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viewpoint

A new look at solar's future

IT IS UNDENIABLE that solar energy is both the present and future of energy production, yet the way photovoltaic (PV) technology is implemented and combined with legacy resources is also evolving rapidly.

We have already seen across Europe and elsewhere how PV-based energy generation has soared compared to legacy resources, growing from less than 1 percent in 2005 to more than 11 percent in 2015. Even as PV cell efficiency climbs higher, new cell designs, hybrid energy plants, power storage and sophisticated A/I energy resource management programs are shaping ways that solar energy is implemented, utilized, stored, and melded into grid supplies.

Solar+Power Management explores the changing shape of PV power in this edition. From education initiatives by InnoEnergy, to grid-scale plant development by SBRE in Israel, solar is not only going mainstream, but entrepreneurs are finding innovative solutions for blending renewable energy with traditional generation methods as never before. Still others are combining intermittent resources including solar, hydro and wind for optimized utility across traditional grids.

"Solar electricity generation overtook geothermal energy in 2008, but it has the potential to overtake natural gas, coal and nuclear too. The solar industry should be aiming for nothing less than a paradigm shift," says Emilien Simonot, renewable energy technology officer at InnoEnergy. While it can be justifiably argued that Europe started the solar revolution, its benefits have gone global. The United States covered substantial ground recently to enable greater use of energy storage as a means to level loads, conserve power and share resources across jurisdictional boundaries. The Federal Energy Regulatory Committee (FERC) voted unanimously to support storage at the grid scale—a huge step towards making the benefits of storage a part of routine energy resource management.

Meanwhile, in Australia the first large-scale solar and battery storage project to be interconnected with the local grid is underway. Conergy and the Australian Renewable Energy Agency (ARENA) partnered on the Far North Queensland (FNQ) area's new (AUS) $59.9 million project testing hybrid energy under daily operating conditions. A significant part of the project is to gauge how well islanding works on a deliberate and calculated scale. Can 3,000 homes and businesses periodically operate successfully on solar and battery resources only, and then switch back (seamlessly) to grid power as needed? We will know in a few months.

The future is solar, and the future is taking shape right before our very eyes.

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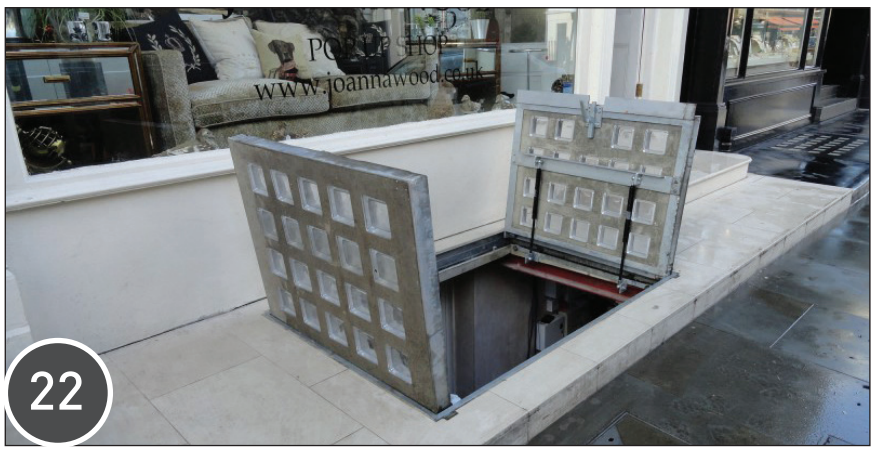


research...

News

Ascent CIGS technology selected for more space tests

Ascent Solar Technologies, a developer of flexible thin-film CIGS photovoltaic (PV) technology, has been selected by the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt; DLR) for further testing to develop custom PV products designed for DLR's upcoming solar array deployment system.

DLR's new GOSOLAR project is testing the technology needed for a large-scale solar power generation system that will use a flexible photovoltaic membrane. Ascent's technology will allow DLR to address the requirements that come with this approach to solar-sail deployment in a gossamer formation.

"We are pleased that DLR has selected our material for testing of their applicability to large solar array deployment," stated Joseph Armstrong, CTO and founding member of Ascent Solar Technologies.

"We have been gaining traction in the deep space community, in part because we have a unique, lightweight and flexible product, but also because our monolithic integration offers greater design latitude that traditional crystalline products do not.

"We have demonstrated the ability to adjust the physical dimensions of our modules to meet the need of customers, and with unique deployment schemes employed by DLR, correctly sizing our solution to accommodate proper stowage and deployment is critical.
"We are honoured to be selected by DLR for deployment of their solar sails in a gossamer formation meant for the extremely punishing space environment," said Victor Lee, president and CEO of Ascent Solar. "Our design allows us to maximise the surface area of our award-winning solar technology while keeping the thin and lightweight profile of the deployed solar sails. We look forward to further development and testing with DLR in the coming years."

Yingli signs 146 MW EPC contract with Jenner

YINGLI SOLAR has announced that its wholly owned subsidiary, Yingli Green Energy Europe, S.L. has signed an agreement with Jenner Renewables, to provide Engineering, Procurement and Construction (EPC) services for 12 ground-mounted PV plants in Chile, with the total capacity of 146MW.

According to the agreement, the project is divided in 2 phases: Cluster 1 includes 4 PV plants and the construction will begin in February 2018 with expected operation by June 2018; Cluster 2, including 8 PV plants, will begin by the completion of Cluster 1.

As the EPC contractor and exclusive solar panel supplier for the project, Yingli will supply its multicrystalline modules type YL325P-35B. Upon completion, each PV plant is anticipated to avoid 20.8 tons of CO_2 per year.
"As an independent power producer operating throughout Latin America, we are very excited to contribute in such a significant way to the development of renewable energy in Chile. This country is at the forefront of implementing a carbon free electricity system by 2040 and our projects definitely support this strategy," said Jorge Calvet, Founder and CEO of Jenner Renewables. "This is part of our renewable energy pipeline of 1 ,500 MW, which we intend to develop over the next 3-4 years in Chile, Mexico, Colombia, Argentina and other countries in the region."

"We are proud to partner with Jenner Renewables on such a significant project, which is the largest EPC project that Yingli undertook independently. In addition to focusing on our historical customers, such as EPC contractors and project developers, we are also seeking opportunities in some specific countries or cooperation with some specific partners to provide EPC services, which we believe could bring higher added value to our high-quality products and therefore increase our service level," commented Mr. Liansheng Miao, Chairman and Chief Executive Officer of Yingli.

"We are delighted to secure this EPC, which proves the adequate service level, competitive advantage and capabilities from Yingli Solar.

This contract is a milestone for us in Latin American region and we will continue to develop the business unit and strengthen our local presence. The framework agreement within both companies includes a pipeline above 1GW, which demonstrates the trust and commitment between Yingli and Jenner Renewables," said Mr. Fernando Calisalvo, the Managing Director of Yingli Europe.

Ecoppia water-free robotic solution

ECOPPIA'S fully automated solar panel cleaning solution is on track to clean over 1GW of panels in the cutting edge Bhadla solar park by year end Ecoppia, the world-leading developer of robotic, water-free photovoltaic solar panel cleaning solutions, announced today the completion of deployment of hundreds of its automated systems in the 2,255 MW Bhadla Solar Park in Jodhpur, Rajasthan India, in a site developed by Engie Solar India, subsidiary of energy multinational ENGIE Group.

Located in a vast desert area, Bhadla Solar Park is prone to frequent dust storms, which can reduce energy generation by as much as 40% in a matter of minutes.

Ecoppia is the only solution able to maintain peak energy production and restore panels post-storm in just hours - without water or external electricity consumption: with the deployment of Ecoppia across its site, ENGIE is expected to save over 1.5 billion of liters of water, and reduce its operating expenses drastically.

The subject project was won at record tariff, lowest in India at the time of bidding, hence it was indispensable to adopt an innovative and bankable technology like Ecoppia to ensure maximum plant productivity.

"We expect to harness Ecoppia's revolutionary cleaning system to dramatically raise output and lower costs. This type of technological breakthrough not only benefits our own business interests, but the solar energy sector as a whole," Engie Solar India commented. "We are proud to be one of the world's first solar energy providers to adopt Ecoppia's cutting-edge, autonomous robotic panel cleaning paradigm".

Continuing Ecoppia's commitment to cooperation with large multinational energy conglomerates and its specific focus on the Indian market, the company is expected to top 1 GW of deployments in Bahdla Park alone, and over 2GW across India. Cleaning over 200 million solar panels to date, leveraging experience gained working with leading energy conglomerates like Adani Power, SunEdison and NTPC, Ecoppia cooperated closely with ENGIE throughout the design and deployment process to maximize rollout efficiency and optimize return on investment.

IBC SOLAR and EVBox join up solar and EV charging

IBC SOLAR AG, has announced a strategic partnership with EVBox, a global manufacturer of electric vehicle (EV) charging stations and charging management software. As part of the agreement, EVBox will deliver EV charging stations to IBC SOLAR for private and public use. These may be easily combined with photovoltaics and energy storage systems.

"EVs will only produce less emissions if they are being powered by clean energy, such as solar-generated power," says Udo Möhrstedt, Founder and CEO of the photovoltaic company IBC SOLAR, who is convinced of this. "When the eMobility market takes off in 2018, photovoltaics, EVs, and charging infrastructure will have to be part of the same discussion." With this, Möhrstedt is providing the vision and future direction of the solar industry as a photovoltaic pioneer.

As of the beginning of February, this new partnership between EVBox and IBC SOLAR aims to combine their strengths to become strategic partners in Germany, among other European countries. EVBox's charging stations can be combined with photovoltaics in a smart and simple way. With a mobile app, customers are able to configure their charging times to maximize the usage of the solar power available in the grid. Private households and businesses that invest in photovoltaics will save greatly by also using solar energy for their vehicles. At a starting cost of 10 cents per kWh (in Germany), a passenger car powered with solar will only cost around 2 euros for a 100-kilometer drive.

Kristof Vereenooghe, CEO of EVBox, adds to this: "We are very happy to have signed this partnership with IBC SOLAR, one of the most important players in the field of renewable energy. Together, we believe we can advance eMobility in Germany, Austria, and Switzerland and help shape the future of transportation. By combining our EVBox charging stations with IBC Solar's solutions, customers will from now on be able to combine photovoltaics, power storage and electric vehicle charging. The future of transportation is very bright indeed.

Swedish MP visits CIGS solar factory

ONE of Sweden's leading politicians, party leader of Centerpartiet, Member of Parliament and former Minister of Enterprise, Annie Lööf, visited the CIGS solar technology firm Midsummer, based in Järfälla, Sweden. "I was very inspired by today's visit!", said Annie Lööf.

Midsummer is a developer and supplier of advanced solar energy solutions for the production and installation of flexible solar cells. It is also a leading Swedish growth and export company. Midsummer has often been named one of Sweden's and Europe's fastest growing technology companies. "The visit to Midsummer confirmed that Swedish companies are at the forefront of climate work", said Annie Lööf. "With technological development and innovation, you create jobs in Sweden and contribute to the green environmental change. I was very inspired by today's visit."

Façade of Onyx Solar's PV glass in Dubai

ONYX SOLAR has participated in the construction of DEWA R&D Centre & Laboratory in Dubai, by supplying 1000 sqm of semi-transparent coloured photovoltaic glass.

The four facades of the building will implement a louver system composed by Onyx Solar amorphous silicon glass with transparency degree XXL and 6 different colours, creating a multi-coloured façade that provides a unique effect to the building.

The two entrance canopies on north and west facades will also integrate Onyx Solar semi-transparent glass to maintain visual continuity in the complete building envelope.

All photovoltaic glass pieces manufactured for this project are 100% customized to fit the design requirements of the building.

This project is a great example of DEWA's commitment with sustainability. DEWA (Dubai Electricity and Water Authority) is a state entity whose objective is to provide an adequate and sustainable supply of electricity and water to Dubai's population. DEWA also focuses its efforts on promoting energy efficiency and the use of renewable energies in United Arab Emirates.

ABB helps IKEA harness the sun's energy in Singapore

ABB has provided the Swedish retailer IKEA with 20 of its innovative TRIO-50 solar inverters to power a rooftop solar system on its flagship store in Singapore, located in the eastern suburb of Tampines. The system is expected to generate 1.3 million kilowatt (kW) hours per year — enough renewable energy to power more than 280 households.

Installation of the solar panels began at the IKEA store in March 2017 and the project went live in December 2017. ABB won the order through its customer, a leading solar system integrator, Phoenix Solar, in the first quarter of 2017. With this rooftop system, IKEA expects to trim an estimated $2.4 million from the store's electrical bills over the next ten years.

Mark Argar, Phoenix Solar Senior Vice President Asia-Pacific, said: "We are proud to partner with ABB to provide IKEA with top-class solar PV systems supporting the company's move towards clean energy. We are committed to advancing wider adoption of solar power in Asia and doing so requires teaming up with technology pioneers like ABB that have the knowledge and skills to do quality installations."

"We strive to help meet growing energy demand around the world while minimizing environmental impact and creating value for our customers," said Tarak Mehta, president of ABB's Electrification Products division. "This project is one such example where ABB's flexible and innovative solar power technologies will allow IKEA to commit to their energy efficiency and sustainability targets. Integration of renewables is an increasingly important element of the world's energy revolution and ABB's Next Level strategy."

Designed to combine the performance and price competitiveness of a central inverter with the portability and flexibility of a string inverter, the TRIO-50 will see further deployment on other IKEA roofs in South East Asia. In Malaysia, 500 kW of the TRIO-50 will power the IPC Shopping Center, South East Asia's first shopping mall anchored by IKEA. In Thailand, the upcoming IKEA store at Bangyai, near Bangkok will feature 1.5 megawatts of the TRIO-50 on its rooftop car-port.

Like IKEA, the rest of the corporate sector is poised to build more rooftop solar plants in the coming few years owing to the rapidly increasing economic viability of solar power. According to GTM Research, commercial rooftop installation costs have declined almost 30 percent in the past five years driven largely by falling solar panel costs. Solar has allowed corporate solar customers like IKEA to achieve financial and operational savings in addition to carbon footprint goals.

Outside the corporate sector, governments in South East Asia have also embraced renewable initiatives, such as Singapore's Economic Development Board's Solarnova projects, Thailand's Alternative Energy Development Plan (AEDP), and Malaysia's Sustainable Energy Authority (SEDA) policies, laying the foundation for sunnier days ahead in the region.

