.

[6] Strobl, G. et al. 1985, "Bifacial space silicon solar cell", *Proc. 18th IEEE PVSC*, Las Vegas, USA, p. 454.

[7] Nordmann, T., Vontobel, T. & Clavadetscher, L. 2012, "15 years of practical experience in development and improvement of bifacial photovoltaic noise barriers along highways and railway lines in Switzerland", *Proc. 27th EUPVSEC*, Frankfurt, Germany, pp. 3843–3847.

[8] R. Hezel 2003, "Novel applications of bifacial solar cells", *Prog. Photovolt: Res. Appl.*, Vol. 11, pp. 549–556.

[9] Made in Zelenograd 2018, "Solar wind" [http://www.made-in-zelenograd.com/companies/solar-wind/#page4].

[10] Burgers, T. 2011, "19.5% efficient n-type solar cells made in production", *Proc. 26th EUPVSEC*, Hamburg, Germany.

[11] Goda, S. 2015, Talk, 11th CSPV, Hangzhou, China.

[12] Joanny, M. et al. 2017, "Bifacial systems overview", bifi PV workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[13] Osborne, M. 2017, "SNEC 2017: The next big solar module trend on display", *PV Tech* [https://www.pv-tech.org/editors-blog/snec-2017-the-next-big-solar-module-trend-on-display].

[14] Saw, M.H. et al. 2017, "Enhancing optical performance of bifacial PV modules", *Energy Procedia*, Vol. 124, pp. 484–494.

[15] Singh, J.P. et al. 2015, "Comparison of glass/glass and glass/backsheet PV modules using bifacial silicon solar cells", *IEEE J. Photovolt.*, Vol. 5, pp. 783–791.

[16] Panasonic 2018, "Silicon heterojunction solar cell" [https://panasonic.net/ecosolutions/solar/technology/index.html].

[17] Fakhfouri, V. 2016, "IEC 60904-1-2: Measurement of current-voltage characteristics of bifacial photovoltaic devices", bifi PV Workshop, Miyazaki, Japan [http://bifipv-workshop.com/index.php?id=myazaki-program].

[18] Zhang, X. et al. 2018, "Power rating and qualification of bifacial PV modules", *PV Tech*, Vol. 40, pp. 90–96.

[19] Wittmer, B. 2017, "PVsyst bifacial shed simulations with PVsyst", bifi PV Workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[20] Kutzer, M. 2016, "Ertragssteigerung durch bifaciale Modultechnologie", 31. OTTI Symposium Photovoltaische Solarenergie, Kloster Banz, Germany.

[21] Zhao, X.S. & Khan, M.R. 2018, "Purdue University bifacial module calculator (PUB)" [https://nanohub.org/resources/pub].

[22] "PV performance modeling collaborative – Bifacial PV performance models" [https://pvpmc.sandia.gov/pv-research/bifacial-pv-project/bifacial-pv-performance-models/].

[23] Van Aken, B. 2016, "Bifacial modelling – Review", bifi PV workshop, Miyazaki, Japan [http://bifipv-workshop.com/index.php?id=myazaki-program].

[24] ITRPV 2018, "International technology roadmap for photovoltaic (ITRPV): 2017 results", 9th edn (Mar.) [http://www.itrpv.net/Reports/Downloads/].

[25] Martin, C. 2018, "Double-sided solar panels are taking off in China – Bloomberg" [https://www.bloomberg.com/news/articles/2018-05-17/watch-out-for-double-sided-solar-panels-taking-off-in-china].

[26] Vermeulen, W. 2017, "400kW bifacial system in NL and comparison with two other systems", bifi PV Workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[27] Sanyo 2010, "HIT Double 190", Data Sheet [http://www.panasonic.com/business/pesna/includes/pdf/eco-construction-solution/HIT_Double_190_Datasheet.pdf].

[28] Yingli Green Energy 2010, "Yingli green energy unveils high-efficiency monocrystalline Panda module at Intersolar trade shows", Press Release [http://ir.yinglisolar.com/phoenix.zhtml?c=213018&p=irol-newsArticle&ID=1435603].

[29] Asbeck 2014, "Asbeck versucht Neustart: Ex-Sonnenkönig kündigt neue Modultechnik an", *Handelsblatt* [http://www.genios.de/presse-archiv/artikel/HB/20141215/ asbeck-versucht-neustart/6E27CF9D-B436-48EF-9CEA-EFC3080CD8F5.html].

[30] prnnewswire 2014, "ET Solar to launch double glass bifacial module at pv expo 2014", News Release [https://www.prnewswire.com/news-releases/et-solar-to-launch-double-glass-bifacial-module-at-pv-expo-2014-247053621.html].

[31] Chunduri, S.K. & Schmela, M. 2017, "Taiyang news – About solar power", *Taiyang News – Sol. Power*, Vol. Bifacial Solar Module Technology 2017 Edition.

[32] Veschetti, Y. 2017, "Review on bifacial cells", bifi PV workshop, Miyazaki, Japan [http://bifipv-workshop.com/index.php?id=myazaki-program].

[33] Romijn, I. 2017, "Bifacial solar cells – A brief overview", bifi PV workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[34] Sinha, A. 2016, "Technology behind the world's largest bifacial PV power plant", bifi PV workshop, Miyazaki, Japan [http://bifipv-workshop.com/index.php?id=myazaki-program].

[35] Zaripova, A. 2016, "Russia: Hevel develops high-efficiency HJT modules", *pv magazine* [https://www.pv-magazine.com/2016/08/10/russia-hevel-develops-high-efficiency-hjt-modules_100025725/].

[36] Osborne, M. 2018, "3sun outlines transition to heterojunction bifacial module production", *PV Tech* [https://www.pv-tech.org/news/3sun-outlines-transition-to-heterojunction-bifacial-module-production].

[37] Presseportal 2018, "Jinergy gibt Fortschritte bei der Serienproduktion von PERC- und HJT-Solarmodulen bekannt – Medienmitteilung jinneng clean energy technology ltd." [https://www.presseportal.ch/de/pm/100064834/100816110].

[38] Bundesamt für Energie BFE 2014, "Eine Testfabrik für HJT-Solarzellen".

[39] Meyer Burger & CEA-INES 2018, "Record 410 watt module with heterojunction solar cell technology", Press Release (May) [http://e1.marco.ch/publish/meyerburger/10_7752/Press_Release.pdf].

[40] Clover, I. 2017, "Simple, powerful, demonstrable: Meyer Burger on why HJT is poised for the mainstream", *Pv Mag.* [https://www.pv-magazine.com/2017/12/13/simple-powerful-demonstrable-why-hjt-is-poised-for-the-mainstream/].

[41] Sunpreme 2015, "Sunpreme launches the world's first bi-facial smart module incorporating integrated Tigo optimisers in partnership with JDS Power thereby achieving 10% higher system energy output and up to 30% longer strings – Sunpreme" [http://sunpreme.com/2015/09/10/httpwww-prnewswire-comnews-releasessunpreme-launches-the-worlds-first-bi-facial-smart-module-incorporating-integrated-tigo-optimisers-300141113-h-tmltceml_cleartime/].

[42] Hanergy Thin Film Power Group Limited, "Technology roadmap", [http://en.hanergythinfilmpower.com/index.php?m=content&c=index&a=lists&catid=27&id=7#slide=1].

[43] Dullweber, T. et al. 2016, "PERC+: Industrial PERC solar cells with rear Al grid enabling bifaciality and reduced Al paste consumption", *Prog. Photovolt: Res. Appl.*, Vol. 24, pp. 1487–1498.

[44] Colthorpe, A. 2015, "SolarWorld launches 72-cell bifacial PV module" [https://www.pv-tech.org/news/solarworld_launches_72_cell_bifacial_pv_module].

[45] Osborne, M. 2018, "Longi Solar's p-type mono bifacial shingled cell module sets 20.66% efficiency record" [https://www.pv-tech.org/news/longi-solars-p-type-mono-bifacial-shingled-cell-module-sets-20.66-efficienc].

[46] Osborne, M. 2017, "Longi touts record bifaciality value of 82.15% for mono PERC bifacial module" [https://www.pv-tech.org/news/longi-touts-record-bifaciality-value-of-82.15-for-mono-perc-bifacial-module].

[47] Trina Solar 2017, "Trina solar launches bifacial PERC module 'DUOMAX Twin'" [http://www.trinasolar.com/en-uk/resources/newsroom/mon-05012017-1500].

[48] Osborne, M. 2017, "Trina solar launches 60-cell mono-PERC 'DUOMAX Twin' bifacial 300w module" [https://www.pv-tech.org/products/trina-solar-launches-60-cell-mono-perc-duomax-twin-bifacial-300w-module].

[49] JA Solar 2018, "72-cell bifacial mono PERC double glass module – Bifacial mono perc double glass module" [http://www.jasolar.com/index.php?m=content&c=index&a=show&catid=82&id=2].

[50] Shan, W. 2018, "Innovative double-glass bifacial PERC modules by JA Solar yield cost-effectively for pv systems" [https://www.pv-tech.org/guest-blog/innovative-double-glass-bifacial-perc-modules-by-ja-solar-yield-cost-effect].

[51] Osborne, M. 2018, "Neo solar power's mono PERC bifacial modules selected for 100mw pv plant in Taiwan" [https://www.pv-tech.org/news/neo-solar-powers-mono-perc-bifacial-modules-selected-for-100mw-pv-plant-in].

[52] NSP 2017, "NSP solar module" [https://www.nsp.com/nspsolarmodules?lang=en].

[53] Sraisth 2017, "Only perc", *Pv Mag. Int.* [https://www.pv-magazine.com/magazine-archive/only-perc/].

[54] Zheng, P. et al. 2018, "Bifacial solar products light new pathway to future pv", *Photovolt. Int.*, 39th Edn.

[55] Fuhs, M. 2015, "Schmid: Pert statt Perc", *pv magazine* [https://www.pv-magazine.de/2015/03/16/schmid-pert-statt-perc/].

[56] Teppe, A. et al. 2015, "Progress in the industrial evaluation of the mc-Si PERCT technology based on boron diffusion", *Energy Procedia*, Vol. 77, pp. 208–214.

[57] "Technology – RCT – the technology company" [http://www.rct-solutions.com//technology-10.html].

[58] "PERT – Schmid Group" [https://schmid-group.com/business-units/photovoltaics/zelle/zelltechnologien/pert/].

[59] Osborne, M. 2014, "Spi 2014: Yingli Green includes mwt and ion implant to 'panda' technology roadmap" [https://www.pv-tech.org/news/spi_2014_yingli_green_includes_mwt_and_ion_implant_to_panda_technology_road].

[60] Yong, L. 2017, "Jolywood npert technology and its application", Presented at the Bifacial PV workshop, Konstanz, Germany [http://bifipv-workshop.com/fileadmin/layout/images/Konstanz-2017/3__Liuyong_JOLYWOOD_nPERT_technology_and_its_application.pdf].

[61] "Panda bifacial 60cf – Yingli Solar" [http://www.yinglisolar.com/en/products/monocrystalline/panda-bifacial-60cf/].

[62] "Panda bifacial 144hcl – Yingli Solar" [http://www.yinglisolar.com/en/products/monocrystalline/panda-bifacial-144hcl/].

[63] Nee, J. 2017, "Process and outlook of industrial n-type bifacial PV module", Presented at the SNEC.

[64] Osborne, M. 2018, "Jolywood taps imec to support development of n-type bifacial solar cells", *PV Tech* [https://www.pv-tech.org/news/jolywood-taps-imec-to-support-development-of-n-type-bifacial-solar-cells].

[65] "LG: steigert Spitzenleistung des Neon 2 bifacial auf 390 Watt (ee-news.ch)" [https://www.ee-news.ch/de/article/38304/lg-steigert-spitzenleistung-des-neon-2-bifacial-auf-390-watt].

[66] "Neon 2 bifacial – LG Deutschland business" [https://www.lg.com/de/business/solar-panel/neon/lg-neon-2-bifacial].

[67] "Our products — Prism Solar" [https://www.prismsolar.com/s/bi60specs.pdf].

[68] Osborne, M. 2017, "Ht-SAAE launches second-generation n-type pert bifacial module", *PV Tech* [https://www.pv-tech.org/products/ht-saae-launches-second-generation-n-type-pert-bifacial-module].

[69] 2017, "Interview – Linyang", *Taiyang News – Sol. Power*, Vol. 2017 Edition Bifacial Solar Module Technology, pp. 29–30.

[70] "Trina solar: the first TrinaPro project with 250mW is on the way – Trina Solar" [https://www.trinasolar.com/en-uk/resources/newsroom/uktrina-solar-first-trinapro-project-250mw-way].

[71] "Adani: Dual glass bifacial 60 cells" [http://www.adanisolar.com/products/60-cell-modules-dual-glass-bifacial].

[72] Hsu, A. 2016, "315W 60-cell bifacial module using n-type mono cells with 21.5% efficiency manufactured on production scale equipment", Presented at the bifi PV workshop, Miyazaki, Japan,

[73] "Jinko Solar – Your best supplier of modules, cells & wafers" [https://www.jinkosolar.com/press_detail_1669.html].

[74] "Eagle bifacial solar modules – building your trust in solar" [https://www.jinkosolar.eu/en/solar-modules/bifacial.html].

[75] Osborne, M. 2018, "ISC Konstanz signs n-type bifacial and IBC cell technology transfer to Valoe for commercialisation", *PV Tech* [https://www.pv-tech.org/news/isc-konstanz-signs-n-type-bifacial-and-ibc-cell-technology-transfer-to-valo].

[76] 2017, "Fully screen-printed monopoly silicon solar cell technology", *PHYS.ORG* [https://phys.org/news/2017-12-fully-screen-printed-monopoly-silicon-solar.html].

[77] Mihailetchi, V.D. et al. 2015, "A comparison study of n-type PERT and IBC cell concepts with screen printed contacts", *Energy Procedia*, Vol. 77, pp. 534–539.

[78] Osborne, M. 2017, "SNEC 2017: World's first full-size IBC bifacial module to be displayed", *PV Tech* [https://www.pv-tech.org/news/snec-2017-worlds-first-full-size-ibc-bifacial-module-to-be-displayed].

[79] Braun, S., Hahn, G. & Nissler, R. 2013, "Multi-busbar solar cells and modules: high efficiencies and low silver consumption", *Energy Procedia*, Vol. 38, pp. 334 – 339.

[80] Schneider, A., Rubin, L. & Rubin, G. 2006, "Solar cell efficiency improvement by new metallisation techniques – the day4 electrode concept", *Conf. Rec. 2006 IEEE 4th World Conf. Photovolt. Energy Convers.*, pp. 1095–1098.

[81] Söderström, T. 2017, "Bifacial HJT SWCT gg modules", Presented at the bifi PV workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[82] Joanny, M. "Module architecture optimisation for bifacial applications, presented at the bifi pv workshop, Miyazaki, Japan, 2016" [http://bifipv-workshop.com/index.php?id=myazaki-program].

[83] Zhao, J. 1997, "20000 PERL silicon cells for the '1996 World Solar Challenge' solar car race", *Prog Photovolt Res Appl*, Vol. 5, pp. 269–276.

[84] Mittag, M. et al. 2017, "Cell-to-module (CTM) analysis for photovoltaic modules with shingled solar cells", *Proc. 44th IEEE PVSC*, Washington, D.C., USA

[85] Singh, J.P. 2017, "Shingled bifacial photovoltaic modules", Presented at the bifi PV workshop, Konstanz, Germany [http://bifipv-workshop.com/index.php?id=konstanz-2017-program].

[86] Hutchins, M. 2018, "Teamtechnik receives stringer order for HJT module line", *PV Mag.* [https://www.pv-magazine.com/2018/02/12/teamtechnik-receives-stringer-order-for-hjt-module-line/].

[87] Schulte-Huxel, H. et al. 2016, "Flip-flop cell interconnection enabled by an extremely high bifacial factor of screen-printed ion implanted n-PERT Si solar cells", *Proc. 32nd EU PVSEC*, pp. 407–412.

[88] Späth, M. 2008, "A novel module assembly line using back contact solar cells", *Proc. 33rd IEEE PVSC 2008*, San Diego, USA

[89] Einhaus, R. 2004, "Nice – new industrial solar cell encapsulation (NICE) technology for pv module fabrication at drastically reduced costs", *Proc. 19th EUPVSEC*, Paris, France

[90] Schneider, A. 2015, "Material developments allowing for new applications, increased long term stability and minimised cell to module power losses", *Proc. 31st EUPVSEC*, Hamburg, Germany

[91] Tang, J. 2017, "The performance of double glass photovoltaic modules under composite test conditions", *Energy Procedia*, Vol. 130, pp. 87–93.

[92] Oreski, G. 2017, "Acetic acid permeation through photovoltaic backsheets: influence of the composition on the permeation rate", *Polym. Test.*, Vol. 60, pp. 374–380.

[93] Koehl, M., Hoffman, S. & Wiesmeier, S. 2017, "Evaluation of damp-heat testing of photovoltaic modules", *Prog. Photovolt.*, Vol. 25, pp. 175–183.

[94] Osborne, M. 2013, "Fire risk fiasco as Dutch government warns over 650,000 Scheuten solar modules", *PV Tech* [https://www.pv-tech.org/news/fire_risk_fiasco_as_dutch_government_warns_about_650000_scheuten_solar_modu].

[95] Osborne, M. 2015, "Solar-Fabrik to issue junction box failure warning on risk of fires", *PV Tech* [https://www.pv-tech.org/news/solar_fabrik_to_issue_junction_box_failure_warning_on_risk_of_fires].

[96] 2017, "Anschlussdosen von Yamaichi fehlerhaft", *photovoltaik* [https://www.photovoltaik.eu/Archiv/Heftarchiv/article-766823-110453/anschlussdosen-von-yamaichi-fehlerhaft-.html].

[97] 2010, "Zahl defekter Solarmodule weiter offen", *photovoltaik* [https://www.photovoltaik.eu/article-439909-30021/zahl-defekter-solarmodule-weiter-offen-.html].

[98] Allagas, M. 2016, "BP solar settlement" [http://www.bpsolarsettlement.com/].

[99] "Solarlok pv edge junction box for bifacial and half-cut solar panel applications – TE Connectivity" [http://www.te.com/usa-en/about-te/news-center/solarlok-pv-edge.html].

[100] Stäubli Electrical Connectors AG/ Switzerland, photovoltaic main catalogue, index e, 01.2018, p. 63.

[101] Madon, F. et al. 2015, "Bifacial NICE modules from high efficiency n-type Bison solar cells", *Energy Procedia*, Vol. 77, pp. 382–385.

[102] "Betasolar® psbo-x junction box lsb-00190 / lsb-00192" [https://www.leoni-solar-windpower.com/en/products-services/junction-boxes/potted-jb/product-information/].

[103] "Changzhou Almaden co., ltd." [http://www.czamd.com/en/product/18_20.

[104] "Amphenol about us", *Triple Pole J-Box* [http://www.amphenol-solar.com/EN/Product/2/67.html].

[105] "QC junction box-171721", *QC Categ.* [http://www.qc-solar.com/product/junction-box-171721.html].

[106] "Zhejiang Zhonghuan Sunter pv technology co., ltd." [http://www.pvzh.com/e_productshow.asp?id=3224].

[107] "Panda bifacial 60cf – Yingli Solar" [http://www.yinglisolar.com/en/products/monocrystalline/panda-bifacial-60cf/].

