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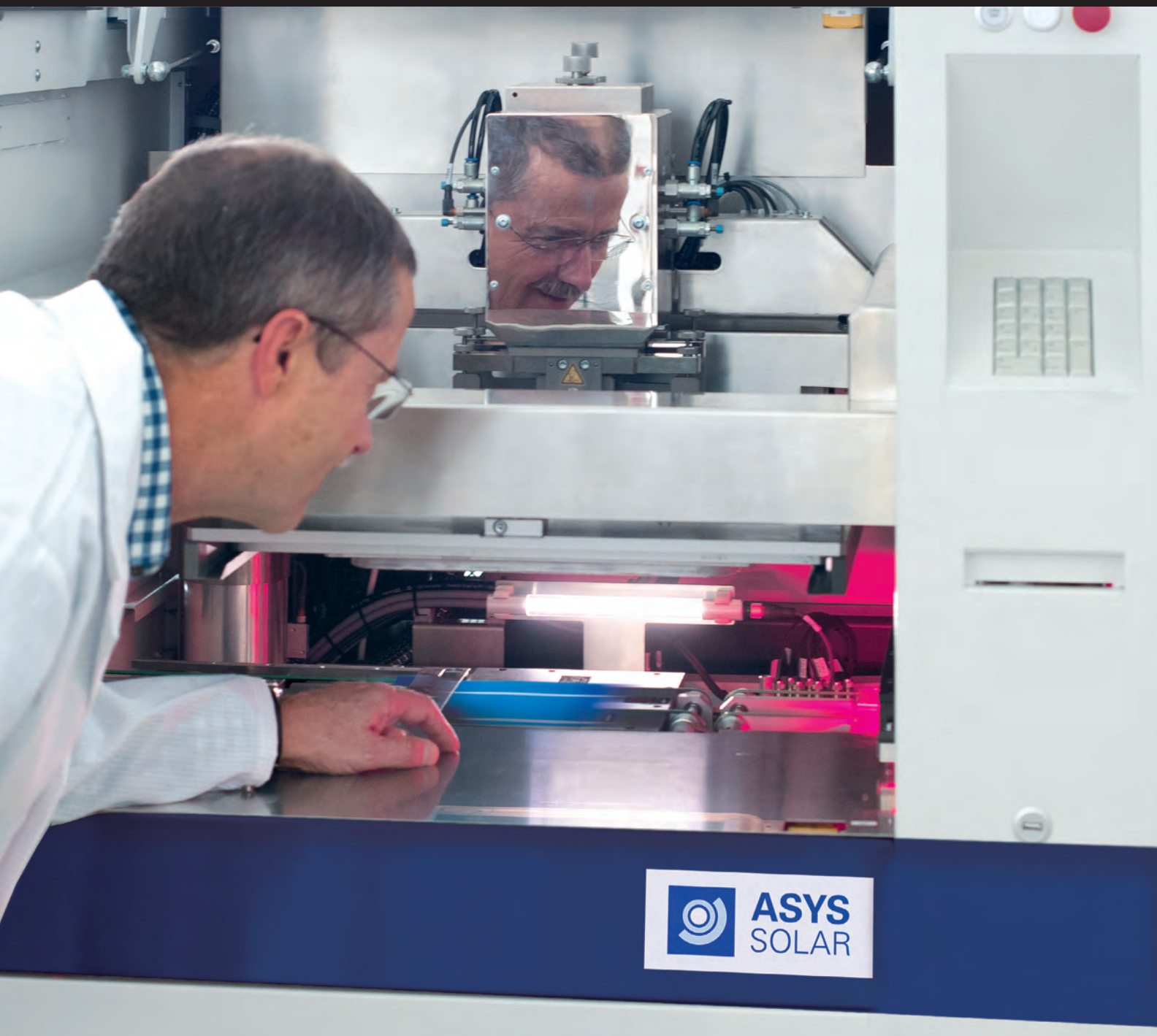

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viewpoint

Power management, the new frontier

WELCOME TO THE LATEST ISSUE OF Solar International in its new form. From this issue forward the product will be called Solar +Power Management.

The solar PV industry has grown up in the last five years. Product and the technology developments have been breath-taking in the speed of their progress. But the solar story has a next chapter and one we must respond to.

No matter a devices' capabilities, how we manage the technology is ultimately what makes it useful. How one piece of technology fits with another elevates its usefulness but infrastructures go well beyond PV cells and modules. Consider power management. Sometimes thought of merely as a software program married to an inverter, power management goes beyond a single function; it is actually a linchpin in how solar fits with other forms of power in a global electricity ecosystem.

Consider how solar has changed since 2005. Solar power plants were once isolated; today, solar is more of a two-way street. Power management used to focus on efficiency islands, but grew as a means to both draw and feed power from/ to utility grids. In the same way, storing power was wildly expensive in 2005 compared to today's options. Storage has gone even further and is now even seen as a viable 'load levelling' solution for power utilities.

Like advances in PV cell architecture, inverters and batteries, effective power management is now showing itself to be a major factor in how well solar and other energy resources can integrate within large scale electrical distribution systems. The next chapter will see solar to move from island to integrated power resource and that is the new frontier. How to merge two worlds into one? Power management.

Power management will be critical driver of solars long-term growth and sustainably and will be key to combining renewable resources with other forms of energy vying to satisfy the world's appetite for power.

PV manufacturing will always stay the forefront of the magazine as it has enabled the PV industry to grow through higher PV module efficiencies. Solar + Power Management reflects the evolution of the solar industry as the focus is now shifting towards power management, grid integration and storage.

Solar+ Power Management will report on the story as it reveals itself globally and help you make informed decisions about your role in the supply chain.

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Smart meter semiconductors rise

THE GLOBAL MARKET for semiconductors used in smart meters that provide two-way communications between meters and utilities will continue to expand in the coming years, providing significant growth opportunities semiconductor manufacturers. Shipments of communicating meters are forecast to reach 132 million units in 2015 and 150 million units in 2019, according to IHS Inc.

Global revenues for semiconductors used in water, gas and electric meters reached $1.2 billion in 2014, with a year-over-year growth of 11 percent and a five-year compound annual growth rate of 8 percent. The average semiconductor cost in two-way meters was approximately $11 in 2014. Average selling prices (ASPs) are expected to increase over time, as industry needs increase for 32-bit micro-controller units (MCUs), memory chips, single system-on-chip (SoC) solutions and other components used in secured communications and other applications.

Based on the latest information from the IHS Industrial Semiconductor Market Tracker, the demand for precise energy measurement and communication has increased the penetration of micro-component integrated circuits (ICs), along with analog ICs. In fact, two thirds of meter semiconductor revenue comes from microcontroller and analog components.

"The semiconductor industry for electric meters is moving toward a single-chip solution for measuring and communicating with the grid station, which is an important industry trend to watch," said Robbie Galoso, associate director, semiconductor market shares and industrial electronics for IHS Technology. "Water and gas meters require fewer semiconductor components; however, they need extra semiconductors for sensing and battery management."

Meters installed in the latter half of this decade will require greater application complexity, better security, improved communication ability, enhanced remote control ability and higher resolution. That means increased need for memory and system-on-chip (SoC) solutions with greater capabilities in a smaller package than in the past. Meters are evolving from those that merely register end-user usage, into complicated machines that can be queried for on-demand data, upgraded remotely, shut off in case of emergency or non-payment and used for variable pricing. "The movement from 8-bit MCUs to higher margin 32-bit MCUs is a key industry trend," said Noman Akhtar, analyst for IHS Technology.

"The integration of these higher function microcontroller units also requires additional capabilities, such as increased memory, which further increases manufacturing costs."

Schneider ranked third in market share for global central inverters

SCHNEIDER ELECTRIC Solar Business has announced that, according to a recent 2014 IHS report, they have been ranked third in market share for global central inverters in revenue terms, representing the highest market share growth in the segment.

Schneider Electric achieved this position through balanced growth in all continents, in very diverse geographies, including Japan, India, Thailand, and the Philippines for the Asia-Pacific area; the USA, Mexico, and South America for the Americas; as well as the UK, France, and Central Asia for the EMEA (Europe, Middle East, and Africa) region.

The 2014 figures include partial shipments to the largest PV site built in the EMEA region, the 300 MW project, located in Cestas, France, where Schneider Electric was the chosen provider for the complete electrical balance of systems, including a 220kV grid-tie substation fitted with an advanced power plant controller driving 400 inverters in the field. Schneider Electric will also provide services for the complete solution, with guarantees on equipment availability for 20 years.

Commenting on the market share figures published by IHS, Arnaud Cantin, Vice-President of the Power Plants Line of Business for Schneider Electric, said: "I would like to thank all the customers who entrusted Schneider Electric with the supply of critical equipment and services for their PV investments, and have enabled us to become a true global leader in the utility scale segment.

By accompanying and supporting our key accounts in global development, we can avoid the risk of being exposed to high variability in single countries, and position Schneider Electric as a future leader in an increasing number of high potential geographies. I strongly believe that our current strengths, coupled with the development of new power conversion and system control technologies for both PV and energy storage applications, will enable Schneider Electric to further develop long-term business relationships with consolidating key actors, and secure our leading position in the segment."

Kingspan Energy acquires ASAP Solar

LESS THAN 90 DAYS after its U.S. launch, Kingspan Energy, a wholly owned subsidiary of Kingspan Group PLC, today announced its acquisition of American Solar & Alternative Power, LLC, known by its trade name, 'ASAP'. The deal represents the first acquisition by Kingspan Energy in the U.S. and bolsters the company's sales, marketing, and project development presence in New England and the New York tri-state area.

"Kingspan Insulated Panels are already very well established in the U.S. commercial and industrial market with their high performance building envelope solutions. The recent addition of rooftop solar via Kingspan Energy means our proposition for building owners is even more compelling.

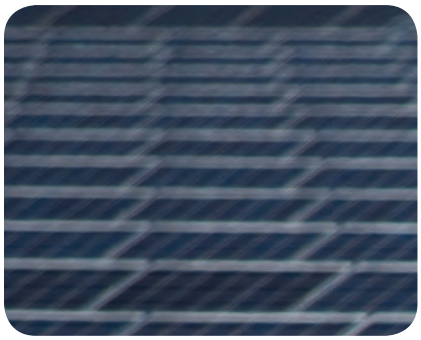
Customers can now benefit from a combined product warranty that covers both their insulated roof panel system and the incorporated rooftop solar PV," says Ralph Mannion, president of Kingspan Energy. "The ASAP acquisition is another positive step for Kingspan Energy as we expand our commercial rooftop solar offering to customers in the Northeast. ASAP's founders Elliot Isban and Jerry Charlup are very experienced in the solar energy space and have built an impressive company. We're delighted to be moving forward together."

Founded in 1990, ASAP has a long history as a commercial and industrial solar energy and high performance LED lighting project developer active from New Jersey to Massachusetts. "Our company has always been very progressive." says Elliot Isban, President of ASAP. "With our focus on commercial rooftop solar and the ongoing expansion of that market segment, we feel very positive about the future."

Yingli announce internet financing platform

YINGLI SOLAR has announced that it completed a bond financing RMB 20 million yuan (USD $3.2 million) for a 4 megawatt (MW) solar project. Yingli's financing partners for the project are Tianjin Xinhai Financial Leasing Co., Ltd. (Xinhai Leasing) and Principal Shield (Xiamen) Financial Technical Service Co., Ltd. The project bonds are now available for the Chinese public to invest in online at www.shicaidai.com, the China-based Internet finance firm to offer P2B (person-to-business) online financial products, including loans and wealth management tools.

Located in Hengshui City in China's Hebei Province, Yingli's 4 MW solar project is now operational. The installation will generate approximately 6.5 million kilowatt-hours of solar electricity annually, equivalent to offsetting the consumption of 2,600 tons of coal and more than 6,700 tons of carbon emissions.



Mr. Liansheng Miao, Chairman and Chief Executive Officer of Yingli, commented, "We are proud to announce our project and its innovative financing method, which empowers individuals to invest in clean power projects while also providing a safe, flexible, and stable investment income. It's our goal to begin replicating this approach as our project pipeline grows, and to eventually build a series of new online financing products that enable the public to invest in clean energy instead of fossil fuels."

Muegge acquires Gerling Applied Engineering

MUEGGE GMBH, which is headquartered in Reichelsheim, Germany, has acquired 100 percent of the shares of the microwave technology specialist Gerling Applied Engineering, Inc. (GAE) Muegge purchased the shares from the managing partner and founder of Gerling Applied Engineering, John F. Gerling, who will continue in his role as company Vice President to manage the company's operation business. In the 2014 financial year, GAE generated sales of around USD 2 million.

'The acquisition of GAE enables us to offer a complete standardised product line across the entire field of industrial microwave and plasma systems in the USA. It therefore provides us with a decisive competitive advantage while extending our footprint and increasing our share of the worldwide market in industrial microwave technology and in the production of complete industrial systems,' commented Dr Klaus Baumgärtner, CEO, Muegge GmbH.

'We have worked closely together with Muegge GmbH and we are excited about the huge potential resulting from this transaction. Intensifying this cooperation by pooling the two companies' extensive expertise will provide a basis for the growth of market share and ongoing enhancement of our products for the microwave and plasma industry in the USA and beyond.

This will enable us to meet customers' requirements even more closely in the future', commented John F. Gerling, the founder and President of Gerling Applied Engineering, Inc. Meyer Burger will include GAE in the scope of the consolidation retrospectively as of July 1, 2015. The parties have agreed to maintain confidentiality concerning the purchase price.

Battery energy storage project shows promise for electricity network

WITH RISING electricity prices one of the biggest issues facing households, Griffith University (Australia) research into energy storage and supply holds the promise of cheaper, better quality power for the low voltage (LV) electricity distribution network.

According to the research from Griffith's School of Engineering and published in the journal Applied Energy, a forecast-based, three-phase battery energy storage scheduling and operation system provides benefits such as reduced peak demand, more efficient load balancing and better management of supply from solar photovoltaics (PV). Researcher Mr Chris Bennett, working under the supervision of Associate Professor Rodney Stewart and Professor Jun Wei Lu, has developed and applied an intelligent scheduling system to a South-East Queensland-based LV distribution network servicing 128 residential customers.