Schletter complete major project in China

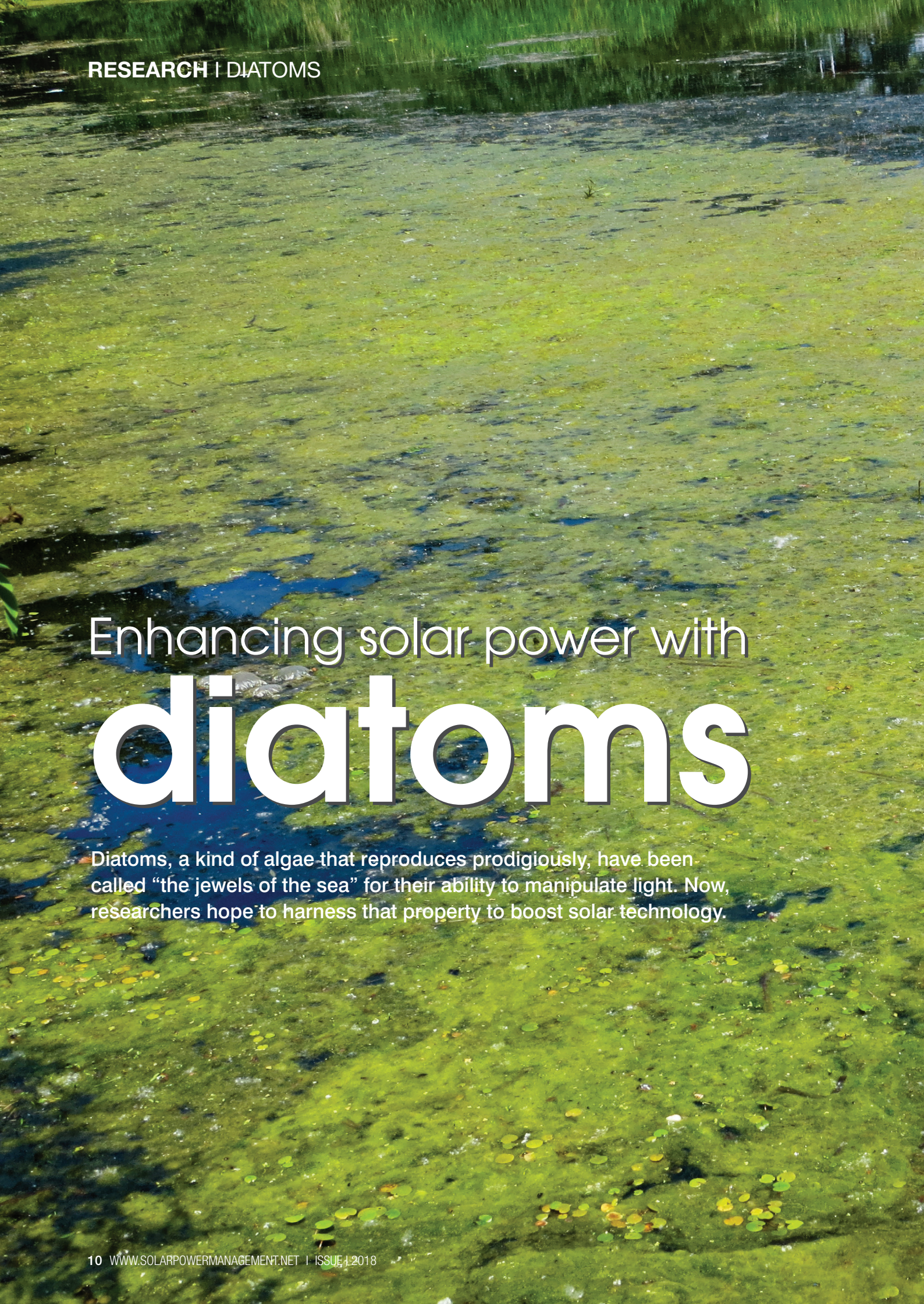
THE SCHLETTER GROUP has completed another major project in China: The Anhui Jin solar farm in Anhui Province, China, generates 35 MW and produces electricity for nearly 20,000 households. With this, the Schletter Group continues its growth in China.

"We are already in an excellent position in the fast-growing Chinese market," Florian Roos, said. He is managing director of the Schletter faciliy in Shanghai, where the mounting systems for the project were manufactured. "This project, which is particularly demanding due to its topography, contributes to further strengthening our reputation as a leader in terms of quality." The Schletter Group employs over 450 people in Shanghai and, with a total of around 2.5 GW of installed PV capacity, is one of the largest foreign suppliers of PV mounting systems in Asia.

The solar farm is situated in hilly terrain with slopes of up to 30 degrees. In order to guarantee the stability of the facility in the sometimes steep and changing terrain, Schletter engineers first carried out a geological survey. On this basis, the installation was then individually designed. The PV mounting system used for the solar panels was Schletter's FS AS UNO. This single-support system has a solid ramming foundation made of hot-dip galvanized steel and is therefore particularly stable and durable.

In addition, a high degree of prefabrication enables fast and easy assembly and thus high economic efficiency. Despite the sometimes steep terrain, the plant could be completed within as little as three months.

The system was installed by the contractor Shan YD EPC. Schletter had previously trained their technicians on site. The Schletter Group has already collaborated with Shan YD on several occasions, including a 5 MWp greenfield installation using the FS Duo system in the northern Chinese province of Heilongjiang. The Anhui Jin solar farm is to be expanded by a further 15 megawatts in the coming months.



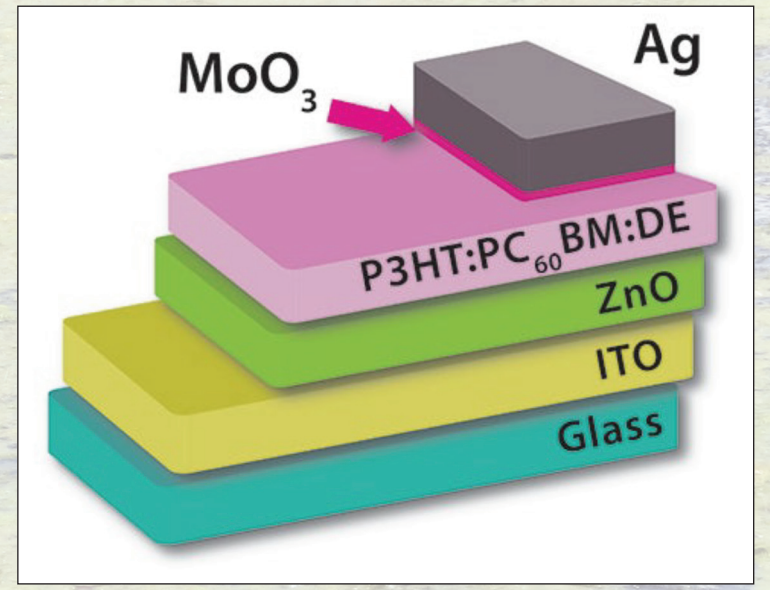
Enhancing solar power with diatoms

Diatoms, a kind of algae that reproduces prodigiously, have been called "the jewels of the sea" for their ability to manipulate light. Now, researchers hope to harness that property to boost solar technology.

IN THE LAB of Andre Taylor, associate professor of chemical & environmental engineering, fossilized diatoms are being used to solve a design problem that has long plagued the development of organic solar cells. The results of their work are published in Organic Electronics.

The abundant diatoms are found in all kinds of water and even in the bark of trees, and possess a skeleton made of nanostructured silica or glass. “It’s really amazing that these things exist in nature,” said Lyndsey McMillon-Brown, a Ph.D. student in Taylor’s lab and lead author of the study. “They help trap and scatter light for the algae to photosynthesize, so we’re able to use something directly from nature and put it in a solar cell.”

These small creatures could prove to be particularly valuable for the design of solar technologies known as organic photovoltaics - a lower-cost option to conventional solar technologies. One challenge of designing these devices, though, is that they require very thin active layers (100 to 300 nanometers), which limits their efficiency in converting light to electricity. Ways to correct this include embedding nanostructures that trap and scatter light to enhance the absorption levels. These approaches, though, are too costly for large-scale production.

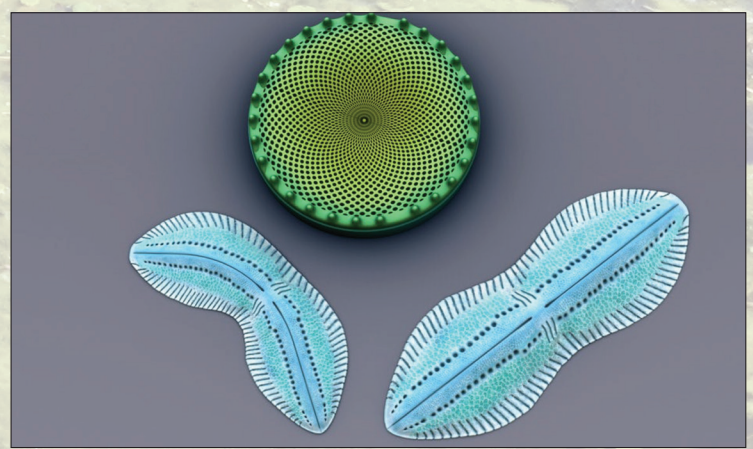


The diatoms were added to the thin active layer in the organic solar cell (Credit: Yale University)
That’s where diatoms can help. They’ve been optimized for light absorption through billions of years of adaptive evolution. The most common type of phytoplankton found in nature, they’re cheap and can be found almost anywhere. The research team, which includes collaborators from NASA, Princeton University and Lincoln University, dispersed diatoms throughout the active layer of the solar cell. By doing so, they reduced the amount of the material needed for the active layer but maintained the same levels of electrical output.

“We were able to see what the right concentration was and how much of this material we needed to put into our solar cells to get enhancement,” McMillon-Brown said. “It’s really beneficial because the active layer materials we use are expensive and very rare.” Although the diatoms were initially too large for the active layer, they were able to fix that with a simple grinding process. “It didn’t interrupt our existing processing steps, so it doesn’t add any complexities or challenges, and can definitely be an easy addition to existing commercialized organic solar cells,” McMillon-Brown said. McMillon-Brown and Taylor said even better results are likely with some adjustments. “We can use different species of diatoms and tailor it to the right size, and we can also use some of the better donor-acceptor polymers for a higher performance,” Taylor said.

Yale researchers have used light-manipulating algae called diatoms to improve the efficiency of organic solar cells(Credit: Depositphotos/sciencepics)
McMillon-Brown said the diatoms seemed like a natural fit for her research as soon as she learned about them.

“My work is on biomimicry, so I’m always looking at existing patterns and structures in nature,” she said. “We’re always on the hunt for new patterns in nature because we believe that nature solves all our engineering problems - we just have to find the solutions.”



A new approach to **rechargeable batteries**

A type of battery first invented nearly five decades ago could catapult to the forefront of energy storage technologies, thanks to a new finding by researchers at MIT.

A TYPE OF BATTERY FIRST invented nearly five decades ago could catapult to the forefront of energy storage technologies, thanks to a finding by researchers at MIT. The battery, based on electrodes made of sodium and nickel chloride and using a new type of metal mesh membrane, could be used for grid-scale installations to make intermittent power sources such as wind and solar capable of delivering reliable baseload electricity

The findings were reported in the journal Nature Energy, by a team led by MIT professor Donald Sadoway, postdocs Huayi Yin and Brice Chung, and four others.

Although the basic battery chemistry the team used, based on a liquid sodium electrode material, was first described in 1968, the concept never caught on as a practical approach because of one significant drawback: It required the use of a thin membrane to separate its molten components, and the only known material with the needed properties for that membrane was a brittle and fragile ceramic. These paper-thin membranes made the batteries too easily damaged in real-world operating conditions, so apart from a few specialized industrial applications, the system has never been widely implemented.
But Sadoway and his team took a different approach, realizing that the functions of that membrane could instead be performed by a specially coated metal mesh, a much stronger and more flexible material that could stand up to the rigors of use in industrial-scale storage systems.

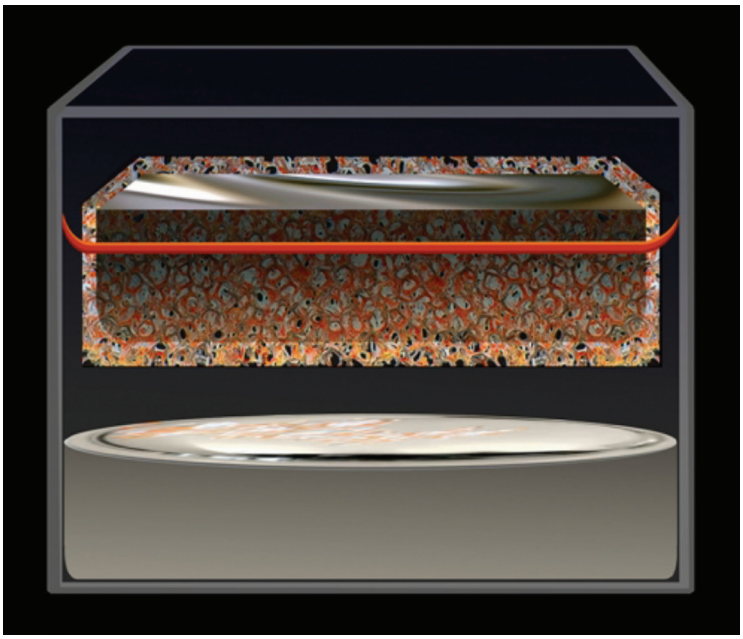
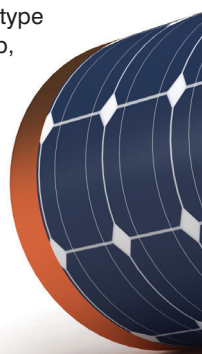


Illustration modified from an original image by Felice Frankel

"I consider this a breakthrough," Sadoway says, because for the first time in five decades, this type of battery — whose advantages include cheap, abundant raw materials, very safe operational characteristics, and an ability to go through many charge-discharge cycles without degradation — could finally become practical.



While some companies have continued to make liquid-sodium batteries for specialized uses, "the cost was kept high because of the fragility of the ceramic membranes," says Sadoway, the John F. Elliott Professor of Materials Chemistry. "Nobody's really been able to make that process work," including GE, which spent nearly 10 years working on the technology before abandoning the project.

As Sadoway and his team explored various options for the different components in a molten-metal-based battery, they were surprised by the results of one of their tests using lead compounds. "We opened the cell and found droplets" inside the test chamber, which "would have to have been droplets of molten lead,"

he says. But instead of acting as a membrane, as expected, the compound material "was acting as an electrode," actively taking part in the battery's electrochemical reaction.

"That really opened our eyes to a completely different technology," he says. The membrane had performed its role — selectively allowing certain molecules to pass through while blocking others — in an entirely different way, using its electrical properties rather than the typical mechanical sorting based on the sizes of pores in the material.