SNEC 2019
PV POWER EXPO
Dialogue & Conference & Exhibition

www.snec.org.cn

13th (2019) International Photovoltaic Power Generation and Smart Energy Exhibition & Conference

June 4-6, 2019

Shanghai New International Expo Center
(2345 Longyang Road, Pudong District, Shanghai, China)

关注SNEC微信

Follow us at WeChat

◎Asian Photovoltaic Industry Association / Shanghai New Energy Industry Association
◎Show Management: Follow Me Int'l Exhibition (Shanghai), Inc.
Add： Room 902, Building No. 1, 2020 West Zhongshan Road, Shanghai 200235, China
Tel： +86-21-33561099 / 33561095 / 33561096 Fax： +86-21-33561089
◎For exhibition: info@snec.org.cn For conference: office@snec.org.cn

[108] "Ningbo Nbqxsolar bifacial solar module" [http://www.nbqxsolar.com/en/productsd.php?tid=114&tids=114&pid=561].

[109] "Durable frameless dual-glass panels for ground mount installations – Trina Solar" [http://www.trinasolar.com/us/product/duomax72].

[110] "Jolywood" [http://www.solarsystems.pro/en/jolywood.html].

[111] "Product detail" [https://www.meyerburger.com/ch/de/meyer-burger/produkte-und-systeme/detail/skyslate-bifacial/].

[112] Hsu, A. 2016, "315W 60-cell bifacial module using n-type mono cells with 21.5% efficiency manufactured on production scale equipment",, Presented at the bifi PV workshop, Miyazaki, Japan.

[113] 2017, "Jolywood n-type bifacial half-cell double glass module – Jolywood Solar – product search – world smart energy week – reed exhibitions japan" [http://d.wsew.jp/en/Exhibitors/4019394/JOLYWOOD-SOLAR/Products/1284841/Jolywood-N-type-Bifacial-Half-cell-Double-Glass-Module].

[114] "Sunpreme launches the world's first bi-facial smart module incorporating integrated Tigo optimisers in partnership with JDS Power thereby achieving 10% higher system energy output and up to 30% longer strings – Sunpreme" [http://sunpreme.com/2015/09/10/httpwww-prnewswire-comnews-releasessunpreme-launches-the-worlds-first-bi-facial-smart-module-incorporating-integrated-tigo-optimisers-300141113-h-tmltceml_cleartime/].

[115] Mittag, M. et al. 2017, "Analysis of backsheet and rear cover reflection gains for bifacial solar cells", *Proc. 33rd EUPVSEC*, Amsterdam, Netherlands, pp. 18–22.

[116] "High voltage pv backsheet, clear pv backsheets – Dunmore" [https://www.dunmore.com/products/specialty-pv-backsheet.html].

[117] van Roosmalen, J. a. M. et al. 2016, "White bifacial modules – Improved STC performance combined with bifacial energy yield", *32nd Eur. Photovolt. Sol. Energy Conf. Exhib.*, Munich, Germany, pp. 42–47 [http://www.eupvsec-proceedings.com/proceedings?paper=38754].

[118] "SolarWorld's bisun solar module with bifacial extra yield – pv Europe – solar technology and applications" [http://www.pveurope.eu/Products/Solar-Generator/Solar-modules/Solarworld-s-Bisun-solar-module-with-bifacial-extra-yield].

[119] Mrcarica, M. 2016, "DSM materials application in bifacial modules light management", Presented at the bifi PV workshop, Miyazaki, Japan,

[120] "LCR – light capturing ribbon – grooved pv interconnect wire" [https://www.pvribbon.com/pv-ribbon-products/light-capturing-ribbon/].

[121] Muehleisen, W. et al. 2016, "Comparison of output power for solar cells with standard and structured ribbons", *EPJ Photovolt*, Vol. 7, pp. 70701.

[122] "3m solar light redirecting film (LRF) T80" [http://multimedia.3m.com/mws/media/1360537O/3m-solar-light-redirecting-film-lrf-t80-white-paper.pdf].

[123] "SmartWire connection technology – Meyer Burger" [https://www.meyerburger.com/user_upload/dashboard_news_bundle/376409e022f7d2ae6f6e29318f8055410774c7fd.pdf].

[124] Russo, J. et al. 2012, "Characterisation of diffuse anisotropic illumination effects to the output of bifacial and holographic planar concentrating photovoltaic panel configurations", *Proc. 38th IEEE PVSC*, Austin, USA, pp. 1312–1317 [http://ieeexplore.ieee.org/document/6317842/].

[125] 2008, "Optics for solar energy: holographic planar concentrator increases solar-panel efficiency", *Laser Focus World* [https://www.laserfocusworld.com/articles/2008/12/optics-for-solar-energy-holographic-planar-concentrator-increases-solar-panel-efficiency.html].

[126] João, G. 2013, "Testing bifacial PV cells in symmetric and asymmetric concentrating cpc collectors", *Engineering*, Vol. 5, pp. 185–190.

[127] Moehlecke, A., Febras, F.S. & Zanesco, I. 2013, "Electrical performance analysis of pv modules with bifacial silicon solar cells and white diffuse reflector", *Sol. Energy*, Vol. 96, pp. 253–262.

[128] Ooshaksaraei, P. et al. 2013, "Characterisation of a bifacial photovoltaic panel integrated with external diffuse and semimirror type reflectors", *Int. J. Photoenergy*, Vol. 2013, pp. 1–7.

[129] Lim, Y.S. et al. 2014, "Design and evaluation of passive concentrator and reflector systems for bifacial solar panel on a highly cloudy region – a case study in Malaysia", *Renew. Energy*, Vol. 63, pp. 415–425.

[130] Poulek, V., Khudysh, A. & Libra, M. 2015, "Innovative low concentration pv systems with bifacial solar panels", *Sol. Energy*, Vol. 120, pp. 113–116.

[131] Osborne, M. 2018, "SNEC 2018: DuPont surprises with transparent backsheet for bifacial modules", *PV Tech* [https://www.pv-tech.org/news/snec-2018-dupont-surprises-with-transparent-backsheet-for-bifacial-modules].

[132] "Backsheet with fluoropolymer – Krempel GmbH" [https://www.krempel-group.com/en/solutions/solar-materials/backsheet-with-fluoropolymer-for-crystalline-modules/].

[133] "Clrpye® – pv backsheet for building integrated photovoltaics – Coveme" [http://www.coveme.com/dymat-clr-pye-backsheet-mono].

[134] "Datasheet sunmodule bisun sw 325 xl duo", *SolarWorld* [https://d3g1qce46u5dao.cloudfront.net/data_sheet/sunmodule_bisun_xl_solar_panel_325_datasheet.pdf].

[135] "Datasheets Sunmodule Bisun Protect", *SolarWorld* [https://www.solarworld.de/en/products/sunmodule-bisun-protect/].

[136] "Poly crystalline half-cut cell module – amur leopard", *RECOM* [https://www.recom-solar.com/half-cut-cell/].

[137] "Quadpower – qp60 tpg", *LinYang Renew.* [http://www.linyang.com/pv/products/module/2549/20715.html].

[138] Photovoltaik4all "Solaredge p505-5 (mc4) leistungsoptimierer", *Photovoltaik4all – Online Shop* [https://www.photovoltaik4all.de/leistungsoptimierer/solaredge-p505-5-mc4].

[139] Kreutzmann, A. 2016, "Gitter statt Rahmen", *Photon*, pp. 32.

[140] "Trina Solar datasheet 72 cell DUOMAX Twin", *Trina Sol.* [https://static.trinasolar.com/sites/default/files/Datasheet%20DUOMAX%20Twin_DEG14C.07%28II%29_July_2017_B_web.pdf].

[141] Rabanal-Arabach, J., Schneider, A. & Cabrera, E. 2015, "Minimisation of electrical losses of pv modules located in places with high solar irradiance", *Energy Procedia*, Vol. 77, pp. 402–406.

[142] Kreinin, L. et al. 2017, "Pv systems based on bifacial modules: performance simulation vs. design factors", *Photovolt. Spec. Conf. PVSC 2017 IEEE 44th*, IEEE, pp. 1–4.

[143] "Calculating-additional-energy-yield-through-bifacial-solar-technology-sw9002us.pdf" [www.solarworld-usa.com/~/media/www/files/white-papers/calculating-additional-energy-yield-through-bifacial-solar-technology-sw9002us.pdf].

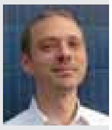
[144] Munsell, M. 2017, "Global solar tracker shipments grow 32% in 2017, NEXTracker leads the market – Greentech Media", *GTM Res. Spotlight* [https://www.greentechmedia.com/articles/read/global-solar-tracker-shipments-grow-32-in-2017-nextracker-leads-the-market].

[145] "Arctech Solar, product 'SkySmart', tracking type: independent horizontal single axis tracker" [www.arctechsolar.com].

Authors

Dr. Hartmut Nussbaumer dedicated his academic career to PV and completed his Ph.D. in 1996. After post-doctoral work he held several management positions in the PV industry, and was CTO of RENA GmbH from 2010 to 2014. He then became a lecturer at the Zurich University of Applied Sciences (ZHAW) in Winterthur, Switzerland, and is currently head of the PV modules group.

Markus Klenk received his Ph.D. in 2001, after which he worked for Sunways AG, first in R&D and later as head of cell and module quality assurance. This was followed by senior technologist positions at centrotherm and RCT Solutions. Since 2015 he has been at the ZHAW, where he continues his PV activities.



Andreas Halm joined ISC in 2008, working on solar cells made of SoG (solar-grade) silicon. In 2010 he switched to developing n-type IBC solar cells, and in 2013 began to focus on module integration. In 2016 he became group leader of the module development group, and has been head of the module department since 2017.

Prof. Dr. Andreas Schneider obtained his Ph.D. at the University of Konstanz in 2004. From 2005 to 2011 he worked for Day4Energy as head of R&D, subsequently joining Jabil and then ISC Konstanz in 2011, where he is responsible for module development. Since 2016 he has been a professor at the University of Applied Sciences Gelsenkirchen.

Turn to p81 for further insights into bifacial tracking design

Both sides of the story

Bifacial tracking | As described in the previous pages, tracking and bifacial technologies combined offer the prospect of higher energy outputs. Javier Guerrero, R&D manager at Soltec, one of the pioneers of bifacial tracking, explains some of the lessons the company has learned about optimising tracker design for bifacial modules

The design of Soltec's SF7 tracker is optimised for bifacial modules

Credit: Soltec

Following the bifacial-tracking success at the 2015 La Silla project in Chile, the seventh generation SF7 tracker was rolled out in 2017 with standard features that provide for drop-in compatibility with, and enhanced performance of, bifacial module applications.

The mission of Soltec's Bifacial Tracker Evaluation Center (BiTEC) is to perform a rigorous assessment of the influences on bifacial-tracking performance that are attributed to tracker design, tracking algorithm and installation parameters.

BiTEC is investigating specific tracker design factors that are known to influence bifacial performance, including: module mounting height above grade, backside obstructions that cause shading and losses, inter-row spacing and tracker positioning algorithms.

Following are some BiTEC investigation results to date in terms of those attributes and specific factors known to influence bifacial performance.

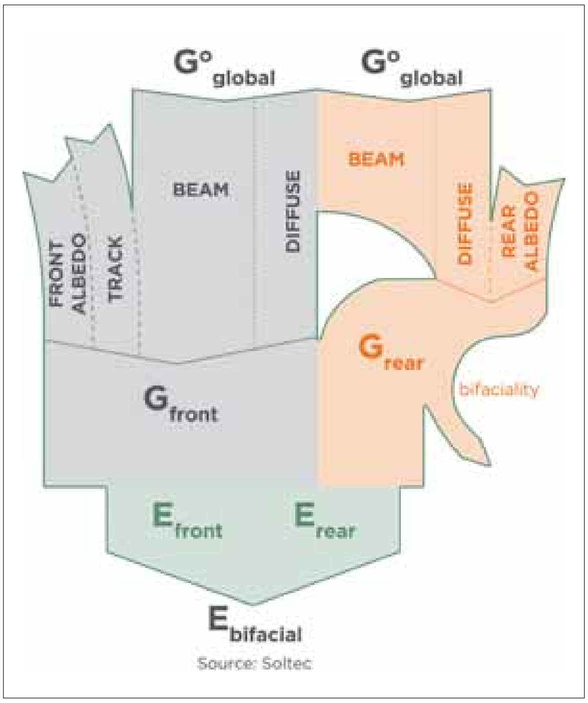
The bifacial gain model

The Sankey diagram in Figure 1 exhibits the composition of bifacial gain. From it, relationships between bifacial ratio, bifacial gain and the summation of bifacial module energy performance (E) can be deduced.

Albedo is a determinant factor in bifacial gain. It is dependent on reflective surface colour, texture and extension. Maximum gain comes from smooth white surfaces and greater reflecting area free of disrupting obstructions. At La Silla, experience highlighted a measureable seasonal variability of albedo as vegetation colours change.

Mounting height

The mounting height of the bifacial module has considerable influence on the quantity of diffuse irradiation that impinges on the rear side of the module. The graphics in Figure 2 exhibit bifacial gain versus height of fixed-mount PV



Source: Soltec

Figure 1. The composition of bifacial gain.

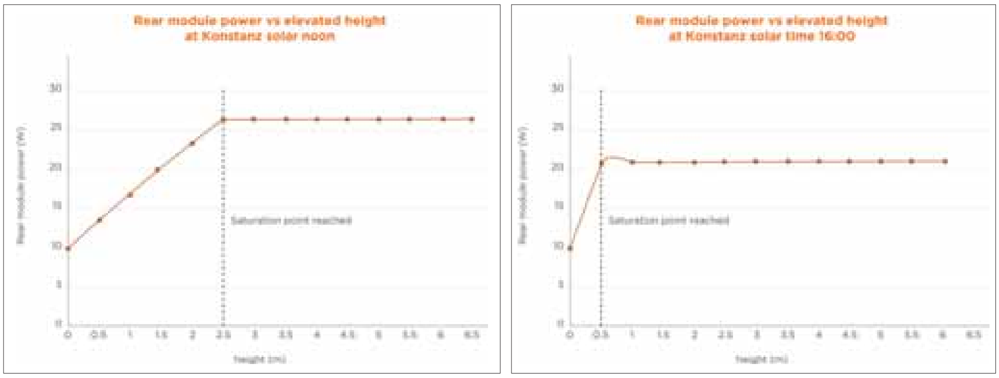


Figure 2. The effects of module mounting height on bifacial gain

that reaches a saturation point of adding value [1].

The economic considerations of module mounting height present a trade-off on increased height (for increased performance) versus increased cost of principally steel material to meet the increased structural demands including with respect to wind-design. The tradeoff analysis is highly dependent upon the albedo potential of any subject site, with greater albedo potential indicating an economic justification for pursuing increased height.

Inter-row spacing

Direct beam radiation is reflected, and greater reflected surface area free of obstructions within "view" of the backside will positively influence bifacial gain. Inter-row spacing is a function of tracker width and the design-specified GCR (ground coverage ratio) or pitch on the east-west plant layout dimension. A GCR of 33% indicates an aisle width between tracker rows equal to double the tracker width, 25% GCR indicates an aisle width triple the tracker width. A wider tracker results in wider aisles and a cleaner view from the backside, and results in the higher mounting height for greatest backside capture (Figure 3).

Both albedo and GCR are fundamental design parameters of traditional monofacial tracking applications. The bifacial application highlights the distinct and critical nature of design considerations and establishing criteria to best capture energy from both sides now.

Backside shading and losses

This aspect finds enhanced bifacial gain performance from a cleaner backside view where structural and cabling elements are obstructions to maximising capture on the backside.

The structural components include the tracker torque tube and (typically) pile-type foundation elements. The cabling components include typical PV source-circuit management of bundled and suspended cabling leading to a mounted combiner box.

Simply fewer installed parts results in less obstruction and greater bifacial gain capture. Other components that cause backside obstruction are mechanical dampers and tracker-drive links.

The ideal torque-tube imposes minimal direct obstruction on the bifacial backside thanks to the sun-facing array-gap that corresponds to torque tube width. Moreover, its top-face can be leveraged as a strongly reflecting surface impinging the bifacial backside most homogeneously.

The ideal cable management solution is embedded within the torque tube and excludes traditional combiner boxes, resulting in zero obstruction influence.

Tracking algorithms

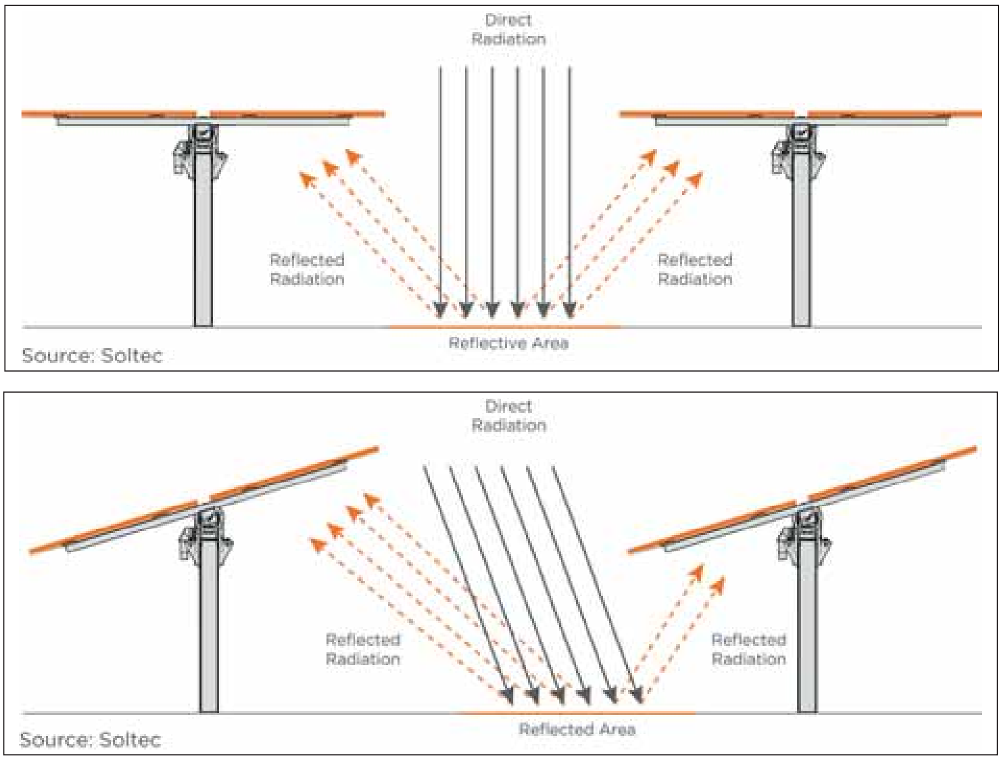
Comprehensive tracker position control enables a bifacial tracking algorithm that maximises performance according to the conditions of the sky and diffuse radiation. Bifacial technology creates a new scenario for tracking algorithms.

Site albedo and radiation characteristics play key roles in the economic balance of "unfocusing" the tracker to favour backside production and potentially trading off front side production. Unfocusing refers to a position control modification away from standard clear-sky monofacial tracking that is typically oriented normal to the impinging direct beam radiation.

Beam radiation is captured only on the front side along with diffuse, while in the bifacial application both sides capture diffuse radiation. The Sankey diagram above exhibits the composition.

With cloud-cover, the bifacial application economic balance leans towards tracker positioning to maximise the combined diffuse components over traditionally focusing on front side beam radiation. Unfocusing algorithms are not unique to bifacial applications, but they are increasingly considered essential to them. The criteria of unfocusing are coming forward from accurate modeling and corresponding field tests at BiTEC.

