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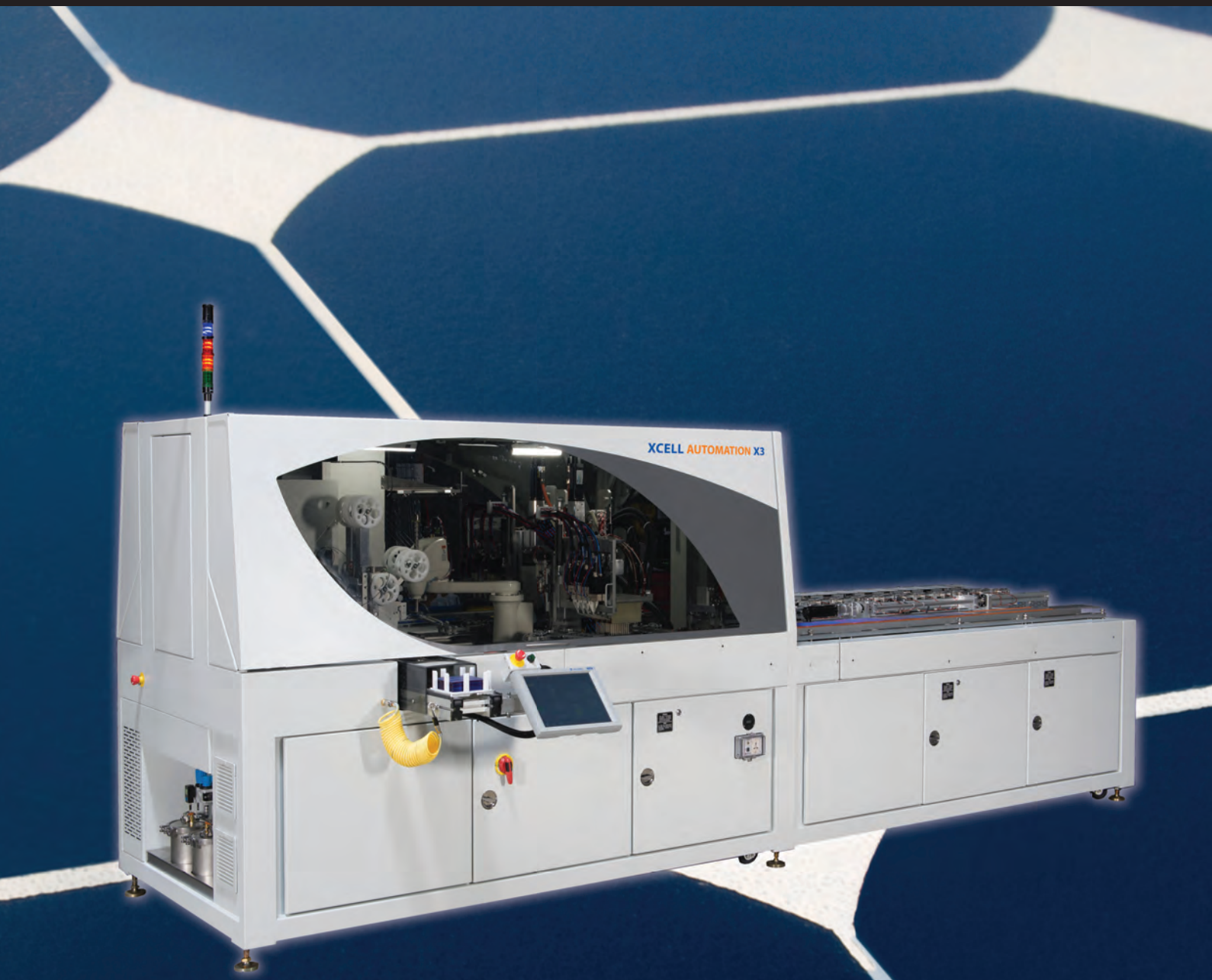

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EU says 'Evasion' is not 'Compliance'

THE LATEST SALVO in a continuing trade battle over access to Europe's multi-billion euro PV market includes tariffs for Malaysian and Taiwanese 'shell' companies owned by Chinese manufacturers hoping to evade 2013 pricing agreements.

The original 2013 anti-dumping deal was made between EU Trade Commissioner Karel De Gucht and several score Chinese companies. It addressed allegations by European manufacturers including Solarworld AG that Chinese manufacturers were receiving unfair government subsidies that allowed them to undercut prices of PV panels made in the EU. Chinese companies entering what had been an almost 'all-EU' market quickly came to dominate Europe's solar energy landscape by 2011; nearly 90 Chinese companies held a 60 percent share of the 21 billion euro market that year. The subsequent 2013 agreement was Europe's bid to ensure fair competition.

The original agreement was not with China, but with Chinese companies. Soon after the accord was reached, a significant number of those companies sought manufacturing presences in Malaysia and Taiwan - countries unaffected by the anti-dumping deal. Within the industry word spread that a sizeable number of the newly built Malaysian and Taiwanese factories were in fact not making solar panels, but were simply warehouses acting as tariff-free transshipment points to Europe. New investigations by the European Commission were subsequently begun and on 5 December 2015 the EU announced that it was looking seriously at extending two sets of tariffs originally scheduled to expire on 7 December. The Commission said new studies would be undertaken to assess the continuing need for tariffs.

The European Commission announced in February that sanctions would be extended to select firms in Malaysia and Taiwan. The EU is now keeping that pledge as it looks into wider issues. Companies exempted from the EU's latest round of tariffs comprise a lengthy list of PV panel makers in those countries that have been in the business for a while, such as Motech and E-Tom (Taiwan) and Flextronics (Malaysia.) Two leading Chinese panel makers that had previously announced plans to manufacture in Malaysia at the height of off-shore migration include ReneSola and Jinko Solar; those plans appear to have been suspended. While the European Commission investigation continues, companies that have been 'twice caught' trying to undercut the pricing accord have been largely silent. The United States has taken an approach similar to Europe in assessing tariffs against PV panel importers who sell modules at prices substantially under those of domestically produced products.

There's no indication that the anti-dumping tariffs will disappear anytime soon.

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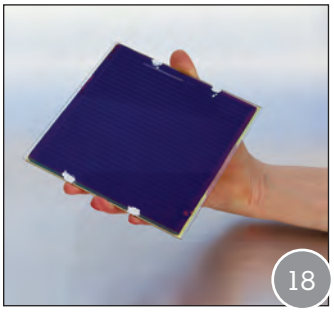

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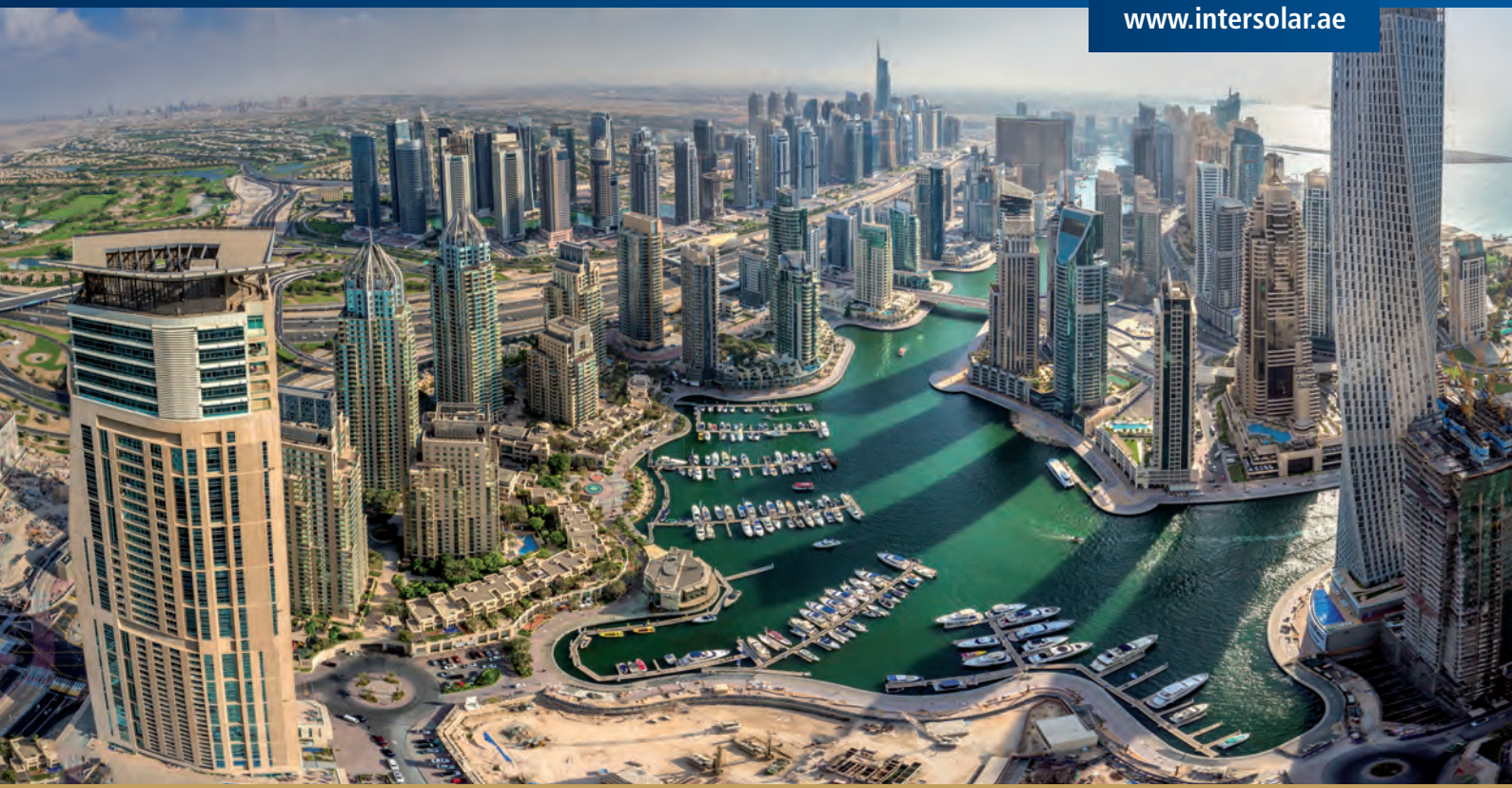

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Energy harvesting to drive semiconductor sales to $3 billion by 2020

WHETHER it's the Internet of Things (IoT), wearables, or industrial automation, new devices and applications are portable, battery-operated and require continuous power.

Wireless connectivity is required for connecting to the Internet. Today's devices collect and transmit data from sensors, are always or almost always on and require power. The semiconductor industry has met the challenge to design devices for low power operation. But eventually batteries still run out of energy and have to be replaced or recharged.

Energy harvesting can extend battery life or possibly replace batteries altogether for continuous operation. The new Semico Research report "Energy Harvesting: The Next Billion Dollar Market for Semiconductors" projects semiconductor sales for this market will reach $3 billion by 2020.

An energy harvesting solution requires more than just the energy harvester or transducer. The key components include a power converter, power

management IC (PMIC), MCU, and energy storage. "An ecosystem of semiconductor vendors is emerging for the nascent energy harvesting market," says Tony Massimini, Semico Research's Chief of Technology. "The ecosystems are gravitating around the vendors of key power components. They are forming partnerships with producers of energy harvesters, battery suppliers, and other components."

This study examines the market opportunity for energy harvesting outside of large installations and commercial power generation. A broad range of markets will employ energy harvesting to either replace batteries or extend battery life. These applications cover wireless sensor nodes (WSN) for bridges, infrastructure, building automation and controls, and home automation (including lighting, security and environmental). Energy harvesting will grow in automotive applications, cell phones, wearables and other consumer electronics.

"The vendors of MCUs, sensors, RF, analog and other components will continue to develop lower power devices", according to Massimini. "While this puts less drain on a battery and will extend its life, it also lessens the load for an energy harvesting solution. Energy harvesting solutions are also expected to improve during the forecast period."

The ASPs for the semiconductor components continue to decline, lowering the costs for an energy harvesting solution. This is driving higher penetration rates.

GE provide 220 MW inverters to TSK

GE'S POWER CONVERSION business has recently signed a contract with TSK to provide 220-megawatt (MW) LV5 series 1,000-volt solar inverters and has established the possibility to expand the collaboration between both companies for future possible projects with the LV5 series solar inverters.

GE and TSK have been strategic partners in the thermal power plant and wind businesses. The new deal expands the partnership into a new growing sector, the solar PV industry.

"It is imperative that we embrace the fast-growing renewables sectors, notably the solar PV sector. GE has been one of our long-term trusted partners and a reliable technology provider. We are excited to further strengthen our relationship by signing the 220 MW solar inverter deal.

GE's solutions like this complement our commitment to sustainably drive the energy sectors in which we operate," said Alfonso Targhetta, procurement and subcontracting managing director, TSK GE's liquid-cooled inverters are rated for outdoor use and have been conceived to deliver in the harshest of conditions imaginable.

"We're extremely proud of our relationship with TSK. Their trust in our technologies speaks volumes about GE's competence in the solar industry. We're confident about the abilities of our technology and remain open for further collaborations within the industry," said Francesco Falco, global sales leader, GE's Power Conversion business.

"In addition to technology innovation, GE can also provide financing, long-term service and digital solutions to help enable efficient solar farms. This is the example of the "GE Store," where GE businesses share knowledge and leverage each other's strengths to deliver more valuable customer benefits," added Francesco.

GE's involvement in some of the biggest solar projects with key market players strengthens its position as a key technology enabler within the industry.

Global solar installations to reach 66.7 GW

MERCOM CAPITAL GROUP forecasts global solar installations to reach 66.7 GW with China, the United States, Japan and India to make up the top four solar markets this year.

"Solar installations are forecasted to grow year-over-year globally despite recent headwinds in the sector with solar stocks, yieldcos, bankruptcies and the negative perception surrounding solar public companies. Solar has grown from just 2.6 GW in 2007 to a forecasted 66.7 GW in 2016 showing impressive resiliency along the way as it becomes one of the fastest growing new generation sources around the world," commented Raj Prabhu, CEO and Co-Founder of Mercom Capital Group.

China installed 15.1 GW of solar in 2015, retaining its top spot as the largest solar installer in the world. Mercom forecasts China to install 18.5 GW in 2016. The additional 5.3 GW installation quota combined with the expected rush to meet FiT deadlines in the first half of the year should help China exceed 2015 installation numbers.

China's Q1 2016 installation figures of 7.14 GW confirm that it is off to a fast start. China recently reduced the FiT by up to 11 percent based on regions. To address the subsidy payment issues and raise additional revenue, the renewable energy surcharge has been increased by 27 percent, and an on-grid power tariff for commercial and industrial customers has been reduced to tackle shortages in the renewable energy fund. To address curtailment issues, the government has proposed a policy of guaranteed purchase of renewable power which it plans to implement gradually.