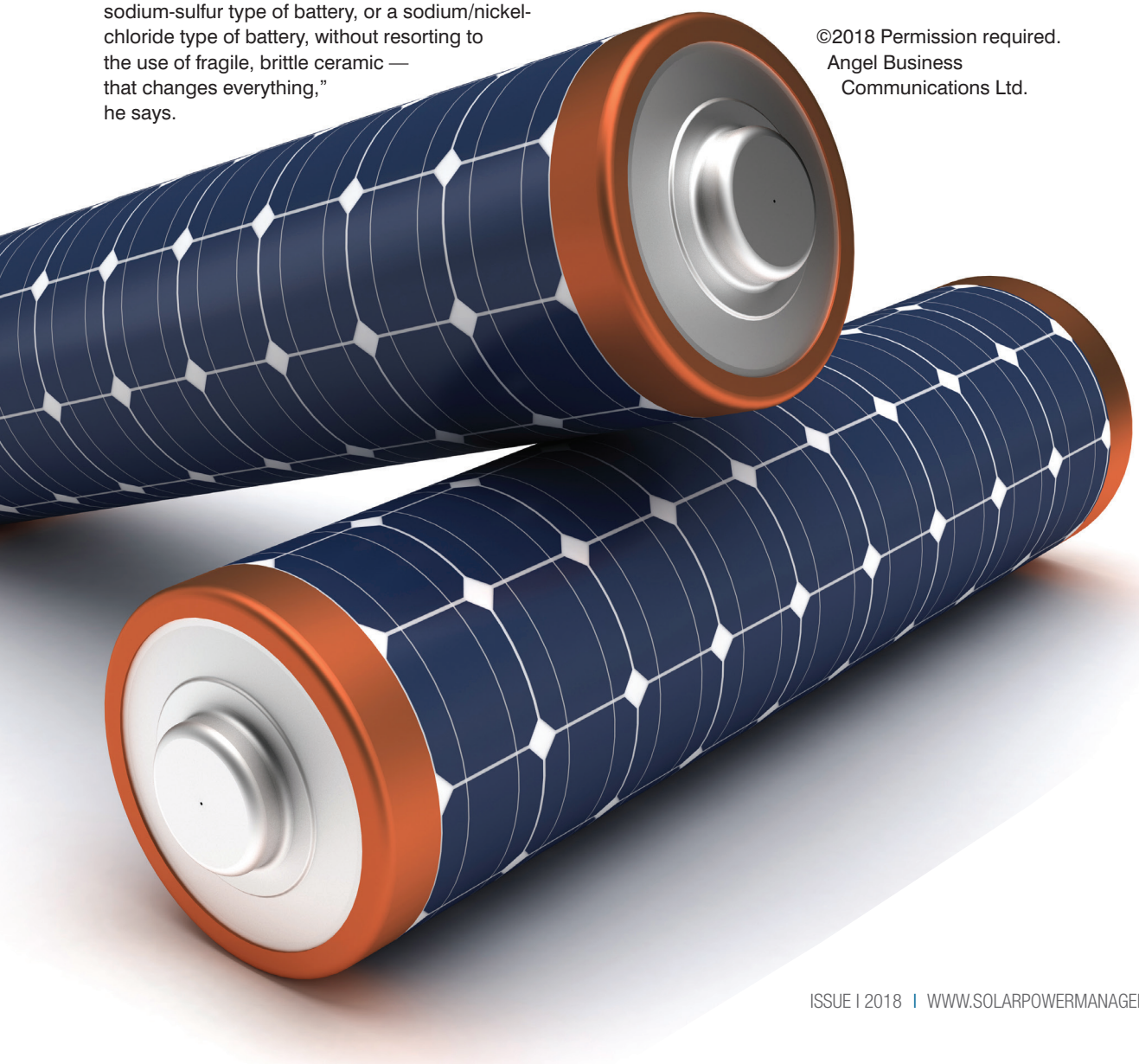
In the end, after experimenting with various compounds, the team found that an ordinary steel mesh coated with a solution of titanium nitride could perform all the functions of the previously used ceramic membranes, but without the brittleness and fragility. The results could make possible a whole family of inexpensive and durable materials practical for large-scale rechargeable batteries.

The use of the new type of membrane can be applied to a wide variety of molten-electrode battery chemistries, he says, and opens up new avenues for battery design. "The fact that you can build a sodium-sulfur type of battery, or a sodium/nickel-chloride type of battery, without resorting to the use of fragile, brittle ceramic — that changes everything," he says.

The work could lead to inexpensive batteries large enough to make intermittent, renewable power sources practical for grid-scale storage, and the same underlying technology could have other applications as well, such as for some kinds of metal production, Sadoway says.

Sadoway cautions that such batteries would not be suitable for some major uses, such as cars or phones. Their strong point is in large, fixed installations where cost is paramount, but size and weight are not, such as utility-scale load leveling. In those applications, inexpensive battery technology could potentially enable a much greater percentage of intermittent renewable energy sources to take the place of baseload, always-available power sources, which are now dominated by fossil fuels.

The research team included Fei Chen, a visiting scientist from Wuhan University of Technology; Nobuyuki Tanaka, a visiting scientist from the Japan Atomic Energy Agency; MIT research scientist Takanari Ouchi; and postdocs Huayi Yin, Brice Chung, and Ji Zhao. The work was supported by the French oil company Total S.A. through the MIT Energy Initiative.



Big boost

for energy storage research

Four projects awarded to ignite a revolution in UK battery research, and address battery challenges faced by industry.

THE FARADAY INSTITUTION has announced up to £42 million in new government funding to four UK-based consortia to conduct application-inspired research aimed at overcoming battery challenges to accelerate the electric vehicle (EV) revolution.

If successful, this research will put the UK on the map as being at the forefront of battery technology worldwide. It has the potential to radically increase the speed with which we are able to make the move to electric vehicles, as well as the speed with which we can decarbonize our energy supply, with obvious benefits to the environment.

The Faraday Institution is the UK's independent national battery research institute, and was established as part of the government's £246 million investment in battery technology through the Industrial Strategy. Its formation was announced in October 2017 by the Business Secretary Greg Clark. The Faraday Institution's goal is to make the UK the go-to place and world leader for battery technology research and it has a clear mission to ensure the UK is well placed to take advantage of the future economic opportunities from this emerging technology.

Business Minister Richard Harrington said, "With 200,000 electric vehicles set to be on UK roads by the end of 2018 and worldwide sales growing by 45 per cent in 2016, investment in car batteries is a massive opportunity for Britain and one that is estimated to be worth £5 billion by 2025. "Through our flagship Industrial Strategy and its Future of Mobility and Clean Growth Grand Challenges, we are committed to making Britain the 'go-to' destination for the development and deployment of this game-changing technology. "Government investment, through the Faraday Institution, in the projects announced today will deliver valuable research that will help us seize the economic opportunities presented by battery technology and our transition to a low-carbon economy."

The topics for the four projects were chosen in consultation with industry, who will partner closely with each of them. This unique collaboration will help to ensure that the research is producing findings and solutions that meet the needs of business. In addition, industrial partners will contribute a total of £4.6 million in in-kind support to the following four projects:

Extending battery life – Led by the University of Cambridge with nine other university and 10 industry partners, this project will examine how environmental and internal battery stresses (such as high temperatures, charging and discharging rates) damage electric vehicle (EV) batteries over time. Results will include the optimization of battery

Electric vehicle charging station in public space. The charging spot support by solar panels, storage batteries

materials and cells to extend battery life (and hence EV range), reduce battery costs, and enhance battery safety. With Cambridge, university partners include University of Glasgow, University College London, Newcastle University, Imperial College London, University of Strathclyde, University of Manchester, University of Southampton, University of Liverpool and University of Warwick.

Battery system modelling – Imperial College London (ICL) will lead a consortium of six other university and 17 industry partners to equip industry and academia with new software tools to understand and predict battery performance, by connecting understanding of battery materials at the atomic level all the way up to an assembled battery pack. The goal is to create accurate models for use by the automotive industry to extend lifetime and performance, especially at low temperatures. With ICL, university partners include University of Southampton, University of Warwick, University of Oxford, Lancaster University, University of Bath, and University College London.

Recycling and reuse – A project led by the University of Birmingham, including seven other academic institutions and 14 industrial partners, will determine the ways in which spent lithium batteries can be recycled. With the aim to recycle 100% of the battery, the project will look how to reuse the batteries and their materials, to make better use of global resources, and ultimately increase the impact of batteries in improving air quality and decarbonisation. With Birmingham, university partners include the University of Leicester, Newcastle University, Cardiff University, University of Liverpool, Oxford Brookes University, University of Edinburgh, and the Science and Facilities Technology Council.

Next generation solid state batteries – The University of Oxford will lead an effort with six other university partners and nine industrial partners to break down the barriers that are preventing the progression to market of solid-state batteries, that should be lighter and safer, meaning cost savings and less reliance on cooling systems. The ambition of this project is to demonstrate the feasibility of a solid state battery with performance superior to Li-ion in EV applications. With Oxford, university partners will include the University of Liverpool, University of Glasgow, University of Strathclyde, University of Cambridge, University College London, and the University of St. Andrews.

Peter B. Littlewood, founding executive chair of the Faraday Institution, said: “To deliver the much needed improvement in air quality in our cities and achieve our aspiration for cleaner energy targets we need to shift to electric vehicles quickly. These research programmes will help the UK achieve this. To be impactful on increasing energy density, lowering cost, extending lifetime, and improving battery safety requires a substantial and focused

effort in fundamental research." He went on to say that "Through steady investment in basic research on specific societal challenges identified by industry and government, the UK will become a world-leading powerhouse in energy storage. "

Professor Philip Nelson, EPSRC's Chief Executive, said: "There is an urgent imperative for us to increase the efficiency of energy storage as we move towards low carbon economies and attempt to switch to clean methods of energy production.

"The Faraday Institution will bring leading academics in the field of battery development together with industry experts to explore novel application-inspired approaches that will address the challenges we face. The UK has an opportunity to accelerate the development of new products and techniques. EPSRC will be working with the Institution and the academic community to help it succeed and keep the UK a prosperous and productive nation."

Richard Catlow, Foreign Secretary of the Royal Society and professor at University College London, said: "Using more electricity will be key in reducing greenhouse gas emissions. Last year the European Academies Science Advisory Council found that advances in large-scale electricity storage is a priority to manage our increasing dependence on renewable energies. The Royal Society welcomes the Faraday Institution's much needed investment in energy storage research."

The Faraday Institution is the UK's independent, national institute for electrochemical energy storage science and technology, supporting research, training, and analysis. Bringing together expertise from universities and industry, The Faraday Institution endeavours to make the UK the go-to place for the research of the development, manufacture and production of new electrical storage technologies for both the automotive and the wider relevant sectors. The first phase of the Faraday Institution is funded by the Engineering and Physical Sciences Research Council (EPSRC) through the government's Industrial Strategy Challenge Fund (ISCF). Headquartered at the Harwell Science and Innovation Campus, the Faraday Institution is registered charity with an independent board of trustees. To learn more, visit faraday.ac.uk and follow @FaradayInst on Twitter.

The Industrial Strategy Challenge Fund (ISCF) builds on the UK's world-class research base and delivers the science that business needs to transform existing industries and create new ones. It accelerates commercial exploitation of the most exciting technologies the UK has to offer the world to ensure that scientific investment truly delivers economic impact, jobs and growth right across the country.

The ISCF is delivered by InnovateUK and Research Councils UK (RCUK), and eventually UK Research and Innovation, the single voice for the UK's research and innovation landscape. The 'Faraday Battery Challenge' is to develop and manufacture batteries for the electrification of vehicles – £246 million over four years – to help UK businesses seize the opportunities presented by the move to a low carbon economy. The challenge will be split into three elements: research, innovation, and scale-up. It is among the first of six investment areas announced by the government to be funded through the Industrial Strategy Challenge Fund.

The Engineering and Physical Sciences Research Council (EPSRC). As the main funding agency for engineering and physical sciences research, our vision is for the UK to be the best place in the world to Research, Discover and Innovate. By investing £800 million a year in research and postgraduate training, we are building the knowledge and skills base needed to address the scientific and technological challenges facing the nation. Our portfolio covers a vast range of fields from healthcare technologies to structural engineering, manufacturing to mathematics, advanced materials to chemistry. The research we fund has impact across all sectors. It provides a platform for future economic development in the UK and improvements for everyone's health, lifestyle and culture.
We work collectively with our partners and other Research Councils on issues of common concern via Research Councils UK. www.epsrc.ac.uk
The Science and Technology Facilities Council (STFC) is keeping the UK at the forefront of international science and tackling some of the most significant challenges facing society such as meeting our future energy needs, monitoring and understanding climate change, and global security.

The Council has a broad science portfolio and works with the academic and industrial communities to share its expertise in materials science, space and ground-based astronomy technologies, laser science, microelectronics, wafer scale manufacturing, particle and nuclear physics, alternative energy production, radio communications and radar. STFC operates or hosts world class experimental facilities including in the UK the ISIS pulsed neutron source, the Central Laser Facility, and LOFAR, and is also the majority shareholder in Diamond Light Source Ltd. STFC enables UK researchers to access leading international science facilities by funding membership of international bodies including European Laboratory for Particle Physics (CERN), the Institut Laue Langevin (ILL), European Synchrotron Radiation Facility (ESRF) and the European Southern Observatory (ESO). STFC is one of seven publicly-funded research councils. It is an independent, non-departmental public body of the Department for Business, Energy & Industrial Strategy (BEIS).
http://www.stfc.ac.uk

Building the **perfect** power plant

An integration of disciplines

Navot Bar, CEO at Shikun & Binui Renewable Energy addresses the challenges of sponsoring, developing and building PV power plants.

IN RECENT YEARS the world has witnessed the growing popularity of photovoltaic (PV) power plants. The construction of green power plants, electricity generation and core technologies are becoming more efficient, and energy prices are falling. The world is awash in incentives for green energy entrepreneurs, mainly various kinds of tax benefits and a commitment to purchase electricity at a guaranteed, and sometimes subsidized, price.

Though the construction and operation of a photovoltaic power plant have become more of a logistic challenge, the development process is still a complex challenge. It is an integration of different disciplines: business development, engineering, law and regulation, and financing, which need to be harmoniously orchestrated. Success depends on the interdisciplinary approach of the project's leading team.

It is extremely important that no team member involved in the project be hemmed in by the constraints of its discipline. If the various disciplinary team members are not flexible toward each other, the project will not be implemented. The disciplines must be intertwined. Business development people do not finish their jobs and send them on to finance or engineering personnel. They work together from the feasibility stage, even before they know whether the project will mature or not, and each has at least some knowledge in the expertise of the other.Whereas in the past the construction of a photovoltaic plant was a complex engineering project, with complex financing issues, today the foundations and building blocks of a PV power plant are well known, and the project is actually a logistic challenge: the proper execution of the procurement, and ensuring that the raw materials arrive on time and are distributed wisely at the site, in order to assemble the plant in the most efficient manner.

Correct pricing of electricity

The initiative to build a photovoltaic power plant usually comes from the developer. The electricity authority in a particular country sets the rules of how one can engage onto the grid. The current common method for choosing a developer to buy the generated power from is a tender, with the electricity authorities or distribution companies setting quotas and the developers competing for the price at which electricity will be sold. Those who offer the lowest prices are the winners. In the past, by the way, the common method was feed-in-tariff, in which the electricity authorities set tariffs and quotas, and whoever managed to get all the necessary approvals and permits at the highest speed became the winner.