Figure 3. Direct beam radiation is reflected towards the backside as a function of site albedo (spacing not shown to scale)



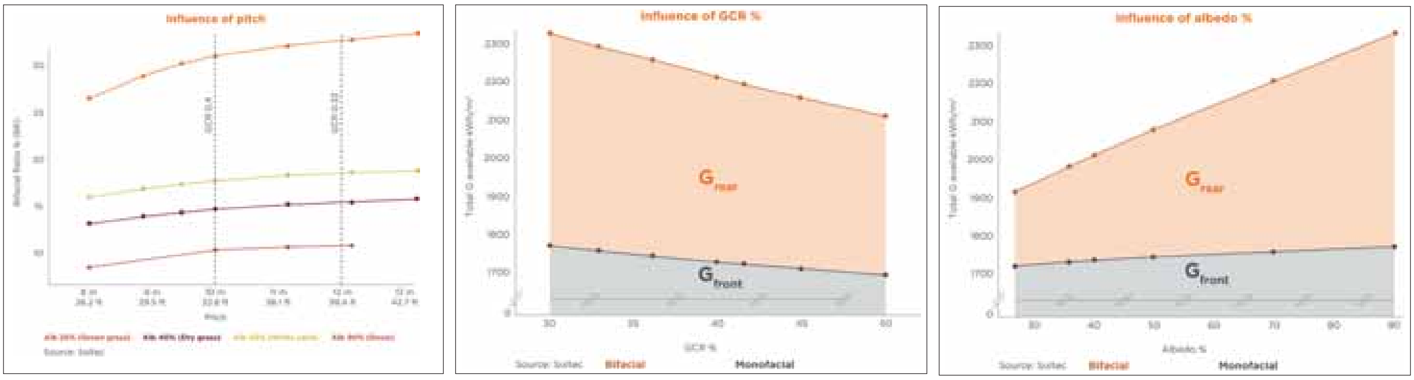


Figure 4. Wider spacing and higher albedo enhance bifacial ratio and bifacial gain

Continuing BiTEC investigation

BiTEC is moving forward with industry collaborators on those topics to help quantify bifacial gain expectations considering tracker alternatives. Furthermore, it is going to greater depth on emerging evidence such as backside irradiation distribution being heterogenous versus homogenous. The latter is preferable, as in the case of torque tube and gap optimisation described above. Highly heterogenous distributions may generate hot spots on the array, and array temperature distributions are being tested.

The BiTEC tracker field is configured to test GCRs of 0.3, 0.4, and 0.44, and to test three albedo types. It will accommodate almost any module and configurations thereof. Comprehensive tracker position control is on board along with sensing of sky and irradiation conditions in order to perform tracker position response functions.

In conclusion

Soltec and BiTEC collaborators are doing diligence to help customers address the emerging bifacial tracking technology opportunity. The investigation has as its end cost-effective innovation and operational criteria to best leverage the bifacial gain opportunity.

Author

Javier Guerrero holds a Ph.D. in renewable energy with a thesis around modelling the electrical behaviour of PV module and inverter combinations. His professional involvement in the solar industry spans over 10 years. Javier joined Soltec in 2015 commissioning the bifacial trackers at La Silla, and he is currently managing Soltec's Bifacial Tracker Evaluation Center in Livermore, California.

References

[1] Wang et al 2015. "Bifacial photovoltaic systems energy yield modelling", Science Direct. Energy Procedia 77, 428 – 433.

Project briefing

RICE, RAYS AND RECHARGE: HOW AN INDIAN VILLAGE GOT 24/7 CLEAN ENERGY

In April of this year, the Indian Prime Minister, Narendra Modi, drew scorn when he announced that every village across India had access to electricity. The reality that 'electrification' in government terminology meant that a mere 10% of households in any one village had power, was not made clear in the initial announcements.

What Modi lacked in specifics in April, his government has not lacked in ambition. During the final implementation of 'DDUGJY', a scheme to connect every village to the grid, he launched the 'Saubhagya Yojna' scheme in September 2017, aiming to achieve complete household electrification by installing solar energy, battery storage, LED lighting, a fan and a plug socket in every willing house, whether urban or rural, by December 2018. This would concentrate on the 30 million below poverty line households not covered by other ongoing electrification schemes.

However, it is also important to remember that power connections in India do not guarantee regular and reliable electricity. Indeed this aspect is often overlooked in the mainstream, overshadowed by the sheer number of people still left in the dark.

Uttar Pradesh, the most populous state in India, dominated by agriculture on the plains of the Ganges, and its neighbours Bihar and Jharkhand, have a combined population of 400 million people (at a crude estimate), of which around half have little or no access to electricity.

Nonetheless, even with electricity, a fledgling rural business will always be stifled if it has no power for six to eight hours on any given day, with frequent and unpredictable blackouts. For total electrification to be of most value, it requires a three-pronged attack: first, to bring grid infrastructure to villages; secondly, to connect each individual household; and lastly, to make the power supplied both reliable and affordable.

Power at the last mile

This is why *PV Tech Power* visited a village in the heart of the North Indian plains where Uttar Pradesh borders Bihar, to see how a bold mix of biomass, solar and energy storage technologies is transforming local businesses by providing round-the-clock clean energy at prices cheaper than those of the main grid – all the while helping to solve India's long struggle with power theft.

Credit: Tom Kenning

Heading east past the town of Kushinagar, a Buddhist pilgrimage site, lies the village of Tamkuhi Raj. The terrain is flat in all directions, with cornfields, brick kilns and a buzz of agricultural activity prevailing.

It is here that a hybrid mini-grid has been installed by Husk Power Systems, one company in particular that has seen the value in adding reliable decentralised power systems to locations at the furthest reach of the grid. The Indian firm started out in 2008 by deploying biomass gasification systems, particularly using waste rice husks as a fuel, before branching out into the hybrid space.

Manoj Sinha, the co-founder and CEO of Husk, has a vision of electrifying his homeland, and though his company is focussed on the northern plains, given the vast number of people with poor quality power access, it is also active in parts of Africa. Sinha, grew up in Uttar Pradesh and experienced a lack of power first hand, so after moving to the US, he returned to India to help improve the situation.

Husk did originally evaluate the potential for solar energy, but that was back when the firm was created in 2008 and PV technology was prohibitively expensive, with prices of around US$5-6 per watt versus the biomass systems' cost of US$1.20 per watt. However, while the rice-husk-fuelled biomass option provided attractive costs, it was limited by maintenance and feedstock requirements. One could technically run it throughout the day, but given the number of moving parts, the systems would come to their end-of-life very quickly.

The complete solution developed when global price points on solar technology followed a dramatic downward curve, making the combination of biomass, solar and energy storage feasible. Husk struck up a strategic partnership with First Solar, the US-based thin-film PV manufacturer and project developer. First Solar's thin-film technology is particularly suited to India's humid climate, due to the way the semiconductor used in its modules responds to changes in temperature, humidity in atmosphere and low light

By Tom Kenning

quality, delivering 5-9% higher energy yield, it claims.

Further explaining why Husk's mini-grid at Tamkuhi Raj adds value, the local regional manager at Husk, Sanjay Singh, says: "Due to India's heavily subsidised power industry, some believed that the end consumer, particularly in marginalised India, had little desire to pay for additional, more reliable sources of power. But, when certain businesses are curtailed, and some cannot run at all, or shops can't be kept operational in the evenings for those local workers who can only shop at night, these people will actually pay for quality power and that's again based on the data we see."

Food and power

In the village, solar power provides electricity to the customers during the day, while simultaneously charging the batteries. The batteries are then utilised at night. The biomass gasification system is only used as a backup, if there is poor weather during the day, which does not allow the batteries to sufficiently be charged up. If the load is particularly high, that can also impact the ability of the battery to supply enough power. The biomass system can seamlessly address this through a five-minute transfer via a manual lever. Once the rice husks are fed into the gasification system, it takes 15-20 minutes to combust. Impurities are then removed before progressing into the gasifier. For the system to generate power for an hour, it requires around three bags of rice husk – a fuel source that is in plentiful supply in the region.

Shopkeeper Dinesh Gupta didn't even have a shop before the Husk mini-grid system started operating in the village. A reliable source of power allowed him to start selling a range of cosmetics such as soaps and creams along with basic clothing items at a nearby market. He uses the power mainly for lighting at night, secure in the knowledge that it can be tapped 24 hours a day.

Munna Yadab, who runs a confectionery shop, has completely cut his power supply from the main grid to get 24/7 supply from Husk. For the first time he can use refrigerators to sell cold drinks and other chilled items that were a struggle during the power cuts of the past. Cumulatively, he is now paying slightly more for this power, but this is because now he can run power round the clock, and the additional price is more than offset by the ability to expand the scope of his business.

Susant Gupta used to run a printing and copying service shop in town with a diesel generator at a cost of 300-400 rupees per day. Having adopted power from Husk and First Solar's mini-grid, he can now run the shop at 1,200-1,500 rupees per month with zero power interruption. He's cut off the main grid supply to only use Husk power and with the confidence of reliable power behind him, he has been able to secure a loan to expand his business.

Gupta says he stood in a line to be one of the first customers to get his power. The local market has benefitted and particularly households that weren't getting any power previously. The biggest benefit is not having to wait for electricity to come in order to run a business, he adds, as power is now 24/7. In the past if they had no electricity for four hours in the morning, then the shop and others like his just sat idle. Husk also runs a water purification service using power from the mini-grid, which Gupta takes advantage of to purchase unbranded and clean bottled water for his home.

These are just a few stories from the market, but spread across multiple entrepreneurs, businesses and educational facilities, you have significant benefit to the community at large, even if the Husk system for now can only supply power to roughly 110 people in this particular village.

Across their various sites, based on a survey by Husk of over 250 commercial customers, over two-thirds were able to increase their revenue by around 200% by getting access to 24/7 power. Even Husk was not expecting such positive results.

This is partly because the locals no longer have to worry about the reliability of electricity.

"Now they can build a life round something that is omnipresent and always available," adds Sinha. "They can buy a freezer and they can keep perishable products that they could not before. They can purchase ice cream-making machines and make ice cream and other additional products, which is the powerful result of providing 24/7 power – bringing real changes to commercial customers' revenue and profitability."

First Solar's Sujoy Ghosh also notes that in Husk's experience, the load growth has

Credit: Tom Kenning

Credit: Tom Kenning

been at 25% year-on-year on their mini-grids as opposed to a national average of 5% year-on-year as projected in the Indian government think-tank Niti Aayog's reports for rural energy growth.

"We think there is a lot of unmet demand in India which is not in the grid and as you start to deploy energy in a more distributed manner into areas which have challenges of access, you are going to see a lot more demand come up," he adds – noting that green mini-grids are also a way to help reduce the vast number of polluting diesel gensets that are still running all over India.

Biomass gasification

The batteries used are lithium-ion, with a 2V 135-hour capacity and an output of 400V. A total of 24 batteries are connected in a series 42/48V, purely to provide backup services. It takes between four to six hours of sunlight for the First Solar modules to charge the battery set.

To maintain the mini-grid, the modules have to be cleaned every two days over a one-hour period since the region is very dusty. This is a simple process compared to the biomass gasification system, which requires trained technicians to carry out a different maintenance schedule every three days.

Making power affordable

Husk's ability to be customer-centric will always stand apart from Indian Discoms (utilities) and the centralised grids, which are simply too large, but regulations do allow for these decentralised mini-grids to integrate with the main grid and Husk is already working with Discoms in Uttar Pradesh to run a pilot. It's not one-way traffic in favour of the decentralised system either, since one of Husk's competencies is being able to collect money from the customer, which has typically been a problematic and bottomless task for the average Indian Discom.

Husk already offers flexible tariff schemes that change depending on what time of the day the power is being used. This is measured using a sophisticated net metering platform, that can be managed from anywhere in the world. It offers discounted electricity prices between 10am and 4pm when generation from solar is at its peak. It also offers discounts to customers using 1kW or more, as this is classed as productive power that is being used for income generation by the consumer, like running a business for example.

"We promote those kinds of activities because it just generates more economic activity in the village. They are happy, their business grows, our business grows so that's a category of customers that we can easily identify through the pre-paid meter and we can devise the perfect category of tariff for them," says Sinha.

Husk also estimates that customers save around 20-30% on energy costs, while also benefitting from the uninterrupted round-the-clock power. There is also a service level agreement wherein if anything goes wrong with the project, Husk will fix it within four hours.

Using a pre-paid meter also means customers are not conscripted into paying for energy supply. When *PV Tech Power* visited the site, out of 110 customers, 90 had opted in for the month, while the remaining 20 had temporarily opted out, either due to being hard up on cash, or being away from home at that particular point in time. Customers have the flexibility to opt back in at any time.

Future

Looking ahead, Husk will retain its focus on Uttar Pradesh and Bihar, but will also enter Jharkhand, with a goal to add between 250 and 300 new sites or power plants by 2021.

The company's plans in Tanzania are to expand to roughly 35 new sites over the same period of time and if more capital resources are secured, it plans to go to West Africa as well.

Sujoy Ghosh says that given the small, kilowatt-scale of most of these projects, it's easy to gloss over their significance, but if you start aggregating them all it becomes clear that this is a "huge opportunity".

By late March 2018, India had sanctioned 4,375 decentralised distributed generation (DDG) solar energy-based projects covering 3,377 villages, of which 2,321 projects across 1,446 villages had already been commissioned.

Reflecting on the benefits of the mini-grid in Uttar Pradesh, clearly it would be prudent for India to concentrate on this third aspect of regular and reliable power just as much as on total electrification. ■

Visit us at Solar Power International | September 24-27 - Anaheim Convention Center | Booth 378

Study on measurement of temperature coefficient of different types of PV modules in outdoor operating conditions in India

Module performance | Temperature coefficient has a well-known bearing on the performance of PV modules. Based on analysis of field data gathered from operational modules in India, Satish Pandey, Rajesh Dhuriya, Gaurav Mishra and Rakshita Mhatre reveal how in actual operating conditions the temperature coefficient of modules is deviating from values provided in manufacturer datasheets, potentially impacting on project financial modelling

The increasing market and profile of photovoltaics means that more applications than ever before are "photovoltaically powered". These applications range from power stations of several megawatts to solar chargers of a few volts. PV modules are incorporated in systems and the customers are interested in a high energy yield from those the systems. The energy yield from PV systems cannot be determined on the basis of the nominal power of the module. Under outdoor conditions irradiance and ambient temperatures are constantly varying, and at non-standard conditions the characteristics of the modules are often not known [1]. In this paper we try to evaluate the temperature coefficient of electrical parameters to determine the performance of PV modules in outdoor conditions typically found in India. In order to evaluate energy yield at actual and datasheet-mentioned temperature coefficients for two regions – Andhra Pradesh (latitude 13.82°N/longitude 78.09°E) and Rajasthan (latitude 27.4°N/ longitude 72.3°E) we have performed PVsyst (V6.41) simulations for corresponding regions. The temperature coefficients as per the manufacturer datasheet are shown in Table 1.

Experimental setup and approach

Real-time measurement of irradiance, module surface temperature and electrical parameters of modules was carried out in Rajasthan, India; five types of modules (two types of thin film CdTe modules and three polycrystalline silicon modules from two different suppliers) were used to compare the temperature coefficient of electrical parameters in real world conditions. All the modules were cleaned before performing the test to avoid the effect of soiling on the measurement. The irradiance at plane of module was measured using a pyranometer. The surface temperature of each module was measured using a PT100 temperature sensor attached to the rear side of the module. Data from the pyranometer and temperature sensor was automatically recorded in a data logger. The electrical parameters (voltage & current) of each module were measured in continuous mode using an I-V tracer, with each measurement taking around nine seconds. All the data was automatically recorded within an interval of one minute. Details of the equipment used are listed in Table 2 and Figure 1 shows the set up.

As per the module characteristic, the efficiency of the module is almost constant

Instrument	Measurement	Make (Model)	Specification	Accuracy
Pyranometer	Irradiance	Kipp & Zonen (CMP11)	0 to 2000 W/m2 285 to 2800nm -40°C to 80°C	+/- 2.0%
Temperature sensor	Module surface temperature	RTD PT100 (110 PV)	-0°C to 148°C	±0.1°C
Portable I-V curve tracer	PV module – electrical parameters	PV-engineering (PVPM100040C)	P: 0-4kW V: 0-1000V I: 0-40A	P: +/- 5% V & I: +/- 1%
Data logger	Data recording	Campbell Scientific (CR1000)		

Table 2. Instruments used for experiment and their specification

Sr. No	Supplier	Manufacturing year	No. of years since operation (years)	Country of origin	Technology	Datasheet temperature coefficient (%/°C)		
						Pmax	Voc	Isc
1	Supplier 1 Model 1	2013	4	China	Poly-Si	-0.43	-0.32	0.06
2	Supplier 1 Model 2	2013	4	China	Poly-Si_ PID free	-0.40	-0.30	0.06
3	Supplier 2 Model 1	2014	3	USA	Thin film-CdTe	-0.29	-0.28	0.04
4	Supplier 2 Model 2	2012	5	USA	Thin film-CdTe	-0.25	-0.27	0.04
5	Supplier 3 Model 1	2011	6	India	Poly-Si	-0.45	-0.35	0.05

Table 1. Experimental procedure parameters

abovesurveying
aerial thermographic surveying

Going above and beyond

Drones are now driving data collection in the solar sector and becoming a fundamental part of asset management

PV Tech caught up with Will Hitchcock, Managing Director and founder of Above Surveying Ltd, a leader in the field of aerial data and asset analytics within the solar industry. UK-based Above Surveying was established in 2015, having recognised that PR measurement and string monitoring alone did not give the full picture of a solar asset's health and that there was an urgent need in the market for large-scale thermographic inspection and analysis.

Above Surveying was the first company to develop a service which was able to deliver accurately and consistently at scale using drone-collected data - unique, in that it measures irradiance and not just imagery- plus a scientific approach to data analysis, coupled with easy-to-navigate reporting.

"We fix an industry dilemma"

Will Hitchcock sets out their vision, "We quickly recognised that this is not just about the drone's capability to survey solar on a much larger scale than was previously possible. It's about fixing a much wider industry dilemma – how do you deliver detailed, consistent and cost effective 100% module thermography across utility scale solar? And even more importantly, how do you report your findings in a way that can be easily digested and effectively used to improve the performance of the asset?

It was with this in mind that we developed our service, complete with a bespoke reporting portal, SolarGain, using exciting, innovative technology to deliver both of these requirements in a single market offering."

Above Surveying works with all areas of solar ownership and management, including technical advisors and O&M companies. As a result, 100% thermographic inspections are now becoming an integral part of solar asset management. This is key to ensuring that the asset is achieving optimum performance and delivering maximum yield.

Having delivered 2.5GW of inspections to date, Above Surveying is now offering its services in Italy, Spain, the US and Australia through a growing partnership network. Will Hitchcock explains that by working with all areas of solar ownership and management their approach is driving higher standards across the industry, "The level of systemic issues we are seeing across the UK asset estate, such as PID, bus bar corrosion and faulty junction boxes, means that even if your asset is hitting its PR targets, such technical problems can already be impacting performance and yield. Identifying and rectifying these issues early is vital if your asset is going to deliver financially for its full life."

Through the SolarGain portal and mobile apps, Above Surveying's clients can interact with the inspection data, whether at their desks or on-site using smart devices. Every reported anomaly can be recorded and managed, along with follow-up testing and rectification work.