The unexpected extension of the U.S. Investment Tax Credit (ITC) in December last year has completely changed the dynamics of the U.S. solar market. Mercom forecasts a conservative 13.5 GW of solar installations in 2016 as vendors are indicating a slower first quarter - at least in terms of new projects - as developers are taking their time to line up suppliers and negotiate contracts. This of course may change in the second half of the year. Japan is expected to install around 10.5 GW of solar this year. Its current solar installation goal is 28 GW by 2020. Japan cut the feed-in tariff in March of 2016 by 11 percent. While the country started off with an overly generous FiT in 2012 of ¥42 (~$0.387)/kWh, it is now down to ¥24 (~$0.221)/kWh. Japan continues to struggle with grid connection, curtailment issues, and an undeveloped pipeline. Of the approved pipeline, only about 15 percent has been installed. Japan is also looking to implement solar auctions in order to cut subsidy costs.

India is expected to install over 4 GW in 2016 which will bring it to the fourth spot globally. India currently has a pipeline of over 21 GW under development and in pending auctions as the country targets its installation goal of 100 GW by 2022. Aggressive bidding in its recent auctions has caused some concerns to the viability of these projects due to unrealistic low bids. The latest India update can be found here.
The top three solar markets in Europe are again expected to be the U.K., Germany and France.

Proliferation of solar auctions around the world is an important development over the last 12 months with subsidy costs from solar becoming an issue in many countries. Germany completed three auctions in 2015, the U.K. and Japan are looking at a similar model, France is conducting solar auctions, and China is also contemplating auctions. India and South African solar policies are primarily based on auctions while Brazil and Mexico are also largely auction-based.

ASM to debut new printing technology at SNEC

ASM ALTERNATIVE ENERGY plans to unveil a brand new solar cell printing technology at the upcoming SNEC PV Power Expo, set to take place from May 24 to 26 in Shanghai, China The new, rapidly responsive XtremePrint deposition system will be shown on the company's award-winning Eclipse XP metallization platform, with capability demonstrations taking place throughout the three-day event. In addition, SolarBlade half-cell technology and SolarWIS wafer inspection capability will be featured on ASM AE stand E3-320.

"XtremePrint is a major milestone for modern solar metallization processes," says Brian Lau, VP of Business Development for ASM AE. "While previous print head technologies delivered topography accommodation, it was generally at the expense of print speed.

XtremePrint is the most rapidly responsive paste deposition system on the market, allowing for real-time topography and feature adjustments without sacrificing throughput."

Renewable energy investments: major milestones reached in green energy

COAL AND GAS-FIRED ELECTRICITY generation last year drew less than half the record investment made in solar, wind and other renewables capacity - one of several important firsts for green energy announced in UN-backed report.

Global Trends in Renewable Energy Investment 2016, the 10th edition of the UN Environment Programme's (UNEP's) annual publication, launched today by the Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance and Bloomberg New Energy Finance (BNEF), says the annual global investment in new renewables capacity, at $266 billion, was more than double the estimated $130 billion invested in coal and gas power stations in 2015. All investments in renewables, including early-stage technology and research and development as well as spending on new capacity, totalled $286 billion in 2015, some 3 per cent higher than the previous record in 2011. Since 2004, the world has invested $2.3 trillion in renewable energy (unadjusted for inflation).

(All figures for renewables in this release include wind, solar, biomass and waste-to-energy, biofuels, geothermal, marine and small hydro, but exclude large hydro-electric projects of more than 50 megawatts).Just as significantly, developing world investments in renewables topped those of developed nations for the first time in 2015.

Helped by further falls in generating costs per megawatt-hour, particularly in solar photovoltaics, renewables excluding large hydro made up 54 per cent of added gigawatt capacity of all technologies last year. It marks the first time new installed renewables have topped the capacity added from all conventional technologies.

The 134 GW of renewable power added worldwide in 2015 compares to 106 GW in 2014 and 87 GW in 2013. Were it not for renewables excluding large hydro, annual global CO_2 emissions would have been an estimated 1.5 giga tonnes higher in 2015. UNEP Executive Director Achim Steiner said, "Renewables are becoming ever more central to our low-carbon lifestyles, and the record-setting investments in 2015 are further proof of this trend. Importantly, for the first time in 2015, renewables in investments were higher in developing countries than developed."

"Access to clean, modern energy is of enormous value for all societies, but especially so in regions where reliable energy can offer profound improvements in quality of life, economic development and environmental sustainability. Continued and increased investment in renewables is not only good for people and planet, but will be a key element in achieving international targets on climate change and sustainable development."

"By adopting the Sustainable Development Goals last year, the world pledged to end poverty, promote sustainable development, and to ensure healthier lives and access to affordable, sustainable, clean energy for all. Continued and increased investment in renewables will be a significant part of delivering on that promise."

Said Michael Liebreich, Chairman of the Advisory Board at BNEF: "Global investment in renewables capacity hit a new record in 2015, far outpacing that in fossil fuel generating capacity despite falling oil, gas and coal prices. It has broadened out to a wider and wider array of developing countries, helped by sharply reduced costs and by the benefits of local power production over reliance on imported commodities."

As in previous years, the report shows the 2015 renewable energy market was dominated by solar photovoltaics and wind, which together added 118 GW in generating capacity, far above the previous record of 94 GW set in 2014.

Wind added 62 GW and photovoltaics 56 GW. More modest amounts were provided by biomass and waste-to-power, geothermal, solar thermal and small hydro.

In 2015, more attention was drawn to battery storage as an adjunct to solar and wind projects and to small-scale PV systems. Energy storage is of significant importance as it is one way of providing fast-responding balancing to the grid, whether to deal with demand spikes or variable renewable power generation from wind and solar. Last year, some 250 MW of utility-scale electricity storage (excluding pumped hydro and lead-acid batteries) was installed worldwide, up from 160 MW in 2014.

EDF Renewable Energy acquires groSolar

EDF RENEWABLE ENERGY have announced the acquisition of Global Resource Options, Inc., a privately owned company, which provides development and turnkey engineering, procurement, and construction (EPC) of solar photovoltaic (PV) projects for developers, financiers, utilities, corporate, government, and other institutional clients.

The acquisition brings to EDF RE an autonomous business unit with a precise focus on distributed generation solar business to meet the growing demands of corporate customers seeking cost-effective renewable energy sources. Closing is subject to customary conditions precedent.

Since its founding in 1998, groSolar has designed, built, procured equipment and installed more than 150 megawatts (MW) (2,000 installations) of solar PV systems across the US. All with one goal in mind -- to provide customers with the most competitively priced, highest quality, on-time solar system to meet or surpass customer needs. The company's strength lies in their

commitment to work in partnership with clients and local stakeholders, managing every step of the process in order to simplify solar development. "We are very pleased to welcome groSolar to the EDF RE family.

The company brings to EDF RE the ability to offer competitively priced distributed generation solar solutions to the growing Municipal, University, School and Hospital (MUSH), corporate, and utility customer base," stated Tristan Grimbert, CEO and President of EDF RE. "The addition of an established and successful distributed generation business line contributes to our long-term growth plan to diversify the customer base and augments a comprehensive range of energy services that the EDF group offers to its customers worldwide."

"groSolar benefits from the ability to leverage EDF RE's deep technical resources and project development experience while remaining an independent subsidiary," stated Jamie Resor, CEO of groSolar. "We worked collaboratively during the due diligence process to ensure that our respective cultures and customer oriented focus would fully align. And today we look forward with confidence to accelerate our reach in the expanding distributed generation solar market as part of EDF RE."

EDF Renewable Energy is one of the largest renewable energy developers in North America with 8 gigawatts (GW) of wind, solar, biomass, biogas, and storage projects developed and an installed capacity of 4.1 GW. As part of the EDF Group, EDF RE works closely with EDF Energy Services and DK Energy.

AT&T and SunPower collaborate on solar IoT connectivity

AT&T and SunPower have entered into an agreement that brings Internet of Things (IoT) technology to SunPower's newest home energy solution—SunPower Equinox. The companies will also collaborate on co-marketing efforts to offer a SunPower home solar system to qualified AT&T customers this summer.

SunPower recently released its SunPower Equinox system to homeowners in the U.S. SunPower calculates that its solution delivers 70 percent more energy over 25 years with 70 percent fewer visible parts compared to conventional solar.

Over the next two years, AT&T and SunPower expect to wirelessly connect at least 100,000 solar electric systems in the U.S. providing customers with reliable access to system performance through AT&T's IoT capabilities. The technology collaboration is designed to reduce onsite homeowner visits by allowing SunPower to wirelessly support solar power systems as needed and in near real-time.

"Our IoT solutions help customers remotely monitor cargo, homes, vehicles, containers and also — solar panels," said Mike Troiano, vice president, Internet of Things, AT&T. "Connectivity is changing how companies operate. We're thrilled SunPower chose us to give them near real-time insights into how their solar energy solutions are performing for their customers and the tools to help manage them remotely."

"Through this IoT collaboration and innovative marketing with AT&T, we are making solar even more mainstream,"

said Howard Wenger, SunPower president, business units. "The SunPower Equinox system is already a game changer for home solar, offering our customers unbeatable power, long-term performance and curb appeal. Now by incorporating AT&T IoT technology into SunPower's solar energy solutions, we are enabling a future of solar energy management that is reliable, simple, and cost-effective."

ORNL tracks how halogen atoms compete to grow 'winning' perovskites

Oak Ridge National Laboratory scientists combined imaging techniques to measure crystallization kinetics of perovskite films following exposure to a mixed halide vapor. Over time, extra halide reactants settle in the film's grain boundaries, demonstrating atomic competition in crystal growth.

RESEARCHERS at the Department of Energy's Oak Ridge National Laboratory have found a potential path to further improve solar cell efficiency by understanding the competition among halogen atoms during the synthesis of sunlight-absorbing crystals.

Oak Ridge National Laboratory scientists combined imaging techniques to measure crystallization kinetics of perovskite films following exposure to a mixed halide vapor. Over time, extra halide reactants settle in the film's grain boundaries, demonstrating atomic competition in crystal growth.

Oak Ridge National Laboratory scientists combined imaging techniques to measure crystallization kinetics of perovskite films following exposure to a mixed halide vapor. Over time, extra halide reactants settle in the film's grain boundaries, demonstrating atomic competition in crystal growth.

Photovoltaic cells that convert sunlight directly into electricity are becoming increasingly prominent in the world's renewable energy mix. One promising area of solar energy research involves perovskites, a material that can potentially convert sunlight into electricity more efficiently and less expensively than typical silicon-based semiconductors.

Perovskite-based solar cells, however, have been hindered by unreliable durability, poor efficiency and unresolved questions.

"Organometallic halide perovskite semiconductors have high carrying capacity and efficiency to rival silicon-based solar cells. These materials are easy and cheap to grow but have been known to degrade," said Bin Yang, an ORNL postdoctoral researcher at the Center for Nanophase Materials Science. A new study published in the Journal of the American Chemical Society demonstrates that in the presence of reactive iodide ions, negatively charged bromine and chlorine are left out of the final perovskite crystal structure – like not making the team in gym class.

"To take that first step and maximize solar cell technology made with organometallic halide perovskites, we need to know how to grow high quality light-absorbing material and establish optimal film growth processes," said Yang, the study's lead author. "The simple printing or spraying of perovskite ink makes solar module costs even lower."

Using high-powered imaging techniques, Yang and the team tracked kinetic activity in organometallic halide perovskites.

Halogen ions, jockeying for a position in the growing structure, affect the movement of charges through the crystals and subsequently impact the efficiency of sunlight's conversion to electricity. "The kinetic activity found in halide perovskites poses significant challenges for advancing high-efficiency optoelectronic materials and devices," said Kai Xiao, study co-author and ORNL staff scientist. The team first used X-ray diffraction for a real-time peek at the stages of crystallization, immediately monitoring the chemical reaction between a mixed-halide vapor and a thin lead-iodide film.

ORNL researchers then extracted chemical, molecular and elemental data from the perovskites using time-of-flight secondary ion mass spectrometry for ex-situ analysis. The mass spectrometer's beams of ions provided a snapshot of information about molecular activity on the crystal's surface and established chlorine's eventual distribution in the grain boundaries, or crevices, of perovskite films. A combination of imaging techniques allowed the

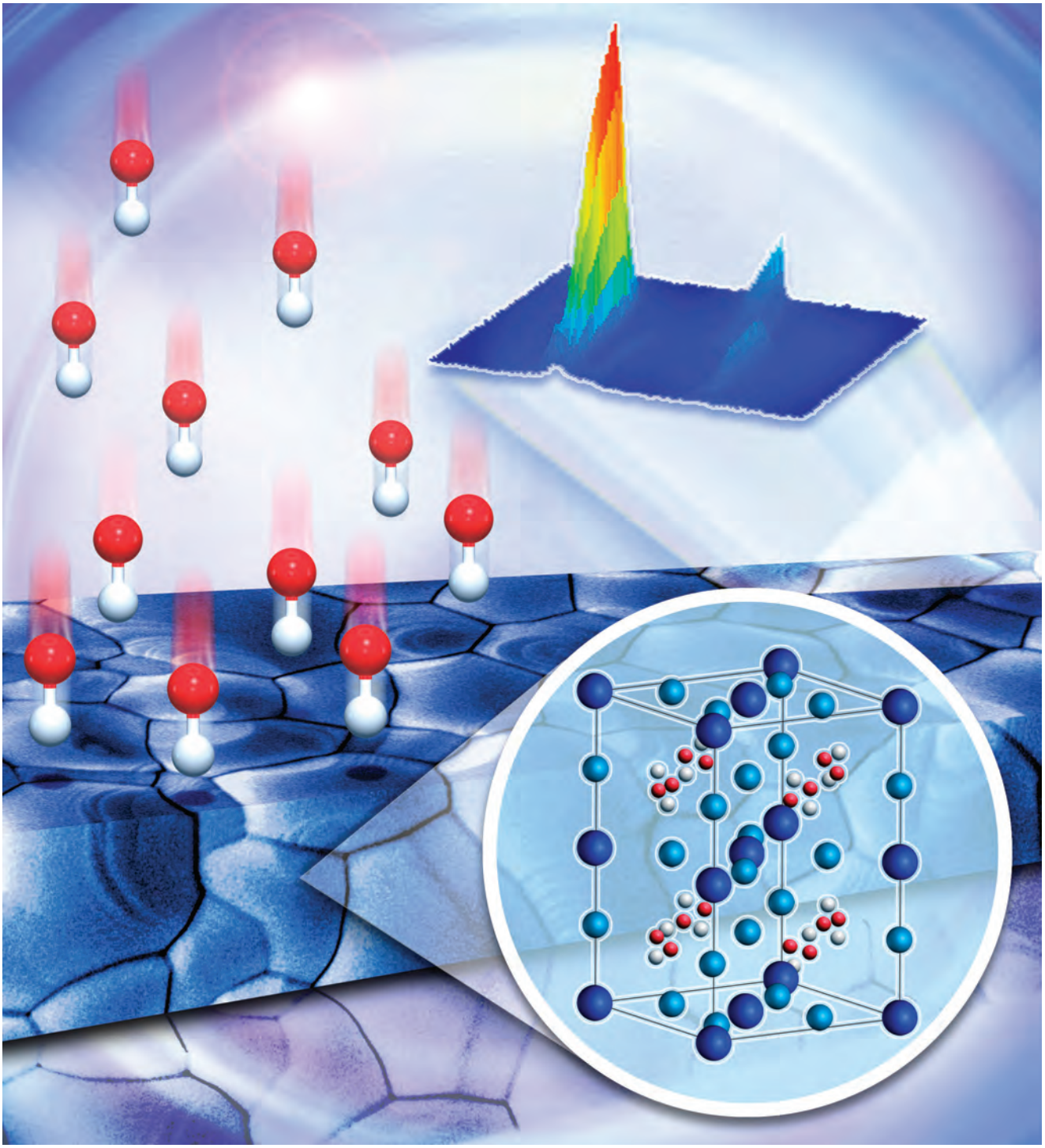


Image by ORNL's Jill Hemman.