"The low voltage network is a typical suburb of a few hundred homes where there is a single area transformer and recently there has been a substantial increase in the number of homes with installed residential solar PV in these settings," says Mr Bennett.

"Daily peak demand in residential networks typically occurs in the evenings in summer and both late morning and evening in winter. But because solar PV generation is dependent on incoming solar radiation, peak generation occurs during the middle of the day, typically when demand in the residential distribution network is low."

"This means there is an incongruity between when energy is generated and when it is required, which can lead to power supply and quality issues.
"However, with a battery energy storage (BES) system comprising Lithium Ion battery banks coupled with smart power control systems, such as STATCOMS, and featuring embedded intelligent forecasting software, we can better manage the LV network."

Associate Professor Stewart says the recent significant uptake of solar PV has in some locations created issues in the LV network, including surplus power being pushed up the grid, unbalanced phases and poor power quality.
"Our solution tackles these immediate issues while also setting the foundation for a future smart grid," he says.

"The two main advantages of intelligent BES in the LV network are that we can mitigate power quality issues attributed to fluctuations in generation from renewable energy sources such as PV, and we can store surplus energy gathered during the middle of the day and distribute it when it is needed in the evening peak period.

"If such a system was implemented across an entire city it would reduce wholesale peak generation charges, alleviate costly upgrades to the grid, reduce the average time of outages and improve power quality for customers."
Associate Professor Stewart and Mr Bennett agree that distributed energy resources and smart power control electronics can revolutionise the grid and reduce the price of electricity for customers.

Mersen announce portfolio of 1500VDC PV products

MERSEN has announced the launch of a complete portfolio of 1500VDC components for the growing solar market. This launch is a comprehensive product offering for early design into 1500VDC systems.

The comprehensive product portfolio includes string and NH style fuses, supporting fuse gear, surge protective devices (SPDs), power distribution blocks (PDBs), and switches. This portfolio highlights Mersen's commitment to providing high technology products to renewable energy markets. By offering a complete portfolio of 1500VDC PV products, Mersen has the ability to partner with customers for custom designed and integrated systems supported by a single trusted manufacturer. Customers can continue to trust Mersen's commitment to outstanding customer service, technical support, and flexible delivery windows to support the rapidly growing and consistently evolving PV market.

"Mersen is committed to supporting product development and expansion of the solar market into 1500VDC systems," states Rich Puffer, Mersen's VP General Manager, Standard Products, North America.

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Global photovoltaic installations exceed 12 GW in Q1 2015

ENERGYTREND estimates that global PV installations will reach up to 52 GW in 2015 and the installed PV capacity in China, the US and Japan will account for about 63 percent. Based on the statistics of EnergyTrend, the global PV installations at the first quarter of 2015 surpassed 12 GW and the full-year goal can be achieved.

According to EnergyTrend's gold member data research, the global five largest solar markets in 2015 are China, the US, Japan, the UK and India, while China, the US and Japan rank the top three. Chinese market will continue to grow and be in the lead of many other countries. Chinese total PV installations at the first quarter of this year alone peaked 5.04 GW, greatly moving towards the project of 17.8 GW in full-year 2015. Although Japan continued to reduce FiT for solar, its PV installations at the first quarter still reached 1,950 MW, which showed that the demand is still quit strong. The US got close to Japan with the installed PV capacity during the same period achieving 1,306 MW. What is worth mentioning is that among the added electric power in the US at the first quarter, the solar PV energy accounted for 51 percent, surpassing the conventional power for the first time.

Besides the US that will continue to boost the PV installations, some countries in the American region will show overall growth. The demands this year in several Central & South American national including Chile, Honduras, Uruguay, etc. will significantly increase as well.

Kingspan's Mannion feels the fit is a natural one. "ASAP and Kingspan share a unique approach to solar project

development, combining energy consulting, engineering, construction, operation, and maintenance in a turn-key package for customers," he says. "ASAP significantly increases our in-house knowledge of New England, Connecticut, New York, and New Jersey".

Isban Agrees. "Joining Kingspan Energy enables the ASAP team to do what we do best, just on a bigger scale, with better access to project financing, a larger marketing presence, and a trusted global brand, all of which are important in the evolving solar PV sector. With the additional opportunity presented by Kingspan Insulated Panels wall and roof applications we now have a compelling integrated solution to bring to market. We're very excited by the possibilities".

Singulus introduces CIGs and CdTe tools

German firm Singulus Technologies has introduced and installed inline sputtering systems for CIGS and CdTe thin-film solar cell production as well as tasks for the manufacturing of heterojunction cells.

The systems are available with vertical as well as horizontal substrate transport and can be configured for various substrate sizes, according to the company. They also suit challenging layer stacks and flexible product mixes. The systems use an inline process in which the substrates are transported on a special designed conveyor system on flat carriers through the system.

The carriers can be configured flexibly for different substrate formats and materials e.g. solar wafers. Different automation options for loading and unloading are available.

The Vistaris system with vertical substrate transport and the Histaris system with horizontal transport had been designed to enhance the efficiency of thin-film solar cells, while cutting production costs by using the state-of-the-art technologies. The machines bring the user the advantage of outstandingly even coating thicknesses and highly homogeneous coatings. Cell performance is appreciably improved.

A modular, compact structure significantly reduces the production area taken up and therefore cuts the investment outlay, says Singulus.

Through its production systems, Singulus Technologies already supplies wet-chemical processing, coating machines and selenisation systems for second-generation CIGS/CIS cells. Inline sputtering systems add a further production stage to the portfolio, which already spans the key processes of CIGS/CIS cell production.

In light of the anticipated volume of investment in production lines for CIGS/CIS thin-film solar cells, Singulus believes the long-term prospects of the solar segment to be bright. Through its new system concepts and innovative processes, the company is promoting the development of solar technology, which will play an increasingly important role in the global energy mix.

Imec tops 11 percent perovskite efficiency

NANO-ELECTRONICS research centre Imec has announced a record 11.3 percent aperture and 11.9 percent active area efficiency for its thin-film perovskite photovoltaic (PV) module. The efficiency was measured over an aperture area of 16cm2. This achievement is the best conversion efficiency for perovskite modules in literature.

Organometal halide perovskites are considered an excellent material for thin-film solar cells as they have shown high conversion efficiencies at cell level. While the power conversion efficiency of this new class of thin film solar cells has increased rapidly in the last few years, further improvements are still needed to make thin-film photovoltaics an attractive technology for industrial production. Larger area processing and narrow interconnections are prerequisites for processing efficient thin-film modules.

Imec's perovskite module achieves a geometrical fill factor of more than 95 percent and an aperture conversion efficiency of 11.3 percent. The active area efficiency was demonstrated with 11.9 percent. These record devices have been fabricated by the conventional lab scale spin coating process. Imec also used a linear coating technique (blade coating) for all the solution based layers, to prove industrially viable fabrication methods. By using this method, the modules achieved a 9 percent aperture area efficiency. These achievements are important breakthroughs in bringing thin-film solar technology to industrial scalability for applications such as building integrated photovoltaics (BIPV).

"Imec is steadily improving the conversion efficiencies of its perovskite solar cells and at the same time adjusting the fabrication processes to enable industrial adoption of this promising technology," said Tom Aernouts, R&D manager for thin-film photovoltaics at Imec. "Leveraging our expertise in organic photovoltaics enables us to make rapid progress in enhancing the conversion efficiencies, ultimately aiming at conversion efficiencies of more than 20 percent for this type of thin-film solar cells."

Imec develops a platform for glass-based perovskite modules and collaborates with Solliance, a cross-border Dutch-German-Flemish thin-film PV research initiative.

Thanks to its high power conversion efficiency and stand-alone integration in building elements, both glass-based and thin-film perovskite PV technology are widely considered as important technologies for the BIPV market.

Moreover, Imec is exploring stacking a perovskite cell on top of a silicon solar cell to increase the conversion efficiency of silicon solar cells. The perovskite cell will capture the light which is not absorbed by silicon, as such enabling conversion efficiencies of more than 30 percent.

US Energy department launches national community partnership

NEARLY 645,000 American homes and businesses have gone solar as of 2014. But despite solar costs falling 45 percent since 2010 for residential customers, many low-income homeowners are being left out of the solar surge. The White House has announced a new partnership with the Department of Energy that increases the availability of solar power to these Americans.

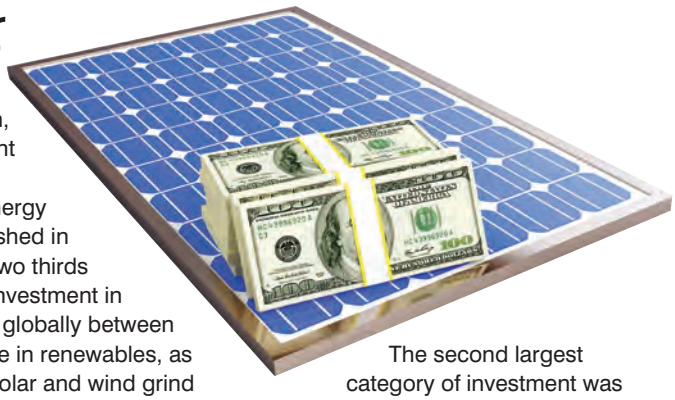
The National Community Solar Partnership will enable those who rent their homes or don't have a suitable roof to reap the benefits of solar and receive credit on their utility bills.

The partnership, which also includes the Department of Housing and Urban Development, the U.S. Environmental Protection Agency, and the Department of Agriculture will build off of the National Renewable Energy Laboratory's Guide to Community Shared Solar, which provides a framework for the development of this model for solar deployment in communities, and provide technical assistance to make it easier to install solar.

With nearly half of consumers and businesses unable to go solar, community solar growth potential is especially important to low-income communities.

In addition to bringing more community solar programs to low-income communities, SunShot's workforce training programs will continue to provide the industry with more in-demand workers by training people from low-income communities for new solar careers.

Clean energy investment continues to lag behind last year



CLEAN ENERGY INVESTMENT worldwide was $53bn in the second quarter of 2015, just 3 percent less than a revised $54.4bn in Q1 2015 but down 28 percent compared to the $73.6bn recorded in Q2 2014. Global investment this year is facing headwinds from the financial markets, with the sharp rise in the US currency over the last 12 months reducing the dollar value of deals struck in other countries; and volatility in share prices, particularly in China, holding back equity-raising by specialist clean energy companies from both public market investors and venture capital and private equity funds.

However, there continue to be bright spots, notably small-scale solar, which enjoyed investment at $20.4bn in the second quarter, some 29 percent up on Q2 2014. Small solar projects of less than 1MW remain on course for a record year, as countries such as the US, Japan and China, and other parts of the developing world, respond to the improved cost-effectiveness of rooftop photovoltaics after the price falls of recent years.

Other features of Q2 were European offshore wind, where two project financings accounted for nearly $4.2bn of investment between them (the 402MW Veja Mate array in German waters, and the 400MW E.ON Rampion project off the coast of England), and Chile's $1.3bn of investment in wind and solar, the highest that country has committed in any quarter to date. Chile has plentiful sunshine and wind resources, and also high electricity prices, making renewables a cost-competitive option.

Michael Liebreich, chairman of the advisory board at Bloomberg New Energy Finance, commented: "The first two quarters of 2015, taken together, have seen investment down 18 percent compared to the first half of last year. It is possible that the Q1 and Q2 2015 figures will be revised up a bit in due course as some more deals are disclosed, but we have been predicting since January that this year would see lower investment than 2014 because of the strong dollar.

"In the medium term, we expect investment to resume its strong growth. Our New Energy Outlook 2015, published in June, forecast that two thirds of the $12.2 trillion investment in generating capacity globally between now and 2040 will be in renewables, as costs per MWh for solar and wind grind downwards."

Looking in detail at the $53bn of investment in Q2 2015, China was the most important contributor, with $15.5bn of commitments, 14 percent higher than in the first quarter of this year, but down 36 percent from a very buoyant second quarter last year. Solar accounted for $6.4bn of the Chinese Q2 total, with one third of that in small-scale projects and two thirds in utility-scale PV parks. The US saw investment in Q2 of $9.4bn, down 4 percent on the first quarter and 21 percent on Q2 2014. In third place among countries was Japan, with investment of $8.1bn, largely in small-scale solar and down 12 percent on the quarter and 10 percent on the year. Distant fourth and fifth were Germany at $3.8bn, up 80 percent on Q1 but down 10 percent on Q2 2014, and the UK at $2.7bn, down 9 percent quarter-on-quarter but level on the year. Sixth was Chile, on $1.3bn, up 56 percent quarter-on-quarter and 40 percent year-on-year.

The largest category of investment in clean energy in Q2 was, as usual, asset finance of utility-scale projects such as solar parks, wind farms, biomass and waste-to-energy generators, biofuel production units, geothermal plants, small hydro-electric schemes of less than 50MW and marine energy projects. This amounted to $30.9bn between April and June, down 3 percent on Q1 and 41 percent on Q2 2014.

Top asset finance deals of the quarter included the Veja Mate and Rampion offshore wind projects, at $2.1bn and $2bn respectively, the Silver State South PV plant in Nevada, the US, at 294MW and an estimated $744m, and the Three Gorges Xiangshui offshore wind array off China, at 202MW and $567m.

The second largest category of investment was spending on small-scale projects of less than 1MW – at $20.4bn, level with Q1 and 29 percent up on the year. Third was public market investment in clean energy, at $2.9bn in the second quarter, up 26 percent compared to Q1 but down 41 percent from the same quarter of 2014.

The biggest public market equity raisings in the quarter were $900m of convertible issues by US solar company SunEdison, and $839m of secondary share issues by Abengoa Yield, a Spain-based "yieldco" owning renewable energy assets.

Venture capital and private equity investment in specialised clean energy companies totalled $564m, down 31 percent from Q1 and a full 60 percent below the second quarter of last year. The VC/PE figure for Q2 was in fact the weakest in any quarter since Q3 2005, almost a decade ago, and far below the peak of $4.2bn in the third quarter of 2008.
Luke Mills, clean energy economics analyst at Bloomberg New Energy Finance, said: "The low VC/PE total reflects the fact that technologies such as wind and PV are now far more mature, and less open to challenge from young companies. However, there is a great deal of early-stage investor interest still in other areas such as power storage and home energy management that could translate into more deals if the wider markets settled down."