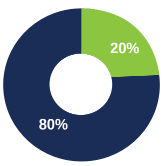
"We have real evidence that our service is driving higher standards in asset management"

Data driven analytics

Will Hitchcock explains, "The quality of our data and our impartiality is the key to our success. We report what we find – good and bad. But crucially we give our clients the ability to easily access and use this data as well as being able to pinpoint a problem right down to the cell level. This data driven level of accuracy and the ability to compare performance across different assets and time periods means that, with a regular programme of inspections, our clients can anticipate and rectify problems quickly, thereby maximising their asset's performance."

Above Surveying's service has been used to map both the spread, and more positively, the recovery of PID impacted assets, demonstrating the way in which quantitative analysis can be derived from drone collected data. On one asset, 82% PID recovery was recorded since reversal units were fitted 9 months prior.

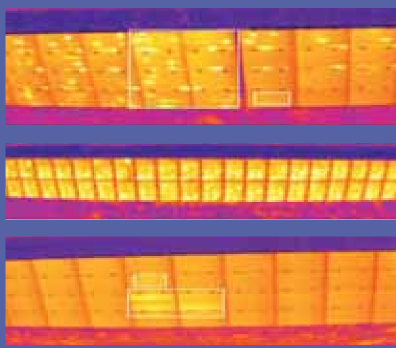
20% of assets are showing early signs of PID.



Above Surveying is working with the very latest technologies to continue to develop their offering and ensure that it remains at the forefront of this rapidly evolving market.

Will Hitchcock concludes: "We are currently working in partnership with the University of Essex and Innovate UK to develop automation across the whole inspection process using computer vision and AI. This is what makes working in solar so exciting; the potential of this technology, the knowledge that you are constantly breaking new ground and the fact that these advancements are driving higher standards in a vibrant sector. I envisage exciting times ahead."

SolarGain
INSPECTION HUB



231 solar assets inspected

29 module manufacturers covered

125MWh/Yr. estimated losses for a 10MW Site

2.5 GW inspected

8.53 million modules inspected

205k modules with anomalies identified

www.abovesurveying.com

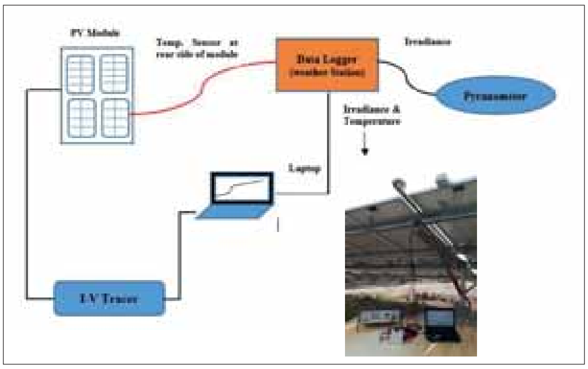


Figure 1. Block diagram of experimental set up with visual representation

for the irradiance level greater than 500W/ m^2 [2]. To avoid the effect of irradiance level on the evaluation of temperature coefficient of electrical parameters of the modules, measurements with the I-V tracer were considered only for irradiance levels greater than 600W/m2 to 1,000W/m2. Further, to minimise the effect of fluctuating irradiance during I-V tracing, the measurements were carried out on a clear sky day.

The temperature coefficient of the electrical parameter was derived from the slope of the plot of measured electrical parameters versus module temperature as follows:

Voltage The measured voltage was plotted against measured module surface temperature and its slope was calculated.

Power The measured power was normalised with respect to measured irradiance. The normalised power was then plotted against measured module surface temperature and its slope was calculated.

The measured I-V characteristic is not affected by the resistance of the measurement cables, as it is carried out by a four-terminal measuring method [3]. In four-terminal measurement, the additional resistances like stray load loss and coupling resistance are avoided, and also the cable terminal resistance is significantly low. The measured values are reported at standard test conditions using translation as per IEC 60891:2009 PV devices procedure for temperature and irradiance correction to measured IV characteristics [4]. Using the measured parameters following curves are plotted:

Irradiance and temperature versus time:

Figure 2 shows the variation of irradiance and temperature with respect to time. The ideal time for testing can be determined from this curve. The time period is selected from the curve for which there is a linear increment in module temperature with increase in irradiance.

Linearity test current versus irradiance:

According to solar cell physics, current is directly proportional to irradiation. So the curve should be linear. Observing the curve in Figure 3, it can be determined what portion of the module characteristic is linear.

Normalised power versus module surface temperature:

The output power of the module linearly decreases as the module temperature increase, as shown in Figure 4.

Normalised Vmpp versus module surface temperature:

It is observed from Figure 5 that the maximum power point voltage linearly decreases as the module temperature increases.

Normalised Voc versus module surface temperature:

Open circuit voltage linearly decreases as the module temperature increases. As shown in Figure 6 the temperature coefficient is determined by the slope of the trend lines.

Observations

The values of temperature coefficient were different in field testing than the standard testing conditions (STC, IEC 60904–3) i.e., irradiation 1,000W/m^2, air mass 1.5 and the module temperature 25°C [5]. However during operation in the field PV modules spend a very short span of time under STC conditions. Thus an important characteristic for a module is to ensure an adequate performance in the field at different temperature and irradiance conditions. For the set of PV modules under test, the values as a function of the temperature for maximum power point, the open-circuit voltage and the maximum power point voltage are taken into account whereas the temperature coefficient of short circuit current (Isc) is very little so not taken into consideration. The power output of these modules is largely determined by the local climatic conditions where they are installed, hence it becomes important to obtain information on their actual field performance.

The plot between irradiance and temperature is shown in Figure 2. According to this graph, the area under the timing 08:41-11:53 is ideal to perform the test. The curve is linear in this region, meaning the temperature increases linearly with increases in irradiance. Along with ambient temperature the module's temperature is also very important for the test.

Results

Output power reduces as PV module temperature increases

According to Figure 4, the slope of Supplier 1 Model 1 is steepest hence the power output given by this module is decreasing rapidly with increasing temperature. Supplier 2 Model 2 has least slope, so its output power is decreasing slowly with increasing temperature.

Equation for evaluation of temperature coefficient (slope value) of power:

Y= Parameter on Y axis (i.e. normalised power in Figure 4)

X= Parameter on Y axis (i.e. module temperature in Figure 4).

R2= Correlation coefficient between x & y

Supplier 1 Model 1: $y = -0.0056x + 1.0987$, $R^2 = 0.9881$

Supplier 1 Model 2: $y = -0.0049x + 1.1329$, $R^2 = 0.9829$

Supplier 2 Model 1: $y = -0.0032x + 1.1078$, $R^2 = 0.9814$

Supplier 2 Model 2: $y = -0.0026x + 1.105$, $R^2 = 0.9645$

Supplier 3 Model 1: $y = -0.0041x + 1.0588$, $R^2 = 0.9671$

Output voltage at maximum power point (Vmpp) reduces as PV module temperature increases

According to Figure 5, Supplier 2 Model 2 shows least linear decrement in output voltage with increase in module temperature and the Supplier 1 Model 1 shows the highest decrement in normalised Vmpp per unit with increased module temperature.

Equation for evaluation of temperature coefficient of voltage at maximum power point:

Supplier 1 Model 1: $y = -0.0051x + 1.0833$, $R^2 = 0.9843$

Supplier 1 Model 2: $y = -0.0045x + 1.0896$, $R^2 = 0.9843$

Supplier 2 Model 1: $y = -0.0039x + 1.1752$, $R^2 = 0.9854$

Supplier 2 Model 2: $y = -0.0025x + 1.0272$, $R^2 = 0.9839$

Supplier 3 Model 1: $y = -0.0048x + 1.1114$, $R^2 = 0.9898$

The equation shows that the slope of Supplier 1 Model 1 is highest so the decrement of maximum power point voltage is rapid for this module with increases in temperature. The slope of Supplier 2 Model 2 is lowest hence the decrement of maximum power point voltage is slow for this module with increases in temperature.

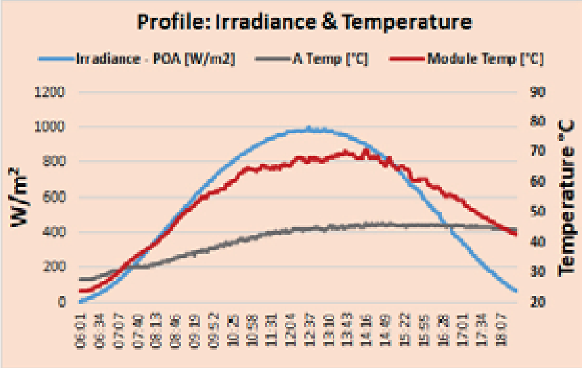


Figure 2. Graph representing linear region in irradiance & temperature curve

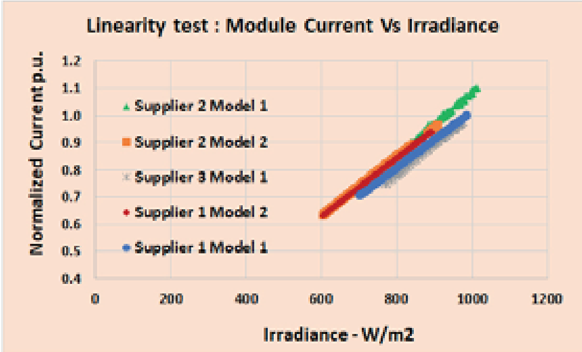


Figure 3. Normalised module current versus irradiance (linearity test)

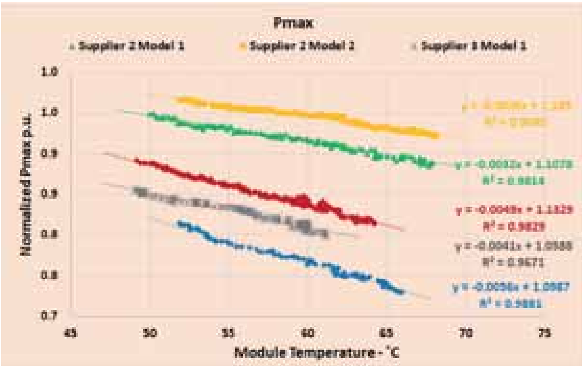


Figure 4. Normalised Pmax versus module temperature

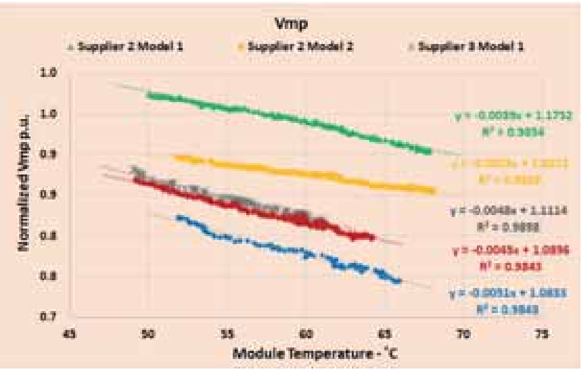


Figure 5. Normalised maximum voltage output versus module temperature

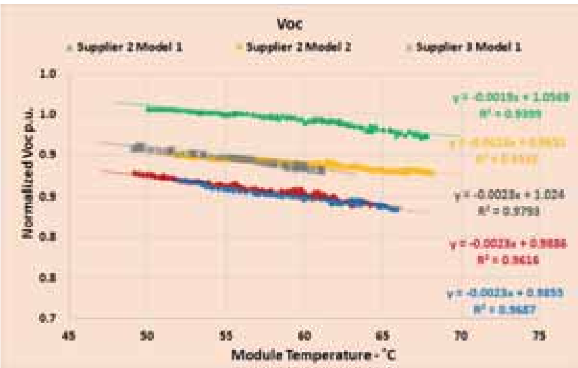


Figure 6. Normalised Voc versus module temperature

Output open circuit voltage (Voc) reduces as PV module temperature increases

Equation for evaluation of temperature coefficient of open circuit voltage:

Supplier 1 Model 1: $y = -0.0023x + 0.9855$, $R^2 = 0.9687$

Supplier 1 Model 2: $y = -0.0023x + 0.9886$, $R^2 = 0.9616$

Supplier 2 Model 1: $y = -0.0019x + 1.0569$, $R^2 = 0.9399$

Supplier 2 Model 2: $y = -0.0013x + 0.9651$, $R^2 = 0.9535$

Supplier 3 Model 1: $y = -0.0023x + 1.024$, $R^2 = 0.9793$

The equations show that, the slope of Supplier 1 Model 1 is highest so the decrement of open circuit voltage is rapid for this module with increases in temperature. The slope of Supplier 2 Model 2 is lowest so the decrement of open circuit voltage is slow for this module with increase in temperature.

Table 3 shows the values of the parameters like maximum power, Vmpp and the open circuit voltage for the various PV modules.

Observations from Table 3 are as follows:

Measured temperature coefficients of power are higher than the manufacturers' datasheets, except for Supplier 3. A possible reason may be due to low quality of wafer/cell processing.

Measured temperature coefficients of Vmpp (voltage at maximum power) are approximately close to temperature coefficients of Pmax; the same is claimed by different module manufacturers.

Measured temperature coefficients of open circuit voltage (Voc) are lower than manufacturers' datasheets.

Table 4 shows predicted temperature losses for respective module suppliers for two locations (Andhra Pradesh and Rajasthan); we have calculated the loss in energy for evaluation of impact of temperature coefficient.

Table 5 shows the energy losses predicted by PVsyst for respective module suppliers due to temperature coefficients given on manufacturer datasheets and those measured in the field in two locations (Andhra Pradesh and Rajasthan).

Table 6 shows the annual revenue loss at tariff US$0.07/kWh calculated on energy loss due to TMod predicted by PVsyst for two locations (Andhra Pradesh and Rajasthan).

Conclusion

It is observed that, in the field, the measured temperature coefficient (Tcpmax) of power is higher than the manufacture datasheet whereas the measured temperature coefficients of Vmpp and Voc are approximately close to datasheet. It is a known phenomenon of PV modules that a higher Tcpmax leads to higher losses in energy yield compared to a lower one. For prediction of energy, Tcpmax plays a vital role as financial models are based on predicted energy during the design stage;

Make & Model	Supplier 1 Model 1			Supplier 1 Model 2			Supplier 2 Model 1			Supplier 2 Model 2			Supplier 3 Model 1		
Temp coefficient (%/°C)	Pmax	Vmpp	Voc	Pmax	Vmpp	Voc	Pmax	Vmpp	Voc	Pmax	Vmpp	Voc	Pmax	Vmpp	Voc
Manufacturer datasheet	-0.43		-0.32	-0.40		-0.30	-0.29		-0.28	-0.25		-0.27	-0.45		-0.35
Measured	-0.56	-0.51	-0.23	-0.49	-0.45	-0.23	-0.32	-0.39	-0.19	-0.26	-0.25	-0.11	-0.41	-0.48	-0.23
Variation from datasheet	-0.13		0.09	-0.09		0.07	-0.03		0.09	-0.01		0.16	0.04		0.12
Observed TC of Pmax	-0.38 to -0.63			-0.34 to -0.54						-0.17 to - 0.35			-0.27 to -0.51		

Table 3.Temperature coefficients of various PV modules. Note figures in red highlight where the measured value is greater than the one given by the manufacturer

PVsyst measured reference temperature	Location	Temperature losses due to temperature coefficient	Units of Measurement	Supplier 1 Model 1	Supplier 1 Model 2	Supplier 2 Model 1	Supplier 2 Model 2	Supplier 3 Model 1
46.54	Andhra Pradesh, India	Manufacturer	%	-9.30%	-8.60%	-6.20%	-5.40%	-9.70%
		Measured on Field	%	-12.10%	-10.60%	-6.90%	-5.60%	-8.80%
		Absolute Delta	%	-2.80%	-1.90%	-0.60%	-0.20%	0.90%
48.43	Rajasthan, India	Manufacturer	%	-10.10%	-9.40%	-6.80%	-5.90%	-10.50%
		Measured on Field	%	-13.10%	-11.50%	-7.50%	-6.10%	-9.60%
		Absolute Delta	%	-3.00%	-2.10%	-0.70%	-0.20%	0.90%

Table 4. Predicted temperature losses of respective module suppliers

	Location	Temperature losses due to temperature coefficient	Units of measurement	Supplier 1 Model 1	Supplier 1 Model 2	Supplier2 Model1	Supplier 2 Model2	Supplier 3 Model 1
Energy loss due to PVsyst Predicted Tmod (kWh)	Andhra Pradesh, India	Manufacturer	kWh/kWp/Year	-164	-153	-111	-96	-168
		Measured on Field	kWh/kWp/Year	-213	-188	-123	-100	-153
		Absolute Delta	kWh/kWp/year	-49.54	-34.51	-11.5	-3.83	14.91
	Rajasthan, India	Manufacturer	kWh/kWp/Year	1719	1719	1778	1788	1663
		Measured on Field	kWh/kWp/Year	1666	1682	1765	1784	1678
		Absolute Delta	kWh/kWp/Year	-53.04	-36.46	-12.25	-4.07	15.86

Table 5. Energy loss due to TMod predicted by PVsyst. Note, negative sign Indicates that manufacturer given losses are lower than actually measured losses in the field

	Location	Temperature Losses Due to Temperature coefficient	Units of Measurement	Supplier 1 Model 1	Supplier 1 Model 2	Supplier2 Model1	Supplier 2 Model2	Supplier 3 Model 1
Annual Revenue loss(-)/gain(+) per MWp at tariff USD 0.07/kWh	Andhra Pradesh, India	Difference	kWh/MWp	-49535.4	-34507.0	-11502.3	-3827.6	14914.3
		Revenue loss	USD/MWp	-$3,429	-$2,389	-$796	-$265	$1,033
	Rajasthan, India	Difference	kWh/MWp	-53035.6	-36465.0	-12251.9	-4071.0	15862.0
		Revenue loss	Rs/MWp	-$3,672	-$2,524	-$848	-$282	$1,098

Table 6. Annual revenue loss at tariff USD¢7/kWh

if the Tcpmax is not as per committed value then generated energy will be lower than the predicted energy, which can disrupt a project's financial modelling. Considering the fact that in the field PV modules spend a very short period at standard test conditions and almost 96% of the time at non-STC condition, which can lead to lower generation of electrical yield, PV module manufacturers must therefore precisely determine Tcpmax values for different operating temperatures, not only standard test conditions.

As per Table 6, the maximum annual revenue loss is US$3,672 and US$3,429 for 1MW plant in Rajasthan and Andhra Pradesh respectively with Supplier 1 Model 1 which is a significant revenue loss that could disrupt the financial model. If we consider 1GW of solar PV portfolio in Rajasthan & Andhra Pradesh, the expected revenue loss would be US$3.67 & US$3.43 million per year for maximum potential and US$1.25 & US$1.17 million per year for average potential respectively. If we consider 25 years of operation for the developer then resulted revenue loss will be huge.

References

[1] J.A. Eikelboom and M.J. Jansen *"Characterisation of PV Modules of New Generations"* June, 2000.

[2] M. Chegaar, A. Hamzaoui1 et.al "Effect of illumination intensity on solar cells parameters" TerraGreen 13 International Conference 2013; Beirut, Lebanon.

[3] H.-D. Mohring, D. Stellbogen, Zentrum für Sonnenenergie- and Wasserstoff-Forschung Baden-Württemberg (ZSW), *"Annual energy harvest of PV systems – Advantages and drawbacks of different PV technologies"* 23rd European Photovoltaic Solar Energy Conference, 1-5 September 2008, Valencia, Spain.