ORNL team to track the outcome of the halogen competition in the solar material.

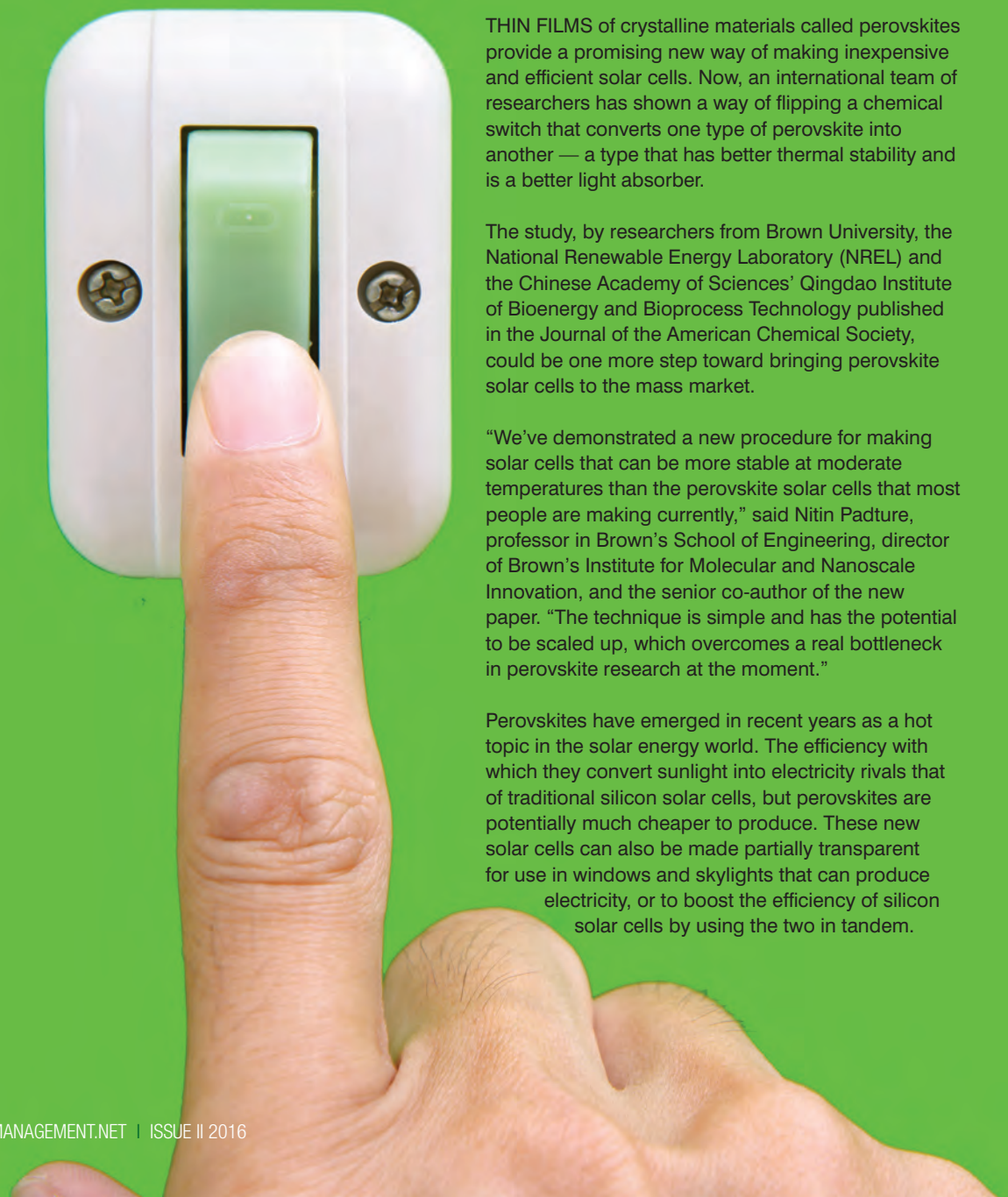
Researchers discovered that while bromine, chlorine and iodine ions facilitate growth in a developing organometallic perovskite structure, only iodine gets a spot in the final crystal. However, though they are left out of the final structure, the molecules build "team morale" as they help promote overall crystal growth. The measurements offered several insights into perovskite crystallization kinetics that will lead to improvements in the synthesis and processing of the materials for high efficiency solar cells, according to Xiao.

m"Identifying the chemical phenomenon of halide competition in hybrid perovskites will help in engineering large-grain perovskite films for better, cheaper solar devices," Xiao said.

Co-authors of the study are ORNL's Jong Keum, Olga Ovchinnikova, Alex Belianinov, Mao-Hua Du, Ilia Ivanov, Christopher Rouleau, and David Geohegan, and East China Normal University's Shiyou Chen.
This research was conducted at the Center for Nanophase Materials Sciences (CNMS), which is a DOE Office of Science User Facility. The work was supported by DOE's Office of Science.

Flipping a chemical switch helps perovskite solar cells beat the heat

International research team demonstrates new approach to making thermally stable solar cells.



THIN FILMS of crystalline materials called perovskites provide a promising new way of making inexpensive and efficient solar cells. Now, an international team of researchers has shown a way of flipping a chemical switch that converts one type of perovskite into another — a type that has better thermal stability and is a better light absorber.

The study, by researchers from Brown University, the National Renewable Energy Laboratory (NREL) and the Chinese Academy of Sciences' Qingdao Institute of Bioenergy and Bioprocess Technology published in the Journal of the American Chemical Society, could be one more step toward bringing perovskite solar cells to the mass market.

"We've demonstrated a new procedure for making solar cells that can be more stable at moderate temperatures than the perovskite solar cells that most people are making currently," said Nitin Padture, professor in Brown's School of Engineering, director of Brown's Institute for Molecular and Nanoscale Innovation, and the senior co-author of the new paper. "The technique is simple and has the potential to be scaled up, which overcomes a real bottleneck in perovskite research at the moment."

Perovskites have emerged in recent years as a hot topic in the solar energy world. The efficiency with which they convert sunlight into electricity rivals that of traditional silicon solar cells, but perovskites are potentially much cheaper to produce. These new solar cells can also be made partially transparent for use in windows and skylights that can produce electricity, or to boost the efficiency of silicon solar cells by using the two in tandem.

Despite the promise, perovskite technology has several hurdles to clear — one of which deals with thermal stability. Most of the perovskite solar cells produced today are made with of a type of perovskite called methylammonium lead triiodide (MAPbI3). The problem is that MAPbI3 tends to degrade at moderate temperatures.

"Solar cells need to operate at temperatures up to 85 degrees Celsius," said Yuanyuan Zhou, a graduate student at Brown who led the new research. "MAPbI3 degrades quite easily at those temperatures." That's not ideal for solar panels that must last for many years. As a result, there's a growing interest in solar cells that use a type of perovskite called formamidinium lead triiodide (FAPbI3) instead.

Research suggests that solar cells based on FAPbI3 can be more efficient and more thermally stable than MAPbI3. However, thin films of FAPbI3 perovskites are harder to make than MAPbI3 even at laboratory scale, Padture says, let alone making them large enough for commercial applications. Part of the problem is that formamidinium has a different molecular shape than methylammonium. So as FAPbI3 crystals grow, they often lose the perovskite structure that is critical to absorbing light efficiently.

This latest research shows a simple way around that problem. The team started by making high-quality MAPbI3 thin films using techniques they had developed previously. They then exposed those MAPbI3 thin films to formamidine gas at 150 degrees Celsius. The material instantly converted from MAPbI3 to FAPbI3 while preserving the all-important microstructure and morphology of the original thin film.

"It's like flipping a switch," Padture said. "The gas pulls out the methylammonium from the crystal structure and stuffs in the formamidinium, and it does so without changing the morphology. We're taking advantage of a lot of experience in making excellent quality MAPbI3 thin films and simply converting them to FAPbI3 thin films while maintaining that excellent quality."

This latest research builds on the work this international team of researchers has been doing over the past year using gas-based techniques to make perovskites. The gas-based methods have the potential of improving the quality of the solar cells when scaled up to commercial proportions. The ability to switch from MAPbI3 to FAPbI3 marks another potentially useful step toward commercialization, the researchers say.

Researchers have developed a simple method for converting one type of perovskite to another form that's better able to take the heat of a solar panel. Padture Lab / Brown University.

"The simplicity and the potential scalability of this method was inspired by our previous work on gas-based processing of MAPbI3 thin films, and now we can make high-efficiency FAPbI3-based perovskite solar cells that can be thermally more stable," Zhou said. "That's important for bringing perovskite solar cells to the market."

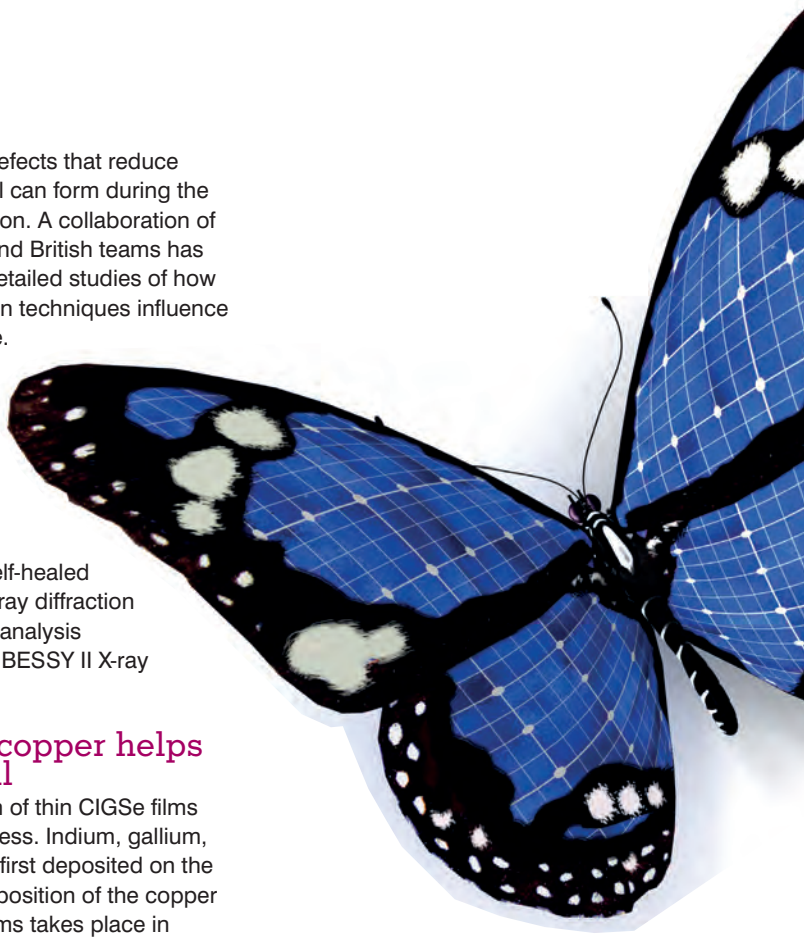
Laboratory scale perovskite solar cells made using this new method showed efficiency of around 18 percent — not far off the 20 to 25 percent achieved by silicon solar cells.

"We plan to continue to work with the method in order to further improve the efficiency of the cells," said Kai Zhu, senior scientist at NREL and co-author of the new paper. "But this initial work demonstrates a promising new fabrication route."

Other authors on the paper were Mengjin Yang from NREL and Shuping Pang from CAS Qingdao Institute of Bioenergy and Bioprocess Technology. The work was supported by the National Science Foundation (DMR-1305913, OIA-1538893) and the Department of Energy (DE-FOA-0000990).

Thin-film solar cells:
How defects appear and disappear in CIGSe-cells

CIGSe modules in standard industrial formats have not yet attained the record efficiency demonstrated at laboratory scale. One possible cause: defects that reduce the efficiency level can form during the course of fabrication.



THE DATA (photon energies over time) show defects (lower signal) which disappear after 120 minutes. This happens at the transition from the copper-poor phase to the copper-rich one. Credit: HZB

An international collaboration of German, Israeli, and British teams has investigated the deposition of thin chalcopyrite layers. They were able to observe specific defects as these formed during deposition and under what conditions they self-healed using the BESSY II X-ray source at the Helmholtz Zentrum Berlin. The results of their research provide clues to optimising fabrication processes and have now been published in Energy & Environmental Science.

Copper-indium-gallium-selenide (CIGSe) solar cells have the highest efficiency of polycrystalline thin-film solar cells. The four elements comprising CIGSe are vapour-deposited onto a substrate together to form a very thin layer of tiny chalcopyrite crystals. It is an exceedingly complex process controlled by many variables. This is why CIGSe modules in standard industrial formats have not yet attained the record efficiency already demonstrated at laboratory scale. One possible cause: defects that reduce the efficiency level can form during the course of fabrication. A collaboration of German, Israeli, and British teams has now conducted detailed studies of how different fabrication techniques influence the microstructure. They were able for the first time to observe the defects as these formed during deposition and under what conditions they self-healed by using in-situ X-ray diffraction and fluorescence analysis capabilities at the BESSY II X-ray source.