Bloomberg New Energy Finance is also announcing revisions to previous years' investment totals, to reflect new information on deals and projects. Clean energy investment in 2014 is now put at $318bn, up from $267.8bn in 2013, $295bn in 2012 and $317.6bn in 2011.

Tata invests further in Swiss CIGS

FLISOM, a Swiss company developing technologies for manufacturing flexible thin film CIGS solar modules, has now received an additional investment of around USD10 million following an earlier investment of just over USD 40 million in 2013 for the pilot-production plant with an annual capacity of 15 MW in Niederhasli-Zurich in Switzerland.

Last year Flisom improved the design of roll-to- roll manufacturing machines for processing and scaled them up from 50cm width to 1 metre width rolls - claimed to be an unprecedented scale of manufacturing capability for continuous processing of cost efficient, high performance monolithically interconnected flexible CIGS solar modules on plastic foil.

This fourth round of funding comes from Flisom's existing strategic investor, the Tata group, a global enterprise headquartered in India. "We are very pleased with this further investment from the Tata group coming on the eve of the inauguration of Flisom's 15MW capacity pilot production plant, and we thank the Tata group and existing investors for their continued support", said Ayodhya Nath Tiwari, chairman of Flisom Company.

"We appreciate the systematic approach towards innovation and the continuous hard work of Flisom's team in developing a unique manufacturing plant, while partnering with Empa, one of the world's leading labs, with several efficiency-related records for flexible solar cells", said Mr KRS Jamwal, executive director, Tata Industries. He further adds, "This investment marks Tata group's interest in next-generation technology for the solar photovoltaic industry."

"With the investment received in 2013, Flisom refurbished an old manufacturing building of 4500 square meter ground area in Niederhasli, in the outskirts of Zurich, to install all the needed machines for solar module manufacturing on 1 metre wide rolls. At the same time, Flisom continued technology development on 50 cm wide rolls at its Dübendorf plant, located on the campus of Empa", says Flisom's chief operating officer, Sudheer Kumar.

Flisom's CEO Ulfert Rühle said: "After the successful installation of machines and other factory infrastructure in Niederhasli, the next step is to transfer the process know-how on these high- tech machines using specifically customised designs."

"The 15MW plant will serve as a proven blueprint for establishing larger production plants having a production capacity greater than 100 MW as well as low capital and operating expenditures. Flisom has been working steadily towards lowering the costs of manufacturing of flexible solar modules", added Rühle.

Ayodhya Tiwari, founder of Flisom and the head of the Laboratory for Thin Films and Photovoltaics, Empa-Swiss Federal Laboratories for Material Science and Technologies, believes that the high efficiency flexible and lightweight CIGS thin film solar cells have great potential to provide low cost installed solar systems, bringing many beneficial features together in a very unique manner.

In addition to the economic benefits, CIGS thin film modules, known for faster energy payback than the mainstream Si wafer technology, will significantly contribute to CO2 reduction.

Empa and Flisom have been cooperating for a number of years to develop industrial-scale production platform for CIGS solar modules.

"Scale-up for large-area solar modules and adapting these complex innovative processes for industrial manufacturability is quite a challenge and requires close collaboration between research labs and industrial partners for transferring research excellence to industrial usability", says Pierangelo Groening, head of the Department of Advanced Materials and Surfaces and member of Empa's board of directors.

Schmid starts distribution of storage solution

AT THIS YEAR'S trade fair Intersolar Europe, Schmid Energy Systems GmbH started the distribution of its electricity home storage series, the EverFlow Compact Storage, based on the Vanadium Redox Flow technology.

The system has been developed completely by Schmid and provides between 6.7 and 30 usable kWh at a power output of 2 to max. 5kW with this system, SCHMID manufactures the worldwide first series product for private households that is based on the VRFB technology.

The battery unit can be remotely maintained and features a micro controller which monitors and optimizes the charging and discharging processes.

By separating the charging unit from the power unit, an optimum system configuration has been found.

Schmid 's EverFlow Compact Storage maximizes the own-produced energy supply of a one- or multi-family house in conjunction with a photovoltaic system, wind turbine or CHP (combined heat and power).

The system is also optimally suitable as temporary power storage or for the needs based provision of electrical energy for electric cars (EV-charging station).

The compact EverFlow storage system can be installed in the basement, in the garage or in frost protected outbuildings – the space requirement is similar to that of a refrigerator. The advantages of the "flow battery" are its safety aspects, in addition to its 100 percent recycling capability.

Scatec and Nizam to build solar plants in Pakistan

DURING PAKISTANI Prime Minister Nawaz Sharif's visit to Norway, Scatec Solar and Nizam Energy signed an agreement to jointly develop and Build-Own-and-Operate solar power plants in Pakistan. The signing ceremony took place in the presence of Norwegian Prime Minister Ms. Erna Solberg and Prime Minister Mr. Sharif.

The development and financing of the 150 Megawatts (MW) solar plants are expected to be completed towards the end of 2015, with construction starting in the first quarter of 2016. Located in Sindh province, the photovoltaic plants involve an initial investment of nearly USD 300 million.

The projects, comprising three plants generating 50 MW each, is to be completed in about a year. An additional 150 MW is planned to be developed in a second stage, bringing the total investment to nearly USD 600 million. The 150 MW plants will be able to power about 150, 000 homes during peak daytime hours.

Mr. Raymond Carlsen, CEO of Oslo-headquartered Scatec Solar ASA (SSO) and Mr. Usman Ahmad, CEO of Karachi-based Nizam Energy (Pvt) Ltd signed the agreement on behalf of their companies.
The solar projects aim to stimulate investment from global and local investors in Pakistan. They will provide more than 1,000 jobs to people in the region during the construction phase. Thereafter, for the long term operation of the plants, 60 people will be employed.

As in all other countries where it operates, Scatec Solar will put special emphasis on transferring technical expertise to the local community.

In the run-up to the UN Climate Summit in Paris this December, there is widespread demand for clean energy. These solar energy projects will combat climate change by reducing CO2 emissions by about 300,000 tons when completed.

Pakistan's Central Power Purchasing Agency (CPPA) will purchase the electricity generated by the joint venture for a duration of 25 years and will receive 50 percent of the revenues from Carbon Credits generated by the project. From the 150 MW solar plants, an estimated 290 Gigawatt hour (GWh) of electricity per year will be added to the grid, which will go up to about 580 GWh when the second stage is completed.

Pakistan faces an acute energy crisis. Electricity shortfall has exceeded 7,000 MW, which is about one-third of peak demand during extreme periods. If this energy deficit is addressed, experts say, Pakistan could increase its GDP by as much as two per cent annually through additional production, exports and employment.

In July 2013, shortly after taking office, the Nawaz Sharif Government introduced a new Power Policy that aims to significantly increase power generation.

Mr. Raymond Carlsen said: "This project is an important landmark in Scatec Solar's journey to provide clean and affordable energy in developing countries. The Pakistani authorities have shown their commitment to addressing the nation's rising energy demand."

New generation of solar home systems making global rural electrification viable

A NEW GENERATION of Solar Home Systems has been developed that is finally answering the call of global electrification. 3G Solar Home Systems, developed by SOLARIC (Solar Intercontinental), has introduced the first utility grade solar home system that is finally effectively providing rural homes across the globe with unrestricted energy access.

The cost of these systems has been brought down so that both top and bottom of the pyramid users can finally afford to power their homes beyond just lighting. Unlike older counterparts that only allowed users to power merely a light bulb, this new technology is the first of its kind that goes beyond just lighting and allows homes to finally be able to power all their appliance needs, such as TV, laptops, cellphone chargers, lights, and fans.

BRAC, the world's largest NGO, started working and distributing these systems to Bangladesh in 2007, and its success globally sparked the solar home system revolution. The systems began to be disseminated to other rural locations in different countries.

These systems were the first to address the issues of rural electrification as there were no other alternatives that catered or were even close to being affordable for rural homes.

These small systems consisting of a battery and a solar panel, used low 12 volt current which had the capability to power one or two light bulbs. For the rural homes that could afford them, they no longer had to rely on primitive means such as kerosene fire to light their homes during night hours. Though it's merely a start, only the top 20 percent earners in rural villages were able to afford these systems and most of everyone else struggled to make the payments. Still over 60 percent of the population could not afford them and chose to rely on primitive and harmful means of accessing light. Furthermore, the capabilities of these older systems were very limited for its high up-front cost as it could only power a couple of lights which barely made any significant improvement to rural lives.

Solarics founder, Didar Islam, says, him and a couple of his other engineering colleagues at Solaric, took a look at the technology and thought, "how could we make it more efficient and more affordable?"

Solaric says, they developed a new technology which they call the "Optimizer", which has finally made it possible to convert 12V battery current to utility level 125V with zero loss, and it does so without the use of expensive inverters. These improvements now promise homes the ability to power all their appliance needs, and the inverter-less high voltage technology has brought down overall system cost. Thanks to this new technology, it is now possible to close the gap between rural and urban households. One of the notable impacts and a large contributor to its success, the optimizer technology, making solar home systems more efficient and affordable, it has removed the need for government subsidy and also removed the pressure on government having to extend their national grid system to rural areas as it can be very expensive and burdensome.

Didar says, "Extending the National Grid to many parts of the country, including rural areas, is not financially or economically feasible and come with many challenges which the use of small Solar Home Systems can help mitigate the need to extend any grid." Thanks to the Optimizers technology, Solar has now become the most affordable and reliable source of energy for rural off-grid people.

The success of these systems are now being recognized world-wide and adopted in rural locations of Tanzania, India, Malaysia, Bangladesh. Recently, Solaric closed a deal with Rex Energy, a solar contractor in Tanzania, to connect 6 million homes over the next six years.

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ASYS is fast and on track

ASYS metallization and automation systems have played key roles in the photovoltaic industry since its start. Solar's Mark Andrews talks with ASYS Group Americas President Markus Wilkens about the company's latest solutions to increase speed and accuracy of PV cell production.

SAYING that a company helped create an industry is no small matter. In the case of ASYS Group and ASYS Solar, it's true and a reason the company continues to set the pace for metallization and other vital wafer production processes. ASYS Solar grew out of the parent company's automation expertise and was there when the thought of solar energy being a leading contributor to global electricity capacity was just a lofty ambition.

Today, solar and PV production is widely considered the world's fastest growing source of new energy

Setting up the XS2 printer. Its new motorized pneumatic print head increases screen life.

production. Analysts predict it could make up 50 percent of the world's energy by mid-century. To support that drive, ASYS is delivering advanced solutions to increase wafer throughput and accuracy while reducing breakage. By speeding wafers through the line with greater print accuracy, the industry can create more inventory of higher-grade products made with less waste than ever before.

ASYS Solar is part of the 10-member ASYS Group. The automation expertise of ASYS, headquartered in Germany, led early PV cell manufacturers to seek them out to achieve the dramatic decreases in unit cell cost that would be required if the technology was to transition from novelty to mainstream. While many factors contributed to the steady decreases in unit cell costs, manufacturing enhancements played a key role since silicon—especially thinned to +/- 160 microns—is hard, brittle and subject to relatively easy breakage at many production stages.

ASYS drew from its varied core competencies to create its recently-announced Alignus 2.0 product, which they consider the next iteration of metallization line engineering that speeds output to 4,800 wafers per hour (WPH) in triple lane systems; they can reduce breakage to 0.15 percent.

While greater speed, accuracy and reduced breakage are key performance metrics, ASYS Group Americas' US-based President, Markus Wilkens, explained that other advances make Alignus '2.0' a noteworthy product line including its superior print head, IV testers and dryers.

"Beyond speed, accuracy and more gentle wafer handling, we made many improvements in the printing technology, the dryers and the testers – all this led us to name the new product 'Alignus 2.0,'" he stated. "For example: The print head pairs the well-proven closed loop pneumatic operation with a new motorized down stop setup, which will improve screen life and reduce operator errors."

While noting that speed is a benchmark any customer can appreciate, moving wafers down the line quickly is not the sole measure of success. "Whenever the customer is manufacturing with advanced processes like double printing or dual printing, they benefit from the plus or minus 12.5 micron accuracy that our Six Sigma printers deliver. This is accomplished in part by our patented vision system embedded in the print nest. The big

advantage is that there is absolutely no movement of the cell between alignment and the actual printing." Wilkens explained that after speed and accuracy, a final major measure of any metallization line's performance is breakage. There has been sizeable improvement over the years as ASYS took a good system and made it better.

"Typically, ASYS metallization lines run with less that 0.15 percent breakage across three print steps, without factoring in test and sort stations. Just seven years ago a 'good' breakage rate was 0.5 percent. Some customers run their ASYS lines and achieve 0.05 percent for the entire metallization day in and day out—that is outstanding," he remarked. While some manufacturers announce new products with one or two enhancements, Wilkens said that the Alignus 2.0 represents sizeable upgrades—10 in all.