[4] Rajiv Dubey, Prandial Batra et.al *"Measurement of Temperature Coefficient of Photovoltaic Modules in Field and comparison with Laboratory Measurements"* National Centre for Photovoltaic Research and Education and Electrical Engineering Department, Indian Institute of Technology Bombay, Powai, Mumbai, 400076, India.

[5] P. Kamkird, N. Ketjoy, W. Rakwichian, S. Sukchai *"Investigation on temperature Coefficients of three type's Photovoltaic module technologies under Thailand operating condition"*, SciVerse Science Direct published paper 25 Nov, 2011.

Authors

Rajesh Kumar is a site engineer in Solar Plant Performance Analysis and PV testing department at Mahindra Susten Pvt Ltd. He has a B. Tech in electrical engineering and had three years' experience working in the solar Industry. He worked at the Jodhpur Institute of Engineering & technology as Assistant Professor from 2013-2015 and joined Mahindra Susten in 2015.

Gaurav Mishra is an assistant site engineer in the Solar Plant Performance Analysis and PV testing department at Mahindra Susten Pvt Ltd. He has a diploma in mechanical engineering and 10 years' experience working in the solar Industry. He worked with Moser Baer Solar Ltd. from 2008-2014 and joined Mahindra Susten in 2014.

Rakshita Mhatre is a graduate engineer trainee in the Analytics Department at Mahindra Susten Pvt Ltd. She has a B. E. in electronics & telecommunication engineering from Mumbai University and joined Mahindra Susten in 2017. Her job profile dominates in areas of solar plant remote monitoring and PV Energy simulation.

Satish Pandey is the head of solar plant performance analysis and PV testing at Mahindra Susten. He holds both an M.Tech and MSc in physics and has over 10 years' experience working in the solar industry. He worked with PV manufacturer Moser Baer Solar from 2008-2013 before joining Mahindra Susten in 2013

KIPP & ZONEN
SINCE 1830

Know exactly when and where to clean

Optimize yield

The only maintenance free solution to measure soiling

Integrated in the leading monitoring software systems

www.kippzonen.com/DustIQ

Visit booth 420 at Solar Power International to get the latest information on this innovation.

Big data under the microscope

Monitoring | The term "big data" has recently become something of a buzzword in PV circles. But how are companies using this data and is it generating useful intelligence or merely information overload? Catherine Early reports

In a world where government financial support for PV technology is becoming increasingly rare, the need to optimise plants and make them more efficient has become critical. There is no longer any margin for underperformance - losing even just a small amount of energy production due to faulty components could destroy a plant's business case.

One solution being actively pursued by many in the sector is the collection and analysis of "big data" – large and diverse data sets that, when combined, could hold the key to innovation that could reduce costs, such as predicting when equipment needs to be maintained rather than reacting after a fault has become apparent.

One company that is already using big data both internally and with clients is Greek solar asset management and O&M firm Alectris. Its Enterprise Resource Planning (ERP) software, known as Actis, incorporates all elements involved in operating assets, such as maintenance services, power purchase agreement billing, project management and financial and technical reporting. Developed as an internal tool seven years ago, the firm uses the software to help its decision making, and manage its costs.

The tool is now gaining traction externally with clients, especially in the US, with some in Europe and Asia also showing interest in the past few months, according to Vassilis Papaeconomou, the firm's managing director. It means that the firm can share all the information it has about an asset directly with its owners, enabling far more detailed reporting.

Big data is becoming increasingly prevalent in PV but question marks remain over how best to use it

"If we have to charge our customer for some maintenance, they can see exactly what activity has taken place to justify that – which component, what type of equipment failure and how this has impacted the overall performance of a plant," Papaeconomou explains. "It gives the ability to look holistically at the data and not see a static report, which would just say 'US$800 – fixing an inverter'."

The firm can also use this data to identify the most common failure relating to the impact of the plant, and from that, to make decisions about whether certain elements need replacing. "You may have 100 failures of a certain type, but they have no impact on the plant. Or you may have another 10 events, but the impact could be substantial – the software enables you to focus on the right elements, and make informed decisions," he says.

What is "big data"?

A solar PV plant is rich in data, from the components themselves, to financial information and weather statistics. But big data analytics is relatively new in the PV sector, and definitions are somewhat fluid. Vassilis Papaeconomou, managing director at O&M firm Alectris, says that care is needed in using the term "big data" in reference to the PV industry. "In solar, we're not talking so much about the volume of data, that's nothing compared with Google and other data companies," he says.

Lars Landberg, director of renewables, strategic research and innovation at certification and consulting firm DNV GL, says that big data is about far more than just the volume of information. There are three other criteria, which he explains in terms of the PV sector.

These are velocity, where a lot of data is coming at you all the time such as high resolution data from SCADA monitoring systems; variability, which refers to different sources of data, such as SCADA software, the stock exchange, and financial transactions; and veracity, which refers to how data from some sources, such as a tweet from US president Donald Trump, could be misleading.

Clients can look at their assets and identify the top five causes for loss of output, and how much more energy could be produced if these problems were fixed, and therefore calculate the business case for doing so, he adds.

Project advisory consultancy Greensolver meanwhile, is using big data in its Greensolver Index tool. The software has been available for the wind industry for a few years, but has recently been launched for the PV sector. The tool can measure performance, irradiation, capacity factor, plant availability and energy generation.

Alexander Harssema, partner at the French firm, explains that the software enables analysis of the average time between failure of an asset, the performance of a contractor in terms of responding to faults, the failure rate of a particular brand of technology.

"We can help clients negotiate better maintenance contracts; for example, we could say that a particular inverter has a failure rate that could be improved if the maintenance provider had a local service station, or more staff on site. That could be the commercial result of this data," he says.

Many firms are carrying out research and development on other applications of big data. One major area under investigation is predictive maintenance, where data could be analysed to pick up unusual activity that could indicate an underperforming asset. Time and money could then be saved by sending out maintenance teams to fix a fault ahead of it affecting productivity of a plant.

Machine learning, where a device would spot patterns in behaviour, could be applied to this use of big data, says Lars Landberg, director of renewables, strategic research and innovation at certification and consulting firm DNV GL. The case for such use of data is rising along with the installed capacity of solar technology. "If you have one power plant, it's easy to detect when something is wrong. But with thousands of PV panels, it would be a huge task," he says.

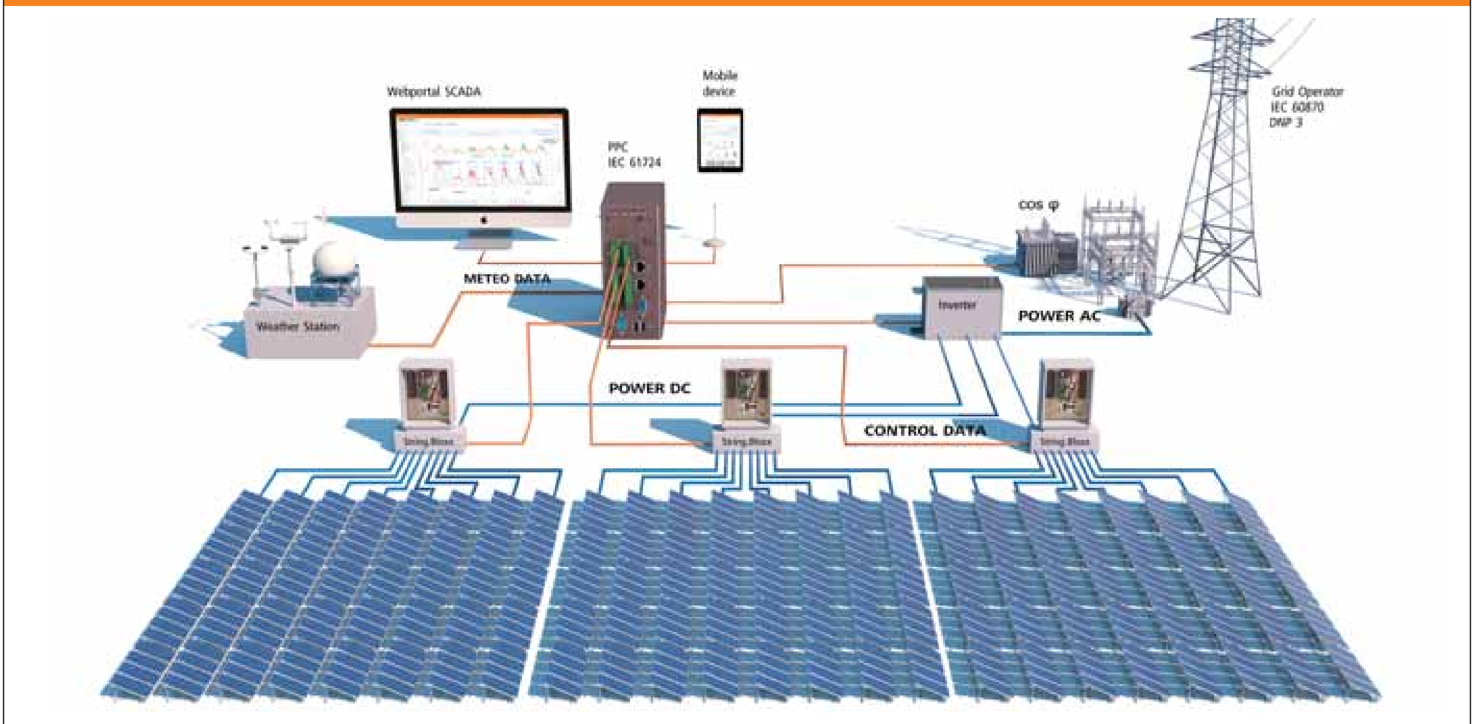
Dr Günter Maier, managing director and chief operating officer of Alternative Energy Solutions, which specialises in PV monitoring data analysis, says that this could be taken a step further, with asset owners using predictive maintenance to improve the efficiency of spare part management, and hold parts in stock centrally rather than having masses of parts at every plant. "In other industries this is common sense, but the PV sector still has some way to go before everything is optimised," he says.

Optimising use

But Edmee Kelsey, chief executive of asset management company 3megawatt, is

Worldwide monitoring
and control of utility scale PV systems

Gantner
instruments



Gantner Instruments Environment Solutions GmbH
www.gantner-environment.de

How will big data, machine learning and AI impact jobs in the PV sector?

A common-held fear is that as more tasks are automated or carried out by drones or robots, the need for human workers will fall. But commentators believe that in the PV sector, the impact is more likely to be that jobs become more productive and rewarding, as workers' time is freed up from laborious tasks.

"There are so many things that can be fixed, professionalised and industrialised using AI. It will help us with tasks that are labour intensive, such as using drones to check solar panels. Think of a worker checking each panel on a large plant, it would take days. If drones and infrared cameras are used instead, you still need someone to pilot the drones," says Cazacu.

Kelsey notes that many jobs in the PV sector are very highly skilled, such as electrical engineers and lawyers. Rather than replacing these types of jobs, digitalisation will free employees up to take a step back and use their experience to analyse problems identified by machines. "In the beginning, systems will still be learning, so you have to have someone who looks at the results and asks if they make sense. Jobs will change and will be more fun and won't have to do repetitive tasks," she says.

Papaeconomou agrees that jobs will become more fulfilling rather than be replaced. He adds: "Workers will become more efficient and can do more complex tasks. If you have a team of five, the number of things they can accomplish a day increases from five to 15."

Khorana notes that there has typically been a shortage of people who want to maintain PV plants in remote areas, despite wages for these roles increasing. "People would rather sit in an office and optimise plants remotely than be away from home for days at a time in the field," he says.

Drones and the data they collect represent a way of easing labour-intensive tasks

sceptical about the practicalities of predictive maintenance. "I can see the value that could come with artificial intelligence (AI) to make sense of patterns of behaviour. But it has to be actionable to make it work. For example, if you have a big power plant and something goes wrong, you still have to send someone out there, so it has to be a big enough problem to justify this."

Calculating the financial case for sending a technician out is increasingly complicated in the post-subsidy era, where power plants are selling energy on the open market, and might also include other elements such as storage, she says.

"You have to calculate the full picture in order to get permission to send someone out to fix a fault. I've no doubt we'll get there with predictive maintenance, but it's very early days," she says.

German plant management firm BayWa r.e is using big data to improve asset management. In July, it signed a partnership with Canadian company PowerHub to develop a cloud-based platform that will provide clients with a near real-time view of operating and financial information, and performance data of renewable energy assets. It also automates workflows, reporting, document and task management and ticketing.

However, despite all this research and innovation, the PV sector is still learning how best to make the use of big data, and where the pitfalls lie. Commentators agree that there is a risk that asset owners and maintenance companies end up with data overload, and that collection of data must be focussed on practical application to be of use.

"One of the big challenges for the industry is that no-one wants to throw any data away in case its useful one day, but no-one knows what it will be useful for," says Kelsey.

"There are lots of potential applications from big data, but if you don't know what you're going to get out of it, how can you say that you need it? All these companies are doing fancy things like sending out drones to take thermographic scans, collecting information every minute, or every 15 minutes – it's good to do that, but you have to know what you're going to use it for because you need to justify the cost," she says.

Data can also be unreliable, and contain gaps. "It's not the case that operators haven't got the teams to analyse all this data. It's more that a significant amount of data is unreliable or wrong. Big data, machine learning and artificial intelligence are all based on data, so the first thing you need to do is make sure the data is correct," says Maier.

Kelsey agrees. "You can spend a lot of time cleaning up data so you have a good dataset that you can go and analyse," she says.

Kelsey also raises a question mark over the usefulness of data given the relative youth of the industry. "Everyone tells me that it gets interesting when plants are 10 years old, because that's when components start to fail. But we don't have experience of that yet, because plants are not old enough. It's a challenge that comes with a young industry, but eventually we'll get there.

Harssema agrees that the data must be made meaningful. "We say that we take data and turn it into information – it's the information that comes from the data that is useful."

However, according to Papaeconomou, there is no such thing as too much information. As long as PV companies standardise the data, and have the appropriate infrastructure to deal with it, it can be made useful, he says. "Once you have these two things, the possibilities are endless," he says.

"Regardless of how much data you have, you design a report to take an abstract of that – then you don't care if there are terrabytes of data," he says.

Data protection

Use of big data brings up questions of data ownership and privacy. Virgil Cazacu, expert for digital transformation at BayWa r.e, says: "It's important to know what data you can touch, and what you can expose to your customers and partner networks, especially since the EU's General Data

Protection Regulation [which came into effect in May this year]. You also need to make the system secure to prevent hacking," he says.

Prashant Khorana, a power and renewables consultant at analysts Wood Mackenzie, believes that data protection issues could be one of the reasons why use of big data is still in the early stages in the PV industry. Asset owners may not want to give a third party access to data, he says.

In any case, it is in the asset owners' interest to keep track of their own data, rather than a third party, says Harssema. "Every solar PV plant will need refinancing, and having operational data is crucial in determining the value of a plant," he says.

While use of big data in the PV sector remains at the early stages of research and experimentation, experts foresee that much greater use is not far in the future. Papaeconomou believes it will not be too long until systems cover the whole lifetime of an asset, from design, through construction, commissioning and operation, rather than multiple systems, as is the case currently.

"Imagine a platform that will cover all your needs for the whole lifetime of a renewable energy asset. It's going to take time to get there, but that's the way we see things developing," he says.

> "All these companies are doing fancy things like sending out drones to take thermographic scans, collecting information every minute, or every 15 minutes – it's good to do that, but you have to know what you're going to use it for because you need to justify the cost"

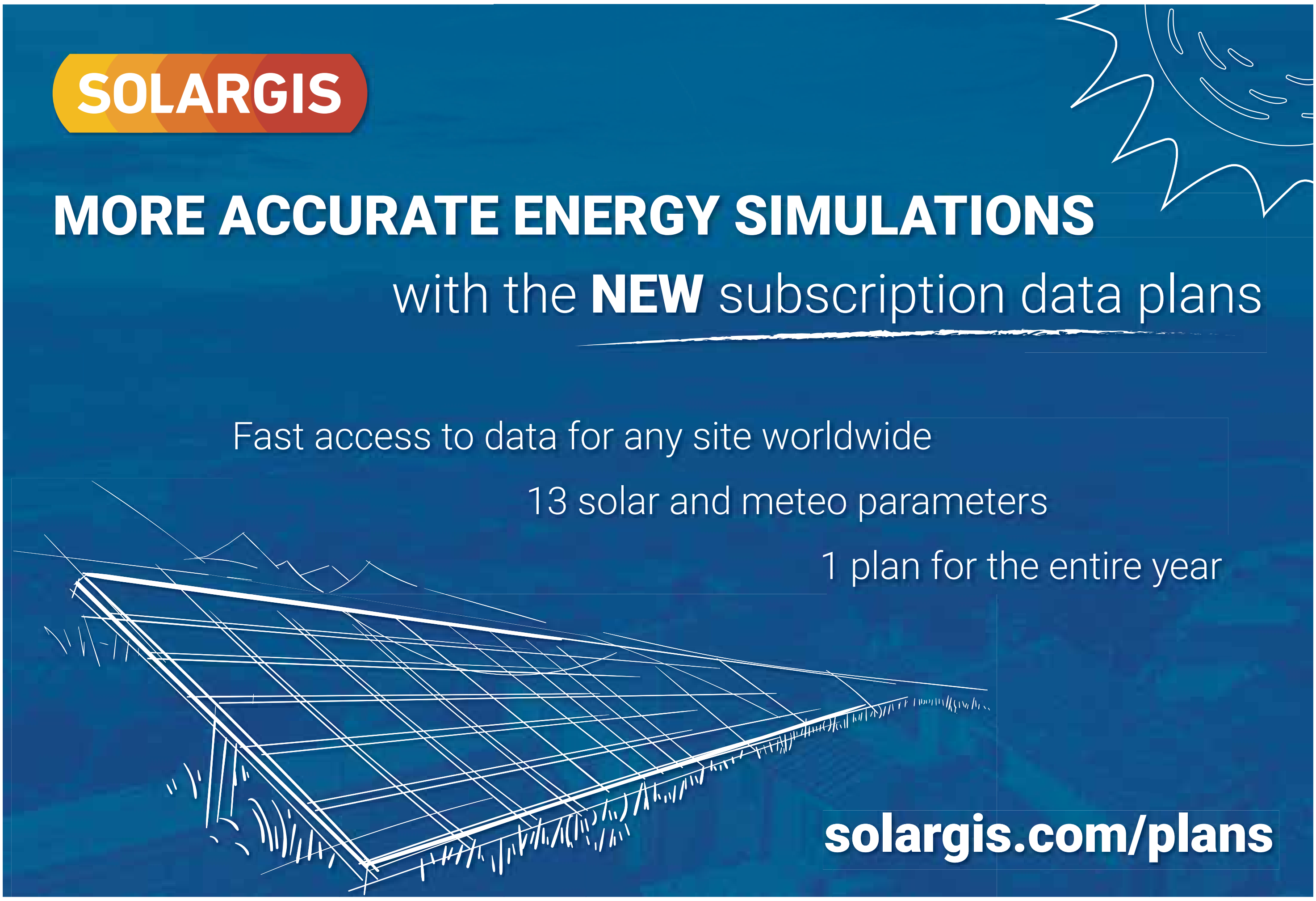
Harssema sees more advanced uses developing for big data in predicting the failure rate of technical components, in particular, degradation rates in different climates around the world. "We're benchmarking different PV plants to identify performance in different geographical regions. We know that PV components deteriorate over time, and temperature is an important part of it, so we want to know what could be the geographical effect of a low temperature area to a high temperature area in the failure rate of a component."