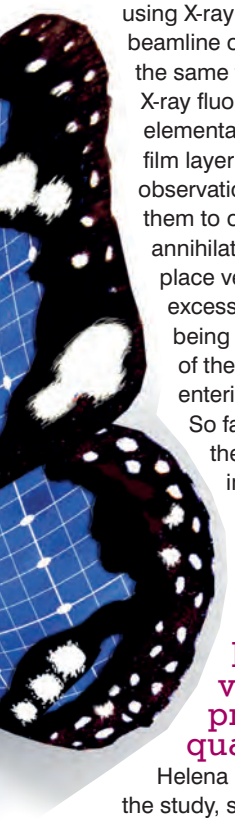
Additional copper helps defects heal

Vapour deposition of thin CIGSe films is a complex process. Indium, gallium, and selenium are first deposited on the substrate. The deposition of the copper and selenium atoms takes place in a second step. These atoms migrate into the In-Ga-Se layer. Tiny CIGSe crystals of chalcopyrite form there. The concentration of copper only reaches the correct value over the course of this second step. The prior copper-poor phase is characterised by numerous defects within the crystal. The defects increasingly disappear with the addition of copper and selenium. If more copper and selenium atoms are added after

reaching the “right” ratio, then these two elements no longer fit into the existing crystal matrix and deposit themselves as copper and selenium grains in and on the polycrystalline CIGSe layer. This is actually problematic, since the grains must be removed afterwards. Nevertheless, they apparently have an important function in reducing the defects to near zero, as the current work shows.

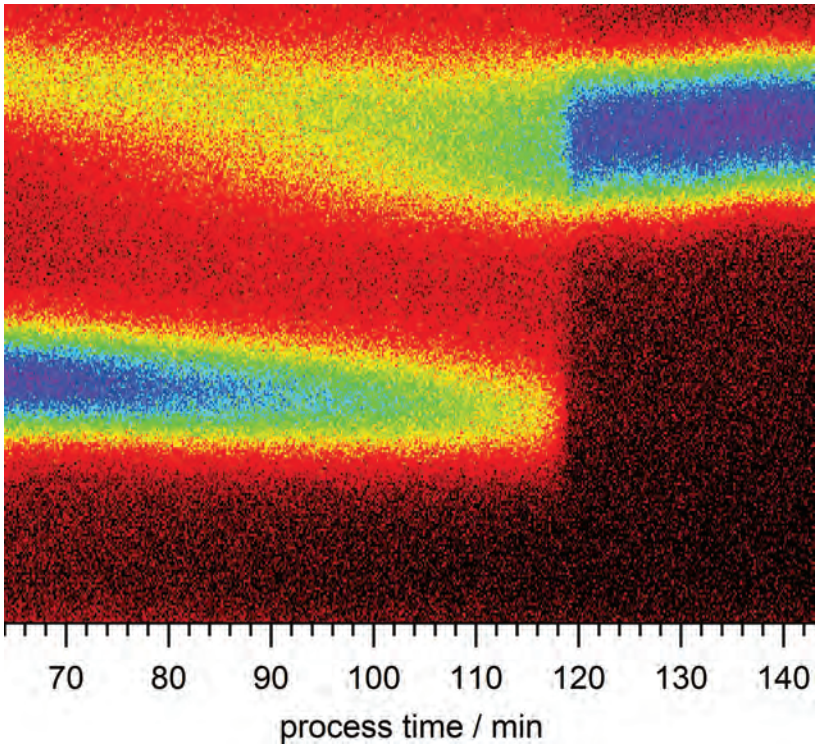
Analysing growing structures of elements in real time

Dr. Roland Mainz and his colleagues at HZB were able to observe the changes to the film structure during deposition using X-ray diffraction at the EDDI beamline of BESSY II - in real time. At the same time, they were able to use X-ray fluorescence to analyse the elemental composition of the thin-film layer as it grew. Simultaneous observation with two methods enabled them to obtain a new insight: “The annihilation of the defects takes place very rapidly – just prior to the excess copper-selenium grains being deposited on the surface of the CIGSe film and the film entering the copper-rich phase. So far, we had only understood the copper-rich phase as being important for the growth of the grains. Now we know that it also plays an important role in the elimination of the defects”, explains Mainz.



Improving vapour deposition processes for high-quality CIGSe films

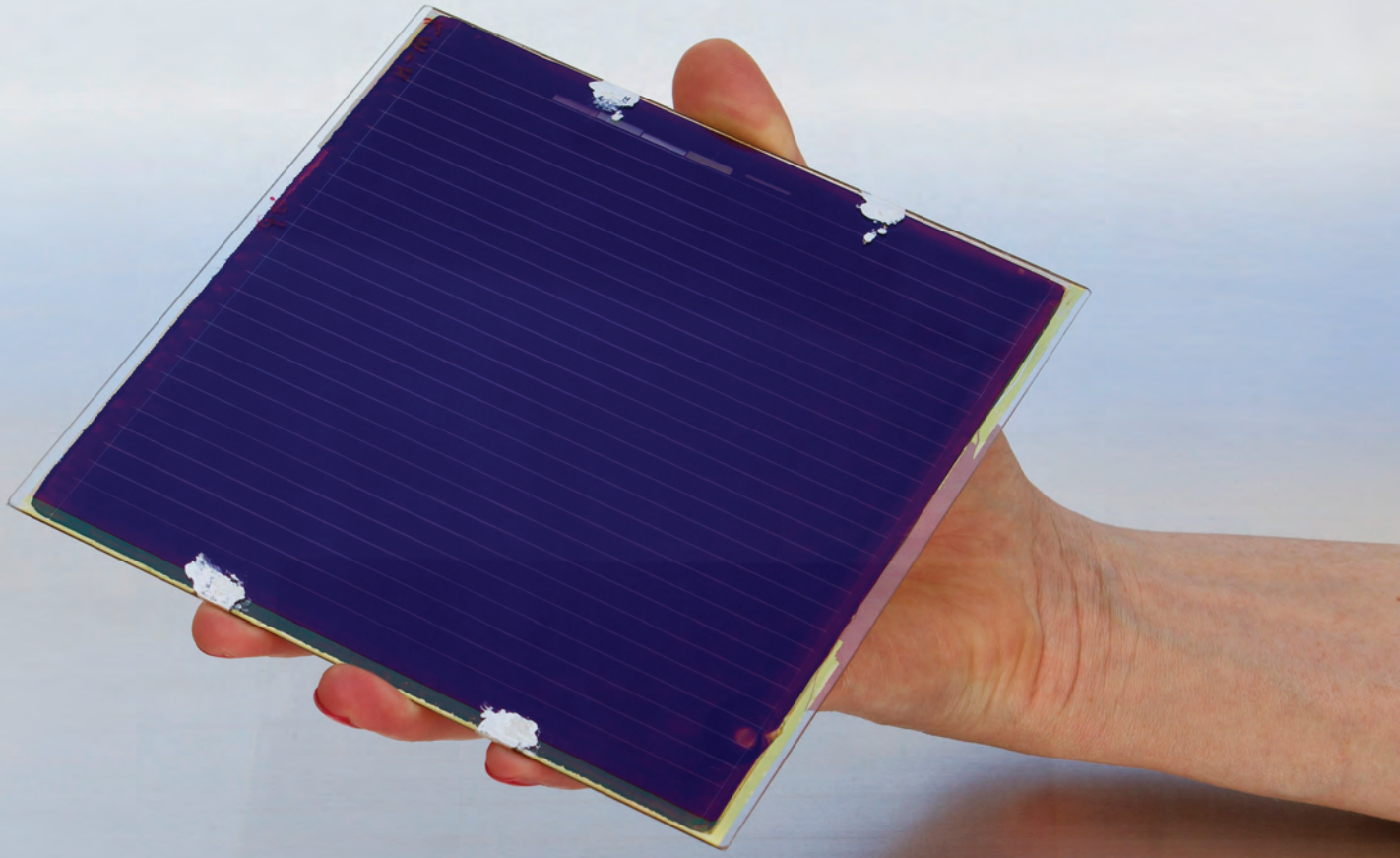
Helena Stange, co-author of the study, simulated the influence of the various types of defects on the diffraction signal. The in-situ observations fit extremely well with the simulations and with the results derived from different imaging processes used to study the samples in various stages of deposition by teams at the Max Planck Institute for Solid State Research in Stuttgart, the SuperSTEM Lab in Daresbury, England, and at the Racah Institute, Jerusalem.



An additional important result is that the temperature during deposition represents a relatively uncritical parameter for defect elimination. As soon as the layer reaches the copper-rich state, it makes little difference whether the process takes place at 400 degrees Celsius or 530 degrees Celsius.

This insight is also of assistance in improving the procedure for depositing onto large surface areas. Instead of trying to maintain as homogenous a temperature as possible over the entire surface, other parameters could be optimised.

he results have been published in Energy & Environmental ScienceEnergy & Environmental Science publiziert: “Annihilation of structural defects in chalcogenide absorber films for high-efficiency solar cells”DOI: 10.1039/C6EE00402D



Solliance paves way to upscaling perovskite PV modules

Holst Centre, imec and ECN partnership realises 10 percent efficiency on an aperture area of 168 cm2

SOLLIANCE, a partnership of R&D organisations working in thin-film photovoltaic solar energy (PV) in the ELAT region (Eindhoven-Leuven-Aachen) has demonstrated a record 10 percent aperture area power conversion efficiency for its up-scaled thin-film perovskite photovoltaic modules. The efficiency was measured on an aperture area of 168 cm^2.

25 cells were serial connected through an optimised P1, P2, P3 interconnection technology. The PV module was realised on a 6x6 $inch^2$ glass substrate using industrial scale-able slot die coating in combination with laser patterning. Furthermore, the PV module was packaged by applying a flexible barrier using a lamination process.

This result could be realised due to the intensive collaboration within Solliance. Based on previous optimisation on 16 cm^2 modules, the Solliance team was able to quickly transfer this to a 6x6 $inch^2$ sized glass substrate using the developed blade coating process and the optimised mechanical patterning technology. In this case a 156 cm^2 aperture area module with 10 percent efficiency was realised comprising of 24 interconnected cells.

This was then used as starting point for the realisation of above mentioned 168 cm^2 PV module. These results demonstrate the up-scalability of this new thin film PV technology. Apart from the electrodes currently used, all layers can be processed in ambient environment and at temperatures below 120°C. This shows the low production cost potential of this new emerging thin film PV technology.

Further, the deposition and interconnection technologies used for obtaining these results are industrially available for Sheet-to-Sheet as well as for Roll-to-Roll manufacturing. The latter allows for creating high volume production in the future. The current world record efficiency of a small lab scale perovskite based PV cell is 22.1 percent.

"The challenge is to upscale perovskite cells to larger size industrially process-able modules with high efficiency and long lifetimes at low cost. The current result, presented on an aperture area comparable to standard commercial silicon solar cells, shows that Solliance, with its in depth know how on processing of organic PV and CIGS and its vast Sheet-to-Sheet and Roll-to-Roll pilot production infrastructure, is excellently placed to realise this upscaling. These 10 percent up-scaled perovskite based PV modules are first and important steps in this development, " explained Ronn Andriessen, program manager of the perovskite based PV program at Solliance.

"We are confident to boost quickly the up-scaled Perovskite based PV module efficiency further above 15 percent by using very low cost materials and processes. But besides demonstrating the up-scalability of these highly efficient Perovskite based PV devices, we are also currently working hard to stabilise further the performance of these devices under real life operational conditions", he added. Solliance is conducting advanced research on the development of Perovskite based PV modules and its applications with its industrial partners Nano-C, Solartek, DyeSol and Panasonic. With this result the Solliance R&D partners and their industrial partners demonstrate the strength of their research framework for the development of industrial Perovskite based PV modules.

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Solliance partners are: ECN, imec, TNO, Holst Centre, TU/e, Forschungszentrum Jülich , University Hasselt and Delft University of Technology. Solliance is supported by the Dutch province of North Brabant, which has dedicated €28 million to Solliance. On June 12, 2014 Solliance opened a new large shared laboratory at the High Tech Campus in Eindhoven with pre-pilot production facilities, complementing the partner's labs which are also available to the other partners.

PV ribbon considerations when increasing busbars

Over the past few years as PV module manufacturers have begun to upgrade from three busbars to four, five or six, it has made their choice of PV ribbon far more important.

THE MOVE to more busbars

Crystalline silicon solar cells with a front-to-rear interconnection still offer a lot of potential for economic and technical optimization. Due to the ever increasing price of silver the recent development has focused on reducing the usage of silver paste in the cell metallization process. One approach is to increase the number of interconnecting ribbons on a cell and leave the cheaper copper to do the conducting instead of the silver metallization. In addition to the lower cost, the efficiency of the solar cells is improved.

Increasing the number of ribbons from the current three to four or to even six reduces the length of grid fingers, the fine silver lines collecting the electric charges from the cell surface to the ribbon. When the ribbons are closer to each other, the width and the thickness of the silver grid fingers can be reduced without increasing the power losses caused by the electric resistance in them. As in any conductor, the resistance is directly proportional to the length and inversely proportional to the cross sectional area of the fingers. If the length of the fingers is split in half, like when increasing the number of ribbons from three to six, the cross sectional area of the fingers can be split in half too without increasing the resistance. This means that 50% less silver paste is needed in the grid fingers.

In addition to the lower material cost, the narrower grid fingers shade the cells less. This reduces the optical losses caused by them. Typically the width of the grid fingers is 90-120 μm and the area about 6-7 % of the total cell area. With the new advanced printing methods the width of the fingers can be reduced to half of the present while maintaining similar thickness.

This increases the efficient area of the cells 3-4 % and more light gets converted to electricity. When the number of ribbons is increased from three to six, no additional electrical loss is caused due to the smaller cross sectional area of the fingers. In addition, when the overall width of the six ribbons remains the same as that of the three ribbons design, the gain of the increased cell area is directly seen as a higher energy output of the cells.

Increasing the number of ribbons on a cell requires a narrower ribbon to be used in order to not increase the optical loss caused by them. A width in the range of 1.0-1.2 mm could be considered with the four ribbons design and 0.6-0.8 mm with the six ribbons design. The ideal width, however, depends on the width of the silver busbar underneath the ribbon.

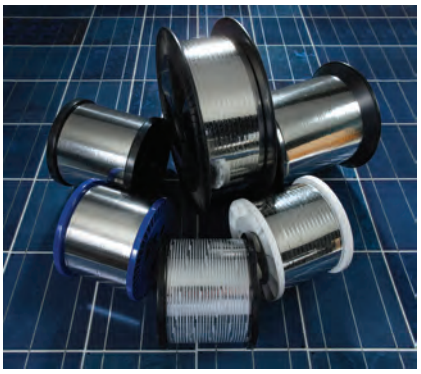
Using a wider ribbon than the busbar causes additional shading on the cell but a narrower ribbon does not bring any optical advantage either. Aligning a ribbon tab on a 1 mm or as narrow as a 0.6 mm wide busbar is not an easy task to do.

PV ribbon cost considerations

It is easy to fall prey to the lowest upfront cost solution when it comes to selecting PV components. After all, driving down the upfront costs of solar photovoltaic (PV) systems through the purchase of the lowest cost components may seem obvious. However, focusing on the long-term return of the project rather than looking only at a short-term payback period may deliver better financial returns. Even the financing of a PV project may come into play as investors are putting their money behind projects that use higher quality PV modules because they provide a better long-term return on the project with less risk.