Therefore, determining in advance the correct prices of the electricity produced at the photovoltaic power station is very important for its economic viability. The prices are determined according to various considerations. For example, in countries where the irradiation is relatively low, prices will be higher. On the other hand, irradiation is not the only variable that affects pricing. Additional variables such as land cost, available financing terms, taxes, local

construction costs and regulatory conditions are taken into account. During planning, it is important to take into account a variety of considerations. For example, when selecting the land plot for a project, the developer prefers that there will be an optimal clear way for sun-light and minimum potential shading from nearby obstacles (which is reflected in the reduction of electricity production hours), and must be aware of the dust regime on the selected surroundings that can impair generation (and may lead to high maintenance expenses).

The developer must also know in advance the state of the power grid in the area of the planned PV plant. For example, there are countries where the power grid is jammed, which causes the developer to get stuck in the middle of the process after he has already invested considerable money and effort. Therefore, the relevant authorities need to release maximum information regarding the state of the power grid, so the developer will know where to find the right land, rather than relying on trial and error.

It is important to note that photovoltaic projects often encounter obstacles, such as regulatory and statutory hurdles, market competition, etc. No project is problem-free, and the developer must know how to eliminate them on the go, and even better – to avoid obstacles before they occur. One good example for reducing obstacles during the development process is the way a developer maintains his relations with the different stakeholders of a project. Having a nearby community involved in a project and benefitting from creating jobs during construction and operation is one classic tool for preemptively eliminating resistance.

When developing a PV power plant, the developer should work with recognized and reliable contractors. At the same time, the developer must supervise the planning, the selection of equipment and the construction, so that there are no surprises at the end of the process. It is also important to make an accurate forecast of the power production level. The environment must be protected, and there are sometimes special situations that must be observed, such as trees that are to be preserved and moved to another place. Shikun & Binui Renewable Energy has a sustainability manager who handles all aspects of environmental protection including community relations.

When the PV power plant is completed up and running, it becomes a safe cash-generating business. The off taker purchasing the electricity (usually a local electricity company, distributors or private power intensive client) is a stable entity. The technology is also stable, as are the expected solar hours. All this makes the PV plant a tool that generates cash at a very predictable, fixed and long-term level. Operational risks are no longer high. Therefore, ownership of the plant during the operating period is very attractive to various entities, such as pension funds and insurance companies, which are interested in acquiring partial or full ownership in the plant.

And the future?

The world is going to hybridize electricity production. One of the disadvantages of renewable energy is that, unlike fossil fuels, renewable energy works only when an energy source exists, such as sunlight, wind or water flow. As the grid increasingly relies on renewable energy, there is a mismatch between production and consumption, or at least a timing mismatch. One solution is to store energy for hours when production decreases or ceases entirely. At utility scale, there are three main storage methods: pumped storage (the Shikun & Binui Group, for example, is currently completing a 300 megawatt pumped storage project in Israel), thermal storage using thermo-solar technology (heat preservation by means of very large containers of molten salt), and batteries. In addition, it is reasonable to assume that fossil fuel production will not disappear, but rather decrease, and the amount of renewable energy will increase.

The largest photovoltaic power plant in Israel

Shikun & Binui Renewable Energy has just started the construction of the largest photovoltaic project in Israel, and one of the largest in the world – 120 megawatts. The project is being built in Kibbutz Tze'elim, in the southern part of the country, and covers 370 acres. The photovoltaic power plant will replace a solar thermal power plant initiative that started nine years ago at the same location. At some point, the government has asked Shikun & Binui Renewable Energy to convert it to photovoltaic technology.

Shikun & Binui Renewable Energy

Shikun & Binui Renewable Energy is involved in all areas of renewable energy. It is a sponsor and a development company. The company has been active in its current form since 2008 and has 55 employees. To date, the company has been involved in dozens of projects.

Shikun & Binui Renewable Energy is located at Airport City, near Ben-Gurion Airport (Israel's main international airport). It has an office in Colombia that coordinates the company's operations in South America, and is about to open offices in the United States.

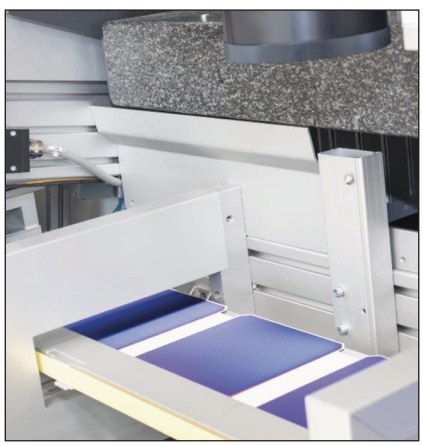
What is unique about Shikun & Binui Renewable Energy is the fact that it is part of a very large global infrastructure conglomerate that conducts a wide variety of projects, such as construction of roads, bridges, railways, power plants, desalination plants, residential buildings and more. Shikun & Binui Group is engaged in all aspects of the projects' life cycle: development, financing, construction and operation. The experience amassed in the infrastructure sphere gives Shikun & Binui Renewable Energy an advantage, and the company benefits from extensive information coming from the world of infrastructure, including complementary knowledge for its projects.

Cutting edge laser solutions for cell processing made by 3D-Micromac

As the world`s most important photovoltaic industry exhibition SNEC, Shanghai, always offers an excellent platform to unveil latest tool concepts and technology improvements, it's worth taking a close look on what is German manufacturer of high-end laser equipment, 3D-Micromac, is bringing to China this year. They pursue a strategy of rethinking existing concepts and process solutions, adding value, eliminating known obstacles and shifting the standard to a new level.

The success is obvious. Various awards have been granted for its creativity and driving the progress of tool development. In just four years 3D-Micromac settled its place amongst the leading equipment suppliers for laser tools in the photovoltaic industry, having the broadest range of equipment solutions.

On-the-Fly Processing of PERC Cells
Most common tool is the microCELL OTF platform used to conduct laser processes like ablation or doping on a silicon wafer. This platform is available in various configurations, ranging from R&D tools with multiple processing stations and laser sources to a dual lane version achieving a throughput of more than 8000 processed cells per hour. Unbeaten throughput is not the only key advantage of 3D-Micromac's top pick. Unique in the industry is the contactless wafer transport, which avoids micro cracks and scratches as well as breakage often seen in competitive machines. The cells are hovered in



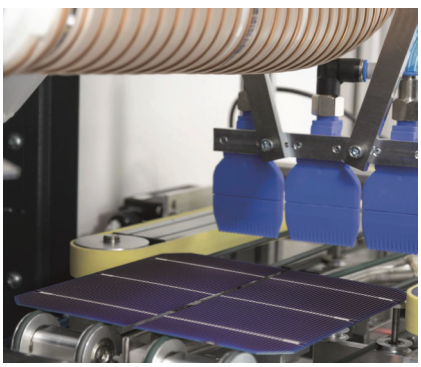
Machining area of microCELL OTF for laser processing of PERC cells

continuous motion onto an air film rather than stressed by acceleration, pickers, vacuum nests and hard stops.

Separation of Half-Cells

The patented process of Thermal Laser Separation (TLS), used on the microCELL TLS platform to cut full cells into halves was brought into mass production last year in cooperation with their industrialization partner.

With this innovation, cutting has been revolutionized. The laser generated field of stress caused by thermal expansion and contraction is used to guide a crack at high speed through brittle material like silicon. Compared to currently used laser ablation steps combined with mechanical force this process features temperatures well below 500°C.
As a result, there is no phase change of the silicon resulting in electrical



microCELL TLS for half cell processing

defects and dust. Second as there is no remaining wafer thickness that needs to get broken, the cut surface is much smoother and without microcracks. By this fact the mechanical strength of the half cells remains on one level as it was with full cells, so >30% higher compared to competitive ablation processes.

Using TLS enables module makers to guarantee a lower degradation rate of their product over the life cycle (due to mechanical benefits) and to start at a higher absolute power value (due to electrical benefits).

Solutions for Thin-Film PV

Those active in thin film photovoltaics (TFPV) can rely on 3D-Micromac's broad range of experience and know how,

microFLEX – Roll to roll system for processing of flexible solar cells

too. The microFLEX platform family is based on a modular concept of various processes when processing flexible substrates. Roll-to-Roll and Roll-to-Sheet designs are available, including not only the laser processing steps. The whole package of winding, unwinding, cleaning, layer deposition, patterning, and much more is available on band widths up to 1300mm at highest precision and throughput.

Using TFPV on large but inflexible substrates like glass sheets, 3D-Micromac's solution is the modified version of its microSTRUCT LS TMS platform, as it is used in the display industry. Processes range from P1, P2, P3 as well as isolation patterning as well as annealing processes.

To summarize, procuring 3D-Micromac equipment does not only mean, choosing long lasting, highly reliable and most efficient manufacturing equipment. The company convinces also with its close customer care, support by the in-house application center and process development team as well as the worldwide service network and spare part management. Put it in a nutshell: micromachining excellence made in Germany.

Further reading
Contact: 3D-Micromac AG, Germany
http://3d-micromac.com
http://lasers-for-photovoltaics.com/
sales@3d-micromac.com

GlassPoint's indoor solar collectors increase efficiency

GlassPoint has leveraged its unique approach to solar thermal energy for oil and gas applications that have proved so successful the company is now building one of the world's largest solar projects in Oman.

By Pete von Behrens, GlassPoint Chief Technology Officer.

SOLAR ELECTRICITY is growing rapidly, but it can't address all energy segments. Worldwide, industry is the largest user of energy—larger than transportation, larger than residential—and two-thirds of industrial energy use is in the form of heat, not electricity. Despite this massive market potential, historically, the global solar industrial heat market has developed slowly. It's made up of vast, but small-scale, niche applications.

At GlassPoint, we discovered one of the biggest and fastest growing industrial markets for solar energy was right in front of us: the oil and gas industry. The traditional energy industry consumes an amount of energy equal to 10 percent of its own production. We set out to design a solar technology specifically to meet this energy demand and are now deploying our solar thermal solution at an unprecedented pace. From the beginning, we knew that cost would be the key to winning over oil and gas producers. When we designed our system, we prioritized cost

By placing its parabolic mirrors inside commercial greenhouses, GlassPoint has substantially reduced weight and support infrastructure, cutting costs in half compared to traditional parabolic trough designs.

efficiency, a metric that encapsulates many design and manufacturing choices; everything from optical precision to thermal efficiency to materials costs for steel and concrete.

In contrast, most other solar thermal systems differentiate themselves by maximizing optical efficiency. This is because they are made up of similar materials (glass mirrors, steel supports, large drive motors) and when the materials of construction are similar, higher optical efficiency can mean higher cost efficiency.

As a result, there have been decades of focus on optical efficiency. The concentrating solar thermal industry has invested hundreds of millions of dollars in improving optical efficiency by a few percentage points. These advances are important and have been critical to the development of the industry, but the incremental advances in optical efficiency simply aren't enough to keep driving costs down. This diminishing rate of optical efficiency improvements led us to shift our focus to other approaches to cutting costs. We combined the age-old design of the agricultural greenhouse with today's gas-fired oilfield boilers to create a radically new kind of solar field.

The result is our "enclosed trough" technology, which moves the solar collectors from the dusty, windy outdoors into a clean, zero-wind greenhouse. That one change enabled us to use lighter materials that are significantly lower-cost. Ultra-thin aluminum sheet mirrors have replaced heavy glass, resulting in 90 percent reductions in collector weight. Total weight of the system including the greenhouse, is half that of older technologies.

The resulting system sacrifices some optical efficiency, but it delivers far higher cost efficiency, due to the huge savings in materials costs, maintenance and resulting operational advantages. Our innovations make solar steam generation newly viable for one of the world's biggest industries, creating opportunities to significantly reduce greenhouse gas emissions along the way. We are now constructing what will become one of the world's largest solar plants of any kind on an oilfield

in south Oman. Once complete, the gigawatt-scale Miraah plant will produce over 6,000 metric tons of emissions-free steam a day, an alternative to steam generated from natural gas, which is used to produce heavy or viscous oil. A 2017 report from the International Energy Agency (IEA) noted that Miraah alone will be bigger than all other industrial solar heat installations combined.

GlassPoint was also recently selected by Aera Energy, a joint venture with ExxonMobil and Shell, to build California's largest solar plant on the Belridge oilfield, one of the United States' largest and oldest oilfields. The Belridge Solar project will include an 850 MWt (megawatts thermal) solar thermal facility generating steam and a 26.5 MWe (megawatts electric) photovoltaic system generating electricity to power other oilfield operations. This scale allows us to achieve volume efficiencies and reduce costs that wouldn't be feasible in smaller installations.

Here's how our enclosed trough technology delivers the lowest cost thermal energy for heavy oil production:

Eliminating wind

Wind is the main cost driver for solar energy. In Oman, home to our Miraah project, more than 70 percent of the available sunlight is captured at wind speeds above 6 m/s, or 13 miles per hour. In these conditions, the buffeting action of the wind will reduce the performance of exposed parabolic troughs and towers. This is because each individual mirror acts like a giant sail in the wind, bending and flexing as the wind blows. Even tiny movements reduce concentration on the receiver, resulting in energy loses. For example, at wind speeds of 8 m/s the Eurotrough design, an exposed parabolic system, experiences losses of 15 percent.

In these traditional outdoor systems, every mirror must be reinforced against the wind, and each one must be extremely precise and extremely robust. To achieve this dual-function, lots of steel and expensive foundations are used to armor and anchor the mirrors into the ground. By bringing the entire system inside a greenhouse, we eliminated the wind load on mirrors altogether. In our system, only the outside wall of the greenhouse needs to be reinforced against the wind. The greenhouse serves as protection, structure and foundation in one, while the sole function of the solar collectors indoors is to turn sunlight into energy. Our mirrors are lightweight, installed by hand, and hung by small wires that are thinner than a pencil. Compared to the traditional Eurotrough design that weighs 25 kg/m^2, GlassPoint's solar collectors weigh less than 5 kg/m^2.

The weight of these materials adds up and has a huge impact on a system's cost efficiency since the heavier the materials, the more expensive it is to transport and install them. GlassPoint reduced the amount of materials used throughout the entire system, cutting the cost of our system in half compared to traditional parabolic troughs.

Solving soiling

Soiling, the accumulation of small particles like sand or dirt, is another major pain point for solar in harsh climates, like dusty oilfields or desert regions

Shown below is a portion of the GlassPoint steam collection and distribution infrastructure at the 1 GW Miraah solar thermal plant.

throughout the Middle East and North Africa. Areas surrounded with sand and high ambient dust are often places of high humidity. When the solar collectors are exposed, the particles will stick to the mirror surfaces, scattering sunlight and reducing system output.

On a typical day in south Oman, soiling rates cause approximately 2-3 percent reduction in performance per day. That means a solar project may lose 2 percent of its energy every day that it goes unwashed. Typical outdoor systems are washed about once a week, often manually or with spray trucks. A week without washing adds up to a 15 percent performance drop.

Dust storms, which may happen a handful of times a year or more, can knock performance 20 percent in a single day. In GlassPoint's enclosed trough design, the mirrors are protected by the greenhouse. An automatic washing system is used to clean the roof of the greenhouse, removing dust and debris every night. By the time the sun comes up the next day, performance has been fully restored and the system is ready to go.