Big data will also find more uses in combination with AI, for example, to balance the grid using storage, or to operate drones to scan PV equipment for faults, commentators predict.

Landberg sees using big data and machine learning together to improve the accuracy of grid forecasting, and also the levelised cost of electricity. Combining information from power plants with weather data and tweets from relevant organisations or politicians could lead to more accurate forecasts of energy prices, he believes.

"We are in the hype phase now, everyone wants to use big data and machine learning on everything, which is good because then we can explore what it really can be used for," he says. "Things will calm down and by having gained experience, people will know when to use it and when not to use it."

Catherine Early is a freelance journalist.



Energy Storage NEWS

SPECIAL REPORT! NOW AVAILABLE AS FREE DOWNLOAD

Global Energy Storage Opportunity 2018

BEHIND-THE-METER. HYPERLOOP. OFF GRID AFRICA.

Opportunities, innovations, markets and business models in energy storage are evolving fast.

This comprehensive report covers territories including the US and Canada, Japan and China, Europe including Scandinavia and the UK, Africa's off-grid sector, sustainable transport with Hyperloop in Dubai and much, much more.

Download it free from:
www.energy-storage.news/resources

Presented to you by:

STORAGE & SMART POWER

Introduction

Welcome to the third quarter 2018 edition of 'Storage & Smart Power', brought to you once again by Energy-Storage.news. Here at the site, we've been enthused by perhaps our busiest year yet for news of new projects and the sheer volume of deployments and exciting new avenues to talk about.

By next year it's likely we'll see countries with more than a gigawatt-hour of battery storage on their grids and it's important not just that the technologies will be capable but also that customers understand what it can do. With lithium-ion batteries increasingly offered as a viable choice for today's projects, the way those batteries behave over their lifetime will need to be factored in because they will need to last a long time and they will need to keep performing.

We're privileged to have Dr Andres Cortes and Ben Kaun of the Electric Power Research Institute (EPRI) write on this topic, with their article 'Is that battery cycle worth it?' on p.107. Degradation, sizing of systems, depth and regularity of cycling – there's a lot to think about and the EPRI authors discuss how battery lifetimes can be maximised while finding environmental benefit, social purpose and revenues from energy storage systems.

Still broadly keeping with the lithium solar-plus-storage theme, one of the ways to add value to residential battery storage systems is to aggregate them in numbers into a 'virtual power plant' arrangement. A few years ago it would have been unthinkable to consider cloud-connected home batteries replacing large fossil fuel generators.

It's not still not going to happen overnight, but some of the UK case studies David Pratt has looked at in our feature article (p.102), as well as a few other key market pointers I came across in my research, demonstrate that the potential is certainly there.

There's also the second and final part of my look at flow batteries – or 'flow machines' as some manufacturers prefer – which I have found a fascinating piece to write (p.111). The four providers of flow energy storage systems I spoke to for the piece represent a small but interesting and vocal portion of the market so far.

I'd like to thank all of the contributors & interviewees for this edition of 'Storage & Smart Power', including: EPRI, Primus Power, RedT, ESS Inc, VRB/Pu Neng, Centrica, Piclo, Moixa, SolarEdge, Sonnen.

Andy Colthorpe
Solar Media

www.energy-storage.news

Visit the site and **subscribe free** to the **Energy-Storage.News newsletter** today. Technology with the capacity to change the world.

China had 340.5MW of energy storage underway in H1 2018

Credit: CNESA

China's Jiangsu, Henan, Qinghai and Guangdong provinces have driven a rapid pace of development of energy storage projects.

Energy storage projects amounting to 340.5MW of new capacity were under construction across four provinces of China during the first half of this year in the country, according to the China Energy Storage Alliance (CNESA).

Jiangsu, Henan, Qinghai and Guangdong provinces are host to projects that when finished would almost equal the total cumulative capacity of operational energy storage systems in China, which was 389.4MW as of the end of 2017.

One 'project', actually consisting of eight separate systems at one site in Jiangsu Zhenjiang adds up to 101MW/202MWh of lithium-ion storage systems on the grid-side of the meter and already went into operation in July. Zhenjiang-based company eTrust Power supplied the largest of the eight systems, a 40MW/80MWh battery.

India's draft National Energy Storage Mission focuses on reducing costs of domestic EV batteries

Battery manufacturing represents a "huge economic opportunity for India", according to a draft 'National energy storage mission' (NESM) document, which outlines how the country could capture value across the supply chain and accelerate the country's adoption of renewable energy.

The Indian government Ministry of New and Renewable Energy (MNRE) commissioned a report on the potential for scaling up domestic manufacturing of batteries for EVs. Written by NITI Aayog – (the National Institution for Transforming India) and US think-tank the Rocky Mountain Institute (RMI), the 36-page report makes key policy recommendations.

An MNRE statement referred to energy storage as "one of the most crucial and critical components of India's energy infrastructure".

Hawaii keeps on going

Hawaii Public Utilities Commission has approved a 22-year power purchase agreement (PPA) deal for the first ever battery storage project on the island of Molokai, which would pair 4.88MW of solar with a 3MW/15MWh lithium battery system.

Utility Maui Electric said energy will be delivered for around US$0.17 per kilowatt-hour, less than the cost of the imported diesel which currently lights homes on the island. The project will be getting a financial boost through the US federal New Markets Tax Credits (NMTC) programme, which is applied to low-income communities that are seeking investment in businesses and real estate.

National Grid to dispatch UK ancillary services via web platform

Britain's transmission system operator (TSO) National Grid will roll out the use of its web-based Ancillary Services Dispatch Platform (ASDP) to a number of services over the next year following the successful dispatch of fast reserve using battery storage.

According to National Grid's Product Roadmap for Frequency Response and Reserve, ASDP is designed to allow National Grid to signal and more directly access a range of previously inaccessible distributed energy resources to meet its dispatch needs.

Additionally, energy storage and other flexibility providers with units as small as 1MW may soon be able to access 'Great Britain's core flexibility market', with National Grid proposing to widen access to the Balancing Mechanism (BM) by April 2019. Aggregators will be able to participate without needing a supplier licence.

Ontario's C&I 'arms race'

As often reported by Energy-Storage.news, Canadian province Ontario pays for grid upgrades and decarbonisation partly through the Global Adjustment Charge, a peak demand pricing mechanism which levies higher rates on commercial customers than residential. This has led to numerous C&I projects that have been used to 'peak shave' businesses' energy demand from the grid in the province.

In the past quarter, announced projects have included a single 144MWh project by Fluence, the biggest behind-the-meter system to date (20MWh). Meanwhile institutional investor Ontario Teachers' Pension Plan committed CA$200 million (US$152.8 million) for the financing of project acquisitions in the Ontario C&I market by Stem Inc that lend themselves well to the US company's AI-driven business model.

Ireland to incentivise solar-plus-storage

Homeowners in Ireland can now access grants worth hundreds of euros to fund the installation of solar and energy storage systems as the government launches its first micro-generation scheme for the technology.

The pilot scheme offers €700 (~US$818.5) per kWp of solar installed up to 2kWp, at which point any installation up to 4kWp must include a battery storage system for which a fixed €1,000 grant is now also available.

Minister for communications, climate action and environment Denis Naughten explained that a typical three-bedroomed semi-detached home would spend about €1,800 on a PV system and save approximately €220 per year on their bills.

Belgian C&I VPP cuts CO2

Next Kraftwerke, offering 'Virtual Power Plants-as-a-service', will integrate a 2MW/2MWh battery at the premises of a commercial customer which will be integrated to offer both front-of-meter and behind-the-meter benefits.

Peleman Industries, a producer of presentation photographs and printed materials, signed a covenant on sustainability with the local municipality of Puurs, Belgium, in 2016 to exceed EU emissions reduction targets for 2020.

Peleman has two wind turbines installed onsite to power its facility. The battery storage system, was supplied by Dutch Stock Exchange-listed Alfen and installed by sustainable energy company Eneco Belgium. It will store and integrate power from the turbines to be used onsite, as well as providing grid-balancing frequency regulation services to the local network.

Virtual reality: VPPs in a break with tradition

Energy management | Cloud-aggregated virtual power plants using residential or C&I battery storage as part of a smart energy management system can benefit the grid, integrate renewables and EVs and hopefully add a powerful long-term value proposition for home storage. Andy Colthorpe and David Pratt report on how some of the UK's first VPP projects are proving the concept

Credit: Oakapple.

"The one word that is most important here is aggregation," SolarEdge's Lior Handelsman says, as we discuss the launch of his company's first commercially available virtual power plant (VPP) solution this summer.

On a hot sunny day in Germany, Europe's biggest market for home energy storage, we were discussing the situation back in the UK and where the VPP concept is starting to take root.

"It is a software platform that starts in the cloud. To take one example: you are a network operator, a DNO, tasked with stabilising the grid and keeping the grid stable. There are so many different distributed generation resources on the grid making your task more and more complex."

Some of the tools to deal with such situations are now becoming outdated, Handelsman argues, and they include investing in grid upgrades such as substations, wires and cabling that can give the network operator a "a little bit of the ability to control the large generators on the grid to stabilise frequency".

Instead, network operators could actually take advantage of the increasing numbers of distributed energy resources (DERs), including solar, wind, EVs – resources that are traditionally considered to add more balancing work for the network operators to perform, including integrating the variable output of generators and accommodating spikes in demand from EV charging.

"If you had a way where you could actually use these systems for you instead of against you – that would be amazing.

"For example if you have a peak in a specific suburb, all you need to do is tell the storage systems in that suburb to feed energy just for a few minutes into the grid to support that peak. Or if you have a peak you ask all the EV chargers in that area to stop charging or throttle down their charging for a few minutes," Handelsman says.

The UK solar sector has taken a few big policy 'hits' in recent times. VPPs are being investigated as a means of adding immediate and future value to installations

The VPP as an alternative to this requirement for big investments is not a new idea. I wrote about the 'Rise of the virtual power plant' back in 2015 for this journal. While it was an exciting concept then, it's an even more exciting reality today. As we can see from the three case studies accompanying this article however, the technology lies mostly at the trial stages and numbers aren't yet huge, but the VPPs that already exist could be vital in informing the future direction of travel for the market.

While we find that providers are not yet at the volumes of aggregated systems performing VPP tasks that they would like, work is well underway to create that value of which the SolarEdge VP for marketing and product strategy speaks.

Defining the VPP

As with a lot of the newer concepts introduced to our industry, the definition of a VPP varies. In theory a VPP could include both front-of-meter utility-controlled assets such as large generators or grid-scale batteries as well as customer-sited behind-the-meter systems like rooftop PV and household lithium battery systems. The key is that all of the aggregated DERs in a VPP network are controllable centrally, through an appropriate software platform.

For the purposes of this article we will look mainly at residential systems. And there's another caveat: when Sonnen launched SonnenCommunity, its 'energy sharing' solution that allows customers to trade the surplus energy in their home batteries with one another a couple of years ago, CEO Christoph Osterman was at pains to point out that at the time, less broad definitions of virtual power plants only covered those instances where aggregated systems would perform the same tasks as peaking gas plants, i.e. to deliver grid services on a big scale.

"When you talk about the VPP in Germany, a lot of the players who are trying to aggregate smaller assets, or decentralised and distributed assets, don't like the [term] VPP, because there's this association with the 'power plant' side of the 'VPP'," Valts Grintals, energy storage analyst at Delta-EE explains.

While the definition has changed as the market has developed, Grintals argues, his research team look at a VPP as aggregated assets – small or large – that are "not just generating the power and feeding it into the grid, [but] also managing demand."

Sonnen has not rolled out SonnenCommunity into the UK market yet. Grintals says this is partly to do with a greater economic sensitivity and the lower appeal of energy independence for individual households, something which has captured the public imagination in Germany (and Austria and Switzerland) by comparison.

However, a couple of dozen Sonnen battery units were recently deployed in the UK in the remote islands of Orkney, linked and aggregated together to perform many of the expected VPP tasks. That said, those systems will be run on software by the project's lead, Solo Energy, and not Sonnen's own platforms. Solo Energy claims that the humble trial could show how "no money down" financing could be possible for residential PV-plus-storage in Britain. So why has the VPP reached the UK in this particular form?

Driven by you

"Really the key driver for something like that in the UK, to make business models that work, will be local network operators' flexibility," Grintals says.

This is something that can be seen from the case studies accompanying this piece. Beneath the level of the transmission system operator (TSO), National Grid, sit the DNOs – distribution network operators. Responsible for delivering power to homes and businesses, the increasing amounts of DERs on their networks are – as Handelsman illustrated with the opening example – creating challenges for the six major DNOs. England is – or was – installing solar at pace before the cliff-edge degression of the feed-in tariff (FiT) and the introduction of Open Utility's Piclo Flex is one attempt to introduce control, flexibility and balance through a VPP-style aggregation. Case study #1 looks at Piclo Flex in more detail.

Proving the case for the VPP

So, the early business models based around flexibility offer the UK, a leading market but still a less prolific adopter of home solar-plus-storage (and by extension aggregated VPPs) than Germany, a chance to properly value the network benefits of cloud-controlled DERs.

Moixa's government-backed trial from a few years ago (see Case Study #2), will have informed some of the decisions we've seen taken as well as what we might see going forward. You can see that there was an immediate financial benefit for participating homeowners, while a modest amount of installed storage capacity had a big effect on peak demand for the local DNO.

Both the technological scope of the VPP concept in the UK and the ability to commercialise it have moved on rapidly since the government-backed Moixa trial, which ran between 2015 and 2017. Case Study #3 looks at the Local Energy Marketplace (LEM), a project from utility Centrica which could be a solution ripe for scaling up across the UK.

Harking back to Valts Grintal's view that the proliferation of VPPs could be driven by network needs, the LEM project centres around DNO Western Power Distribution's need to purchase flexibility services. The marketplace idea has been backed by National Grid and could be a model for rollout across the country.

Opening up technical requirements

Now that several years of successful operation have passed and lessons learned based on hard economic realities, the VPP space is evolving so rapidly that even as this edition was going to press, we had another game changer in the UK to talk about.

National Grid's Balancing Mechanism (BM), worth an estimated £350 million (US$444.2 million) a year to participants, rewards those able to increase or decrease generation or consumption. This flexibility is bid in to half hourly settlements periods with National Grid paying out what is needed in order to keep the system balanced. Under the proposals to widen access to the Balancing Mechanism (BM) by April 2019, aggregators will also be able to play into the market for the first time without needing a supplier licence. One aggregator, Limejump has already entered its virtual power plant into the BM. Another, Flexitricity, said that on rare occasions, prices can reach £2,500/MWh (US$3,167), compared to around £50/MWh (US$63.35) in wholesale markets.

Indeed one of the historical barriers to adoption in ancillary services markets has been the minimum technical requirements which have required several megawatts of capacity to be available. Primary Control Reserve (PCR) in Germany historically required 5MW or more for eligibility which perhaps explains the reluctance of battery system providers to roll with the term 'virtual power plant' from the very beginning.

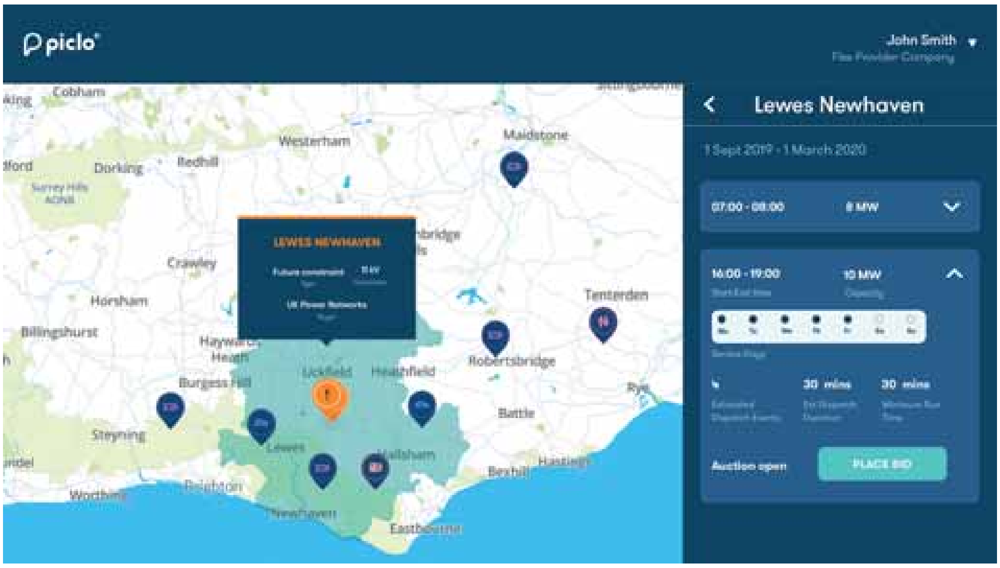
So we have VPPs commercially available for solar rooftops from the likes of SolarEdge, VPPs that could allow the low-cost financing to make more of those solar (and storage) rooftops a reality from Solo Energy's trial on Orkney and increasingly, as we've just seen with the Balancing Mechanism, ever expanding opportunities for virtual power plants to make their mark in the real world from behind the meter to the front.

CASE STUDY #1: A software platform enabling VPP aggregation

As the low carbon transition takes hold in the UK, DNOs are taking action accordingly, making changes to their own practices to keep pace with the change.

With record levels of distributed energy resources connected at the distribution level rather than at transmission, the country's network companies are moving towards an active neutral facilitation system operation role, seeking out new forms of flexibility to account for and make use of the DERs on their systems.

Enter Piclo Flex, the proprietary software



Credit: Piclo

Piclo Flex software dashboard

from Open Utility, which enables distribution system operators (DSOs), as they are becoming known, to launch auctions for flexible capacity from a range of providers who have uploaded their capabilities to a VPP-style platform.

The possibilities of carrying out auctions on a national scale using Piclo's virtual power plant stands to revolutionise how networks procure flexibility, a fact that has already attracted half of the UK's network companies.

UK Power Networks is furthest progressed, with plans to run its next flexibility tender on the Piclo Flex platform.

Dubbed "an online dating" service for DNOs and DERs by Sotiris Georgiopoulos, head of smart grid development at UKPN, Piclo Flex gives network operators visibility over what is available in their regions, from energy storage to generation and turndown-capable resources.

James Johnston, chief executive and co-founder of Piclo, explains: "This is a place for flexibility providers, meaning anyone that operates or manages flexibility, whether they are an aggregator, a supplier or a battery operator, maybe chargepoints, an industrial customer, community groups…"

This allows them to plan how to meet their needs accordingly, while providing greater transparency to flexibility providers seeking to determine the opportunities for additional revenues.

"The DSOs have different options for where they want to launch their tenders, and what we want to do is prioritise where they are more likely to get success stories," Johnston adds.

UKPN tried to pull together its own market VPP last year, seeking over 34MW of flexibility services across its network. But while the initial tender attracted great interest from the market, little materialised as providers called for more certainty and transparency over the flexibility procurement process.

Georgiopoulos hopes the Piclo Flex platform will offer a simplified approach to meet the concerns of providers and "unlock flexibility" at a time when the network is becoming ever more congested.

"We have a winter peak demand of 16GW, we have about 9.3GW of DER, 200MW of batteries connected on the network, a gigawatt of batteries on the pipeline and some scary numbers about electric vehicles. So the future is here...and in that context flexibility is going to be key and how we unlock flexibility is going to be key," Georgiopoulos explains.