Often these lower upfront costs are offset by lower long-term returns due to maintenance, under-performance, degradation or failures. Therefore, it is important to understand the value each component represents in the overall life cycle of the solar module. The time and effort to conduct a thorough comparison of the various PV system components can be time well spent.

The cost of PV ribbon is relatively small compared with the other components of a solar module. Then consider an industry-standard 25-year warranty and the life cycle performance expectations of a PV module. Do you really want to cut corners on the solar ribbon that lies at the heart of a PV module? In addition to the long-term performance considerations of a solar PV system, PV module manufactures should also consider the production costs associated with the components they choose. Increases in scrap, equipment downtime, and lower yields are a few of the financial consequences that can be incurred from the use of low-grade



PV ribbon. Some of the most common issues with low-cost ribbon include width variation, poor camber, and solder coverage issues – including bare spots. Solder coating thickness is often less than the specified value because the ribbon supplier is attempting to keep their own costs down. Any of these issues can cause increased downtime and can compromise the performance and long-term viability of the module.

The continued trend toward thicker ribbon and thinner cells necessitate a product that will allow module manufacturers to realize these changes without compromising performance and yield loss. As the ribbon becomes softer, maintaining low camber (straightness) becomes increasingly difficult. The ability of ribbon manufacturers to offer a product that is both soft and straight is crucial for the next generation of solar modules.

Yes – it is more complicated than simply choosing the lowest cost PV ribbon, especially when not all solar PV ribbons are created equal.

Key advantages of using Sunwire PV ribbon

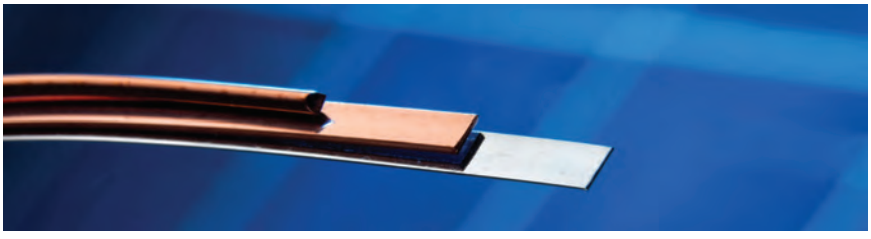
The evolution of Luvata's photovoltaic ribbon branded Sunwire® includes substantial reduction in camber, especially at the flanges of the spool. This, together with the extreme softness of the material, allows PV module manufacturer to align the ribbon precisely over the busbars of the cell to enable maximum electrical output.

The Sunwire manufacturing process is both integrated and highly automated, which results in a product of superior quality and consistency. The proprietary plating process is designed to deliver plating thickness consistency along with excellent solderability. The fully-automated spooling process ensures that winding is consistent from the beginning of one spool to the end of the next, resulting in reliable and predictable de-spooling for the customer on their stringer machines.

In addition to a manufacturing process that ensures full solder coverage on all sides of the ribbon, Luvata employs a proprietary vision system developed exclusively for PV ribbon to monitor the ribbon surface. This system continuously inspects both the top and bottom of the ribbon to ensure its consistent quality, cleanliness and dimensional conformity of each spool.

All of these factors contribute to reduce scrap and downtime, while improving yields for PV module manufacturers. Without a doubt module manufacturers' needs and requirements continue to change and PV ribbon manufacturers must keep pace. Sunwire has continued to evolve to meet these challenges and is today perhaps the flattest, straightest, softest and now narrowest PV ribbon available.

As PV module manufacturers look to increase the number of busbars, it is a opportunity for them to take a closer look at the impact their choice of PV ribbon has too.



About Luvata

Luvata is a world leader in metal solutions manufacturing and related engineering services. Luvata's solutions are used in industries such as renewable energy, power generation, automotive, medicine, air-conditioning, industrial refrigeration, and consumer products.

The company's continued success is attributed to its longevity, technological excellence and strategy of building partnerships beyond metals.

Employing over 6,400 staff in 18 countries, Luvata works in partnership with customers such as SolarWorld, Siemens, Toyota, CERN and Carrier. Luvata is owned by Nordic Capital funds V and VI.

Sunwire Evolution
Sunwire's evolution is the journey from where we began, to where we want to be in reaching grid parity and beyond.

From a product that made the automated mass-production of photovoltaic solar panels possible, to the straightest, softest, flattest and narrowest PV ribbon available on the market today.

Sunwire's evolution continues to bring notable leaps forward in the evolution of solar photovoltaic ribbon.

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THE PROFESSIONALS CHOICE FOR 20 YEARS

Xcell Automation may sound new, but for 20 years it helped the industry's top brands and contract manufacturers find success. Whether as ASCOR, Komax Solar, or Xcell Automation, their stringers have made modules by the millions for European, Asian and American solar markets.

XCELL AUTOMATION is not a new name in the photovoltaic (PV) industry. Xcell has been a key player in automating solar panel manufacturing since 1996. Its 20-year story of innovation demonstrates how far industry pioneers have come since igniting the renewable energy revolution.

CEO Brian Micciche is an automation expert whose gift for tackling challenging situations led him into the solar business. He was ASCOR's founder in 1994 when the company was organized to deliver custom automation solutions for various industries. He has led the company since its inception through its foundation, a merger with Komax AG in 2000, and finally through a management buyout (MBO) in 2014. They tackled their first solar energy automation project in 1996 and have been a major presence in the solar industry ever since.

In the early years of photovoltaic technology, manufacturing was more like a cottage industry than the global enterprise it is today. Manufacturers sought to bring cost efficiency, speed and precision to the forefront, and Xcell's knack for turning challenges into opportunities was game changing. The company grew by automating various processes as solar prospered. In 2000 the company became part of the Komax Group. That relationship provided the capital and global footprint necessary to become the market leader for solar cell stringing machines. Believing in the long-term potential of solar energy, the management took over the business again in 2014 through the MBO.

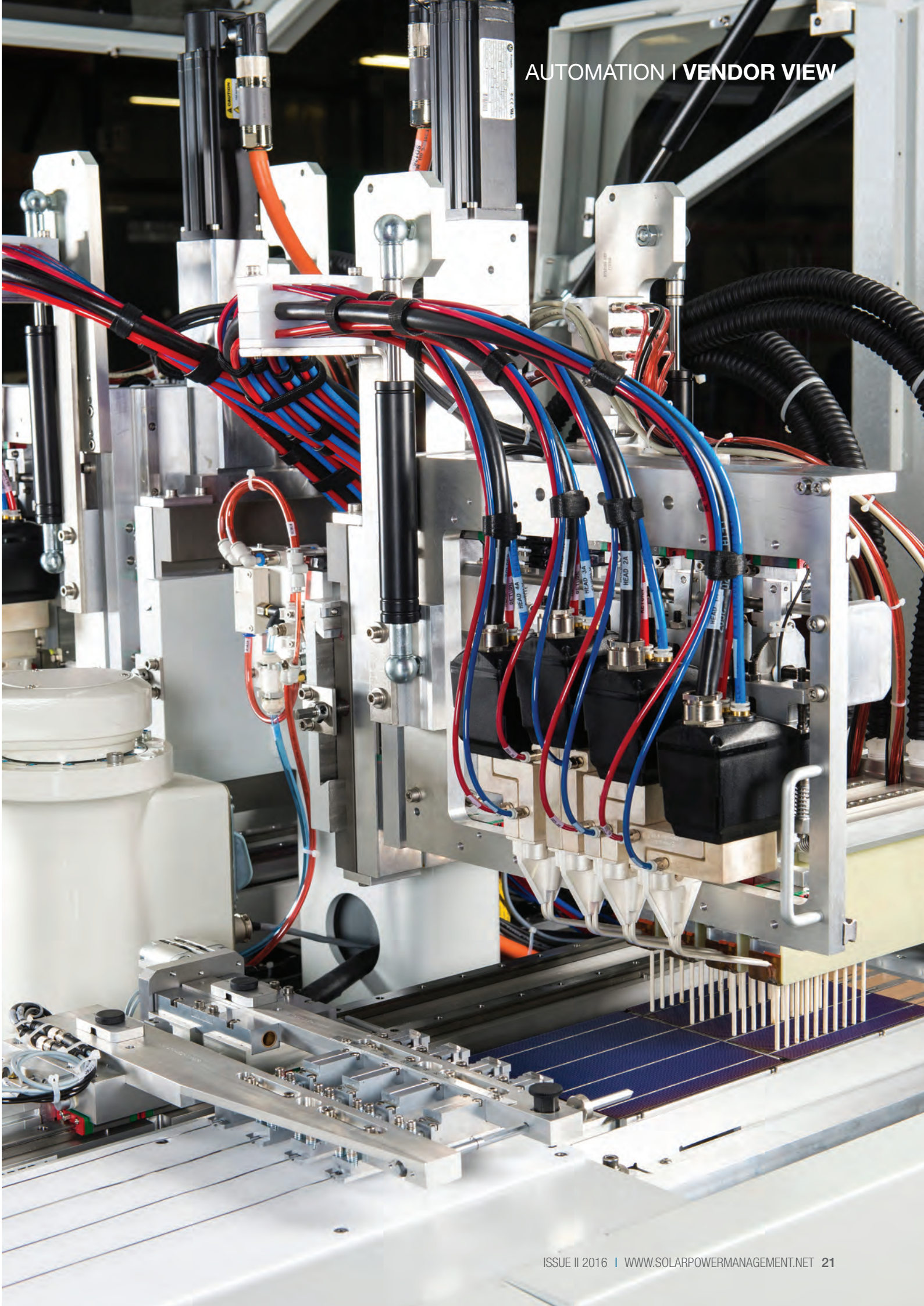
"If you look back at how we got into the solar business, it was because we were very good at automating and customizing assembly applications for a variety of industries. That led us to develop custom applications for early solar manufacturers," Micciche said.

Xcell now offers a highly-flexible line of stringers and layup systems used to interconnect solar cells into panels/modules. In a sense Xcell Automation is two companies in one. Its standard products customers benefit from two decades of international solar energy experience while its innovation experts work with customers to solve today's most unique problems. Each aspect complements the other.

Today the company's X3 stringer is a flagship product, with throughput of up to 1,800 cells per hour and the ability to handle all bus bar layouts and half-cell formats as well as mono, poly (P- and N-Type), PERC and bifacial designs.

"Stringers in solar manufacturing basically do one thing: they apply wire. But the big difference between one stringer and another is how they solder," Micciche remarked. "We now offer standard equipment as well as custom solutions. Meeting custom requirements was our beginning and the fact that we are still doing it today is evidence of the faith our customers place in Xcell Automation."

At their most fundamental level, stringers 'apply wire' as Micciche said. But the beauty of what they do lies in what separates one from another. Xcell Automation products can be defined in a sense by how well they solder. Across the industry, stringers use either infrared (IR) lights, lasers or induction to solder energy-carrying wires and bus bars onto silicon cells

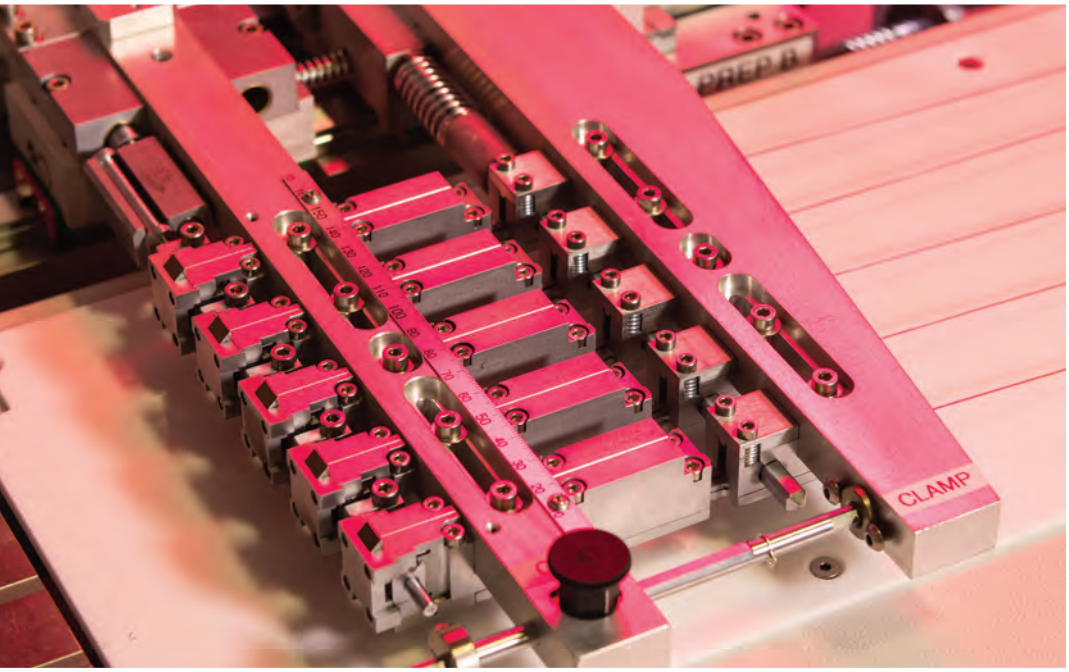

HEAD 4A
HEAD 3A
HEAD 2A

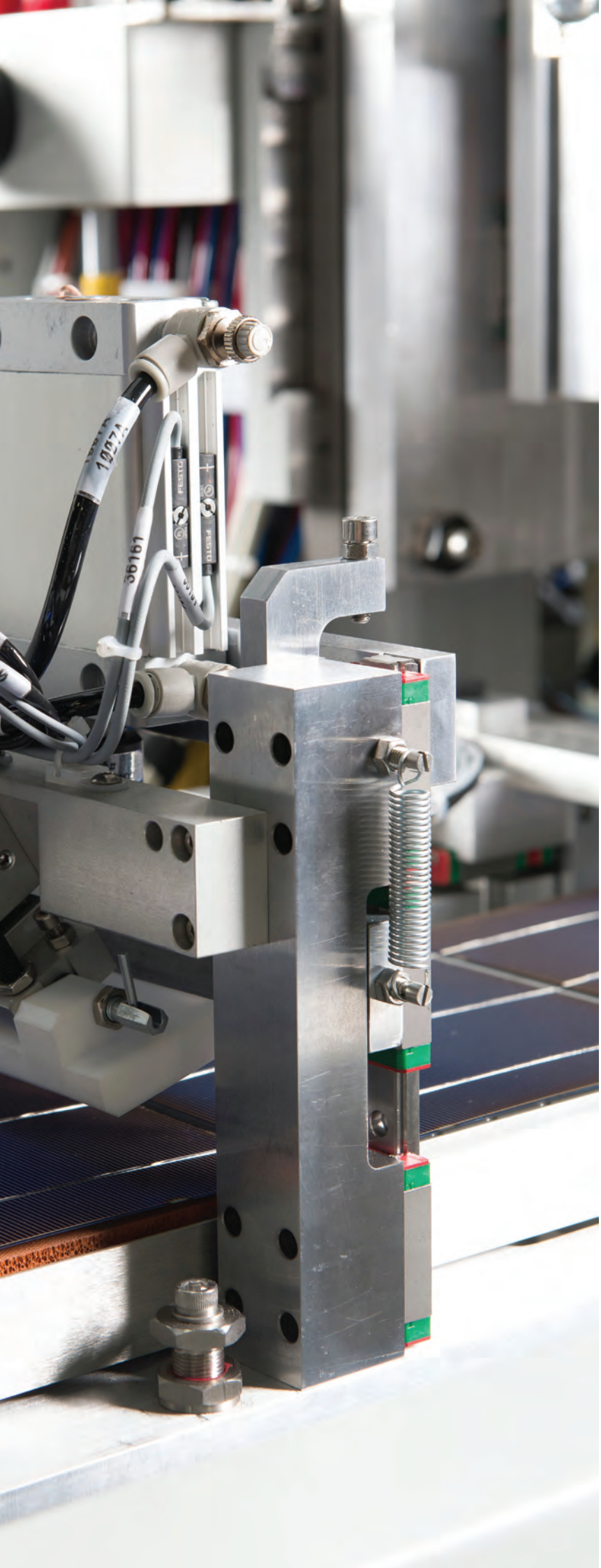
that go on to become PV modules. Xcell Automation determined that the precise control afforded by induction soldering gives their customers the best throughput, accuracy and energy efficiency.