Developing a new kind of solar… to operate indoors

The greenhouse enclosure eliminates the wind load and prevents soiling, dramatically reducing capital and operating costs compared to outdoor systems. Of course, the greenhouse adds cost, but not as much as one might think. In fact, the most novel thing about GlassPoint's innovation is actually not that novel.

The greenhouse industry has been perfecting and cost optimizing this technology for the past century. Greenhouses are designed to maximize the transmission of sunlight and withstand extreme weather events. Our optical efficiency is lower than outdoor systems due to the extra layer of glass transmission through the roof and shading caused by the structure. However, these loses, which total around 20 percent, are made up for in three ways:

The Miraah solar field will span an area of 2 km^2 once complete.

On a typical day in south Oman, soiling rates cause approximately 2-3 percent reduction in performance per day. That means a solar project may lose 2 percent of its energy every day that it goes unwashed. Typical outdoor systems are washed about once a week, often manually or with spray trucks. A week without washing adds up to a 15 percent performance drop.

1) decreased capital costs by using less materials 2) reduced performance losses from soiling and wind deformation and 3) reduced operating expenses due to automated washing. The plant's lifetime is also extended by shielding the components from the harsh outdoor environment.

Our focus on cost efficiency drove us to innovate beyond all notions of solar thermal and develop an entirely new kind of solar—one that operates indoors. Anything that's been developed to work outside on traditional systems, won't work for GlassPoint's enclosed trough. That means we're still early in our innovation journey, and continue to explore ways to simplify the design, reduce overall materials and achieve further savings in our next generation designs. These innovations coupled with the scale of the oil and gas industry have allowed us to achieve unmatched cost efficiency, which is paving the way to future applications, some on the oilfield and beyond.

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Towards the tipping point

The 2017 edition of Technology Radar has found that renewable energy was largely felt to have achieved cost parity, although hydrocarbons retained their dominant position in the global energy mix. This is a reflection of the energy transformation currently under way across the globe; as communities, businesses and organisations increasingly recognise and act upon the urgent need to decarbonise economies.

WHILST this is a global challenge and the end goal is universal, the solutions are not uniform. In fact, the best energy ecosystem for any given country depends on a set of characteristics that are specific to that nation – including the natural resources available, geo-demographics, energy demand, market design, policy, technology, public appetite and social acceptance. It needs to take into account what resources are available, how can they be harnessed, how the population and industry needs and uses power (and will in the future) and therefore how the network needs to operate and adapt.

Taking this as its starting point, this research looks at the degree to which renewable energy has gained traction throughout the world – and what needs to happen to accelerate it. Based on a large survey of renewable energy professionals across the global sector and the insights of a number of industry leaders, the research illuminates the outlook for renewable energy – and highlights the technologies that are expected to deliver the greatest impact.

We are heartened by not only the optimistic outlook, but by the measured and realistic approach that is displayed throughout the results and insights in the research. Grid transformation must be based on sound understanding of each country's individual ecosystem, and it is clear that this is advancing alongside technology, policy and investment.

If there were doubts that renewable energy sources can compete with oil, natural gas and coal in power generation, developments in the past two years should have dispelled them. According to the International Energy Agency (IEA), 2016 was a record year for renewable energy projects, which provided two-thirds of new global power capacity.
By July 2017 China, the world's biggest generator of solar photovoltaic (PV) power, had already met its

2020 target for installed PV capacity. Earlier in the year, Germany's electricity regulator awarded bids for the country's first subsidy-free offshore wind farms; in December, the Netherlands' government followed suit. And September saw sharply reduced subsidies in auctions for similar projects in the UK, as well as the opening of the country's first subsidy-free solar PV farm.

This continuing growth of solar and wind capacity in many parts of the world, and the increasing incidence of projects involving low or no subsidies, have led some observers to proclaim the arrival of a 'tipping point' for renewables. This is the point at which one or more renewable energy sources match fossil fuels used in the grid in terms of their cost competitiveness.

Basing this sort of assertion on individual projects is a risky move. After all, every project has its own circumstances and economics, and these can differ—sometimes considerably—even within the same country. Nonetheless, tipping point predictions do provide an indicator of the progress made to date and of what is still required to reach the point where renewables overtake fossil fuels in each country's energy balance.

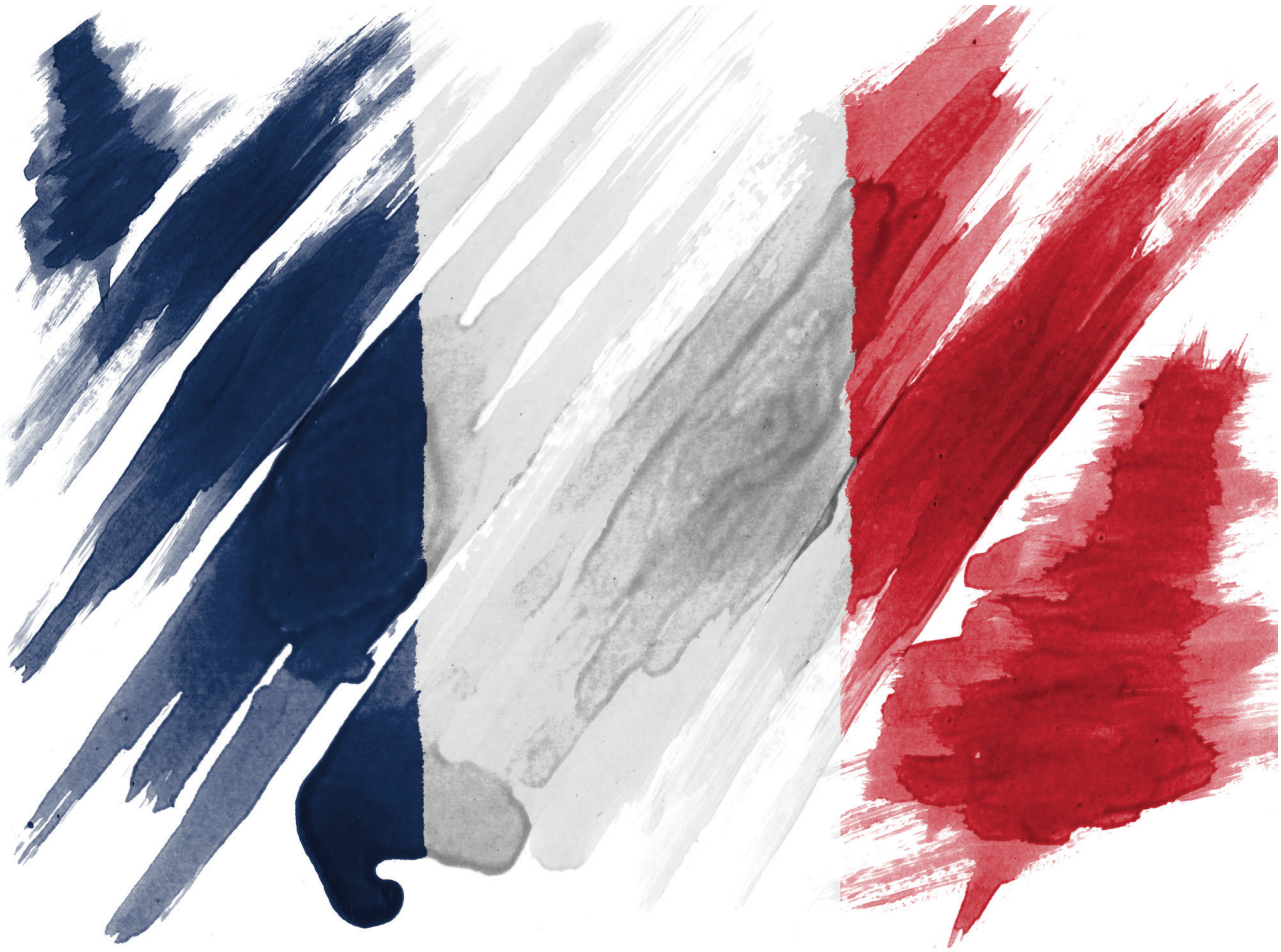
This 2018 edition of the Lloyd's Register Technology Radar provides an industry perspective on the challenges that need to be overcome for renewables to become the primary form of energy consumed in countries. It is based on the views of 792 senior executives from around the world who are close to their companies' renewable energy activities or renewable technology development.

As a group, they are cautious about their expectations of when renewables will overtake fossil fuels. But they are also optimistic that technology innovation in different fields will have a sizeable impact in the next five years on the performance of renewable energy generation, transmission and storage. Many eyes are fixed, for example, on the development of storage technologies. But it is important not to underestimate the cumulative impact of a series of less dramatic process improvements – especially those powered by digital technologies.

Key findings

- **The tipping point is still in the future.**
  Despite recent advances, grid parity for major renewable energy sources is still several years away for most countries. The industry expects parity for solar to be achieved earliest in China (2022/23), and for wind earliest in Germany (2024).
- **A decisive tilt in the energy balance will take longer.**
  Taken together, renewable sources are expected to surpass fossil fuels in countries' energy mixes first in Europe and North America (by 2025), in the Middle East by 2028, and in Asia Pacific and Africa in 2033 or later.
- **More than grid parity is needed to shift the energy balance.**
  Achievement of grid parity is not by itself enough in most countries to tilt the energy balance decisively in renewables' favour. Issues with grid connection, transmission and storage often combine to limit the impact of individual projects.
- **Technology advances can change the equation.**
  Continued technology innovation could accelerate progress towards achieving grid parity. Most of the attention is on advances in solar and storage technologies that could have a big impact on performance, but these may take time before having the desired impact on cost.
- **Technology innovation overshadows policy as a growth driver.**
  Most executives believe that technology advances will do more to improve the economic case for renewables than policy or regulatory factors. But policy change remains a potential inhibitor in both developed and developing markets.
- **Incremental advances will have an outsized impact.**
  In wind energy, boosts to scale and optimised processes will be more influential in improving performance and cost-efficiency than breakthrough technologies. Larger offshore turbines and rotors, for example, and streamlined installation and maintenance practices (with the help of analytics) are expected to improve wind farm economics.
- **Digitisation will drive performance improvement.**
  Hopes are high for a favourable impact from digital technologies on renewable energy generation and transmission. For example, companies are looking to use predictive analytics, demand management and even machine learning to improve the operational performance and economics of energy transmission.
- **Cutting innovation costs is a top priority.**
  Uncertainty over returns constrains technology innovation in many firms, and this has much to do with the high costs of deployment. Better logistics and installation processes will help to ease deployment constraints.
- **More standardisation is needed.**
  In newer renewable energy technologies, such as wave and tidal, experts believe that significant improvements in economics await industry convergence around the design of key technologies.

To download your complimentary copy of the full report, visit **lr.org/techradar**



French CfD one year on

Everoze reflect on last year's hot topic for the French renewable industry: the new Contract-for-Difference mechanism. As technical and commercial advisors, they consider it within the larger and more fundamental landscape of the market entry of renewable projects.

SO, the moment has finally come: French "new" renewables enter the electricity market. In other words, set apart a few exceptions [1], after December 2018, all new renewable power projects installed in mainland France will no longer be entitled to receive a Feed-in-Tariff (FiT). They will have to sell their produced electricity on wholesale markets.

Sure enough, the consecutive revenue shortfall [2] from a pure merchant model would have been far too brutal, therefore two additional revenue streams will be made available for producers:

- Capacity certificates sales
- Contract-for-Difference (CfD)

The legislation

All the information of this article is available within the official decrees published in the French Official Journal. In particular, the following references focus on the new mechanisms for renewable electricity:

- **Arrêté 6 décembre 2016.** NOR: DEVR1636694A – *conditions for wind farms applying for support in 2016*
- **Arrêté 10 mai 2017.** NOR: DEVR1708388A –

conditions for wind farms of 6 turbines or less applying for support in 2017 or after

- **Cahier des charges de l'appel d'offres version du 8 novembre 2017** – *specifications for the November 2017 wind power auction*
- **Cahier des charges de l'appel d'offres publiée le 11 décembre 2017** – *specifications for the 2018 utility scale solar photovoltaic power auctions.*

The capacity market

With the aim to strengthen the national grid's stability, in particular when responding the winter consumption peaks, a capacity certification and market mechanism entered into force in 2017.

Rationale:

- **Retailers** / **demand-side players** (typically energy utilities) have the obligation to cover their power needs during peak hours [3] through the acquisition of capacity certificates. These needs depend on the total consumption and thermosensibility of their clients.
- **Producers** have the obligation to certify their capacities and to make them available during peak hours. Each technology has a specific calculation method to determine which amount is to be certified.
- **Capacity market:** producers can market their certificates either on the EpexSpot stock exchange, either through bilateral contracts.

Specificities for non-dispatchable renewable power technologies

Since stand-alone wind and solar plants cannot be dispatched, certification and availability verifications are specific compared to dispatchable generation.

The contract for difference

The CfD mechanism aims to protect renewable power projects from wholesale market price variations over the course of a 20-year contract. In concrete terms, each project will receive, or pay, the difference between a reference tariff and a reference market price [4]. Schematically:

If we focus on onshore wind farms and utility-scale photovoltaic plants (> 500kW), three situations need to be considered as for the reference tariff definition:

1. Wind farms with 6 turbines or less

Will go through an "Open Gate" process for CfD obtention. The reference tariff will be revised annually by public authorities in order to match cost evolutions of the industry [5].

Three specificities should also be appreciated for these projects:

- Their CfD will be cut down by a standardised value corresponding to the revenue obtained through the capacity market
- They will benefit from a "trading premium" (2.8€/MWh) aiming to cover trading costs [4]
- The CfD is capped for a volume of produced electricity [5]

2. Wind farms with either more than 6 turbines or at least one turbine rated over 3MW

Will compete over the reference tariff through auctions.

3. Photovoltaic plants

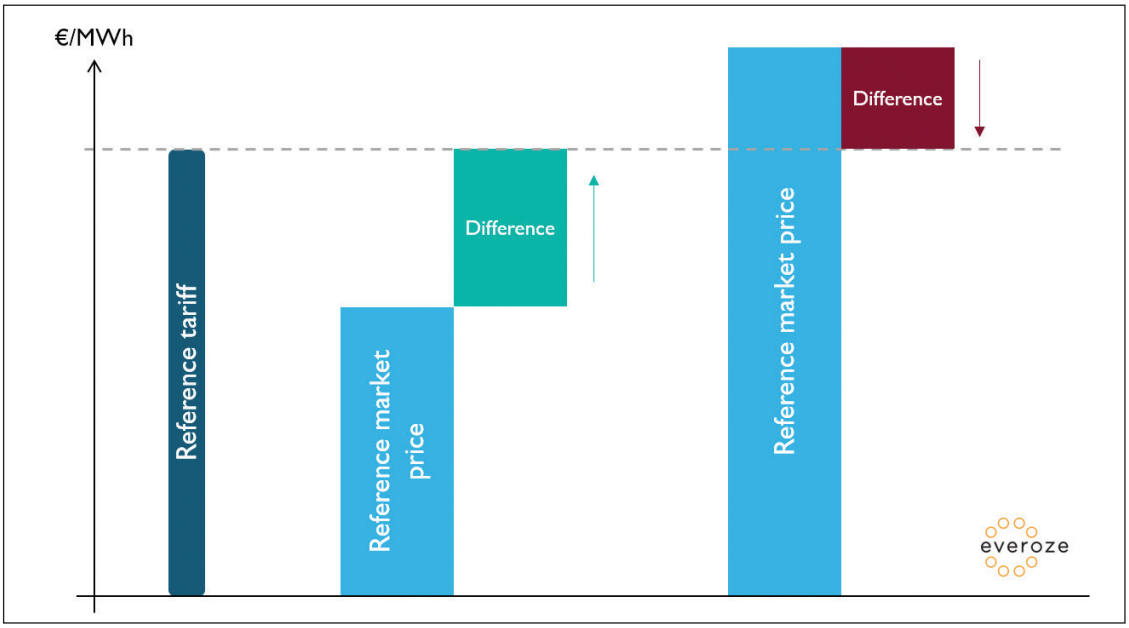
Will compete over the reference tariff through auctions organised following project types (utility scale, rooftops, …). CfD is capped for a number of annual full load hours.