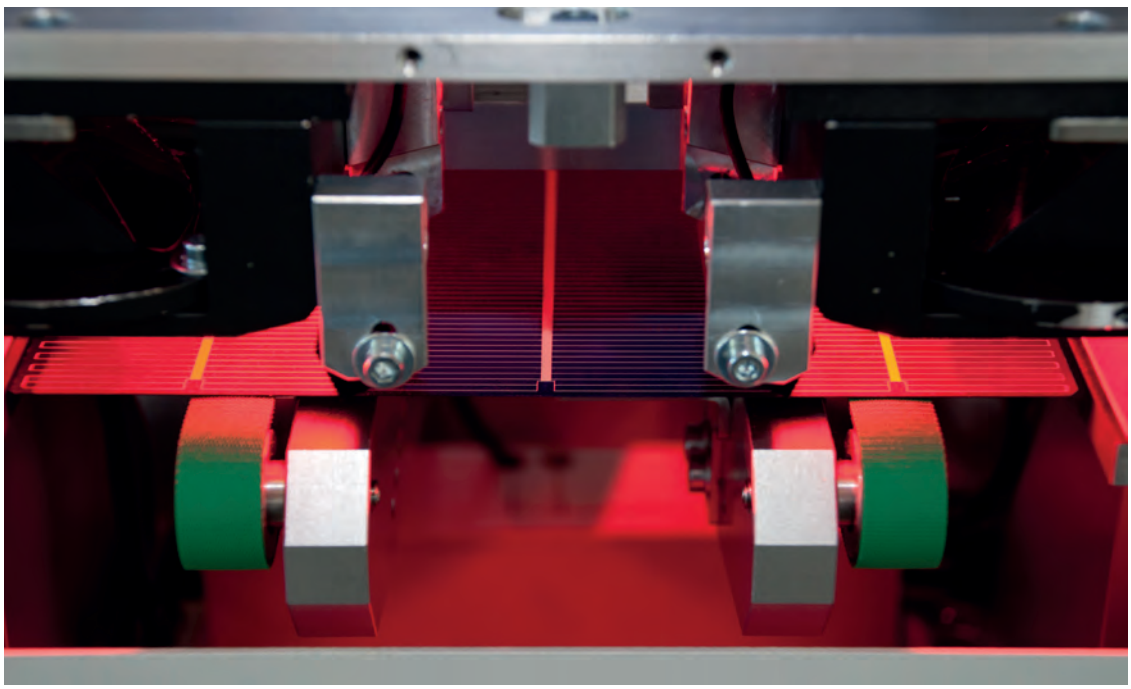
"Another enhancement is in the XS2 printer that utilizes an air knife to remove any breakage automatically, which improves uptime significantly. Fourth generation dryers have been redesigned with advanced VOC management that includes a heat exchanger to pre-heat incoming fresh air as well as an oxidizer to treat outgoing process air.

These approaches contribute to less interruption for maintenance and also reduce power consumption." Handling wafers along the production line is always a key performance metric since transport – if not functioning smoothly and consistently – can result in backlogs, breakage and full production stops. ASYS now offers its transport mesh for the dryers with various design options and stand-offs along with three different automatic cleaning options to fit customers' preferences. IV Testers are another critical production element.

By introducing their own tester, developed by ASYS subsidiary Botest, the company was able to address some shortcomings of other available testers in the market including calibration procedures, the number of measurement points or the cost of consumables. With advanced options including electroluminescence and hot spot detection, the ASYS A+A+A+ tester delivers extremely precise data and can detect contact issues, finger interruptions, micro cracks, changes in material, foreign objects and low efficiency regions– all while contacting the solar cell only once. All these measurements allow engineers to fine tune the process and improve yields, which help to bring down the cost/Watt. The IV Tester was designed specifically for high efficiency cells including n-types with its long, programmable pulse length. Hysteresis measurement is also possible and automatic correction is in the process of being deployed before the end of the year.

"Altogether, Alignus 2.0 represents more than 10 new developments and feature enhancements compared to the original Alignus product that debuted in 2012," Wilkens remarked. "At ASYS we take a synergistic approach from all the different industries we serve, which delivers market-leading performance for our solar customers."

In discussing industry progress that ASYS has helped achieve, Wilkens noted that while the first tool for printing solar cells harkens back to installations



Inside ASYS screen printer with integrated double print inspection. ASYS has installed more than 4GW of Double Print metallization lines. Among n-type cells, ASYS is holding a leading position.

of an EKRA printer in Germany (1987,) there have been remarkable advances since those days. Today's process tools more closely resemble those that evolved from technologies ASYS helped pioneer in the early 1990s. Metallization lines have grown substantially in terms of capability, flexibility, precision and throughput.

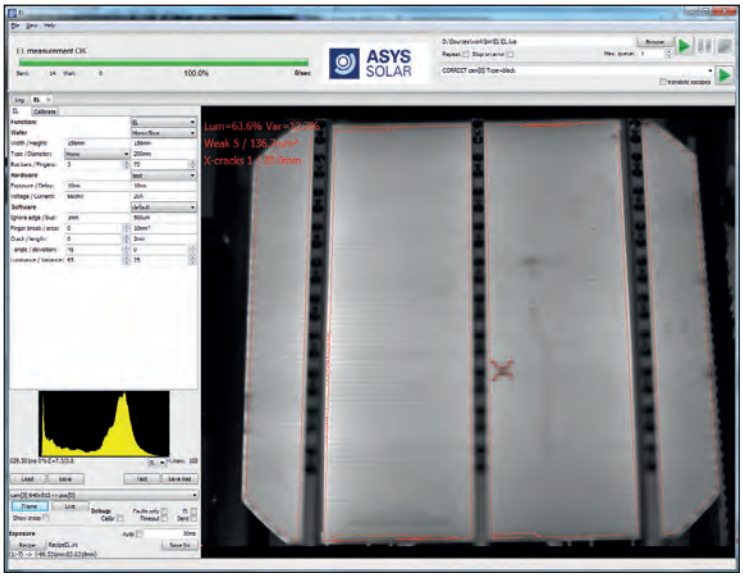
"I believe the value that ASYS delivers—beyond superior technology, is an understanding of the customers' business and what they want to achieve, and that is across multiple manufacturing industries. We can assist them in handling a specific product in 20 seconds, or 2 seconds. In the solar industry, our philosophy has always been: simplify whatever it takes to move a silicon wafer from A to B," he said. ASYS has been very successful following its simple credo. The fact they have a 50 percent market share of the world's dual lane manufacturing capacity is proof of the trust placed in ASYS. While safely handling 300 micron wafers was once a benchmark they established and supported, demands have increased. Today, 160 micron wafers are common and Wilkens noted that those are transported 75 percent more quickly with a 75 percent reduction in breakage, comparatively speaking. The company plans to support fast, safe handling of 120 micron wafers when those enter production.

The solar industry is very diverse. Because it evolved in many places around the world, there are many different cell architectures and many varied fabrication and printing techniques. This has channeled ASYS' development programs to handle practically anything the industry needs.

"Four or five years ago, 'everyone' talked about SE on the front side. The next trend was dual and double print. Today, PERC seems to be gaining grounds. In other words, solar is still in transition as the industry matures. There is no single best, cheapest technology, which led us to create line modularity—the customer can add, remove, reconfigure and upgrade as needed, making ASYS the smart choice as a hedge against technology risk."

Because photovoltaics has always been an industry of new ideas and changing technology, ASYS is constantly looking ahead. Wilkens sees that cost will remain a key driver in the years to come. To be competitive with fossil-fueled electricity generation, higher efficiencies, better yields and higher throughputs are central to success.

Just as PERC is seeing wider adoption today, Wilkens recalled past development cycles when jetting and plating were tried, but with sizeable manufacturing issues; PV cell makers moved on to other approaches, just as they will in the future.



Making the invisible obvious: The enhanced cell tester with EL and hotspot measurement increases the high quality yield of cell production. It delivers extremely precise data of contact issues, finger interruptions or micro cracks for example.

Despite many changes in PV cell manufacturing, screen printing remains a key technology since it is established and fast—a process that sees regular enhancements. Wilkens believes these qualities will make screen printing in one form or another a standard application for years to come.

No matter what ASYS does to refine and create new metallization technology, it also sees the importance of supporting the human interface along new production lines. "ASYS is working on PULSE, which is a software solution that allows operators, by means of a smart watch or tablet, to be more responsive and proactive when interfacing with production tools, contributing to more uptime. The software monitors all equipment and automatically sorts warnings and errors based on priorities.

"The human factor is still a key for success. So no matter the tool and technology we create, managing ways for operators and plant managers to positively affect the production process will be part of our strategy. ASYS is seeking solutions for our customers' long-term success and the growth of the industry," he said.

As an industry pioneer with more than 25 GW of installed capacity created using ASYS metallization lines, the company seeks ways to anticipate and solve its customers' next requirements. Just as speed, accuracy, reduced breakage and many other enhancements will play a role in the future of PV cell manufacturing, making the technology easier to understand and control is at the heart of each new product that ASYS creates.

The problem with power

As power demands surge, electricity networks are under strain. Can SiC power electronics save the grid? asks Rebecca Pool.

AS OPERATORS OF residential electricity networks across Europe strive to meet escalating demands for power, SiC-on-silicon power devices from Anvil Semiconductors are set to make a real difference.

The UK-based SiC device developer is taking part in a £500,000 UK government-funded initiative to develop cutting-edge technology to boost the efficiency of power distribution across UK networks. Working alongside a host of key power players – Schneider Electric, Western Power Distribution, Turbo Power Systems, Exception EMS and Aston University, UK – Anvil will develop SiC-on-silicon Schottky diodes and MOSFETs for power electronic converters.

As Jill Shaw, chief executive of Anvil highlights: "We will be supplying our devices to our partners, but these will be new, so we are well and truly involved with working to get the best out of these devices."

New power, old infrastructure

The project follows a government-funded feasibility study to find a cost-effective way to integrate the rising levels of distributed power generation and storage to existing electricity infrastructure.

Recent figures from Imperial College London, UK, estimate that come 2020, a hefty 10 million homes in the UK could have solar panels, up from around half a million today. Meanwhile, Navigant Research predicts sales of light-duty electric vehicles will more than double from today's 2.7 million to 6.4 million by 2023.

However, integrating such distributed power generation and storage to today's electricity networks brings myriad issues. An influx of photovoltaics, for example, can lead to unacceptable local voltage rises on the network while more electric vehicles means more demand for power. Factor in the uncertainties of predicting the loads and demands in a future two-way power, and clearly it's time for the network to adapt.

However, the feasibility study brings hope. Research indicates that increasing the local network phase voltage on existing electricity infrastructure to

400 V would be a cost-effective way to handle the rising power demands and local voltages. And this is where Anvil's SiC-on-silicon devices are set to play a key role.

To step down the network voltage at each house to 230V, low-cost power electronics converters (PECs) will need to be installed in a meter box outside each home. So with this in mind, project partners are now developing a prototype that Western Power Distribution will deploy in a small-scale demonstration network of around 100 homes. And of course, developing new, low-cost 3C SiC devices for the PEC is a must. "The converter needs to be small and 99 percent efficient due to [space and] heat restraints within the meter box," highlights Shaw. "This drives the need for silicon carbide, but conventional devices just can't do this cheaply."

"Only by using our devices can you make this solution cost competitive, or cheaper than digging up electricity cables and replacing them," she adds.

Making MOSFETs

But a lot of work must take place first. As Shaw says: "We've developed the Schottky diodes but haven't yet got the MOSFETs so our partners [Turbo Power and Schneider] are developing prototype PECs around more expensive bulk SiC devices."

Right now Anvil is working with The Tyndall Institute, Ireland, on 'its first stage' MOSFETs. According to Shaw, device production started a few months ago, following process development to convince her and colleagues that they could get the performance they wanted out of their MOSFETs. And a finished device is expected in around six months.

"In about a year's time we will provide our MOSFETs," adds Shaw. "These will replace the [bulk SiC devices], and a converter will then be produced for the trial networks," she adds.

At this point, Western Power Distribution will test the converter on its trial site, and if successful, will be a long-term customer for the project partners. But this is just the beginning. After the three-year project, Shaw expects a period of further development for commercialisation. The potential market is huge, and the impact on Anvil could be profound.

"Assuming we meet Western Power's requirements, the operator will then start integrating the converter [at peoples' home] across its distributed network," she says. "But clearly Schneider has recognised that there is a lot more of a market than Western Power."

"So if successful, Schneider will commercialise the converter and [it could reach] all the distributed network operators in the UK and the rest of Europe," she adds. "This is a worldwide issue that's got to be coped with. And this is a relatively cheap and easy way of doing it."

Below: Solar panels, a proliferation of electric vehicles and more are stretching today's electricity networks to the limit; silicon carbide-on-silicon devices can help.

Right: A technician at Heraeus' facility in Germany mixes component elements for a new line of photovoltaic cell silver pastes.

Go Green

with Heraeus metallisation pastes

Heraeus Photovoltaics is a leading developer and manufacturer of silver metallisation pastes for PV cells. Mark Andrews spoke with Heraeus about their development of lead-free alternatives with greater efficiency than previously possible.

HERAEUS has long been committed to green technology and environmentally responsible practices to improve efficiencies, conserve resources and protect environments wherever its products are made or utilized. Every day this vision "comes to life" as Heraeus continues to develop and deploy technologies, materials and products that have a positive impact on our local communities and the world.

Photovoltaics represents one of the company's key initiatives in supporting a "Green Environment." Heraeus produces a number of products for the photovoltaics industry that range from processing components to providing the metallisation pastes in solar cells that conduct energy converted from the sun's rays. But the goal goes beyond just providing sustainable, clean energy products to the world. Heraeus' mission is also to protect the environment once product lifecycles have ended.

The growing demand for photovoltaics

Due to a variety of factors, such as government incentives providing an excellent investment alternative; continual reduction in installation costs; and the effort to leverage cleaner, safer energy sources, the photovoltaics industry has continued to grow rapidly. The Solar Energy Industries Association (SEIA), Deutsche Bank analysts and many other industry watchers predict double-digit growth in 2015 in many photovoltaic supply chain segments. Metallisation pastes represent a key component in the production of crystalline silicon solar cell modules. From 2007 to 2014, approximately 8,000 tonnes of paste was demanded for the front-side of c-Si solar cells. From 2015 to 2018, analysts are predicting an additional 250 GWs of solar installations will be deployed requiring approximately 7,000 tonnes of front-side metallisation paste.

These additional PV installations worldwide will provide a cleaner, safer and greener energy source. But how green is green energy? While Heraeus is not expert in all the factors related to renewable energy manufacturing and production, it is a respected leader in metallisation pastes, so this article will explore areas in which advances are being made that will not only continue to boost efficiencies, but also make producing green energy greener.

Lead-based metallisation pastes

The expected 250 GWs of PV installations over the next several years will have a very positive environmental impact compared to carbon-emitting, fossil-fueled power generation. However, the production of the metallisation pastes employed in making photovoltaic cells usually incorporates lead containing glass frit for optimal performance. To produce the required volume of front-side leaded metallisation

paste for the projected demand through 2018, approximately 175 tonnes of lead is required. This is a significant amount of lead to process for paste manufacturing and cell screen printing, not to mention the fact that all this lead will eventually need to be taken out of service once led containing solar cells reach the end of their lifecycles.

Leading paste manufacturers, such as Heraeus, take great caution in handling leaded frit in the production of metallisation pastes and production waste disposal due to the hazards associated with lead.