"We have been offering induction since in 2006 and have fine-tuned processes since then," said Micciche. "Induction allows for real time, closed loop control of the soldering process per bus bar. Because our machines are so flexible and programmable, once an ideal solder 'recipe' is determined, it can be saved and returned to at any time. This allows the customer to switch back and forth between different products quickly and to be assured that the precise temperature profile will be followed. It also offers the lowest total cost of ownership compared to other solutions, cutting energy consumption by as much as two-thirds."

'Flexibility' comes up often when Xcell's leaders talk about their products simply because of the large variety of open market solar cells that go into finished modules. This is a challenge ideally met with highly flexible stringers like Xcell's X3. "The world's largest contract manufacturers rely on the flexibility of Xcell's stringers due to the large variety of cells that they must interconnect. As much as 80 percent of the solar market can use stringers like our X3. But the other 20 percent need a truly customized product," stated Xcell sales and marketing vice president Pete Kostic.

"As one example among many others, we made a custom tool for 3M to apply their conductive adhesive tape to the aluminum back side of a solar cell, which eliminates the silver printed bus bars on the rear side. After this tape is applied onto the cell, it can





be soldered together in a traditional stringer using normal commercially available copper ribbon," Kostic noted. "Like we did in this example, we can work with our customers to develop their technology and then scale with them as they go into mass production. As we scale with our customers, value engineering is key to minimizing their capital expenditures."

Another challenge Xcell Automation has mastered globally is greenfield solar plant installations.

"Xcell automation has cooperated with numerous customers to implement greenfield factories in various low labor cost regions of the world. These greenfield factories present many challenges that range from facilities and general infrastructure to human resources. Xcell has demonstrated over and over again that we behave as a partner and are committed to the end result, assuring that the customer is achieving their goals," Micciche said.

"We evolve along with our customers. We are more flexible and dynamic as a private company now. Customer input is vital, and they respect our expertise. We are very willing to work with our customers in very private ways developing technologies that interest us both," he added.

In 20 years, Xcell Automation has not only seen the industry change, but has driven many of the changes that enabled manufacturers to work more efficiently and to compete globally. Xcell helped take solar cell manufacturing to the point in 2015 that analysts labeled renewable energy (mostly solar) as the fastest growing energy resource in the world.

As CEO Brian Micciche remarked, Xcell is a 'soup-to-nuts' company that leverages its customization expertise to make world-class standard products. Uniquely, Xcell can also take custom ideas from the prototype stage all the way to high volume production, using value engineering to maximize their partners' investments. Xcell also works with world-renowned research laboratories and facilities including Fraunhofer ISE (Germany) to stay abreast of technologies that seem to change almost daily. And as a highly-flexible private company they are able to partner closely with customers through exclusive arrangements, joint ventures and just about any other conceivable business relationship.

"We have the flexibility and willingness to spend time with the customer to develop the tools that support where they want to go. We are here to help you develop the next Big Thing," Micciche said. With an industry-leading 20 years' experience and satisfied customers across the globe, Xcell Automation is a manufacturer's best choice for achieving their ambitious goals.

CAN SUNEDISON RISE AGAIN?

The bankruptcy filing by solar energy behemoth SunEdison says more about the global energy investment market than it does the long-term health of renewable energy.

SUNEDISON'S historic rise as a top-tier renewable energy company made it a darling of investors well beyond the purview of traditional photovoltaic (PV) supporters. But its fall tells us more about investing practices than it does the future of renewable energy as an industry.

What we learn from SunEdison is a cautionary tale of how analysts and brokers recommend stocks. No surprise: they recommend money makers. But how closely do they look at how the profits are made, and whether profits are sustainable? After the Great Recession we learned that loose lending practices coupled with faulty, reckless investment strategies cratered the world economy. Unrealistic profit expectations also led to ends justifying means. But what is unrealistic? Is it surprising that the market fell in love with SunEdison because it delivered gains when others were losing or delivering comparatively average results? Not at all; it has happened again and again.

SunEdison enjoyed early success, which investors noticed at a time when traditional energy companies were on the wane. SunEdison profited from its yieldco model, a process of creating public subsidiaries to operate solar farms that fund a parent company's operations and pay dividends. It was not a normal profit motive but rather SunEdison's years-long acquisition spree that created the appearance of healthy growth when real profits lagged. It is widely held now that the company's fall was mostly its own doing, but it had plenty of enablers in the form of bankers, who pocketed fees with each acquisition, and investors, who reaped attractive dividends at a time when other economic sectors were struggling.

To dig into what happened with SunEdison one needs to examine broader markets and energy stocks in particular. Remember that a diversified investment portfolio has for decades meant some involvement with fossil energy stocks. But business-as-usual in the oil patch has been far from 'usual' since hydraulic fracturing (fracking) grew quickly out of the ashes of the Great Recession. By 2012 it provided more than 2 million jobs in the US – no small feat for a new kid on the block. Fracking may have been around since the 1950s, but it wasn't until the practice matured and world oil prices were high that potential gains seemed to outweigh risks.

Energy companies with fracking operations in the US were making a serious contribution to world fossil fuel production levels by 2012. Their impact started to upset the grip of OPEC and other major producers. Oil was trading two years ago at more than $120 (USD) a barrel; moneyed investors were happy. But in 2014 oil prices started to solidly slip due in part to new producers – the frackers – upsetting energy paradigms at a time when energy demand had started to fall.

In well less than a decade large-scale fracking established itself and the United States went from being a net importer of natural gas to a net exporter. Coal production plunged; the stability of coal as an industry was challenged. Eventually the largest coal producer in the US – Peabody Energy – would file for bankruptcy protection (13 April 2016). It is no wonder that investors were looking for new ways to generate cash. When asked for alternatives to Old School Oil financial advisors replied, 'how about investing in something everyone needs – energy – but this time it is renewable energy from the sun?' Too many investors said: 'sign me up.'

SunEdison's prospects looked bright when other energy sectors were suffering. The company seemed to have a no-fail system for building solar energy projects that paid regular dividends. The company began an acquisition spree in 2014 fueled by yieldco profits to keep the growth going.

What was not apparent then was that yieldco profitability can drive a buy/sell mentality that generates cash but also creates the appearance of long-term growth. This can be an addictive cycle that drives corporate managers to purchase too many assets to sustain a growth façade.

In July 2015 SunEdison could not have looked better to investors. Yet even as its fortunes seemed to head only up the tide was turning. While SunEdison was rising the world also got a look behind the curtain of China's economic forecasts; things were not rosy. Investors who had been bullish on China bailed. Money raced into other ventures including SunEdison even while world stock markets started to reel from the China news. This unsettled world oil markets that much more, adding proverbial coal to the fire that drove investors to find a 'better' energy portfolio. SunEdison's strategy was flawed, but few noticed.

After the dust settled, Jenny Chase, head of solar analysis for Bloomberg New Energy Finance remarked that, "It doesn't work to try to be the biggest and get the biggest market share at the expense of profits." Well said, even if late in the game.

SunEdison's acquisition spree included some sizeable names in the renewable energy sector, notably TerraForm Power and Vivint Solar. SunEdison paid around $2.2 billion (USD) to purchase Vivint's rooftop solar business, also in the summer of 2015. That deal came just before markets turned truly

bearish and the United States Federal Reserve hinted again that an interest rate hike was coming – the first since 2008.

"One of SunEdison's problems was that they had no idea what was going on within its (own) divisions because it had so many of them," said Chase.

In defense of what is and isn't possible for the average investor, almost none have the access needed to see inside a CEO's mind. That's why institutional investors created mutual funds that promise to play watchdog so the 'average' investor doesn't have to pour over countless annual reports and quarterly statements. But who is watching the watchers? SunEdison was creating subsidiaries so fast that it could not possibly assimilate them all. Worse still, the pressure on a publicly-traded company to continually show growth had led SunEdison to pay a lot for its acquired companies; financing its debt was about to get more expensive.

SunEdison's bankruptcy says more about management strategy and investment advice than about the solar industry. Companies such as SunPower and First Solar have managed businesses similar to SunEdison's, but without acquisition spending sprees. They are doing comparatively well.

SunEdison's stock took a drubbing before it was delisted. It peaked at $33.40 (USD) a share in July 2015, falling to $0.34 a share before it died. In its bankruptcy filings it declared assets of $20.7 billion and liabilities of $16.1 billion. Amongst its top vendor-creditors is PCS Phosphate Company, which it owes $193.64 million.

Before its bankruptcy SunEdison sold assets including the UK portion of its rooftop solar business that went to British company Ecotricity. Remarking about the purchase of SunEdison properties, Ecotricity founder Dale Vince said, "This is an exciting and important step for Ecotricity. As a company, we want to help more people generate their own power at home. The government's cuts to the feed-in tariff, and its broader attack on the renewables industry, have caused a significant problem for companies like SunEdison: we have seen some go bust and others quit the UK market as a result, (costing) a lot of jobs…as the price of the technology continues to fall, we're confident that it's only a matter of time before we can resume the work SunEdison started and help more homes take advantage of solar power." How about that? A business strategy that values sustainability and long-term growth, something SunEdison needed.

While some companies like Ecotricity benefited from SunEdison's buying binges, others face consequences. SunEdison announced it will permanently close its Pasadena, Texas polysilicon production plant later in 2016. It also has an agreement to sell its Malaysian wafer facility to LONGi and analysts are openly pondering the ultimate position of its polysilicon facility in South Korea. More wreckage is looming.

SunEdison's slide from being a 'do-no-wrong' company to 'bankruptcy icon' says more about the dynamics of international investments and stock market valuations than it does anything else. Bloomberg New Energy Finance reported in March that global 2015 investments in clean energy reached $285.9 billion (USD), up 5 percent. Installed clean energy capacity reached 134 GW, up from 106 GW in 2014 and – perhaps most strikingly – that the relative importance of developing countries continues to increase as these nations adopt renewable energy faster than they choose fossil-fueled power.

While SunEdison now serves as an example of how not to succeed in renewable energy investment, there are plenty of companies worldwide that are working within the system for the benefit of consumers, investors and the planet.

Look closely when an investment advisor says, 'this company cannot lose.' Everyone loses occasionally. What matters is their long-term sustainability plan and willingness to make good profits for investors without unreasonable risk-taking.

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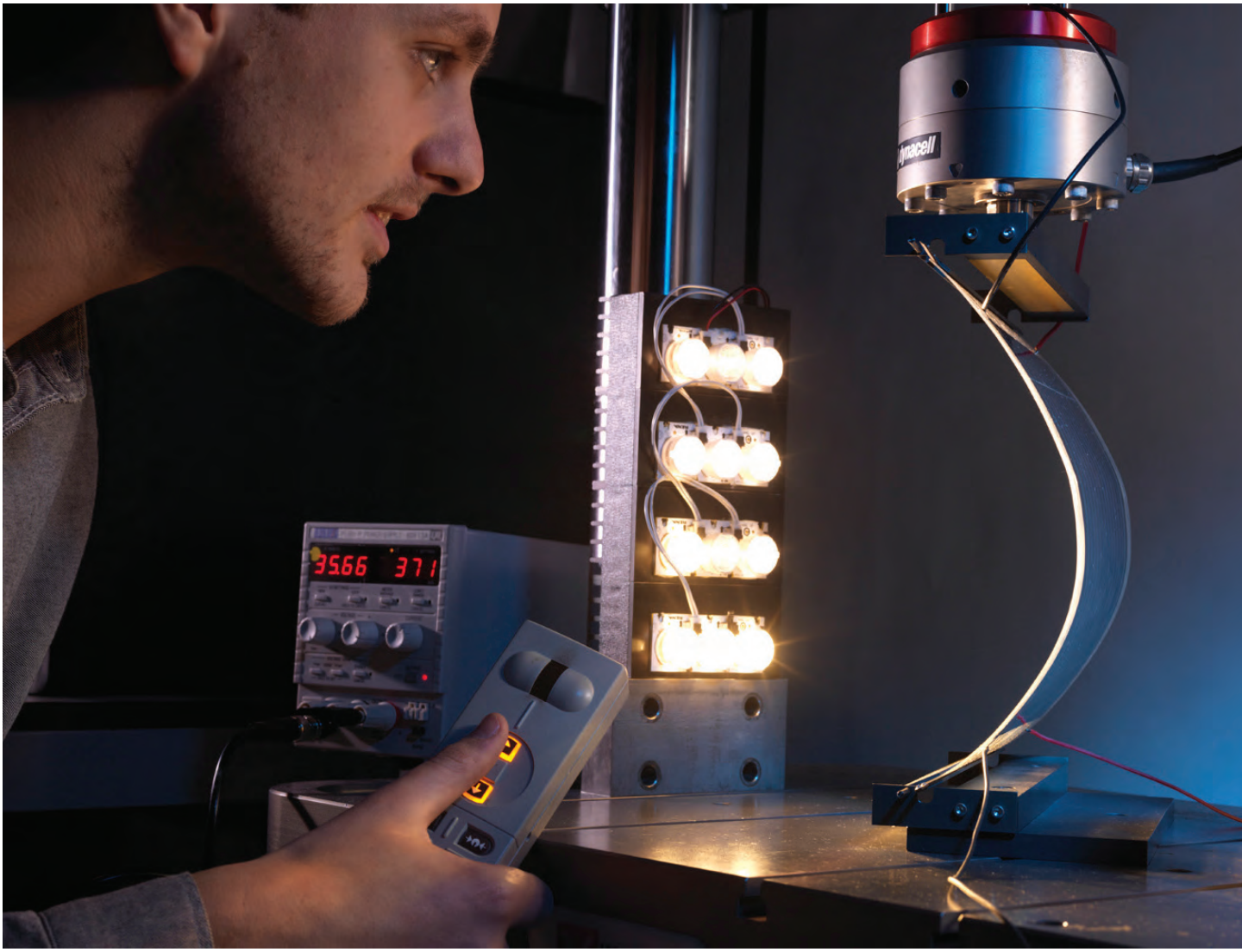

Breakthrough techniques fuel next-generation PV cells

The EU-funded TREASORES Project team including Eight19, a Cambridge University spin-out company, have succeeded in developing techniques to manufacture roll-to-roll (R2R) photovoltaic (PV) solar cells that are efficient, flexible and cost-competitive.