For a given project, the reference tariff of the CfD is concluded for a 20-year period, only adjusted annually for inflation. Important to point out that wind projects (regardless of size) who applied for support in 2016 benefit from specific conditions that are available in the official decree of December 6th, 2016.
The chart top, right does not cover these.
It is important to note that the CfD scheme will not apply during negative price hours (day-ahead market). More precisely, a project will get some compensation back only if the following conditions are met [6]:

	Dispatchable generation	Non-dispatchable renewables
Availability during peak hours	The plant must inject to the grid at least as much power than the certified amount.	The plant is considered available only if the certified capacity is ready to inject to the grid, regardless of resource levels.
Certification value	Roughly worth the rated power of the plant, reduced by a coefficient representing constraints on fuel supply.	Based on a historical analysis of the plant's capacity during peak hours, reduced by a technology-specific coefficient. Ex. Of certification (10 MW rated power): - Wind farm: 1.67 MW - PV plant: 0.33 MW - Small hydro plant: 2.29 MW - Thermal plant: 8 MW

Technology specificities for capacity certification

Basic principle of French Contract-for-Difference mechanism



- **Wind farms:** if the project successfully stops during 20 hours of negative prices of the year, the compensation will be paid for all the following ones (during which the plant is stops as well). The project will receive 35% of its rated power at the reference tariff.
- **Photovoltaic plants:** the principle is the same, set apart (i) the count runs for 15 hours, only between 8:00 and 20:00, (ii) the number of compensated hours is capped [7] and (iii) the project receives 50% of its rated power at the reference tariff.

Example: *40 negative price hours during the year. A wind project fails to turn off for the 5 first hours, then correctly stops for the following 35. The project therefore starts getting a compensation at the 26th negative price hour.*

The immediate consequences

As a result of the 2017 changes, new renewable power projects will have to manage 3 main revenue streams (compare to one with the former system). Three revenue streams also mean at least 2 different contracts, adding a dose of complexity to plant management and operation. Indeed, projects companies will have to sign agreements with aggregators (either in-house or third party) for both their electricity sales and their capacity certificates.

The risks

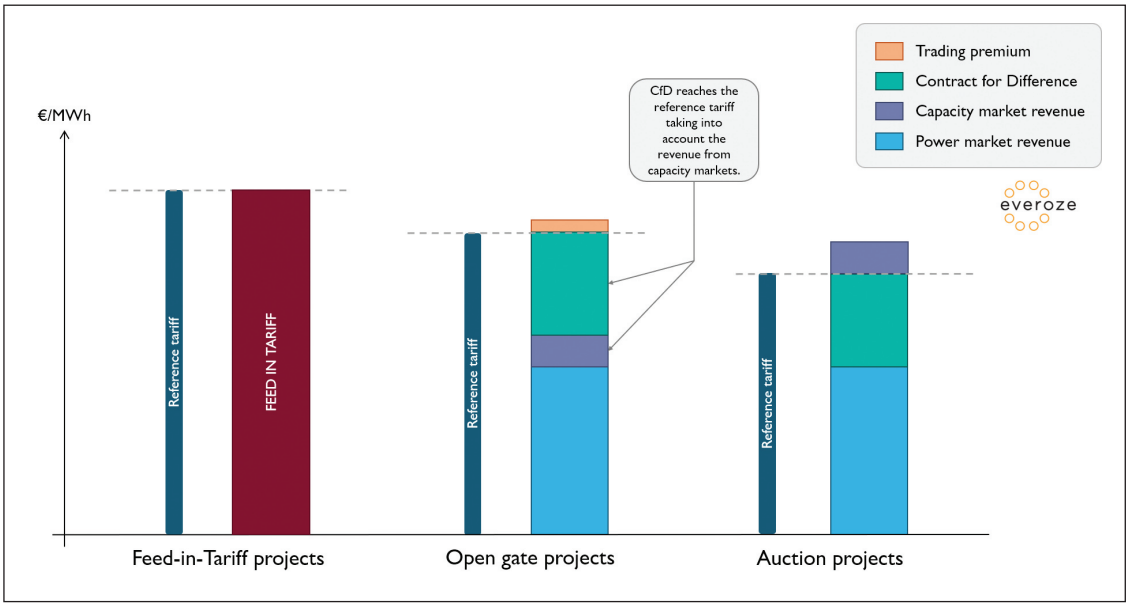
On the face of it, this "market entry" may seem quite comfortable, especially for open gate projects (which represent a significant proportion of French onshore wind farms). After all, market price fluctuations are backed thanks to the CfD mechanism. Are there any real reasons to be worried?

At Everoze, as technical advisors, we decided we might also take a closer look to these novelties to help our clients through to a smooth transition. Eventually we ended up identifying two main risks that, in our opinion, deserve specific attention when it comes to project assessment:

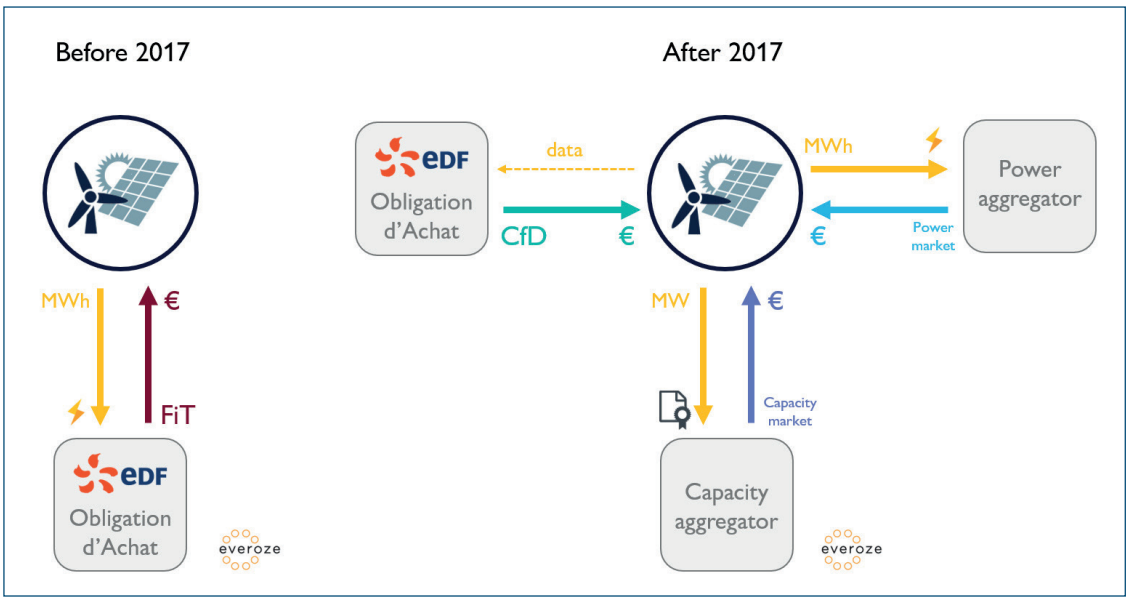
- **Captured price deviation –** Seems like CfD projects will always receive the reference tariff. Can we be sure of this? Where is the trap?
- **Market access risk –** What it involves and who is involved. Could this change in the future? How will this impact technical or commercial aspects of a project? We will detail our view on both of these risks within our two upcoming blogs. So make sure you keep tuned if you want to safely pass the baton between FiT and CfD!

CfD mechanism limitations following plant type

Project type	Open gate wind farms	Auction wind farms	PV (tracking system)	PV (no tracking system)
Cap definition	Annual energy cap Cap ~ **56.2*D*N** (MWh) D – rotor diameter N – n° of turbines	No cap	2200 full load hours	1600 full load hours
Reference tariff once cap exceeded	40 €/MWh	No cap	0 €/MWh	0 €/MWh



Revenue streams breakdown for French renewables in the new merchant context



New contractual organigram for French renewables' energy sales

Further reading

[1] According to European exclusions, very small projects (< 500 kW) and emerging technologies (such as tidal and high-altitude wind energies) may benefit from specific support mechanisms

[2] 2017 average day-ahead market price ended up at 45€/MWh to be compared to the last FiT contracts above 80€/MWh

[3] Determined by the national grid operator (RTE) which will give a one-day notice to producers. Only between November and March

[4] Details in our upcoming blogs

[5] As an indication: the base reference tariff for 2017 for open gate wind projects spreads between 72 and 74 €/MWh inversely related to rotor diameter

[6] These conditions may be subject to revisions on the occasion of each auction

[7] (N° negative price hours) < 1600 – (Full Load Hours)

European solar success:
We need education and innovation

The phenomenal global success of solar has been driven by innovation in the last decade. But there is one key driver that will be crucial to unlocking more solar success in Europe: Education!! Emilien Simonot, renewable energy technology officer at InnoEnergy discusses the need to broaden skills and knowledge.

THE STORY of solar photovoltaics (PV) in Europe has progressed at a breathless pace in recent years. For example, while in 2005 solar contributed just 0.3 per cent of all electricity generated across the EU-28, by 2015 that figure had risen to 11.2 per cent. This is rightly celebrated, and industry commentators wonder how much further solar can go, speculating on topics such as falling cell costs and the integration of storage.

These are good and worthwhile things to talk about. Solar's success has been driven by innovation and we need that to continue. But there is one conversation we are not having in Europe (or at least, are having too quietly) that will be crucial to unlocking more solar success: we need to talk about education.

Solar's today and tomorrow

Solar panels are no longer new. Solar is considered to be a mature technology and many Europeans will be familiar with images both of large solar farms and rooftop installations at both the commercial and domestic scale. They are no longer a rare sight. But nor are they as common as they can be, or – in my opinion – as they should be. Solar energy has the potential to be one of the most widely available and cheapest sources of energy in society. Solar electricity generation overtook geothermal energy in 2008, but it has the potential to overtake natural gas, coal and nuclear too. The solar industry should be aiming for nothing less than a paradigm shift.

Partially this will be enabled by new technology. Building-integrated photovoltaics (BIPVs) promise

us new solar technologies integrated into buildings and materials – such as windows or roofing tiles that also generate energy. Energy storage also promises to change the game, helping asset owners and operators get the most out of their assets and avoid wastage. However, the potential impact these technologies can have will be hampered if we do not get some of the 'soft' challenges of solar right – the same ones preventing even broader uptake of today's technology.

Soft problems, hard to solve

The challenges in bringing a solar project to life now are often not financial ones. Instead, companies are finding themselves getting stuck on all the elements around the project. For example, two key examples are regulation and the technical aspects of managing a solar asset.

Take regulation: not only do you have all the normal planning permissions and network codes that are applicable to any energy asset, you have a new set of challenges with the rise of distributed renewable energy. For example, if someone is a prosumer – an end user who produces their own energy (with solar) and sells it to, as well as takes it from, the grid, what are the rules around payments? Does this asset owner have to contribute in some way to broader transmission costs (which they may not use directly, but benefit from in terms of security of supply)? These are complicated matters that require expertise. The same goes for the installation and ongoing management of solar assets, especially larger ones. A new breed of solar asset management companies is emerging to support the sector here, but there is still a deficit of knowledge in the industry when it comes to ongoing management and reassessment of the business case for solar.

In Europe, this knowledge is absolutely vital, as the requirements change from country to country. Take Germany and France, both economically powerful Western European countries which share a border and a currency. The cost of a panel is identical or near-identical in each market. However, in France where the market is less mature, the total cost of a rooftop installation could be as much as four times more – all down to the so-called 'soft' costs. For energy companies looking to capitalise on market opportunity across Europe – and potentially beyond – the knowledge to navigate these differences can be the divide between success and failure.

The need for fast and effective education

These skills will undoubtedly evolve organically within the energy industry. Indeed, they already have. However, progress is nowhere near fast enough or wide enough.

We cannot wait for the next generation of talent – those who grew up in a solar age – to come through and take leadership positions. We need today's energy industry – from asset operators to executives – to understand the solar market. To get the business case, to be able to steer through regulation and to have clear sight of the future where solar has disrupted traditional models even more than it has done so already.

In essence, we need education. And we need it in a form that is able to reach those already entrenched in the workplace, who need support to better do their jobs. Traditionally, this might have been done via seminars or workshops, sending people into offices to instruct a handful of learners. Given the pace and scope of solar's proliferation across Europe, that is too slow and too piecemeal.

Instead, we must look to modern learning models that are reinventing how we can learn and grow throughout our careers. Massive Open Online Courses (MOOCs) are a key innovation here. They combine the flexibility of the Internet with the institutional expertise of top universities and professional organisations. Courses can be collaborative, interactive and fit around a professional's existing (no doubt busy) schedule. Furthermore, as the classrooms are virtual, there are no space or geographic constraints on participation. At Innoenergy, we have partnered with Enerclub to provide just such a course, available both through our own portal and on FutureLearn. We hope to help unlock Europe's solar innovation potential through exactly this type of education.

So, let us talk. Let us talk about the need to broaden skills and knowledge in the energy industry to deal with and thrive on the influx of solar power into our energy mix. Let us talk about education and how it can help foster innovation and guide us towards a cleaner energy future. And, finally, let us talk about what kind of education can help us get there.

InnoEnergy works across disciplines and borders to support Europe's energy future. Describing itself as, the innovation engine for sustainability across Europe, InnoEnergy fosters education, discovery and business creation services to launch new companies as it works with inventors and industry, graduates, employers, researchers and businesses of all sizes for the long-range benefit of EU citizens.

Publisher's Note: *This is the first instalment in a two-part series from InnoEnergy. In the next edition of Solar+Power Management, we will explore the evolution of Smart Cities and ways that urban planners can engage public support and better utilize data to benefit all residents.*

Emilien Simonot, renewable energy technology officer at InnoEnergy

Price capturing:

French renewables' new hobby?

In this second feature dedicated to the entry of French renewables into the electricity market, we focus on a risk specifically related to the new Contract-for-Difference (CfD) mechanism: project captured price deviation. Everoze poise the question: Is the captured price a relevant indicator and should one take it into account for a project? The answer is yes.