Potential health issues can arise from acute and chronic exposure to lead. Workers are exposed to lead oxide dust during batching and to lead fumes when melting glass. Over-exposure to lead can damage a person's nervous system, kidneys, reproductive organs and urinary tract. In the work environment, occupational exposures are carefully controlled and employees are monitored for exposure issues. To safeguard employees, companies spend millions of dollars in control systems, equipment, training, protective wear and testing.

For every ton of paste manufactured, there are several kilograms of lead waste that must be disposed of properly. The EPA demands that companies in the US be held responsible for lead "from cradle to grave." While somewhat different standards apply in other areas of the world, lead is generally considered a highly regulated element in manufacturing. Heraeus and other paste manufacturers are responsible for the safe disposal of all lead containing wastes, and invest additional resources with third-party companies for safe disposal. Lead is bio-persistent in the environment and must be stabilized so as to not cause issues to the environment that can eventually impact the human population. Basically, lead used to manufacture products never goes away.

Lead-free metallisation pastes

Due to the issues associated with lead, lead-free front-side metallisation pastes for solar cells have been available for many years from various manufacturers. However, there has historically been a tradeoff between environmentally friendly lead-free pastes versus the higher performing leaded versions, with customers generally preferring higher performance.

A technician oversees production of new silver pastes at the Heraeus West Conshohocken, Pennsylvania (USA) facility.

In 2012, Heraeus developed a lead-free paste for front side applications that was tested by alpha customers. In small volumes, this R&D paste was available along with Heraeus' very successful SOL9273 series of pastes. Results using customer wafers showed a higher performance from the leaded SOL9273 series, with a difference ranging from 0.12 to 0.28 percent in absolute efficiency for the monocrystalline cells and about 0.17 percent for the multicrystalline cells tested.

Though lead-free paste was available, customers did not value this characteristic enough to choose the lead-free version due to its lower efficiency. The direct feedback Heraeus received from a technical service representative was that any lead-free paste's efficiency would have to be similar to the lead-based products for customers to be interested in purchasing the lead-free paste. Heraeus experienced no production order requests for the lead-free products; the product in development was therefore never commercialized.

With advancements in technology, the performance of lead containing metallisation pastes has improved. At the same time Heraeus has advanced lead-free paste development, and has made significant strides. This year, Heraeus has introduced several new high performing pastes in the SOL9621 Series that has demonstrated high cell efficiency gains and good adhesion. Heraeus scientists also developed a new series of pastes in parallel, the SOL9631 Lead -free Series, that has very quickly demonstrated equal performance to the company's best front-side pastes in testing by alpha customers. For the first time Heraeus could eliminate the long- and short-term issues associated with leaded products while maintaining if not advancing efficiency.

Heraeus SOL9631 Lead-free series

Heraeus' new SOL9631 Lead-free Series of front-side metallisation pastes has the potential to be a platform for future product innovations. Leveraging co-ownership of the Shoei Chemical Inc. patents TWI453930 and TWI432539, Heraeus' new series of pastes incorporates lead-free tellurium oxide glass frit.

Preliminary alpha testing with select customers has already demonstrated that the SOL9631 Lead-free Series has similar performance to the SOL9621M paste, with greater than 0.1 percent cell efficiency gains due to reduced contact resistance; higher fill factor and higher open circuit voltage relative to current commercially available pastes.

Heraeus expects with further modifications to the current formulation, the SOL9631 Lead-free Series will exceed the performance of the SOL9621M by year-end. "Innovation provides many unique and positive outcomes. At Heraeus, strategically focused innovation will drive bundled benefits that provide added value to our customers and society," according to Dr. Weiming Zhang, Head of Innovation for Heraeus' Photovoltaics Global Business Unit.

"Our organization recognizes that every product we create has an impact on the world we live in. By providing industry-leading metallisation pastes for solar cells that lower the cost per watt of cells and modules, we help enlarge the footprint and impact that renewable energy has on our environment. By providing lead-free pastes with equal to greater performance capabilities, we reduced the environmental footprint solar will have at the end of its lifecycle."

Heraeus appreciates the potential impact the SOL9631 Lead-free Series can have not only by improving the performance of solar cells and modules, but also positively affecting the environment and the resources that are currently required to handle lead-based metallisation pastes.

Through the broad use of lead-free front-side metallisation pastes for solar cells, the PV industry will now have the ability to reduce the environmental footprint created by waste generated in manufacturing and disposal of cells and modules that contain lead. The expenses associated with these tasks would be greatly reduced, if not eliminated completely.

The safety issues and expenses involved in handling lead for manufacturing of metallisation pastes would be eliminated. All these benefits would potentially be gained without sacrificing performance—key reasons why Heraeus is excited about these latest developments for the photovoltaics industry and the environment we all share.

Amazing old fossil lava pattern and new fern growing through it in Hawaii Volcanoes National Park, Big Island, Hawaii

Hawaii leads the way

Hawaiian legislators have embraced an 'All-Renewables' energy future. America's 50th state is on track to be the 1st to shut the door on fossil fuels.

When Hawaiian legislators voted in May to end dependence on imported fossil fuels it made headlines worldwide. Hawaii now derives about 22 percent of its electric power from renewable resources and plans to raise that to 100 percent by 2045.

This historic action, expected to be signed into law soon by that state's governor, will make Hawaii the first state to de-carbonize its electric grid. The rallying cry in response to this bold initiative has already been heard: if Hawaii can do this, why can't we?

While a strong 'we-can-do-this' spirit is critical, let's also realize that Hawaii's situation is somewhat unique, and like other areas leading the solar charge, the right pieces have to fall into place before decisive action results.

Unique Needs/Unique Solutions

Hawaii's geography dictates electrical grids are independent from Hawai'i to O'ahu. Their decentralized system existed through necessity, but it also happens to be a good basis for adding decentralized power systems like photovoltaic.

Second, Hawaii endured decades of dependence on expensive imported diesel fuel to generate electricity—their power rates had been three times that of mainland cities.

When fuel prices climbed higher in 2008, Hawaiians said, 'enough's enough!' Leaders in government and utilities jump-started work on wind power and solar installations. Geothermal is also part of the mix since that's one of the few advantages of living alongside volcanoes.

Third, the state's Hawaiian Electric Company has had a partnership with major PV solar manufacturer Enphase Energy, which has helped encourage residential and grid-scale initiatives. Most residents live on the Big Island of Hawai'i, concentrating most residential solar panels in one area, supported mostly by a single company working with HEC. That advantage was realized in February when Enphase remotely reprogrammed 800,000 microinverters with the push of a button—no trucks had to roll.

Enphase's Ameet Konhar, senior director for strategic initiatives, remarked that his company's unique relationship with HEC is a model they hope will spread to other locations.

"We are definitely invested in Hawaii's energy future," remarked Konhar in a recent interview. "We feel Hawaii is leading the world in how to integrate all the levels of PV into the overall scheme of things. One hundred percent renewables is a bold gesture...It is exciting to (help them) work to resolve the technical challenges. How do we make the grid even more reliable? Data exchanges and using technology and new storage solutions will all play a role...to make (electrical) power more predictable and reliable there."

Konhar said that his company's unique microinverter technology with two-way data exchanges systems can be monitored through Enphase's cloud-based systems. Upgrading the software in Hawaii was a matter of downloading new parameters; it was also an important step in showing how residential and grid-level systems can work together.

Fourth, Hawaii appreciates the impacts of climate change and global warming more than any population not

surrounded by water. Peter Crouch, a power grid simulations expert and dean of engineering at the University of Hawaii, said every citizen understands that if climate change is not halted, Honolulu's Waikiki area could be under water by 2100.

Yet not every place in America with a substantial coastline takes Hawaii's approach, illustrating that change comes through many motivating factors. Consider Florida. The 'Sunshine State' ranks third in the United States for daily sun exposure, yet comes in between 13th and 24th for solar adoption. Why so low in a state with so much sunshine?

The trade group 'Solar Energy Industries Association' asserts that Florida lags behind due to state policies. Florida also enjoys relatively inexpensive electricity thanks to greater reliance on natural gas.

What hasn't caught fire is free enterprise leveraging an abundant natural resource, the sun, along with regulatory policies that could kick-start the process. And then there's the elusive factor of what drives peoples' priorities: Florida has nearly double the coastline of Hawaii (1,350 miles), yet citizens don't seem as worried about rising ocean levels even though Miami is as vulnerable as Honolulu. But the tide may be changing. A state ballot initiative headed by 'Floridians for Solar Choice' champions efforts to allow buying solar-based power from companies other than regulated monopolies. Right now Florida is one of only four states that doesn't allow private enterprise to create solar-based power systems.

What drives people to take charge of their futures? The same factors that have for so long driven human ingenuity: money, passion, freedom, security and altruism, like making sure today's beachfront vistas aren't 50 feet underwater by 2100.

A take-charge spirit has already manifested in Hawaii and other US states looking at the long term. Florida has a chance to step-up its game soon thanks to Floridians for Solar Choice and the growing ranks of businesspeople who see a future for solar in America's Sunshine State. But until that happens, it's 'Aloha time' if you want to visit America's leading solar state.

Putting CPV on rooftops

High-efficiency CPV could become a reality for rooftops by uniting microscale solar cells with a planar microtracking concentrator technology

BY Jared Price and Chris Giebink FROM the Pennsylvania State University AND Xing Sheng and John Rogers FROM THE University of Illinois at Urbana-Champaign.

PROSPECTS FOR concentrating photovoltaics (CPV) are at an all-time high. Driven by a maturing industry and increasing emphasis on the value of high efficiency, the global installed capacity of CPV is forecast to triple to 1 GW over the next five years.

None of this capacity, however, will be installed on rooftops, which is where a significant proportion of solar panels are being deployed by the broader PV industry. Amidst this growing trend toward decentralized power generation, the conspicuous absence of rooftop CPV begs the question: Is CPV missing an opportunity?

Creating a viable CPV technology for rooftops is not trivial because it requires overcoming both practical and aesthetic challenges. While standard PV panels are compact and can mount flush with the roof, CPV modules are traditionally bulky, requiring a precision tracking system to orient each module toward the sun throughout the day. These aspects are not problematic for ground-mounted systems where there is ample space to move and prevent shading. But on rooftops they are a non-starter: Space and structural support are limited, and there is a need to preserve aesthetic appeal, because few of us would want to have the equivalent of an array of mini satellite television dishes scattered across our roof.

A radically different CPV architecture is therefore needed, which must deliver the efficiency of a traditional system, but do so in the form factor of standard, fixed-panel PV.

Our team at Penn State University and the University of Illinois at Urbana-Champaign is making progress on this front by combining a translation-based tracking technology with microscale photovoltaic

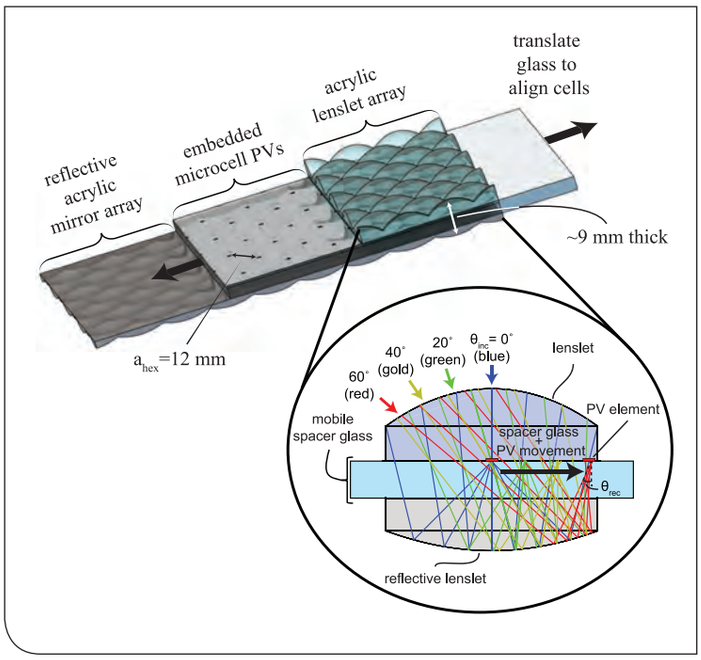


Figure 1. Moving the cells relative to the lens ensures that sunlight is concentrated on the device throughout the day.

cells embedded inside the concentrator optic itself. The result is a quasi-static CPV panel less than 1 cm-thick that operates at fixed tilt with an imperceptible amount of movement. Over the course of a sunny day, such a panel could deliver 50 percent more energy than a state-of-the-art silicon equivalent.

Embedded microtracking

To accomplish solar tracking without reorienting the panel, we have adopted a planar translation-based approach, with optics that remain fixed while PV cells slide laterally to follow the moving focal spot (see Figure 1).

This type of design is not a new idea. The performance of various forms of translational tracking have been explored before, but their utility has been limited by image field curvature, which degrades the focal spot in the solar cell plane for light incident at oblique angles beyond about 20°. This is a substantial drawback, because a latitude-tilted panel sees sunlight incident at angles of up to 60° over the course of 8 hours. Consequently, previous translational tracking schemes could only operate efficiently for a few hours each day.

We resolved this problem by adopting a folded optical path. With this configuration, light is refracted by a top lenslet, reflected by a bottom lenslet and finally focused on an intermediate plane – a sheet of glass patterned with a corresponding array of solar cells. The interfaces between this plane and those of the top and bottom lenslet arrays are lubricated by optical oil, which also serves to eliminate parasitic reflections.