IT STARTED THREE YEARS AGO as a European Commission project to enhance the cost effectiveness, performance and manufacturability of organic photovoltaic (OPV) solar cells. Participants not only succeeded, but along the way developed new processes and techniques that can change how the solar industry creates thin film PV cells.

While its charter concept was simple on paper, the feats accomplished by 15 TREASORES project partners involved nine manufacturers and six research institutions in five nations led by the Swiss Federal Laboratories for Materials Science and Technology (EMPA). The project's daunting name

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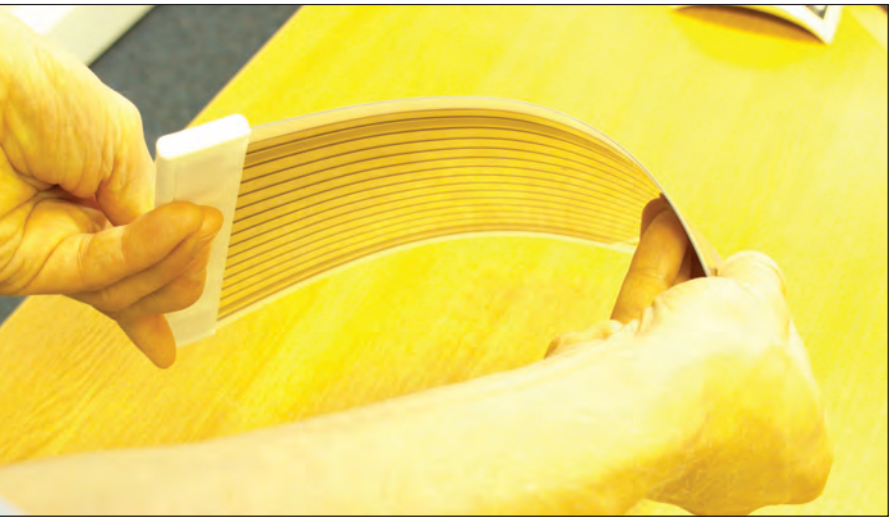
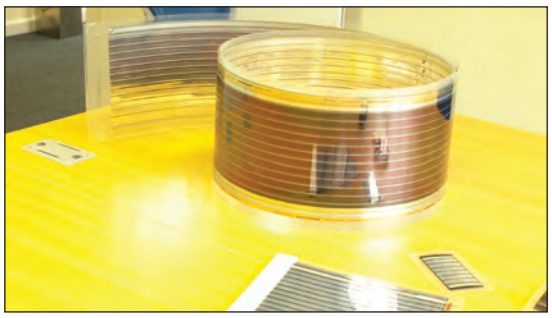




(pronounced 'treasures'), belies its bureaucratic roots, yet nevertheless sheds light on the challenges participants faced. TREASORES represents the EU's bid to create Transparent Electrodes for Large Area Large Scale Production of Organic Optoelectronic Devices.

Consider the project's scope. The European Commission asked participants to: make solar cells remarkably flexible; create new generations of electrodes; make processes applicable to organic light emitting diodes (OLEDs) as well as PV cells; make their new flexible electrodes transparent; make everything inexpensively; eliminate as many toxic materials as possible; cut greenhouse gas (GHG) emissions and create cells that are manufacturable using conventional techniques such as those used to print plastic signs and banners. The EU also asked the group to do it all in three years instead of the usual five or more years that EC-funded programs frequently allow.

No problem

By the project's mid-term review, participants had already made great strides toward the goal of low-cost solar cell production technologies. Flexible OPVs have great potential because they require only a minimum amount of comparatively inexpensive materials to produce and can be manufactured in large quantities by roll-to-roll (R2R) processing like those used to create plastic signage. But to be successful these devices also require transparent electrodes and flexible active and non-conductive barrier layers.

One of the key challenges in making flexible OPV cells is getting the electrodes that help collect and transfer electricity to be highly bendable. They need to also transmit as much light as possible; totally clear would be ideal. Greater transparency means the electrodes can collect light more easily and at the same time not create barriers to light reaching photosensitive layers. Conventional solar cells that dot rooftops and the landscape are often rigid and optically opaque— light doesn't transmit through them and their brittleness and weight (not to mention production costs) makes conventional c-Si PV cells impractical for many applications, especially in off-grid areas and developing nations.

Transparent electrodes

More than 20 types of flexible, transparent electrodes were tested in the program. It became apparent early on that the definition of 'best electrode' depends on its final application. For example, a very smooth surface is crucial for high quality OLEDs, but less important for OPVs. Also, if the solar cell will be installed on a curved surface, the electrode's electrical resistance should not change spatially— doing so would reduce overall module performance.

Materials tested included carbon nanotubes, copper fibers and silver, chosen in part because they were either already available commercially, or were expected to enter markets in 2016. The new electrodes have been tested with several types of optoelectronic devices in R2R printing setups using rolls of over 100 meters in length; they were found to be especially suitable for next-generation light sources and solar cells.

Setting new standards

Currently there are no industry-wide standards for flexible, transparent electrode characterization and classification. As part of TREASORES, and in collaboration with the Versailles Project on Advanced Materials and Standards (VAMAS), the National Physical Laboratory (NPL) developed a map of the landscape of current and upcoming standards in the field, which was published as an open report.

Having identified what was missing, NPL worked with TREASORES project partners to develop a robust test procedure to allow reliable and independent comparison of the different transparent and flexible electrode technologies being developed.

"Engagement across the value chain was key to

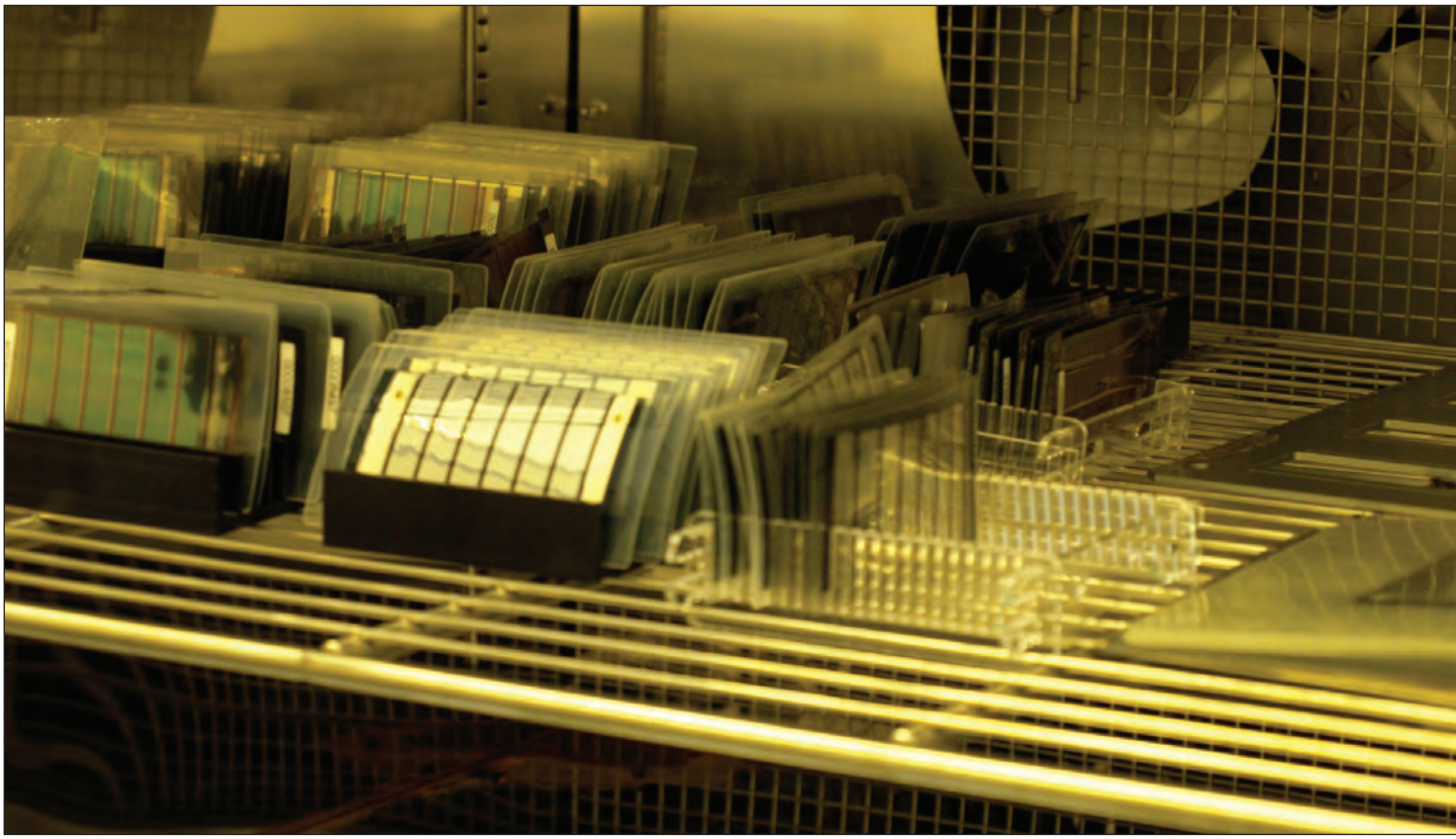
ensure the development of a reliable test procedure for independent comparison and classification of different flexible, transparent electrode technologies at the National Physical Laboratory," said Fernando Castro (PhD), principal scientist, NPL. Castro led NPL's TREASORES efforts as lead scientist.

The NPL developed pioneering test methods that allow in-situ measurement of electrical performance of not only the flexible electrodes but also of complete flexible solar cells. It is also working on the development of an international standard making use of the know-how developed during TREASORES. Castro acts as a UK expert within the International Technical Committee 119 – Printed Electronics of IEC (International Electrotechnical Commission) to generate internationally agreed upon measurement procedures to assess the electrical stability of flexible, transparent electrodes under mechanical stress.

The NPL's test rig measured the device power conversion efficiency of Eight19s flexible modules while they were bent repeatedly. The initial results were very encouraging as no reduction in performance was observed after 200 bends to very small radii. One concern was that repeatedly bending the module might fracture or damage the encapsulating adhesive protecting the device from oxygen and water in the air, which would reduce its lifetime in the longer term. However, a blind accelerated aging test comparing non-flexed modules with modules after being subjected to continuous bending showed no difference in performance or lifetime. These results are extremely encouraging, researchers said.

"We feel that Europe is a leading force in the photovoltaic area. The EC funded (TREASORES) well and we built up quite a head of steam. So the main remaining challenge now is to carry this over into full manufacturing. The R2R industrial capabilities already exists across Europe including handling the film materials….In principle our processes rely on those types of machines, so (transferring technology) should be straightforward," remarked George Dibb (PhD), higher research scientist, NPL.

TREASORES was not specifically created as a private sector employment stimulator, but it was apparent from the outset that creating low cost manufacturing techniques mainly utilizing existing infrastructure and R2R capabilities could have that net effect: more manufacturing jobs. While the new OPVs have not yet entered full production, it is clear that companies like Eight19 Ltd are headed in that direction. The opportunity for other manufacturers is clear. "While labor costs are higher in Europe, with R2R the issue isn't staffing—the manufacturing can be



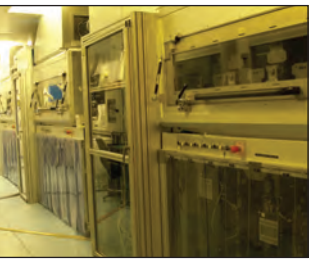
> “The NPL’s test rig measured the device power conversion efficiency of Eight19s flexible modules while they were bent repeatedly. The initial results were very encouraging as no reduction in performance was observed after 200 bends to very small radii”

done with smaller staffs, and the low materials costs outweighs labor costs. The challenge becomes getting the right people and training them effectively,” remarked Jurjen Winkel (PhD), principal scientist, Eight19 Ltd.

Making a better OPV cell

The highly flexible OPVs structure is usually built up layer upon layer on a transparent plastic base. The exact compositional nature depends on the type of electrodes used. Layers can be applied as aerosols or as a mesh created and then applied. Eight19 Ltd. specializes in transferring techniques and processes developed in a university setting into medium- or high-volume manufacturing. While a number of approaches were tested, Eight19 favors layering barrier and electrode sections to create an electrically viable and encapsulated device stack. When complete the stack can be only one micron thick - a fraction that of a human hair, which is typically 70-times thicker.

The group explained another important discovery they made was the significance of keeping all layers within the OPV cell very dry by using a nitrogen processing environment. Further, that encapsulating active layers with protective coatings as quickly as possible was also key. Early tests determined that some manufacturers had accidentally embedded an undesirable amount of water in test cells, specifically in the flexible plastic substrate layer. Water can inhibit or further compromise a solar cell’s performance. The NPL used its capability to measure water contained in plastic films and this collaboration was crucial to the development of water-free transparent plastics.



Looking ahead

How techniques pioneered and perfected by the group are utilized and promoted is up to the EC and participating organizations. There may be licensing in the conventional sense. Some participants organized to take research ideas and productize them for manufacturing such as Eight19 Ltd. will determine how to incorporate ideas they created into future company projects.

In the course of TREASORES, the group found that the current lack of standard test methods for flexible and transparent electrodes slows down progress as results obtained from different companies cannot be reliably compared. During this project the NPL developed a robust test methodology to allow classification of the key properties of different electrode types (more than 20 were tested) and ranking, depending of specific end user requirements (OPV, OLED, etc.)

Applications for new OPV cells include all the areas that conventional mono- or poly-crystalline silicon cells have not already found a niche—practically anywhere that low cost, flexibility, weather resistance and indoor/outdoor performance is important. TREASORES has already tested cells from the mid-point of the project in Uganda for more than a year and the results were very positive.