AS INTRODUCED in the first feature, the CfD mechanism protects renewable projects from market price variations. Indeed, the contract terms consist in giving (or taking) to the project the difference between a reference tariff and a reference market price (also called *M0*, expressed in €/MWh).

The reference tariff is determined through different processes depending on the project's nature and the CfD award process. But what about the reference market price?

First of all, the reference market price is calculated on a monthly basis so that a given project will receive each month the following CfD revenue (see table below):

Furthermore, *M0* is defined for each technology (on the national scale) as the price captured on the day-ahead wholesale market within each month. The *Commission de Régulation de l'Énergie (CRE)* is in charge of publishing two values of *M0* on a monthly basis: one for the solar industry and one for the wind industry.

Finally, the captured price refers to the average market price weighted of the hourly production (see table bottom left):

It must be noted here that the captured price so defined is intended to be a metric of the value of a project's production if entirely traded on the day-ahead market; the most liquid spot market. In practice, the party responsible for trading production on the market may apply a different trading strategy, involving forward sales, and day-ahead / intra-day spot sales. Hence, they will achieve a different price. However, the captured price metric so defines remains a good indication of how the specific value of a project's production.

$$R_{CfD} = (T_e - M_0) * P$$

R_{CfD}	the overall project's revenue from CfD	[€]
T_e	reference tariff	[€/MWh]
M_0	reference monthly market price	[€/MWh]
P	project's monthly production	[MWh]

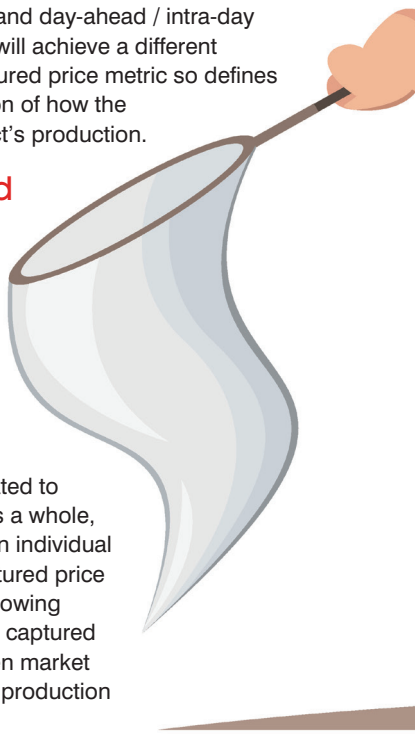
$$M_0 = \left(\sum_{h \in month} T(h) * P_{tech}(h)\right) / \left(\sum_{h \in month} P_{tech}(h)\right)$$

$T(h)$	day-ahead market price at hour *h*	[€/MWh]
$P_{tech}(h)$	technology (wind or solar) national production at hour *h*	[MWh]

Project captured price deviation

Each project gets compensated for the difference between the market and the reference tariff. So, what's the problem?

As one might have foreseen, the *M0*, as related to a technological sector as a whole, has no mean to match an individual project's day-ahead captured price (also called *Mp*). The following graphs illustrate how the captured price can differ for a given market price profile and a given production amount.



Therefore, the specific shape and seasonality of the project's production profile will influence its captured price and will determine its deviation regarding the national value (*Mp vs M0*).

What drivers?

As concluded above, each production profile and seasonality will lead to a unique specific project captured price [1]. Therefore, any parameter likely to modify this profile will have an impact on the *Mp* value.

For instance:

- Local resource profile
- Project power curve (technology specific)
- Curtailments (noise, birds, bats, shadow, grid, …)
- Maintenance strategies
- Failures

Due to market price variations, operational events and strategies such as curtailments, scheduled and unscheduled maintenance, or even performance enhancements, can have a significant impact on the captured price.

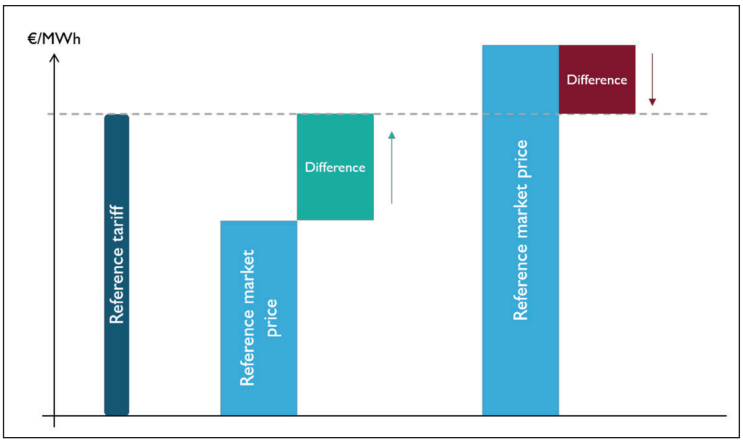


Figure 1: French Contract-for-Difference mechanism principle

The charts illustrated how this can apply for a wind project subject to a curtailment at night.

In the case of solar, a good example is the impact of tracker systems on PV plants. By modifying the power curve, they not only improve the power output, but also push the captured price up. A *Statkraft* study of the German market in 2016, concluded that PV plants equipped with tracker technology captured an additional 0.5 €/MWh compared to fixed systems.

On the other hand, and quite obviously, the local resource profile is the major driver for the production profile (for a given technology), and

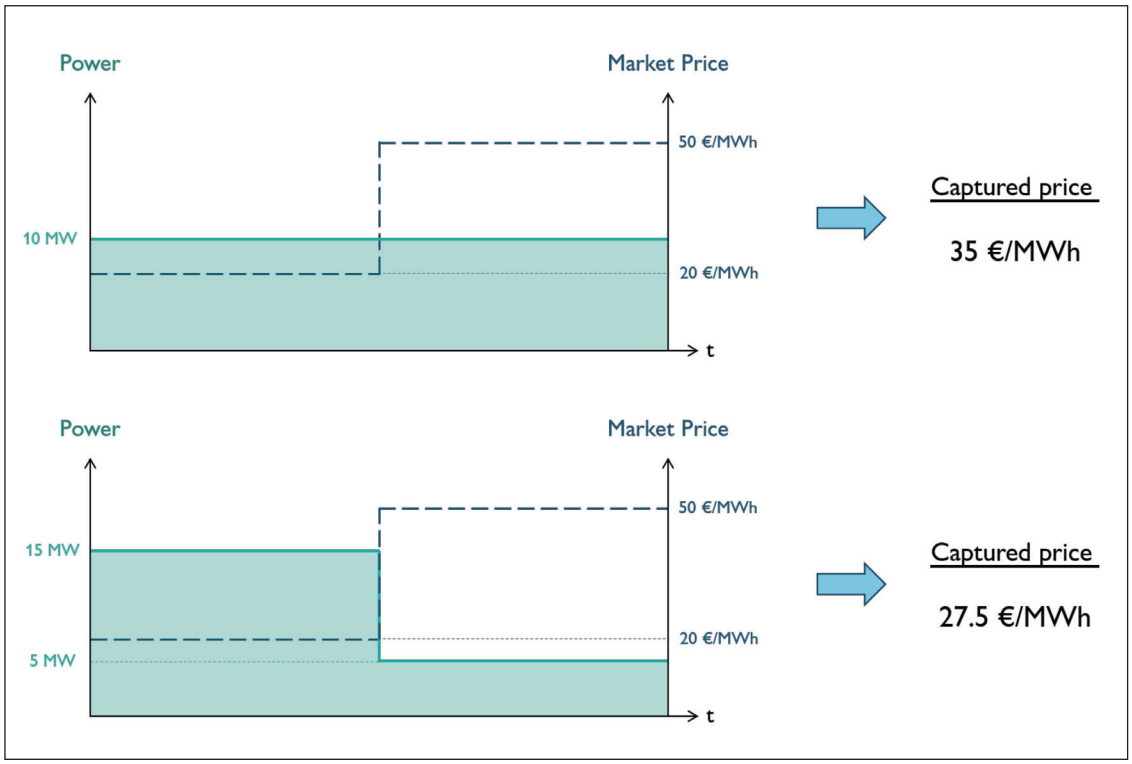


Figure 2: For a given produced amount of energy, the production profile can lead to a different captured price

regional trends can already be observed. On this matter, Everoze has developed a deviation model for onshore wind projects in France, based on historical data [2]. As a result, an estimation of the average relative deviation to *M0* in each region of France could be calculated, which is illustrated below for wind energy:

From a market price capturing perspective, we can see it is more interesting – on a historical reasoning – to have projects in *Occitanie* (up to +5%) than in the *Hauts-de-France* (down to -2.5%). Indeed, projects located in this southern region of France, tend to have a different wind regime than in the North, making them produce more when market prices are higher.

At the end of the day, projects with a positive deviation to *M0* will receive directly or indirectly more than the reference tariff than the ones with a negative deviation:

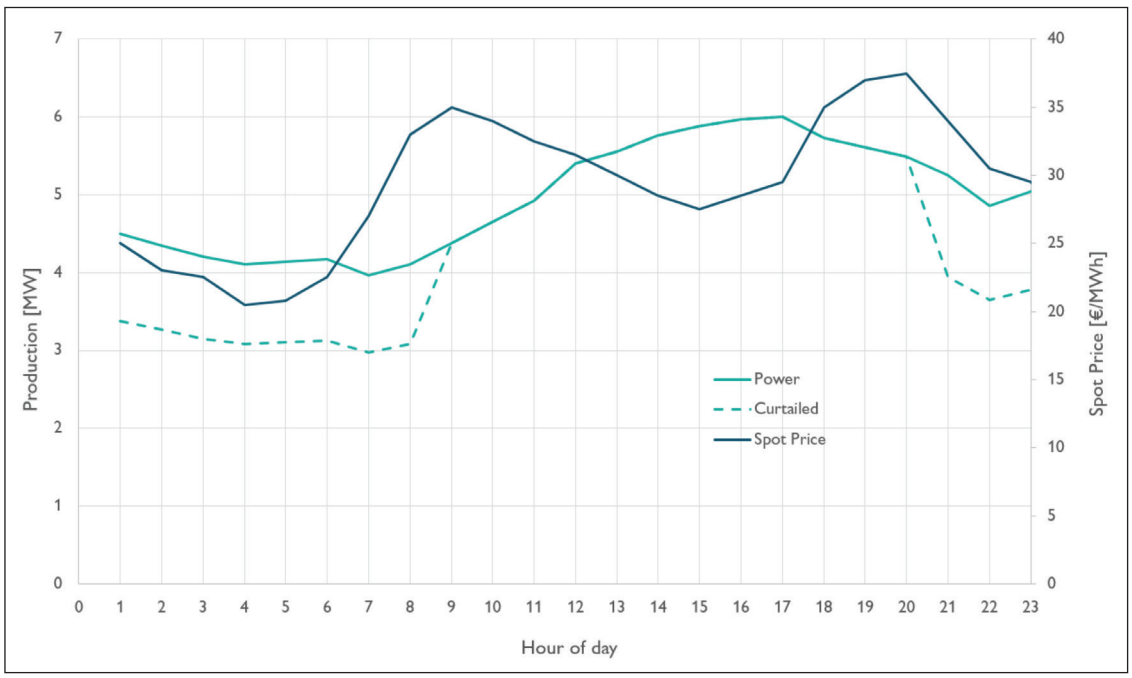


Figure 3: Example of a night curtailment impact on captured price

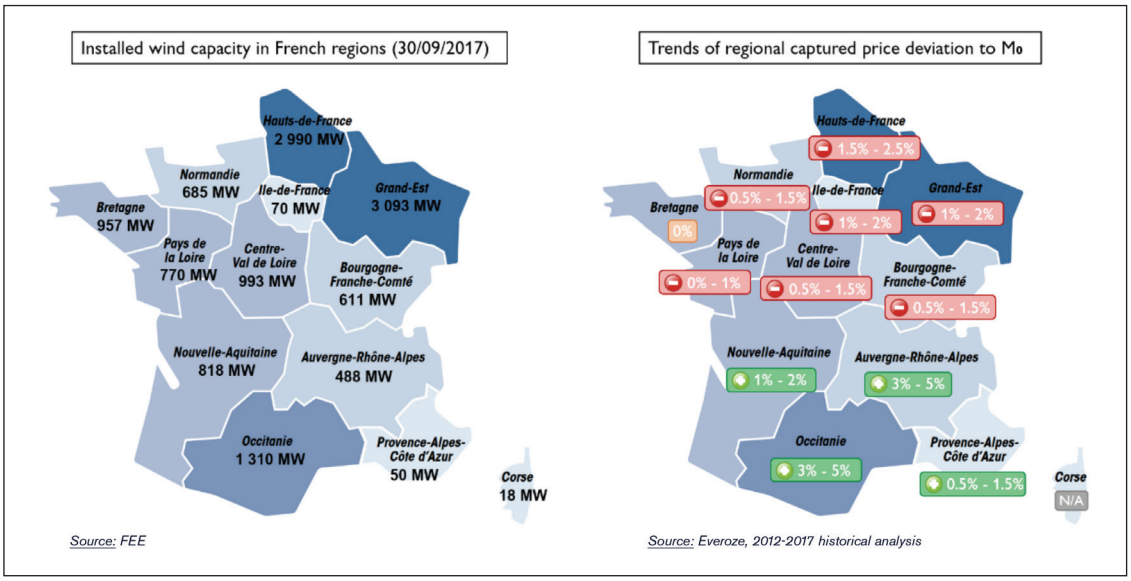


Figure 4: Everoze's historical analysis shows regional captured price deviation trends

How can all this affect a project individually?

In fact, these local trends are taken into account by the players the most directly involved in the marketing of the projects' production: the aggregators. Indeed, the aggregation contract will generally include the *M0* parameter through a tariff for each MWh sold on behalf of the producer defined as:

$$M = M_0 - A$$

M	tariff collected by the producer	[€/MWh]
A	aggregation fee (positive or negative)	[€/MWh]

An aggregator will define *A's* value based on the project's specificities including expected captured price. In broad terms, to cover the cost and risk of captured price deviation, the smaller the Mp relative to *M0*, the bigger the aggregation fee *A*. This means that the sponsors have a direct interest in getting a sense on deviations from *M0*. If the aggregation contract does not involve the *M0* parameter, this assessment is also essential.

Are we done?

Captured price deviation is a notable risk regarding the revenue of renewable projects selling on electricity markets. Even more since the integration of an increasing proportion of renewables in the system will likely amplify this trend.

As mentioned previously, a brand-new player as arrived in town, eager to bear this risk on captured price deviation: the aggregators. However, it would be wrong to consider that aggregators allow projects to be risk free regarding their merchant nature. Indeed, their key role as intermediary and facilitator on the electricity markets will necessarily have an impact on the way renewable power projects sell their production, bringing along new kinds of risks.