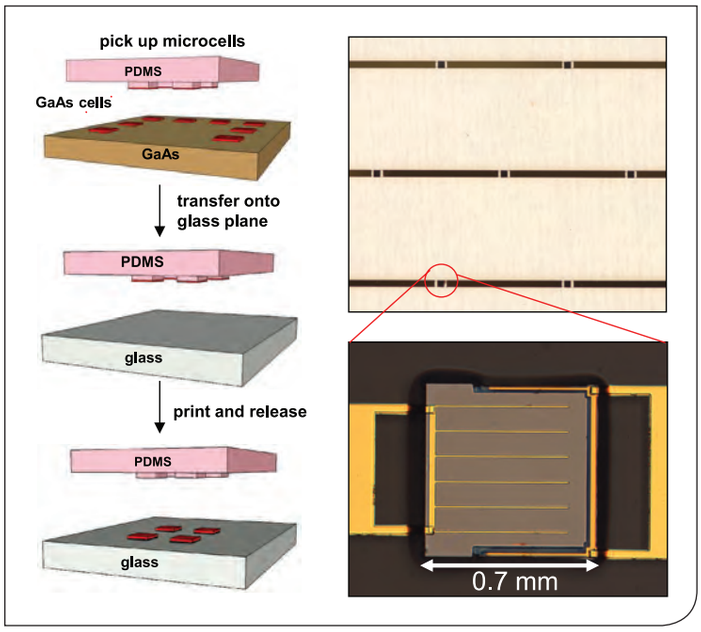
Tracking is achieved by sliding the middle solar cell sheet laterally. Sunlight is focussed on cells that have an area of less than 1 mm2, enabling the size of the associated lenslets and the thickness of the overall concentrator stack to be kept small. By employing this design, cells are embedded in a 'microtracking' panel that can accept light over a 120° full field of view, which corresponds to operation for more than 8 hours per day. Incoming radiation is focused by a factor of more than 200, and daily average optical losses are kept below 15 percent.

Microscale cells

The benefits of the microcells are more than just enabling a compact panel. Thanks to their small size, the power delivered to each of these cells is orders-of-magnitude lower than that impinging on a conventional CPV cell, which is typically around 1 cm2 in size. This simplifies thermal management to such an extent that, according to our work and that of others, the cell does not require active cooling.

Another advantage of working with microcells is that they have a lower series resistive loss. This leads to a more robust performance when the cell faces the inherent illumination non-uniformity of the microtracking concentrator focal spot.

Our fabrication of the microcell sheet begins with the growth of the device structure on a GaAs substrate by MOCVD. Inserted between the device stack and the substrate is a lattice-matched AlGaAs sacrificial layer, which is removed by wet etching to separate the cells from the substrate. The resulting chips, which are only a few micrometers thick, are picked up with a soft elastomeric stamp and placed



Left: Figure 2. The transfer-printing process that is used to produce microcell arrays has a very high throughput.

precisely on a glass (sliding middle sheet) substrate with a high-throughput process, known as micro-transfer printing. This process can print millions of cells per hour with a yield exceeding 99.5 percent while producing micrometre-scale placement accuracy (see Figure 2). Following transfer of the cells, metal interconnects are deposited to create a network that optimizes the power produced by the module.

We evaluated our microtracking design by fabricating a small-scale prototype incorporating seven, series-connected GaAs microcells. These were sandwiched between a pair of custom, 3D-printed, plastic lenslet arrays made by our collaborators at LUXeXcel, Inc. Testing involved measurements in the lab, and then outdoors during several sunny days in central Pennsylvania, where the panels were held at a fixed tilt (see Figure 3). Despite a relatively large surface-form-error in the printed lenslets, for over 6 hours we could maintain a factor of 100-150 increase in the short-circuit current compared to that of an adjacent bare cell. Turning to commercial off-the-shelf planoconvex glass lenses improved the concentration factor to 200 suns and extended the operating time to 8 hours.

Taken together, these initial results have validated the basic microtracking concept and set the stage for testing at a larger scale. When this is carried out, we will improve the concentrator performance by optimizing the lenslet optics for higher concentration and by applying an anti-reflection coating to improve their optical efficiency.

To higher efficiencies

In addition to improving the optical performance of our concentrator system, we are also pursuing ultra-high efficiency cells by moving to quadruple junction, four-terminal devices. By transfer-printing different sub-cells on top of one another, we avoid the current- and lattice-matching issues that have challenged monolithic four-junction cells to date. This approach expands the range of feasible sub-cell materials and opens up the possibility of increasing the number of junctions to five or more.

We have used transfer printing to combine a InGaP/GaAs/InGaAsNSb top cell with a germanium bottom cell. The resulting four-junction photovoltaic delivers a total efficiency of 44 percent at 1000 suns (see Figure 4). Extrapolating our concentrator

In addition to improving the optical performance of our concentrator system, we are also pursuing ultra-high efficiency cells by moving to quadruple junction, four-terminal devices. By transfer-printing different sub-cells on top of one another, we avoid the current- and lattice-matching issues that have challenged monolithic four-junction cells to date

performance together with these high efficiency cells suggests that a microtracking CPV panel could deliver 50 percent more energy over the course of a sunny day than a state-of-the-art silicon module of equivalent size. Delivering high-performance is no guarantee of success for rooftop CPV – modules will also have to deliver long-term operational reliability, while retailing for a price that makes them competitive with existing PV panels. It is likely that the key to reliability will be environmentally-robust plastic or glass lenslet arrays, since all the cells, moving interfaces and lubricating oil are sealed and protected within the concentrator stack. Making meaningful cost projections at such an early development stage is tricky, but the combination of wafer recycling, high-throughput transfer printing and inexpensive injection-moulded optics indicates that the ingredients are there for a low-cost system.

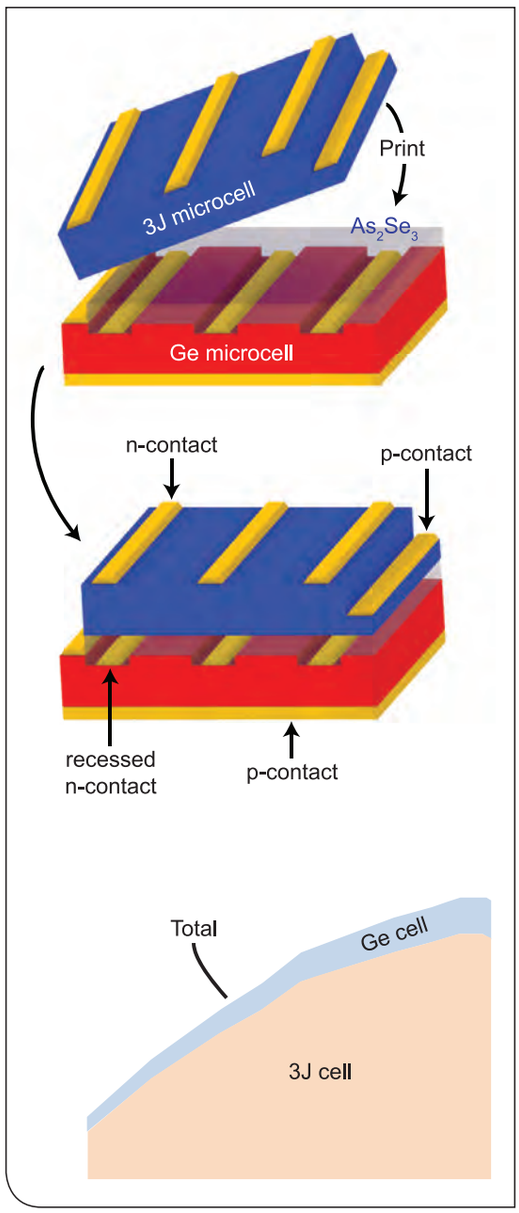


Figure 4. A mechanical assembly approach can create four-junction microcells that deliver a higher efficiency than their triple-junction predecessors at a range of concentrations.

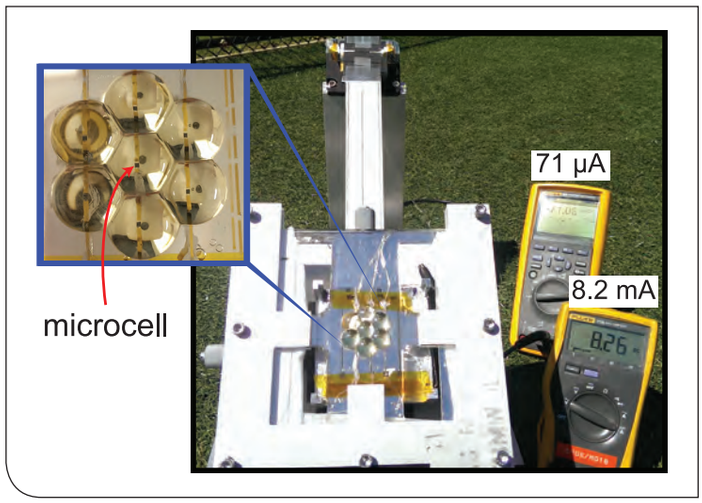


Figure 3. Outdoor testing of a small-scale prototype using three-dimensional-printed lenslet arrays.

It is important to emphasize that microtracking CPV complements – rather than competes with – conventional CPV. The latter is ideal in applications where space and movement are not constrained, while our microtracking approach opens up an opportunity to deliver a step-change in the efficiency in constrained-space rooftop and urban installations. This expands the number of markets that CPV can serve, and we hope that it will accelerate the broader adoption of this technology.

Further reading

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From power to energy:

Paradigm shift in energy transition

Christopher Burghardt the Vice President for Europe for First Solar speaks to Solar UK and gives his view on what really matters to consumers and why the industry needs to evolve.

IF THE GLOBAL ENERGY TRANSITION is any indicator, solar photovoltaic (PV) technology has come a long way from being a subsidy-driven optionality to earning a meaningful position in the global power generation portfolio. Driven by market fundamentals - falling PV prices, increasing efficiencies, and the rising costs of grid electricity from other sources - solar PV is now being installed at an unprecedented pace by utilities, developers, and large corporations around the world.

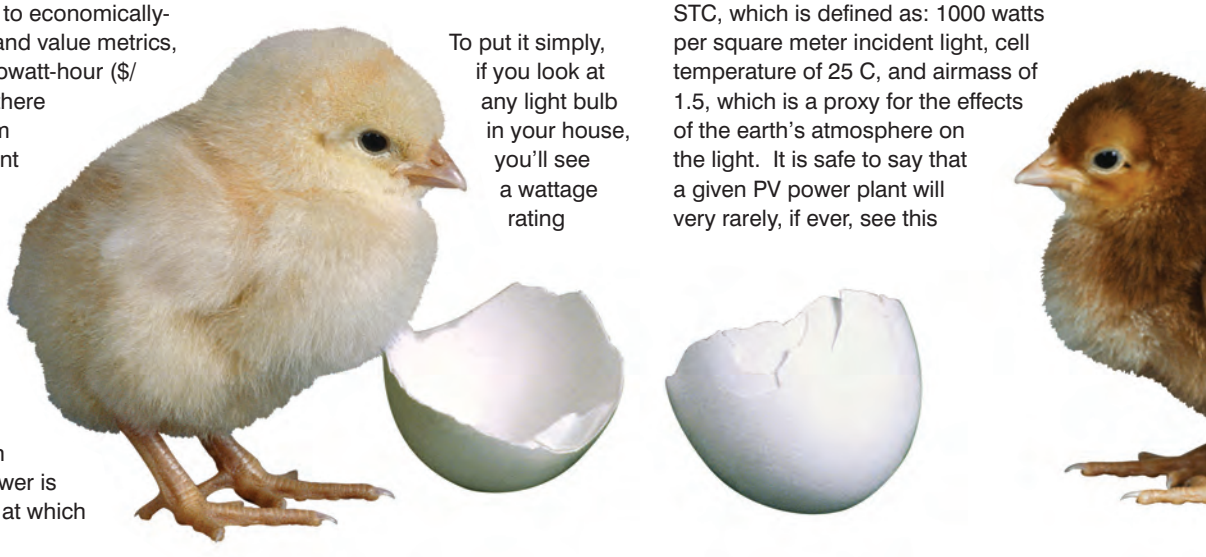
It is in this dynamic context that the solar industry needs to focus its attention on what really matters to its customers, and the end-user: energy. This means evolving from a narrow focus on simple and, often misleading, metrics such as Dollars-per-watt ($/W), to economically-relevant performance and value metrics, such as Dollars-per-kilowatt-hour ($/kWh). In other words, there needs to be a shift from evaluating a power plant or its components on a nameplate capacity basis to, instead, measuring a system by its energy yield.

To explain this shift we must first clarify the distinction between Power and Energy: Power is the instantaneous rate at which energy is consumed, often expressed in Kilowatts (kW) or Megawatts (MW). Energy is the amount of power consumed over time, expressed in Kilowatt-Hours or Megawatt-Hours. Even within the industry, these important concepts are often confused.

Commonly used power ratings like efficiency, module nameplate power, or plant nameplate power capacity are certainly important signposts. But they, by no means, tell the whole story because PV plants deliver value as energy generation systems, and not simply a collection of components with individual attributes. While these metrics make it easy to discuss PV systems they fail to accurately capture the value driver that truly matters: system energy yield.

To put it simply, if you look at any light bulb in your house, you'll see a wattage rating printed on it. This power consumption rating – for example, 100 watts - represents the instantaneous rate at which that light bulb uses energy, and is a measure of power. If you leave this bulb on for 10 hours, it will consume 1,000 watt-hours (100W x 10 hours) or one kilowatt-hour (kWh) of energy. At the end of each month, your utility company will charge for the energy (kWh) consumed. Simply put, energy is what spins the meter.

The same is true with power plants. Every PV power plant has a nameplate capacity rating, which is the power it is capable of producing in standard test conditions (STC), often denoted in Megawatts Peak (MWp). All PV modules receive a nameplate rating at STC, which is defined as: 1000 watts per square meter incident light, cell temperature of 25 C, and airmass of 1.5, which is a proxy for the effects of the earth's atmosphere on the light. It is safe to say that a given PV power plant will very rarely, if ever, see this



particular combination of environmental conditions once it leaves the lab or factory and is placed into the field. That is why a given 100MW PV plant will perform very differently from another 100 MW PV plant if the technology, system design, environmental conditions, or control and operational philosophy is different. And in the power plant world, no two plants are alike.

The actual energy generation of a PV power plant depends on sunlight and other factors. These power plants often operate in harsh environmental conditions, such as extreme temperatures, high humidity, and dusty weather. A solar PV plant typically starts generating energy when the sun rises each day, with the amount of energy generated and the module temperature both continuing to rise until after solar noon, while declining towards sunset. And when operating in climates such as the Middle East or Africa, cell operating temperatures reach far above the 25 Celsius assumption used in the standard test conditions used to define a plant's nameplate capacity.