To this end, UKPN has already placed four of the 10 locations it previously sought 14MW of flexible capacity for onto Piclo Flex for an auction to take place in Q4 2018.

A number of 'flex sellers', ranging from domestic battery storage firms to energy suppliers and demand-side response providers, have already signed up to potentially fulfil the DNO's needs, with Open Utility targeting several more before the auction takes place.

The possibilities of the platform have already attracted SSE and Electricity North West to plan their own flexibility procurement, with Piclo eyeing up National Grid as a potential participant in its national VPP potential.

CASE STUDY #2: Dropping bills and lopping peaks

In the UK, VPPs are being used to aggregate large-scale, front-of-the-meter storage or smaller, behind-the-meter commercial and industrial capacity to offer balancing and frequency response services to the grid.

Residential models have taken longer to emerge, with providers often coming up against consumer apathy towards managing energy use within a context of limited funding.

But domestic storage providers are nonetheless working to crack this market. One early example is Moixa, which was awarded a contract in 2013 by the government's now defunct Department of Energy and Climate Change (DECC) to deliver a trial across 250 locations.

The system rollout was separated into multiple asset cohorts, the largest of which was Project ERIC, where Moixa worked alongside Oxford City Council to deploy 82 systems in homes alongside solar, as well as in a school and a community building.

Running between 2015-17 as the UK's first large-scale domestic solar-and-storage project with around 500kWh of storage capacity, the project aimed to reduce the average peak grid load and increase solar consumption, with the added benefit of lowering household bills.

It enabled Moixa to test and manipulate the whole fleet together, as well as smaller


Credit: Moixa

Moixa's battery systems were used in the government-supported trial from 2015-2017

inter solar

connecting solar business

Join the world‘s leading exhibition series for the solar industry

INTERSOLAR EVENTS 2018–2019

www.intersolar-events.com

AUGUST 28–30, 2018, SÃO PAULO, BRAZIL

SOUTH AMERICA’S LARGEST EXHIBITION & CONFERENCE FOR THE SOLAR INDUSTRY
www.intersolar.net.br

DECEMBER 11–13, 2018, BANGALORE, INDIA

INDIA’S MOST PIONEERING EXHIBITION AND CONFERENCE FOR THE SOLAR INDUSTRY
www.intersolar.in

MARCH 5–7, 2019, DUBAI, UAE

INTERSOLAR@MIDDLE EAST ELECTRICITY: MENA‘S MOST COMPREHENSIVE SOLAR EVENT
www.intersolar.ae

APRIL 4–5, 2019, MUMBAI, INDIA

INDIA’S MOST PIONEERING EXHIBITION AND CONFERENCE FOR THE SOLAR INDUSTRY
www.intersolar.in

MAY 15–17, 2019, MUNICH, GERMANY

THE WORLD’S LEADING EXHIBITION FOR THE SOLAR INDUSTRY
www.intersolar.de

JULY 9–11, 2019, SAN FRANCISCO, USA

NORTH AMERICA’S PREMIER EXHIBITION & CONFERENCE FOR THE SOLAR INDUSTRY
www.intersolar.us

FOLLOW US

collections of systems such as that in Oxford, to optimise its software, hardware and asset management services in a wide range of real world scenarios.

Meanwhile, the project also allowed household participants to see their live and historical energy data and make behavioural changes as a result to save cash. This, Moixa says, was a main aim of the project: to help social landlords and their tenants optimise their solar consumption by shifting it to peak times of day and save money.

For the Project ERIC participants, 1.8MWh of electricity was saved from grid sources thanks to 0.6MWh of solar battery consumption and 1.2MWh of solar generation. Annual household bills were reduced by over £170 (US$216.42) based on an electricity unit price of £0.14 per kWh, and consisting of up to £80 from the battery and £90 from solar.

Debbie Haynes, energy efficiency projects office for Oxford City Council, says: "It was great to learn that Moixa Smart Battery and solar package can help residents save money, particularly those who use quite a lot of electricity in the evening but are out during the daytime."

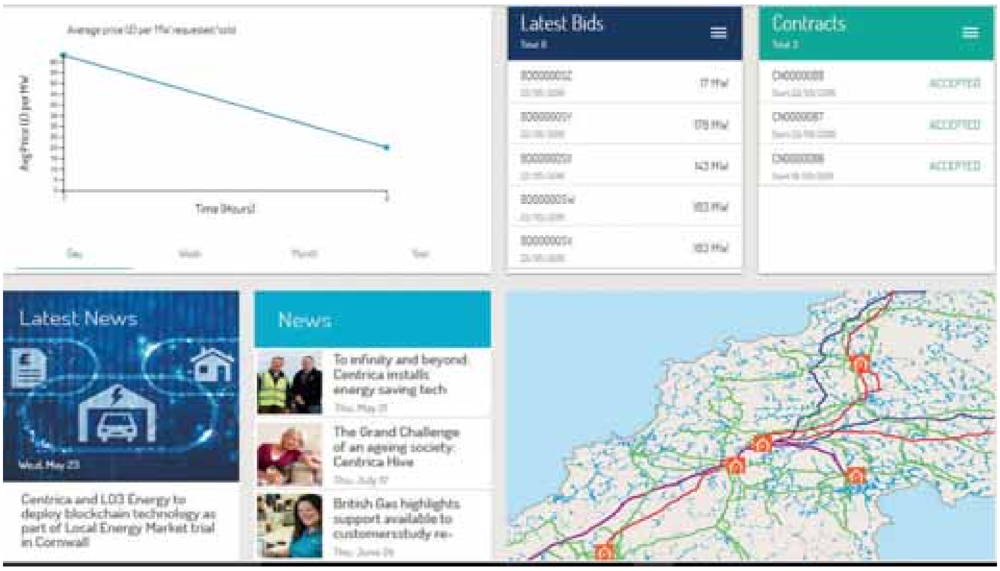
But for Moixa, the key was to provide invaluable learning about its VPP model and how it could help balance the local, and potentially national, grid. The company told *PV Tech Power* that the project allowed it to "prove out" the VPP concept to show that it could deliver balancing services, while delivering what Moixa dubbed 'local-to-meter' value for DNOs, who were reportedly struggling with specific constraint areas on their networks.

By aggregating the batteries to reduce the exportation of solar, the local network was spared from the significant impacts caused by generation on a constrained network.

These experiences, learnings and subsequent adjustments have allowed Moixa to develop a GridShare platform that offers one of the largest domestic VPP resources for battery storage capacity at around 1,000 systems, a model being pursued in earnest by a number of other market participants. Moixa is also exporting the tech to Japan, under a programme with utility TEPCO, which has invested in the UK company.

CASE STUDY #3: A local market-place meets the blockchain

Energy services company Centrica, owner of one of the UK's big six energy retailers



Credit: Centrica

Centrica's Local Energy Market (LEM) is under-way in south-west England

British Gas, is looking to turn the south west of the UK into a virtual power plant in its own right, starting with the Cornwall peninsula.

The Local Energy Market (LEM) project will connect homes and businesses in the region, alongside local renewable generators, to an online virtual market place, allowing them to sell energy capacity to both the grid and the wholesale energy market at times of increased or decreased demand.

Solar and residential storage from around 100 homes will be utilised, as well as a range of other technologies including the UK's largest flow machine installation – the 1.1MWh Olde House project – hundreds of blockchain-enabled smart meters, and the flexible capabilities of around 50 businesses.

The £19 million ($25.1 million) project, which takes the bulk of its cash from the European Regional Development Fund, creates an online market, whereby network company Western Power Distribution in this case will create a bid when it foresees a need for market flexibility. This could be as a result of weather forecasting showing increased output from the region's solar and wind assets, or periods of low demand or network outage.

Posted on the LEM around 10 days prior to system requirement, it will specify the time of day, expected need across the operational window and where this need will be.

"This is one of the key differences with what National Grid currently does with flexibility and what a distribution business needs to do. It's very, very localised," says Roger Hey, future networks manager at WPD.

Business and aggregators already signed up will receive a notification of the bid and have the opportunity to take part, creating an offer in response with their own operational availability along with a price for their flexibility.

WPD will then review its received bids, comparing them on price and other metrics such as where physically on the system the asset sits, if it will solve multiple constraints, and reliability or previous performance.

Once accepted, a contract is in place between WPD and the flexibility seller whereby an arming fee is paid, similar to an availability payment in other frequency response markets. If called upon, an additional dispatch fee is also paid, however it will not be known if this is required until hours before the event.

As the transmission system operator, National Grid is already involved and backing the project with a view to integrate its own day-ahead and intraday needs as early as next year.

Duncan Burt, acting director of operations at National Grid, says: "Cornwall's Local Energy Market is at the forefront of deploying technologies and the way it is thinking about going right down to the domestic level to deliver that. The lessons that we learn here will absolutely be applicable right across the UK."

Matt Hasting, programme director at Centrica, says: "We're seeing this very liquid, dynamic marketplace evolving and what we're trying to do with the local market is bring the markets up to speed with where technology is heading.

"We want to build a future energy system and we want to learn about it by doing it in practice."

Is that battery cycle worth it? Maximising energy storage lifecycle value with advanced controls

Battery degradation | Smoothing and firming are often discussed to make renewables appear more like conventional generation to the grid operator, but how smooth and how firm does that generation need to be? How can the attributes and operations of energy storage be appropriately measured relative to cost? Andres Cortes and Ben Kaun of the Electric Power Research Institute discuss recent work addressing these issues

Energy storage is a compelling complement to wind and solar, because of its high flexibility and ability to operate as both load, when it charges, and generation, when the energy is deployed. Energy storage addresses many of the challenges to grid operators providing safe and reliable electricity for customers, and due to rapidly declining costs, performance improvements of lithium-ion batteries and an emergence of "grid-ready" energy storage products, commercially viable grid energy storage has now arrived, in certain applications. As energy storage becomes more widely available and economically feasible, it may make renewable generation, when paired with energy storage, a more viable option to provide reliable electric generation – and load demand – services in more areas of the world.

Storage anywhere

Energy storage can be deployed everywhere in the power grid, connected to transmission (T), distribution (D), or on the customer-side of the meter. Storage may be co-located with renewables, conventional generation, loads, or it may be standalone.

Depending on location, storage has the potential to provide different services to support reliable, affordable and environmentally responsible electric power. These services may produce value that is traditionally accrued by generators, T&D, or end customers. A single energy storage system may be able to stack multiple services for multiple grid stakeholders. Table 1 provides a list of services, or value streams, that energy storage systems have been found to address.

Energy storage connected to the end customer could potentially address services

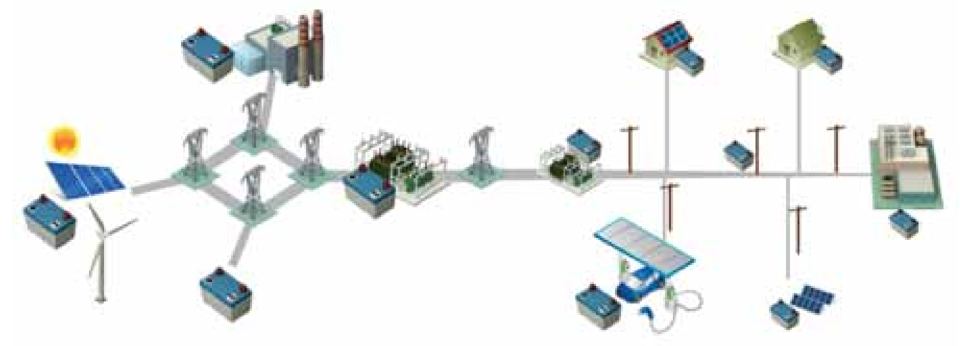


Figure 1. Illustration of potential energy storage applications

Source: EPRI

Domain	Timing of Decision	Service Category	Grid Services
Resource Planning and Operations	5-15 years ahead	Resource Planning	Resource Planning
	3 years to 9 months ahead	Resource Adequacy	Resource Adequacy (Generic)
			Resource Adequacy (Flexible)
	System Operations	Energy	Day-ahead Energy Time-shift
			Real-time Energy Time-shift
		Ancillary Services	Frequency Regulation
			Spinning Reserve
			Non-spinning Reserve
			Frequency Response / Inertial Response
			Flexible Ramping
Transmission	5-15 years ahead	Transmission Planning	Transmission Capacity Investment Deferral
	Months ahead to real-time	Transmission Operations	Transmission Congestion Relief
Distribution	3-10 years ahead	Distribution Planning	Distribution Capacity Investment Deferral
			Equipment Life Extension
	Day-ahead to real-time	Distribution Operations	Distribution Losses Reduction
			Microgrid Load Flexibility
Customer	Monthly	Bill Savings	Demand Charge Management
	Real-time		Time-of-use Energy Time-shift
	Day-ahead to real-time	Customer Reliability	Backup Power and Power Quality
	Day-ahead to real-time	Utility Programs	Demand Response Program Participation

Table 1. Potential services provided by energy storage

Source: EPRI

upstream to support distribution, transmission and generation functions, because its dispatch also propagates upstream. In contrast, a transmission-connected system typically cannot provide downstream services. Larger systems take advantage of economies of scale, which may offset access limitations for certain value streams.

Is that cycle worth it?

Service stacking comes with the costs and complications of multiple, potentially competing, commitments, which may also increase the wear and tear on energy storage systems. When designing an energy storage project, it is important to understand the value and associated requirements for each service addressed. Energy storage is still a relatively expensive resource, so excessive sizing or operation without an associated payback may cause a potential project to become uneconomic.

A common and desirable use of energy storage is often called peak shaving i.e. reducing the amount of power drawn from the grid beyond a specified limit. This typically maps to more precise services, such as resource adequacy (i.e. peaker plant substitution) or transmission or distribution upgrade deferral (i.e. non-wires alternatives). The sizing, availability and location of energy storage for these services are critical, but the required dispatch may be infrequent when the grid is under stress, to achieve the desired benefit of deferring or avoiding an alternative major capital investment.

Other services, such as spinning and non-spinning reserves, may also be desirable with energy storage with very low operating costs because they essentially require energy storage to act as a reserve with no dispatch. Energy storage may also be able to offer these services while charging, by committing to stop charging if needed.

Frequency regulation, the instantaneous balancing of grid supply and demand, is more nuanced. On one hand, battery storage can change its dispatch almost instantaneously to match grid imbalances, unlike conventional generators which have significant inertia. However, the continuous charge/discharge cycles associated with frequency regulation stress the most commonly deployed battery technology, lithium-ion. While participation in the frequency regulation markets may be initially lucrative, this should be balanced against loss of capacity, efficiency, and premature replacement of battery modules in these projects.

Energy time-shifting, sometimes called arbitrage, is another nuanced service. While buying (or charging) energy at low prices and selling (or discharging) at high prices sounds like a good idea, the spread in price must overcome roundtrip efficiency losses and the degradation of potential battery deep-cycling.

The valuation of energy storage projects can be a complicated and location-specific matter. Due to the limited energy in an energy storage device, modelling the state-of-charge over time is essential to understand which services may be stacked together into a viable business case. To support this type of modelling and simulation, EPRI, with support of a California Energy Commission grant, developed and released the publicly available Storage Value Estimation Tool (StorageVET: www.storagevet.com).

Industry approaches to manage battery storage degradation

Battery storage degradation typically manifests as a loss of energy retention capacity, reduction in power delivery capability and efficiency, and eventually need for replacement of batteries. Depending on the state of a battery system, replacement might imply only the change of few worn out modules or a total replacement.

Battery storage suppliers sometimes provide lifetime guarantees under assumed operating conditions or an assumed service dispatch. For example, they may guarantee a 10-year life if the battery system is cycled only one time per day at full depth. This can be limiting in cases where the energy storage system changes over time as the needs of the installation change, which is probable over a 10-20 year project life. Other developers provide more sophisticated information, which may assess "equivalent cycles" that the battery system can undergo before requiring replacement.

One degradation management approach applied by industry is to oversize the physical capacity of the system, while maintaining the nameplate capacity constant. This approach allows battery systems to deliver to expectations of the customer for a longer period of time by keeping the degradation hidden. As a drawback, this approach increases the upfront cost of equipment. Other approaches may include the addition of battery storage capacity over time as the system degrades, which may offer additional flexibility to assess project needs over time, while taking advantage of future, assumed cost reductions in the future.

Figure 2. Capacity degradation of lithium-ion batteries for different combinations of average state-of-charge and temperature. For example, the green plot shows the degradation of a battery operating at 65% State of Charge and 60 °C

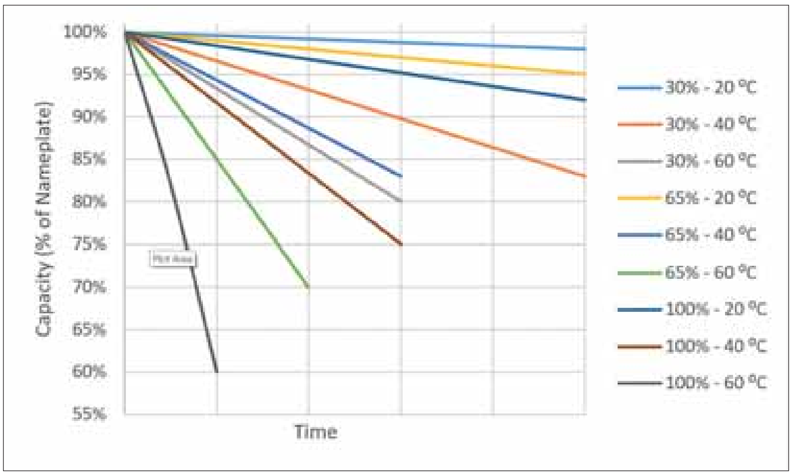
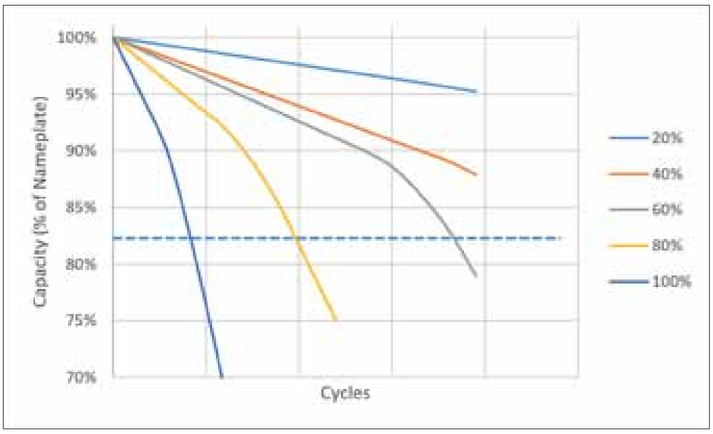


Figure 3. Capacity retention degradation impacts of cycling depth-of-discharge



35th EU PVSEC 2018

35th European Photovoltaic Solar Energy Conference and Exhibition

The Innovation Platform for the global PV Solar Sector

24 - 28 September 2018

SQUARE - Brussels Meeting Centre

Brussels, Belgium

Book your EU PVSEC ticket online

www.photovoltaic-conference.com • www.photovoltaic-exhibition.com

Factors influencing battery storage degradation

Lithium-ion batteries represent the vast majority of current energy storage deployments. Between 2013 and 2018, it represents 94% of the deployed capacity of battery storage in the US [1]. It should be noted that there are other storage technologies not covered here, which may have different degradation drivers. Additionally, lithium-ion batteries are a diverse class with a number of different chemistries and formats; this section aims to provide indicative descriptions and does not attempt to explore all these nuances.