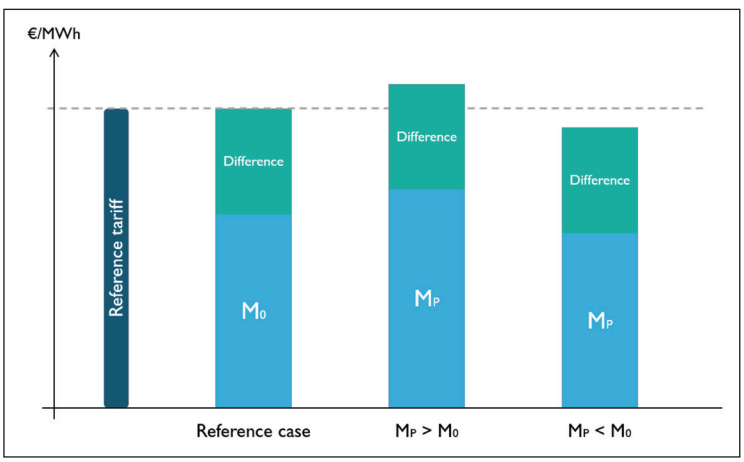


Figure 5: Following its captured price, a project may receive more or less than the reference tariff for each MWh produced

Further reading

[1] This blog focuses on the day-ahead electricity market, since it is the basis for the CfD mechanism and that most volumes are traded on this market. Of course, renewable power projects can benefit from other revenue streams such as the intra-day markets or PPAs, which can influence the "real" captured price.

[2 Day-ahead market prices and wind power production data on the 2008-2017 period.

Paving the sidewalks with solar

Solar Sidewalks will enable city councils to replace concrete pavements and use the electricity to significantly offset their power costs. John Halsted, the inventor of Solar Sidewalks explains how.

OTHER ORGANISATIONS likely to benefit from the installation of Solar Sidewalks© are Stadiums, Schools & Universities, Armed Forces, Hospitals, Refugee Camps & Disaster Areas, Companies and Individuals.

As far back as the Victorian era, steel frames with glass inlays were installed in pavement spaces of major cities to let natural light into basements. This type of pavement slab is still in production today and is being manufactured to the required ES and BS standards. This sidewalk (below) has been manufactured by New Age Glass of Chichester, West Sussex, England and has been installed in central London. It has a similar look to the Solar Sidewalk paver.

In the case of the Solar Sidewalk, instead of allowing light to pass into a basement, the light is trapped immediately under the surface of the sidewalk by a pad of PV cells which convert the light into electricity. Both the composite surface and the PV cells are set into a metal, or aluminium, frame for durability and strength. Electricity generated is fed into either battery storage as DC and/or inverted to AC and fed into the national grid. Unlike the Solar “Freakin” Roadway product, the Solar Sidewalk has been designed for pavement spaces only and is not for driving on. Having said this, the paver has been manufactured to a BS and EU standard which specifies it should be able to take the weight of an average family car.

The composite surface gives greater grip in inclement weather. Even though glass floors have been installed in major tourist spots world-wide, anecdotal research has shown that the public has grave concerns about walking on a surface of 100% glass, even if it is safety approved and manufactured to a national standard.The public has a valid fear of the glass becoming too slippery when wet. This fear is compounded by the fear of the glass surface shattering during a fall resulting in severe injuries.

In addition to which, the all-glass tiles have to have a non-slip layer applied to the surface. Installations in the Netherlands have found that this quickly wears out and has to be continually re-applied. The Solar Sidewalk does not suffer from this problem.

The Solar Sidewalk product is considered novel as the manner of this application has not previously been done before, nor is it being done right now; so, the opportunity to take a commanding market lead beckons.

Areas of impact: First world applications

In a first-world environment, city and town councils will be the primary beneficiaries with their thousands upon thousands of kilometres of paved streets. The combined effect of 10,000 m^2 to 30,000 m^2 of Solar Sidewalk pavers in a city-scape will enable councils to significantly offset their electricity bills allowing them to divert freed-up funds to more critical areas e.g. Social Care.

Installing Solar Sidewalks in city spaces will also provide the infrastructure to meet, at least, the UK and EU governments drive towards electric vehicles as Solar Sidewalks will en able vehicles to be recharged at the curb side city-wide. Other devices, like mobile phones, tablets etc also have the potential for recharging at the curb side. Other organisations likely to benefit from the installation of Solar Sidewalks pavers are:

- Sports stadia
- Schools & Universities
- Armed Forces
- Hospitals
- Refugee Camps & Disaster Areas
- Companies and Individuals to a lesser degree

United Nations Development Program (UNDP)

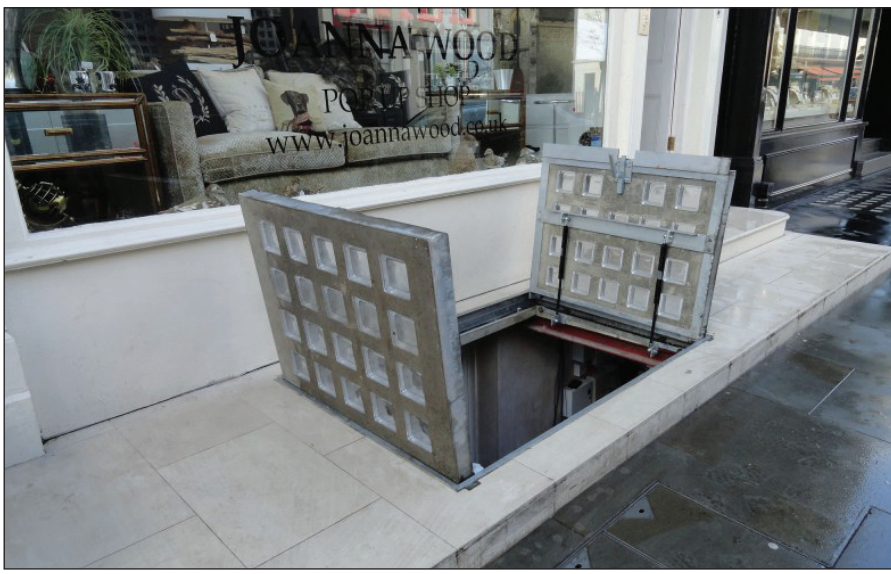
I am in regular contact with Helen Clark who was the Administrator of the UNDP from 2009 to 2017. She is now heavily involved in promoting renewable energy around the world and to this end has provided contact details within the UNDP. The UNDP has requested that I advise them when the product will be available as it has great potential for providing instant power to Refugee Camps and Disaster areas.

Third world applications

Not only will first world urban centres and organisations benefit, but Solar Sidewalk© pavers will also benefit Third World countries, many with enormous energy needs. Most of these countries are situated within the tropics and sub-tropics which have longer sunshine hours than countries outside this zone. The Solar Sidewalk will also benefit remote and rural communities, in some cases delivering electricity for the first time, which will have an effect on improving the quality of life in the long term.

Electricity will enable the creation of micro-industries. Remote and rural communities will in some cases receive electricity for the first time which will influence improving the quality of life in the long term. A few examples would be:

- Micro-water purification plants – delivering Clean, Drinkable Water
- The ability to install pumps and other equipment for sustainable local fisheries
- Conservation, storage, processing and packaging of fresh fruits e.g. Bananas, Papaya, Mangoes, Avocados etc.
- Improved Lighting & Heating – eliminating/ reducing the need for cooking fires and heating which in turn will reduce injuries and fatalities from burns
- Improving/reducing the rate of Climate Change



Pavement access flaps

by reducing the rates of deforestisation and CO2 created by burning wood. This will improve the Quality of Air / reducing air pollution, as the need to burn wood will be reduced

- With hard-surface solar paving, communities will also be able to be kept cleaner as dirt and refuse can be swept or washed away more efficiently than if on a sandy surface.

Having electricity on tap in remote communities may also encourage governments to start linking villages to their national grids as excess power can then be fed into the grid for use elsewhere in the region.

Potential earnings

Example: The City of London has a paved area of circa 20 city blocks. Using industry standard data, a standard city block 100m square, with a 2.5m width of pavement, has the potential to generate between 800 kilo watt hours (KwH) and 2,000 KwH per annum. This has been calculated after factoring in the mean hours of sunlight per day for London. Using the current Feed In Tariff, 20 blocks of London paved with Solar Sidewalk© pavers has the potential to earn London City Council between £2.1m and £3.1m annually.

NOTE: *This will vary depending on sunlight hours received. Tropical installations will realise greater power generation and hence, savings.*

As opposed to selling the Solar Sidewalk for a one-off "bite at the cherry", it is proposed that the product is manufactured and installed at no cost to the councils with a profit share of the funds generated and/or avoided. This revenue model has been chosen for 2 reasons:

1. Councils do not have funds to spare – even if it could save them money.

Solar sidewalk (C) test bed

2. This model gives rise to earnings in perpetuity as opposed to receiving "one bite of the cherry" at time of sale.

It is proposed that the profit share commences with a high percentage, say 75%, being paid to the company which will pay for the manufacture and installation. Thereafter, it is planned that the share percentage would reduce from 75%, by 5% per annum, to a minimum of 10% to 15% which would remain in place in perpetuity. The lower end would realise the company between £50m and £75m p.a. in perpetuity. Considering there are circa 4,400 large cities and circa 380,000 large towns in the world (source: Wikipedia) the potential annual earnings are considerable.

Overall technical impact

With hundreds of thousands of square kilometres of Solar Sidewalk© Pavers generating thousands of Kilowatt Hours (KwH) per day, the need to build bigger power stations will be reduced. In addition, power distribution costs are reduced because electricity will be generated locally. Juliet Davenport, CEO of Good Energy and many others in the renewable markets, believe the days of large power stations are nearing their end. This is something I also firmly believe and it is one of the reasons why I have invented two renewable energy products; to help meet this demand.

Project's current development stage

A prototype/proof of concept has been developed (see below).

This prototype was used in a video segment recorded by the BBC1 and broadcast on BBC1 on 8 December 2017 – see **https://www.facebook.com/solarsidewalks/videos/1775638659404504**

This Prototype was not to prove the solar cells worked, but rather to show that the paver surface would not fail if walked upon, which is clearly shown in the video.

As previously mentioned the output can be connected to a DC/AC inverter or to a DC Battery Storage unit.

Next steps: Phase 2 - pilot site

£60,000 is required to assemble and install 25 pavers in a pilot site. The site will be run for 6 months during which time output from the pilot site will be metered and recorded so that accurate performance data can be collected. As the site will be in a commercial environment, it is expected to create an income stream from the electricity generated.

The PV cells are provided by UPV Solar of Tamil Nadu, India. Assembly will be done by John Halsted and Andrew Wallis of Redwood Electrical

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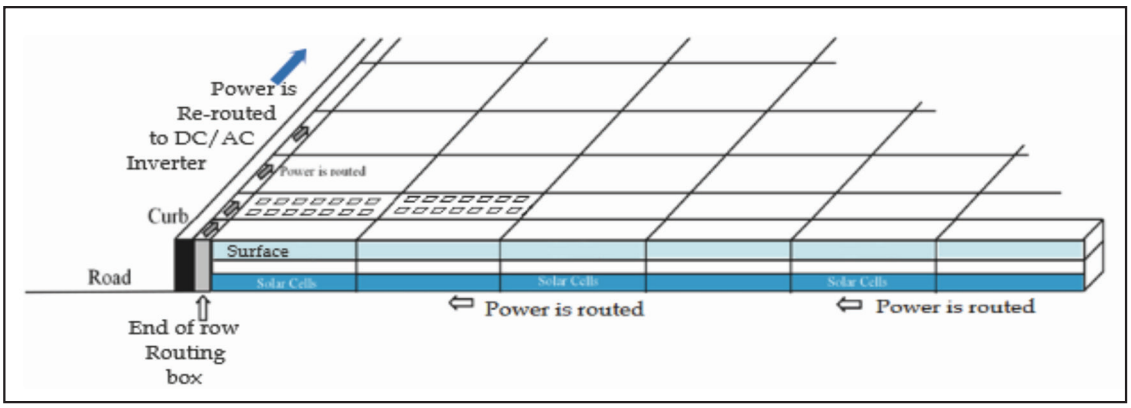


Early system design

with installation being carried out by Andrew Wallis of Redwood Electrical, Camberley –www.redwoodelectrical.co.uk The company has been assessed and accredited by the NICEIC, (the Nation Inspection Council for Electrical Installation Contractors) the ECA (Electrical Contractors Association) and is a Which? Trusted Trader.

Each paver currently costs approx £1,200 to assemble. The bulk cost is the paver surface and frame, provided by New Age Glass, Chichester. Discussions are ongoing with New Age Glass, regarding discounts for bulk orders. We have identified the following as potential locations of a Pilot Site - Poundbury, Reading University, Reading City Council or Wokingham City Council or a local charity in need of financial release. We are also open to suggestions from investors.

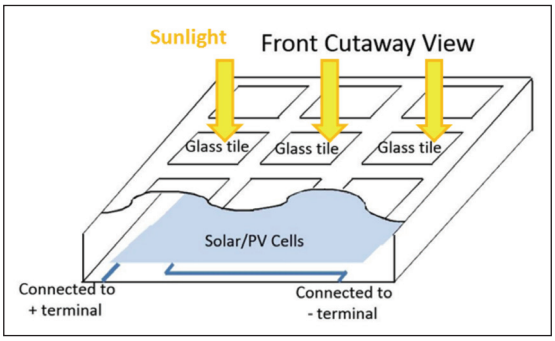
Phase 3 – International rollout

While the Pilot is being run, planning will commence for an international rollout. The product launch will be in the UK, Ireland and Europe.

Thereafter we are proposing launching in Brazil as Brazil has a positive renewable energy program and policies in place. Brazil is the “powerhouse” of South America and would be a good base for assembly and exporting and installing to other South American countries, most of which have long sunlight hours. In addition, we already have a person on the ground in Brazil. Mr Jonathan Nunn is a UK citizen and a colleague who moved to Brazil approximately 3 years ago. He has already been conducting work on the project’s behalf.

Thereafter I propose the product is launched in turn in India, China, Africa and Australasia. It is estimated that £500k will be required to launch and install the product in the UK and Europe and that a further £500k will be required for each subsequent continental launch.

However, as the income generated will occur from Day 1 of installation, it is likely that the income will be realised within 30 to 60 days. This income will be used to offset the required costs of subsequent launches.



Early paver design

Product design

The initial product was designed so that individual pavers could be plugged together like Lego® blocks with DC current being passing through each from one to the next. This design would also allow for easy expansion of any implementation. It would have also meant quick and simple maintenance of pavers. Unfortunately, this design was not used because the technology to enable the easy passing of the current from one paver to the next has not yet been designed. The design has instead progressed to that shown in the prototype images (see above). However, the “plug and generate” design has not been discounted as a future development, if only because of its simplicity.

Initial product designs

The combined output from the Solar Sidewalks© will be routed to an inverter, with the DC current converted to AC. This in turn will be fed into the mains system which usually runs under city streets. An alternative is to use a proportion of the electricity to top up a battery storage system which can be used to charge electric vehicles.

Intellectual property

The product has been granted a Patent Pending status for the Solar Sidewalk – ref Application Number 62/496,554. The product will not be using patents of products from other companies as Solar Sidewalks© will be providing the specification and each of the providers company will be producing a part of the final product.

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