And not all PV technologies are created equal: First Solar's thin film modules are proven to deliver higher energy yield than conventional silicon-based modules in hot climates. In other words, in the same configuration, 1MW of First Solar modules will yield more energy than 1MW of crystalline silicon-based modules due to this inescapable fact of semiconductor physics. And this effect must be considered in the energy predictions and financial models used in the development and evaluation process of new solar power plants.

Solar power plants are much sought-after assets, valued by investors and financiers for their low risk profile, consistent annual energy production, 25-year-plus longevity and, critically, ability to deliver against long-term power purchase agreements. So, how can one ensure an attractive long-term investment with accurately predicted energy yields? As an owner of a power plant, whether it is a small system on your residential rooftop or connected to the high-voltage utility grid, profit is generated when the Levelized Cost of Electricity (LCOE) is less than the selling price or avoided costs of energy. LCOE is calculated by dividing the total costs by the total expected energy produced over the lifetime of the plant.

When predicting the energy output of a plant, a number of technical and environmental variables must be taken into consideration: irradiance, temperature, humidity and soiling conditions. In addition, the system design, loss factors, and grid requirements must also be considered. The proven long-term degradation assumptions of the PV module technology and the bankability of the company behind it must also be taken into account particularly since 25 years is a long-term horizon for any investor.

By paying attention to the LCOE, the industry is moving away from the historic mindset of, "How much do I pay per watt of capacity?" to the more meaningful, "How much do I pay for a kilowatt-hour of energy?" Considering the fact that the main product of a power plant that can be monetized is its energy, this is a logical, economically-sound approach.

Solar energy has rapidly evolved into a mainstream energy source over the last few years and, by all indications, is poised to become a major energy resource in Europe and globally in the long-run. With this in mind, the solar industry needs to distance itself from its legacy metrics while effectively articulating its value proposition: the delivery of clean, affordable and reliable energy.

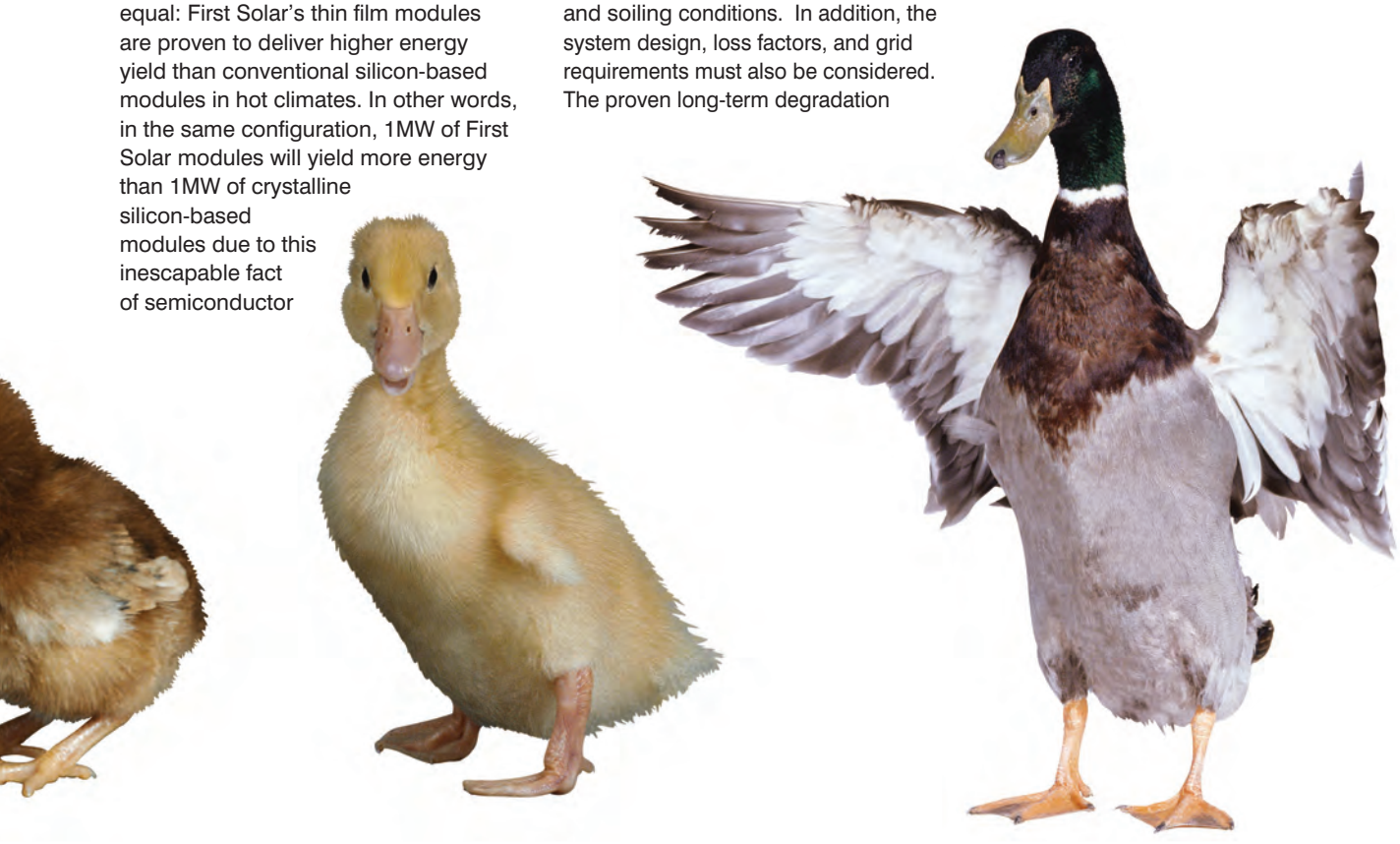


Figure 1. Mono-crystalline silicon boules produced by the Czochralski process.

Can argon recycle system offer significant cost savings?

The trend in the market is to move to higher efficiency solar cells manufactured from high performance multi-crystalline or *n*-type doped mono-crystalline which increases demand for argon. With argon production essentially fixed potental argon prices will increase rather than decrease. This potential cost increase can be reversed with argon recycle and with practical recycle rates approaching 90 percent the contribution of argon to the cost of manufacturing can virtually be eliminated. Dr Rob Grant, founder and CEO of Gas Recovery and Recycle tells Solar & Power Management how this significant cost saving is possible.

CRYSTALLINE SILICON SOLAR CELLS account for over 80 percent of the solar PV market. They are fabricated from substrate wafers sourced from a variety of silicon ingots; either multi-crystalline or mono-crystalline and either p-type or n-type doped, cells of the highest efficiency being fabricated from n-type mono-crystalline substrates. No matter which kind of substrate wafer is to be used to fabricate the solar cell the manufacturing processes that lead to the wafer are at a first pass the same.

Silicon feedstock is melted at ~1,600ºC in a quartz based crucible in a vacuum furnace that is purged with high purity argon to manage the impurity levels within the system. The molten silicon is then crystallised either by slowly pulling a single crystal ingot out of the molten silicon, a process known as the Czochralski process, CZ, that produces single crystal ingots, Figure 1, or allowed to slowly crystallise en-mass from the bottom of the crucible, a process known as directional solidification, DS. Typically these processes take ~60 hours or so to complete and require argon purge throughout the process cycle to keep the impurity compounds at acceptable levels – see breakout box. To produce the highest efficiency solar cells typically requires the highest purity silicon wafers which in turn require high argon purge gas flows to keep the impurity levels in the vacuum furnace at an acceptable level.

The trend in the market is to move to higher efficiency solar cells manufactured from high performance

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- Egypt now has a target to generate 20% of its energy from renewable sources by 2020. The country's leading solar production line will have an annual capacity of 4300 MW by 2017**
- In 2015, there were 154 exhibiting companies from the solar sector occupying a gross space of 7,200 square metres, with more than 6,500 solar industry professionals in attendance.

* Source: MESIA report ** Source: NREA (small solar systems / large solar and wind plants)

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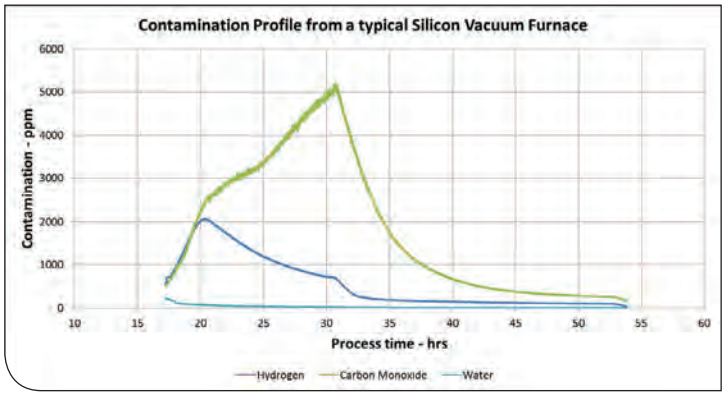


Figure 2. Recovered Argon impurity profile.

The typical impurities in the exhaust argon are independent of the furnace type and originate from the materials used in the process – quartz (SiO2) crucibles to contain the liquid silicon which gives rise to gaseous SiO, the insulation materials that degas moisture that then reacts with the graphite heaters to generate CO and H2 along with additional reaction of some of the SiO with the graphite heating elements to generate extra CO. While the SiO condenses and forms particulates which are typically trapped prior to the vacuum pump the CO and H2 are entrained in the argon gas stream and need to be removed in any recycle scheme. The typical impurity profile from a vacuum furnace is shown in figure 2 with the maximum contamination reaching many thousands of ppm and occurring towards the start of the process while the silicon is in the melt stage.

multi-crystalline or n-type doped mono-crystalline which in turn places an increased demand for argon. With argon production essentially fixed this will inevitably mean that argon prices will increase rather than decrease. This potential cost increase can be reversed with argon recycle and with practical recycle rates approaching 90 percent the contribution of argon to the cost of manufacturing a solar cell can virtually be eliminated.

Why Argon?

Argon is chosen over other potential purge gases, such as nitrogen, for its chemical inertness; argon is not known to form stable compounds with any other element in the periodic table. Nitrogen, on the other hand, will readily form compounds with other elements and in particular silicon forming silicon nitride, a hard ceramic material used in drill tips and bearings etc. Argon is extracted from air, where it is the third most abundant element after nitrogen and oxygen. The separation process is energy intensive and takes place at ultra-low temperatures of almost -200oC at which temperatures air liquefies and the various component parts can be separated by distillation. The argon, in its liquid state, is transferred to road tankers for the journey to the customer's facility where it is transferred to a cryogenic storage tank prior to vaporisation and use in the vacuum furnaces.

A typical solar ingot manufacturer will use between 2 to 4 million m3 of argon per 1 GWp of silicon wafer output depending on the type of process and ingots produced with the exhaust gas from the vacuum furnaces vented to atmosphere. At prices up to $2.0 per cubic metre of gas, argon represents a significant cost to the manufacturers and is at the percent level as a proportion of the total wafer cost. With the drive to reduce wafer costs, along with the desire from manufactures to improve profitability, recycle of argon is becoming a compelling argument.

Argon recycle strategies

A typical furnace facility will have many tens of furnaces located in a furnace hall, Figure 3, and in order to recycle the argon it first needs to be recovered from the exhaust lines of the vacuum pumps associated with the individual vacuum furnaces, then purified and returned to the vacuum furnaces. There are two philosophies to the recycle of exhaust gases from process tools: Point of Use recycle where the exhaust gas is diverted to a local purification system close coupled to a limited number of tools, say <10, and Central processing where all the facility exhaust lines are combined together and fed to a single, larger, purification system.

The pros and cons associated with such approaches are summarised in Table 1 below but it is interesting to note that in the microelectronics industry, faced with the similar problem of Point of Use or Centralised scrubbing, almost all fabrication facilities have adopted the Point of Use approach, largely for the flexibility that it offers.

There is a "common sense" rule in gas recycle and that is to avoid adding any extra gas/contamination post the process tool that then needs to be subsequently removed before returning the gas into the process again. Unfortunately, by its very nature, the centralised system approach breaks this rule by mixing the exhaust gas from furnace pump-down, which contains air, with the exhaust gas during process runs which just contains the process contaminants. Thus Centralised systems, by their very nature, are forced to employ additional purification technologies to remove O2 and N2

as well as the CO, H2 and hydrocarbons from the process proper; this is not the case for Point of Use systems.

Purification technologies

There are a number of purification technologies available in the market today but the majority of these have been developed for the microelectronics industry to purify process gases which are contaminated, at worst, at the ppm level and purify them to the ppb level. For the solar photovoltaic application the contamination levels that need to be removed are at the 1,000 to 10,000 ppm level and the required recycle gas purities are in the 99.999 percent to 99.9999 percent range i.e. N5.0 – N6.0. The current generation of microelectronics type purifiers would typically breakthrough in minutes at these levels of contamination and so are not suitable as the primary purification stage for a process taking up to at least 60 hours but they do have a place in further cleaning photovoltaic specification gas to the higher specification microelectronics grade where that is required.

A different approach is needed and the majority of potential Ar recycle system providers have adopted a similar chemical strategy but with grossly different implementations. Typically this involves a combustion step to convert the CO and H_2 to CO_2 and moisture followed by an adsorption or separation step to remove the CO_2 and moisture leaving high purity argon. For the Point of Use system supplied by GR2L, the ArgonØ, this is exactly the approach taken, it uses a unique chemical looping combustion reactor that utilises solid state oxygen carriers to ensure oxygen free recycled gas. A chemical looping combustion reactor typically comprises a packed bed made of a metal/metal oxide couple that is repeatedly cycled from the oxidised state (metal oxide MO) to the reduced state (Metal M) and back again as shown below for CO oxidation i.e. continuous looping between steps 1 and 2. The process is strongly exothermic and is stoichiometric rather than catalytic in nature. The overall process is chemically the same as gas phase oxidation although during the gas clean-up, step 1, there is no introduction of any gas phase oxygen. In fact the reactor will very effectively, and simultaneously, remove any O_2 from the gas stream that may be present. The gaseous oxygen required for regeneration, step 2, comes from ambient air and so the CLC approach does not require any additional gas supply.