Degradation of lithium-ion batteries is impacted by several variables. Known drivers of degradation include: temperature of operation, average state of charge over its lifetime and depth of charge-discharge cycles. Educated management of degradation is instrumental for economic planning and operation of energy storage projects, as well as any warranties or performance guarantees that may be provided by the equipment suppliers.

The first driver of battery storage degradation is related to time at average state of charge, which is separate from cycling. Empirical data has shown that lithium-ion batteries at rest lose energy retention capacity depending on the temperature and the state of charge at which they are stored [2].

Figure 2 illustrates that energy retention capacity degrades faster at elevated temperatures, if the state of charge is higher. Considering these degradation drivers is beneficial for ageing prediction during the planning process. In operation, lithium-ion battery storage systems may extend life through effective thermal management and by avoiding long durations at a high state of charge. However, this needs to be weighed against the potential efficiency effects of active thermal management, as well as the potential for energy storage to be called for unexpected dispatch. Forecasting of needs and energy storage control approaches are particularly important to manage these trade-offs.

Charge and discharge cycling of lithium-ion battery storage is another important source of degradation. Deeper cycles affect lithium-ion battery degradation more than shallow ones.

Figure 3 illustrates this relationship. Additionally, some batteries have a characteristic of accelerating degradation later in life, as shown by the "knee" shape in Figure 3.

Understanding and modelling the relationship between operation and degradation facilitates optimised planning of energy storage projects, by improving the accuracy of prediction of success or failure. It also improves the operation by allowing the design of dispatch strategies that take into account the cost of cycling-related degradation.

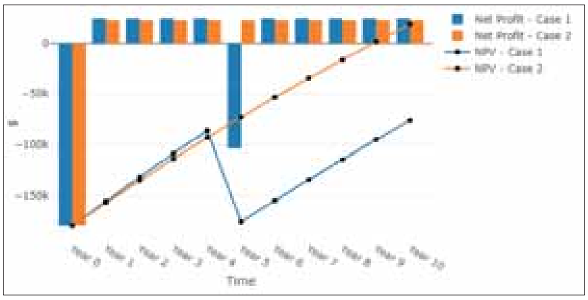


Figure 4. Cash flow of two projects. Represented in blue follows a more aggressive strategy that ignores degradation but obtains more revenue. Orange follows a more conservative strategy that leads to less degradation

Modelling degradation in energy storage project economics

EPRI's StorageVET® may be used to understand how an energy storage project may be designed and dispatched to maximise project lifecycle value. The tool uses optimisation-based modelling to simulate the operation – dispatch and capacity reservations – of the storage system offering one or more grid services, while keeping track of aspects like degradation and grid service compatibility. It can represent different levels of relative value of grid objectives with respect to charging/discharging activity, to find how more aggressive activity might lead to higher revenue, but also higher replacement costs, ultimately helping find the most effective trade-off [3].

A simple example to understand the trade-off between value of operation and cost of degradation is provided in Figure 4. We model a battery system performing energy time-shift (arbitrage). The Net Present Value element corresponds to the system when it performs two cycles of full charge/discharge every day for 10 years, during the most profitable times of each day. At the end of the sixth year, it requires a replacement.

The same project is modelled again, but this time performing only one cycle of full charge/discharge each day, during the most profitable hours. This scenario yielded a lower revenue due to energy time-shift, but this is outweighed in impact by the reduced cost of avoiding a battery replacement altogether during the 10-year project life.

Using a tool like StorageVET® or similar optimisation software, the user may test different "penalty functions" for energy storage cycling, essentially guiding the optimisation to require larger minimum price spreads for the energy storage system to cycle. Because the impacts of degradation often become evident farther in the future, it is important for system operators to recognise these general trade-offs early in projects.

Real-world energy storage project reliability

Battery storage projects are still relatively nascent in a commercial sense. As a result, the industry is still learning about the real-world sources of degradation and downtime for integrated systems. These systems are complex with many subsystems, where many sensors, communication channels, power electronics, thermal, and computational systems work together to accommodate performance requirements. As a result, insufficiently robust integration or unanticipated events may cause failure at different points within the system.

EPRI and other entities, such as the US National Labs, are working toward the development of common testing and measurement of both lab tested and commercially fielded systems. A group of EPRI member utilities are currently working on a multi-year effort to build a common database with energy storage performance track record and learn more about the observed sources of downtime and performance in real-world energy storage projects. Building a track record of reliability for energy storage projects is critical for supporting cost-effective investment of energy storage that supports the reliability and affordability of electricity for all members of society. ■

Authors

Dr. Andres Cortes is a technical leader at EPRI focusing on energy storage controls and techno-economic modeling of energy storage, distributed energy resources, and microgrids. Andres received his Ph.D. in mechanical engineering from University of California-San Diego.

Ben Kaun manages EPRI's Energy Storage programme, a public benefit research initiative supported by approximately 50 electric utilities and governments internationally. The programme is working to advance power system analysis techniques, test and demonstrate technologies, and advance integration practices for energy storage systems.

References

[1] G. M. Research, "U.S. Energy Storage Monitor," GTM, Boston, Q2, 2018.
[2] A. D. H. G. Sebastien Grolleau, "Predicting lithium-ion battery degradation for efficient design and management," in EVS27 *International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium*, Barcelona, Spain, 2013.
[3] Electric Power Research Institute, "StorageVET® V1.0 Software User Guide: User and Technical Documentation for the Storage Value Estimation Tool," Electric Power Research Institute, Palo Alto, CA, 2016.

Long time coming: Part 2

Battery technology | First developed by NASA, flow batteries are a potential answer to storing solar – and wind – for eight to 10 hours, far beyond what is commonly achieved today with lithium-ion. In the second of a two-part special report, Andy Colthorpe dives deeper into questions of bankability, market segmentation and manufacturing strategies

Credit: redT Energy.

In the last issue of *PV Tech Power,* it was mentioned that there are "specific circumstances" in which long durations of energy storage, going from four to typically around eight hours, are already economically feasible. Lazard's Levelised Cost of Storage analysis from November 2017 highlighted that flow batteries could be more cost-effective than lithium already for peaker plant replacement, distribution substations and micro-grids. Peaker replacement with a vanadium flow battery system could deliver LCOS of between US$209 and US$413 per MWh, while a lithium battery energy storage system could do the same starting at US$282, albeit with a lower upper price limit of US$347 per MWh.

The three main market segments

Jim Stover of manufacturer VRB/Pu Neng says there are three readily addressable market segments: large-scale utility storage, behind-the-meter commercial and industrial (C&I) on larger sites typically of 250kW to 8MWh, and micro-grids. Stover says the latter in particular are "great because you're going against diesel fuel. At US$1 a litre, most engines, gensets will be about 23 US cents a kWh so you could be close to 30 cents per kWh to operate a diesel genset on an island, or a remote micro-grid."

Craig Evans of ESS Inc, which makes the patented 'all-iron' flow battery, agrees that "coupled with renewable energy, as those prices [for distributed solutions] come down, diesel gensets look less attractive".

"We're kind of seeing a reversal of the format, of diesel genset being the baseload. Now diesel is becoming the backup and solar-plus-storage becomes the baseload for those types of grid," Evans says.

However, with almost every project typically a custom engineering and design job, Jim Stover admits uptake of micro-grids in general has been slower than other distributed energy project types, despite the economics making it "easy to compete" with diesel via solar-plus-vanadium battery storage.

It doesn't yet have the same track record or mainstream visibility as lithium-ion but flow energy storage is finding niches for commercial deployments beyond the initial trial phase

Stover says the larger end of the market is of more interest to VRB, "10MW or larger", per project, and highlights telecoms towers or community batteries as a viable niche. Just a few weeks ago, Australian flow battery provider Redflow announced a deal to deploy up to 60 energy storage systems to assist the rollout of digital television in Fiji, to give a current example.

For C&I energy storage, most of the industry headlines are being made by shorter duration 'peak shaving' projects in the US, or TRIAD avoidance in the UK. Taking out only an hour of peak demand at a time on a monthly basis can be quite effectively done with lithium, as Lazard's analysis found. However, vanadium could be viable as a future-proofing proposition, albeit for larger commercial customers than has been seen in the US peak shaving C&I market.

As mentioned in the previous issue, RedT CEO Scott McGregor argues that 'policy targeting' of peak shaving in specific territories might make economic sense today, but offering a C&I customer "their own distributed energy solution", using flow batteries combined with solar PV, can offer them a de-risked, long-term infrastructure investment. As on-site self-consumption of solar is to be encouraged, so too is storing that solar for longer durations.

"You want to capture more, cheap PV and you want to take out more hours of what you purchase on the grid. Then you are actually de-risking your investment. No one can take that away from a commercial customer," McGregor says.

"It's a reverse of how people have looked at energy storage [commercially]; 80% in our business models are relatively risk-free returns for the commercial customer. No policy, no subsidy changes can take that away. [The remaining] 20%, yes we'll help them extract what they can out of grid services and other stuff."

At grid-scale, we have heard about several huge projects planned in China as part of the nation's first unified energy storage strategy, in many cases to provide long duration smoothing or load shifting of solar and wind. Meanwhile a verification project of 15MW/60MWh at a substation in northern Japan will be coming to the end of its planned third year of data collection and used by utilities and grid operators to assess the technology's efficacy for solar and wind power integration.

So the overall trend is that the front-of-meter grid-scale market remains dominated by lithium, again due to the lack of economic impetus for longer durations of energy storage and as we will see later, due to factors influencing bankability.

On the other hand, RedT's Scott McGregor thinks that one of his company's latest projects – a lithium-vanadium hybrid system in Australia – could show the way forward. By combining the power capabilities of lithium with the energy properties of vanadium, McGregor says the 300kW/1MWh system (120kW C-1 rated lithium battery + 900kWh of flow), can use the vanadium for long duration and the majority of frequency response services, saving the lithium for "big spikes of power", thus "protecting the lithium battery" from degradation. As we have seen with a handful of larger C&I projects recently, the installation combines front-of-meter services with behind-the-meter onsite benefits.

The bankability arms race

Clearly, lithium-ion has something of a head start on other electrochemical energy storage technologies, in that the batteries used are a commodity driven on by li-ion's ubiquitous use in cellphones, laptops, tablets and of course, electric cars.

This contributes to the relative ease of financing energy storage projects using lithium batteries, as the technology has now been in use long enough for stakeholders to be comfortable with the idea of using them in other applications – albeit with lingering concerns around fire safety and end-of-life treatment of used batteries.

ESS Inc's Craig Evans adds that big companies in the lithium-ion space are able to put large projects on their balance sheets, while enjoying the cost reduction curve associated with the scaling of consumer electronics and EV markets. However, Evans is confident that particularly over time, the durability of flow batteries and the ability to offer 20-year warranties with no degradation of battery cells will start to win customers over.

In practical terms, flow energy storage providers can also be proactive in seeking bankability. Evans says that ESS Inc is working on creating assurance schemes so that his company's systems can be insured.

Jorg Heineman of Primus Power also says that despite the perception of competition, lithium-ion has "paved the way" for wider acceptance of grid-scale storage. Primus Power is "making huge strides on bankability", Heineman claims. Now on the third iteration of its product, EnergyPod, the company has amassed close to nine years of field data from existing installations. Primus' tech has already received a favourable bankability study by infrastructure group Black & Veatch, Heineman says. In addition the company is now in discussions with two insurance companies about having a warranty backstop as well as a revenue assurance protection product.

While these "key steps to bankability", as Heineman calls them, are being made he says also that currently booked business spans a range of sizes, applications and locations over the next two to three years, adding vital proof points for prospective customers, investors and other stakeholders.

Of course, this proof that the technology works in the real world is the cornerstone of that bankability. As Jim Stover from VRB says, there's no substitute for "for the hours, the years and the dollars spent to develop and commercialise a product."

Case in point: each of our interviewed providers would claim a big advantage of flow energy storage is that the electrolyte and the battery itself suffers no degradation over potential decades of operation. Most flow battery makers already offer 20-year warranties and argue that the lack of requirement for augmentation, as would be found with lithium batteries, mean a rugged durability over a lifetime's use. Lazard's analysis of storage costs acknowledges that this lack of need for augmentation could be significant economically, but austerely notes that due to the relatively short history of the technology in the field, we have not yet seen those claims to be proven correct on a big scale.

But it is therefore just a matter of time. Stover claims VRB/Pu Neng may have already reached 800,000 hours of operation on flow battery systems of differing scale and at locations ranging from laboratories on a research basis, to customers on a commercial basis. Other battery chemistries such as Aquion's much-talked about saltwater electrolyte devices that have emerged from the lab into the market have not scaled in the way the makers hoped for, Stover points out.

He says that the company was "thrilled" with the success of test deployments at China State Grid since 2012, which included a rigorous 240-hour test against four different applications including peak shaving, renewables load-shifting, frequency response and renewables smoothing – "sort of micro-responses to fluctuations in solar and wind". This initial 2MW/8MWh trial run helped inform China's 2017 energy storage strategy document, including the several, multi-hundred megawatt-hour flow battery projects green-lit for development over the next decade.

Proving and improving

As well as the bankability of the technology class itself, there is still the question of competition among the makers of these systems. How will they differentiate? For some, like Australia's Redflow, it's about using cheap, readily available components like plastic tanks. Conversely for others like Primus Power, a single-tank design and titanium electrodes are the touted improvements. As we heard in the last issue, ESS Inc is perhaps unique on the other hand for utilising saltwater and iron instead of vanadium or zinc bromine.

Primus Power's CEO Tom Stepien told Energy-Storage.news in 2017 that the decision to use titanium electrodes instead

From 2014's Primus Power EnergyPod (left) to the most recent third generation (right, with wind farm in background)

Credit: Primus Power

of graphite, as are used in other flow batteries, is due to the metal being "more expensive on a weight basis, but actually less expensive on an energy basis", and not subject to changing its composition over time due to corrosion. This time around, Stepien says that even including the titanium, the raw material costs of producing EnergyPods are low.

"The way I think about the cost, it's really simplistic at a high level: it's raw material plus processing that raw material. If you have a low raw material cost like we do, then because we have a single tank, we don't have a separator [membrane], we have such a head start," Stepien says.

Indeed, the Lazard LCOS analysis acknowledges that flow batteries designed using a single tank, single loop and no membrane could allow for "simpler and less costly designs".

"Our raw material cost in dollars per kWh is less than US$60, plastic, titanium, electrolytes, 60 bucks unprocessed. Today we are paying five to six times that to weld our steel, to injection mould the plastic and so on.

"We have a system that's US$50, US$60 times six – 400-500 bucks per kWh is the material cost of our completed Energy Pod. If you build a couple of hundred – it doesn't take 10,000, just a couple of hundred – that transformation cost is below two times. There's a line of sight to get below US$200 for that same unit. Raw material wins. If you want something cheap as dirt, get it as close to dirt as possible," he says.

The other question is whether flow batteries should continue to ride the tide of the energy storage market as it is today, gradually finding deployment as the need for long duration storage inevitably spreads in tandem with solar and wind. Navigant Research analyst Ian McClenny says that the redox pairs of vanadium and zinc-based chemistries "yield competitive, but lower power densities" in comparison with lithium-ion.

If flow batteries were to attempt to compete with lithium head-to-head, they would require the development of different chemistries that "yield higher power density and are safer", better separator, electrode materials and architecture to improve chemical conversion would still be needed, as would ongoing reductions in balance of system costs. Yet, the example of RedT's lithium-vanadium hybrid system shows, it might not have to be a straight shootout between the two technologies after all. Ironically, one of lithium-ion's 'weaknesses', offers the opportunity for flow to complement its more mainstream cousin.

"What has come now to the market – which is a fact – is that it's the cost of degradation on the lithium which is the problem for grid storage," McGregor says.

"What has come now to the market – which is a fact – is that it's the cost of degradation on the lithium which is the problem for grid storage"

"Trading using a [lithium] battery, you have to work out what the cost of that use is. With flow you don't have a cost because there is no degradation. [So] a flow solution is good for, yes, medium, long-term duration on the grid services but it's actually much more valuable for short term services. You use the lithium when you're making lots of money and the flow is for everyday use."

Vertical integration versus OEM

From a manufacturing standpoint, the different providers' strategies are almost as diverse as their technology offerings. VRB/Pu Neng, for instance, is 82% owned by US/Canadian mineral resources group Ivanhoe Capital, which is led by financier Robert Friedland and fits into the mining industry veteran's IPulse group of companies. Jim Stover says that Friedland's group had spotted potential to capitalise on its "upstream vanadium expertise", as well as a track record of working in China and purchasing Pu Neng in 2016 (the rebranding as VRB is currently ongoing, while the Chinese subsidiary will retain the Pu Neng moniker). While corporate headquarters are in Vancouver and other offices are in the US, the manufacturing takes place in China, near Beijing.

"It's important to be vertically integrated here, to produce a vanadium battery. Because the electrolyte typically is 30% to 50% of the cost of the battery, depending of course on the length of energy duration," Stover says, adding that VRB is preparing to present solutions for large-scale solar installations in the Middle East that involve an 8-13-hour energy storage duration.

"At that point, the electrolyte is maybe 70% to 80% of the cost of the battery so it's important to have that upstream vanadium electrolyte capability."

Conversely, Tom Stepien says that Primus Power "would be out of business if it built a factory" and like several others in the space, outsources manufacturing to a major contract OEM. Everything excluding the stack is made by Foxconn, the US$140 billion annual revenue assembly partner for Apple's iPhone. With this arrangement, Stepien claims Primus Power effectively "already has a Gigafactory".

"If you put enough billions of dollars in the Nevada Desert you can get the transformation cost [of lithium battery materials] low because you've got a lot of automation. This is not automated assembly. These are 2 metres by 2 metres by 2 metres; this is not a robotic, semiconductor-type manufacturing. You can add automation in a smart way but outsourcing manufacturing allows us to focus on our core."

Although Tom Stepien at Primus says it is "never of interest" to fully vertically integrate, earlier in 2018 the company netted investment from Anglo-American Platinum, which just happens to supply metals used as catalyst to the titanium electrodes of Primus' EnergyPod systems. The plating of zinc onto titanium electrodes and the rest of the stack's assembly takes place in the US. The stack and balance of plant and other parts made by Foxconn meet at an assembly centre in the US.

"We can deliver to Johannesburg at the same cost as we can deliver to LA with this regional integration, worldwide delivery model that we've developed. It's not our idea, other people have done that. We love that model. It makes a tonne of sense for young technology companies like us."

Jim Stover is confident the cost reduction trajectory for flow energy storage, while not as dramatic as that experienced by solar, will be at least competitive to lithium, despite the danger that the latter's popularity could "crowd out innovation" in other technologies.

"Lithium is on about 15% cost reduction per doubling of manufacturing capacity – [that's the] 'learning rate'. Solar is on about 23-25% per doubling and that's why it's come down so fast. We see ourselves – going back to 2010 or so, we see a similar progression of about 15- 16% reduction in cost per doubling in manufacturing capacity [for vanadium redox batteries]." ■

advertisers & web index

next issue

Aerial plant inspection

Combining pyranometer and satellite data

Middle East and North Africa focus

SUBSCRIBE TODAY! **www.pv-tech.org/power**

JA SOLAR

Harvest the Sunshine

Premium Cells, Premium Modules

+86(10)6361 1888   www.jasolar.com

Booth No：

3.124

Renewable
Energy India Expo

A UBM Event

18–20 SEPT,2018

India Expo Centre,Greater Noida