The group expects OPVs to be incorporated into building materials (roofs, cladding, and other super-structure components), so an entire building could contribute to the energy needs of its occupants. In addition to traditional rooftop or field array solar generating projects, OPV device technology could be leveraged by internet of things (IoT) designers so that the low-level power needs of wearable electronics, in-home devices and other applications could recharge themselves whenever exposed to light. Indeed, several of the OPV test devices responded best to light spectrums typically encountered indoors or in very northern or southern latitudes, so their efficiency actually increases in some settings.

“As a result of the project we demonstrated that we can analyze OPV materials from start to finish and involve the entire supply chain. Also, an electrode with a barrier layer can be configured and produced at the same time. We also demonstrated the testing of flexible electronic modules and methods for standardizing barrier materials and their electrodes can collectively drive forward manufacturing as shown by some really great demonstration devices from within the project,” Dibb remarked.

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Intelligent solar home systems set to transform rural energy access

Off-grid solar is becoming the "new normal" for providing basic electricity services in emerging countries.

ACCORDING to the 'Off-Grid Solar Market Trends Report 2016' report published in March 2016 by Bloomberg New Energy Finance and Lighting Global (a World Bank program), the off-grid solar market has experienced impressive growth across the globe over the last 5 years. Examples of these products include portable lanterns and solar home systems, thanks to technological advances in LED lights and the transformative power of mobile payment. In Kenya, more than 30 percent of people living off the grid have a solar product at home the report estimates.

Azuri Technologies was a pioneer of the 'pay-as-you-go' solar home system technology in Sub Saharan Africa in 2011, where mobile phone networks are combined with solar technology to offer energy and appliances as a service. Today we see off-grid solar is advancing rapidly beyond just lighting and phone charging. Lighting remains an essential offering but it's clear that consumers want, and increasingly expect, more. This evolution has been enabled by the growth of pay-as-you-go technology, which removes

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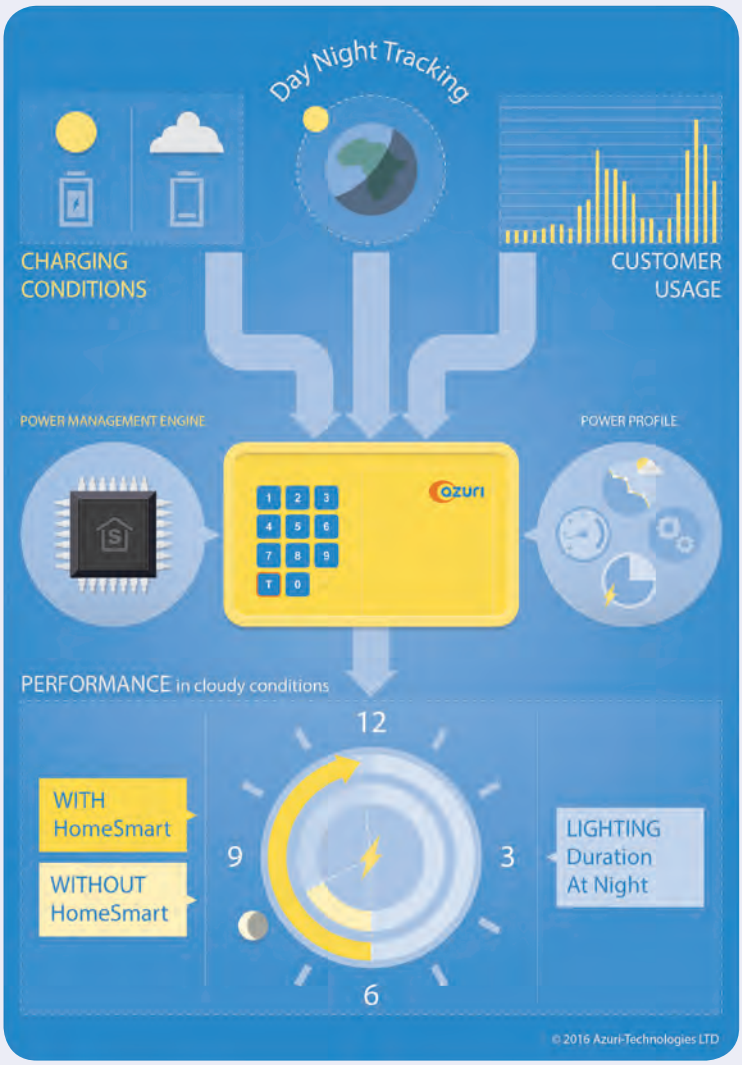
the high initial cost of products and replaces it with a subscription fee. Solar home systems capable of powering appliances such as TVs and fans are likely to capture an increasing market share and in rural Africa, the demand for such energy-consuming services is expected to increase hugely in the coming years. According to a new study on the impacts of small-scale electricity systems by the International Institute for Applied Systems Analysis (IIASA) and the World Resources Institute (WRI), it is not just whether or not you have electricity but whether it is reliable, affordable, and sufficient to power different services.

"Permanent light"; Come rain, or shine

Historically, it is this question of reliability that has been the unstated drawback of the thousands of small solar home systems that have brought power for the first time to off-grid consumers in sub Saharan Africa. The systems store power during the day and provide light, phone charging and other services at night. But they all suffer from a common problem: on days where there is insufficient sunshine, the systems turn off early at night time, leaving households in darkness. It is difficult for customers to have confidence that their light will work all night. An effect similar to that of "range anxiety" now emerging in electric car users.



Customers require certainty that when the light is switched it will come on, irrespective of whether the previous day was sunny or cloudy. It is possible to manually dim systems but few people do and this requires unnecessary user intervention. The challenge is to have a fully automatic system that delivers just the right quantity of power all through the night. With this in mind, Azuri Technologies has developed a technology solution for its solar home systems to solve this problem. Its HomeSmart™ technology is the first use of intelligent automation in small solar home systems, designed to provide light every night even in cloudy daytime conditions, and effectively eliminate "solar range anxiety".

HomeSmart first works out a performance target by monitoring or 'learning' the customers' typical power usage. This becomes the performance the system aims to achieve under all conditions, a bit like the way a smart thermostat does for the latest domestic central heating. At night, if sufficient stored power is available, the system operates like normal. However, if the stored power is reduced, (because there was insufficient sunshine during the day), the system subtly adjusts the brightness of lights and the rate of phone charging in order to meet the duration of light that the customer is used to. These changes are normally imperceptible to the eye. In this way, HomeSmart brings "permanent light" to consumers for the first time. The machine-learning is a combination of measurement and heuristics to turn historical usage patterns into a demand target that the optimisation engine can deliver to. Just as Azuri's PayGo removes financial and product risk from the consumer, HomeSmart helps take away any operational concerns. The customer no longer has to second-guess how much sunlight there has been or how much the lights have been running as their system itself can be relied up to deliver the expected performance every day.

Affordable access to reliable power

The HomeSmart power management system features in the latest solar home system, Quad, to be introduced to the off-grid market in Africa. The entry-level product features a 10 watt solar panel and long life Lithium Iron Phosphate batteries, with high quality LED technology to light a whole rural household for 8 hours per night and a USB port for phone mobile charging. Just like the other solar home systems in the product range, Quad is unlocked for use by the purchase of top-up credit, and while bringing a new level of quality and intelligence to the rural off-grid

market, still costs less than the kerosene and phone charging fees being replaced. A customer can top-up their Quad product, either weekly or monthly, via mobile money over a mobile phone.

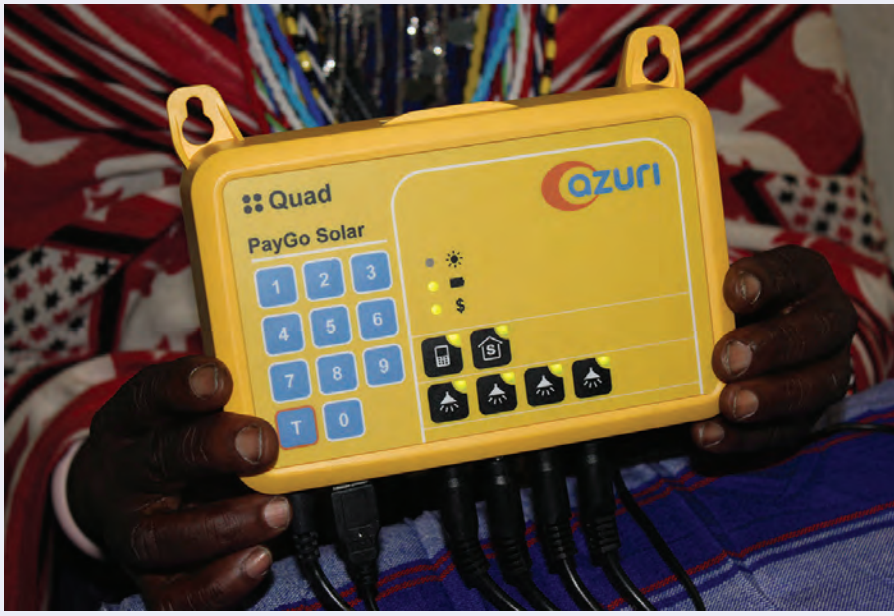
These regular top-ups pay off the cost of the system over a period, after which the customer can choose to either "unlock" it with a special code and access energy freely, or move up the 'Energy Escalator' by upgrading to larger systems and higher value services. Quad is designed with durability in mind, to cope with a harsh rural environment and to ensure that off-grid customers can still access quality home lighting and mobile phone charging long after they have finished their payment period.

The aim over time is to enable families to access progressively more electricity and ultimately enjoy 'full-home electrification' with light, phone, radio, fan, TV and Internet access. HomeSmart reflects the company's commitment to enabling rural African consumers to benefit from top quality products whose performance and efficiency exceeds that found in most typical homes and businesses in developed markets.

A smart solar future

Unlike the 20th century, where technology originated in "developed" markets and eventually found its way into emerging economies, we are seeing solid evidence of "reverse innovation", where the latest technologies start in emerging countries. The use of mobile money in Kenya is the poster-child for this, where approximately 30 percent of the entire country's Gross Domestic Product is transacted over mobile money. But this is by no means the only example. Companies are experimenting with drones to deliver vaccines where roads have been washed away, and large information systems are being used to optimise the way services are being delivered to rural communities.

While we are beginning to see the idea of self-learning intelligent automation appear in high-end households in developed countries, Azuri's HomeSmart is the first time that such intelligent technology has been applied to entry-level solar home systems. However, the impact in off-grid communities is much greater. In a developed nation, intelligent automation may save around 25 percent of energy costs. In a developing nation it's the difference between being able to see at night and not. Smart meters, devices and technology are changing consumers' relationship with energy consumption. While Western consumers may still require some convincing about Smart Tech in their homes (because energy is, by comparison, plentiful), in rural Africa the use of smart home technology is being rapidly adopted. With the emergence of the



Fourth Industrial Revolution the home is an extension of the customer. Rather than the occupant adapting to the home, the home works for those who live inside it.

The development of AI and other technologies for application within the home are gaining increased attention, with Facebook founder Mark Zuckerberg recently highlighting the potential of AI within the home. HomeSmart is the latest step in Azuri's 'Designed for Life' family of best-in-class solutions specifically aimed at today's increasingly tech-savvy rural consumer.

In Africa alone, 590 million people lack viable power. There is huge potential opportunity for energy efficient solar technologies like HomeSmart to transform rural energy access across Sub-Saharan Africa. We are at the start of a rural market movement that is defining the energy efficiency experience of the future.

Smart meters, devices and technology are changing consumers' relationship with energy consumption. While Western consumers may still require some convincing about Smart Tech in their homes (because energy is, by comparison, plentiful), in rural Africa the use of smart home technology is being rapidly adopted

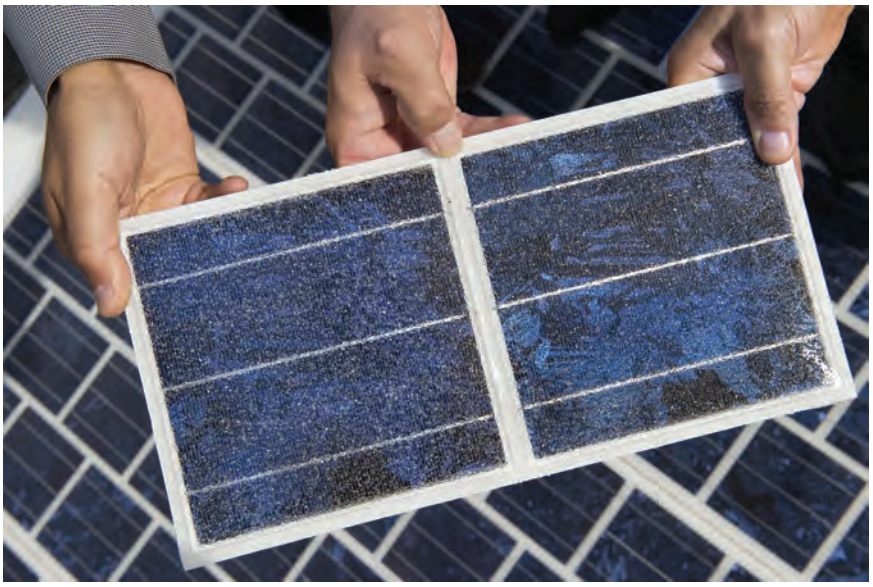
azymuth

France to pave 1,000 km of road with Bouygues' Wattway panels

SÉGOLÈNE ROYAL, France's minister of ecology and energy, has said that the government intends to pave 1,000 km of road with PV panels in the next five years, supplying power to millions of people. The minister told a conference of transport authorities that the tenders for the "Positive Energy" initiative had already been issued and the tests on the panels would begin in the spring.

According to France's Agency of Environment and Energy Management, 4 m of solarised road is enough to supply one household's electricity needs, apart from heating, and one kilometre will light a settlement with 5,000 inhabitants.

So the maximum effect of the programme, if successful, could be to furnish 5 million people with electricity, or about 8 percent of the French population. The solarising of France's roads involves gluing 7mm-thick strips to the surface of the carriageway. The basic technology for this has already been developed by Bouygues subsidiary Colas.
The company's Wattway panels (pictured above), which took five years to develop, were unveiled in October. Ségolène Royal, France's minister of ecology and energy, IN 2009 (Mikani/ Wikimedia Commons) Wattway cells collect solar energy using a thin film of polycrystalline silicon, but are resistant to the passage of heavy goods vehicles and offer sufficient traction to prevent skids.



Ms Royal has proposed to pay for improvements in France's transport infrastructure by raising taxes on petrol, which she said was "natural" given the falling cost of oil.

She estimates that this could contribute between 200 and 300 million euros ($220-440 million) to the cost of improvements such as road solarising. A number of countries are pursuing the energising of roads. Last year a Dutch consortium built a 100m-stretch of power generating road in the Dutch town of Krommenie, and in the US a husband and wife team is pursuing the idea after a successful crowd funding campaign.

> "So the maximum effect of the programme, if successful, could be to furnish 5 million people with electricity, or about 8 percent of the French population"

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