$CO(g) + MO(s)$	$CO_2(g) + M(s)$	1
$½O_2(air) + M(s)$	$MO(s)$	2
$CO(g) + ½O_2(g)$	$CO2(g)$	3

Figure 3. CZ furnace hall Photograph courtesy of Norsun, Norway

The Centralised systems are inevitably more complex as they also need to remove the O_2 and N_2 introduced into the recovered gas during the pump-down from atmospheric pressure of the vacuum furnaces and also accommodate the wide variations in total flow as different furnaces end and start their respective production cycles at different times. The concentrations of O_2 and N_2 can vary from as much as 10,000 ppm down to effectively zero; these wide variations in feed gas and impurity concentration present a problem as in general purification systems work best with stable flows and concentrations. One manufacturer from Japan, attempts to avoid the problem by dynamically measuring the feed gas flow and impurity concentration to adjust an O_2 feed into a precious metal catalysed combustion reactor to just below stoichiometry – thus most CO and H_2 is converted to CO_2 and moisture but not all but the gas does remain oxygen free. This mixture is then passed into a series of Pressure Swing Adsorption, PSA, beds to remove the residual CO & H_2 and the N_2, CO_2 and H_2O. The system is reported to operate at a recycle rate of approx. 80 percent with a gas purity of N4.0. Additional purification steps can be added to meet the gas purity requirements from the customer.

Unfortunately the catalyst in the precious metal catalytic combustion reactors used is susceptible to poisoning by compounds found in vacuum pump oil (for example sulphur compounds) and so these systems are only suitable for dry vacuum pumped installations. While the current trend is towards dry

Table 1. Pros and Cons of PoU verses Centralise argon recycle

	PoU recycle	Centralised recycle
Footprint	**Small** - can be co-located with the process equipment	**Very Large** – needs to be located in a separate building next to the process facility
Installation	**Phased** install with the process equipment, no doubling up of Ar supply or exhaust	Single **one-off** facility wide installation, must double up on Ar supply and exhaust lines
Retrofit?	**Yes** - Easy to retrofit	**No** - Very difficult to retrofit
Need to remove Air?	**No** – exhaust gas from pump-down vented until air free, then diverted to recycle	**Yes** – exhaust gas from pump-down is mixed with the other air free exhaust gases
Use with Wet vacuum pumps?	**Yes** – can be used with both wet and dry vacuum pumps	**No** – can only be used with dry pumps, oil vapours poison the catalyst
Utilities	Electrical power, Compressed air, cooling water	Electrical power, Compressed air, cooling water, high purity O_2 or H_2, Cryogenics

vacuum pumps to evacuate the vacuum furnaces at least 50 percent of the installed base utilise oil lubricated vacuum pumps and so rule out Ar recycle systems employing precious metal catalytic combustors.

The ArgonØ PoU recycle system

The ArgonØ, figure 5, from Gas Recovery and Recycle Limited, GR2L in the UK, is designed to recover, purify and recycle exhaust purge gas from both CZ and DS vacuum furnaces and the system uniquely copes with both oil sealed and dry vacuum pumps. It utilises chemical looping combustive purification technology jointly developed with Cambridge University that enables recycle rates of at least 95 percent with recycled argon gas purities exceeding industry expectations.

The system is Point of Use and can connect to multiple vacuum furnaces, subject to a maximum exhaust gas recycle flow limit of approximately 15 Nm3/hr, enabling straightforward retrofit to current vacuum furnaces along with a phased installation, in line with the installation of the vacuum furnaces, in new establishments. In one location in Taiwan an ArgonØ system connected to eight DS vacuum furnaces typically recycles approximately 11 tonnes of argon per month with an ArgonØ recycle rate of better than 95 percent. None of the ~60 high performance ingots produced per month show any variation outside of normal measurement parameters. Sam Huang, Vice General Manager, said "I have to say that the ArgonØ is a more flexible and compact system compared with a centralised system concept" adding "the installation process was straightforward and resulted in minimal disruption to our production schedules".

Figure 5. The ArgonØ Point of Use Recycle System.

In summary the GR2L ArgonØ gives ingot producers the opportunity of reducing their Ar consumption, reducing their carbon footprint, give added effectiveness to their supply of Ar and does not impact the quality of their ingots. These benefits enhance the profitability for the ingot manufacturer at a time when margins are under extreme pressure.

Rural urbanization through **Nano-Grids**

The focus on providing electricity to rural homes around the globe has grown tremendously but still many barriers remain with the major ones being access to financing, subsidy, and available technology that is both effective and also affordable for low income homes. Shahan Ahmed spoke to Solar & Power Management about the options available.

LAUNCHED IN 2006, the Solar Home System program launched through Infrastructure Development Company Limited (IDCOL) has started a new solar revolution in Bangladesh. With its success, these systems are now being disseminated around the globe including Asia and Africa. The systems are providing rural families the opportunity to finally light up their homes with electric powered bulbs and charge their mobile phones at home. Though Bangladesh has joined as one of the fastest developing countries around the globe, it still has a long way to go as it is still one of the least developed countries compared to others.

Gross National Income per person is $900 per year, which is only 2 percent of Japan. Infrastructure is very poor and 20 million Households are still off-grid and do not have access to any forms of affordable electricity. The Solar home system project has been extremely successful as these systems are now connecting thousands of homes every month in Bangladesh, but the systems so far remain limited to just powering merely a couple of light bulbs.

To provide these homes with a quality of service that will help them truly develop from one stage to another, more is required, perhaps on the innovation side. Solaric, a US and Bangladesh joint solar innovation company has introduced a new solution known as Nano-Grids. These systems are a turn-key community sharing energy generation system that has shown a track record of success and is promising to close the gap between rural and urban homes by providing unrestricted electricity access to rural homes at a cost that is 70 percent below other alternatives including diesel and its Solar Home System counterpart.

Solarics founder and developer of the technology behind the Nano-Grid systems, Didar Islam, says, ‘‘It’s not just about turning on the lights, but about enabling rural homes to finally move from one stage of development to another” In order to truly help rural areas where living standards are still primitive and predominantly rely on farming, providing them with merely a light bulb may not be enough to help them improve their standard of living and improve economic conditions. Many of these Nano sites have already been established and each site has been running successfully while also supporting the rural economy through its business model. The entire systems cost is shared by the village which has removed the need for any donors or government subsidy; a model that has not been seen till now when it comes to approaching rural electrification and the company has proven it to work.

The systems have created entrepreneurs in every village who, by putting down a bulk of the investment required, are now co-owners of these systems and are earning income through operating and providing the service to the connected homes. The entrepreneurs are able to use their income to provide further services and open new shops and establishments that can help transform these rural areas and bring it closer to urbanization.

At Recent a visit by Nikkei News reporter, Nihon Keizai Shimbun, to a rural village in Bangladesh known as Rohadi, he visited Mr. Shojib, a local entrepreneur who invested in a system and is now providing 45 homes with unrestricted energy access and earning a decent monthly income by doing so.

From Shinbuns visit, he saw a village which once used kerosene lamps for lighting and were unable to afford any forms of electricity, finally introduced to the light bulb. Furthermore, he saw families using fans, and watching color television.

“I asked the people, what programs do you watch on TV? Together, at the same time, the town people shouted programs like Indian drama series or Discovery Channel, something that these people were not able to imagine before” says Shinbun. He also stated that the people of the town gathered around the entrepreneur’s home and saw him as a hero because the improvements the Nano-Grid systems has made on their lives was an overwhelming experience.

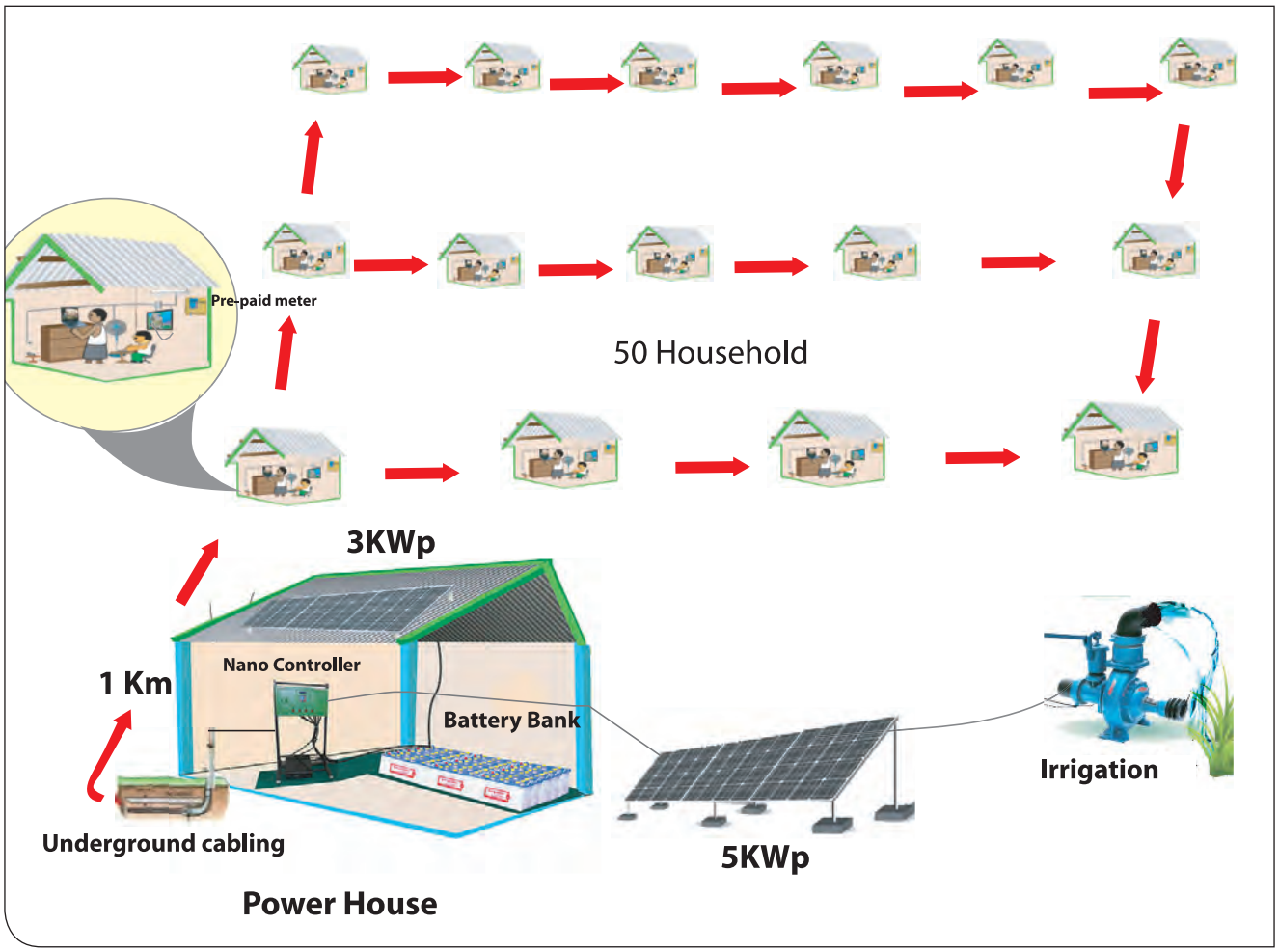
Solaric says, Nano Grids can provide rural homes unrestricted energy access around the clock for only $5 per month which allows them to power up to 4 lights, a fan, TV, and computer. The systems also support any AC or DC irrigation pump which farmers can run at a far more affordable price than the diesel pumps they use now.

Furthermore, the systems allow families to pay for more or less depending on what they are able to afford or demand which is allowing almost every home to have at least some level of energy access.

Until recently, you would simply see rural villages, at most, dimly lit through kerosene lighting or older generation Solar Home Systems. Looking through the windows of many rural homes now, you will see rural homes are now lighting multiple rooms in their homes, watching television, and using computers.

By definition, these homes that were once considered rural, will soon no longer be considered as such. US Ambassador to Bangladesh and Solaric, Dan Mozena says, “I see a future where rural areas of Bangladesh and abroad empowered through Nano technology, and Nano-Grids are showing the way for the world on how rural electrification should be done”.

It appears Nano-Grids show a great potential in bringing a future where the gap and differences between urban and rural areas no longer exist.



Panasonic

going from strength to strength

The global success story for Panasonic continues.

SINCE BEING FOUNDED IN 1918, manufacturing giant Panasonic has built its brand and reputation upon two fundamental standards – world class quality and unparalleled reliability. It is a philosophy that has allowed them to become the one of the largest electronics manufacturers in the world, generating over $70 billion in revenue over the last fiscal year.

This philosophy is also clearly engrained in its burgeoning solar business, part of the company's Eco Solutions division alongside other technologies including LED lighting, EV charging stations and air conditioning.

Since acquiring Sanyo in 2009, Panasonic has become one of the leading solar module manufacturers in the world through its patented HIT technology, combining mono-crystalline and amorphous silicon layers to produce high power efficiencies across its solar PV module range.

In March this year, the company introduced the newest addition to its HIT panel line-up, the N285. In comparison to the highly successful N240 and N245 PV modules that have been a staple of the solar industry in recent years, the N285 has been designed specifically with the European market in mind.

Most visibly, the module features a more compact design than previously seen in its HIT range, particularly the length of the panel. By reducing the size of the panel, installers are able to install more of them on a typical sized residential home, as well as needing less space between module rows on flat roofs.

The more compact design makes the N285 optimally suited to the thriving UK market and the country's 4KWp residential feed-in tariff (FiT). Based on the rooftop space required by the average UK residential solar PV system of 3 kWp, a comparable N285-based array will have an installed capacity of 3.99KWp, thus aligning with the FiT requirements and maximising the energy and earnings generated for the typical UK homeowner.

In a first for Panasonic's HIT module line, the N285 also incorporates a unique water drainage design. Positioned on the corners of each panel, the distinctive feature allows for constant discharging of accumulated water, preventing water from drying on the module and causing dry stains that inevitably reduce power output.

"The N285 represents our most advanced, reliable and high quality solar module to date", explained Daniel Roca, Senior Business Development Director. "After successfully launching the N240 and N245 module for the global PV market, we fully analysed the ever changing requirements of PV installers as well as identifying improvements we could make to generate the maximum power, savings and return for European consumers. As a result, we've been able to design a module that is perfectly suited to the European rooftop market."

Since introducing the N285 at London's Ecobuild show in March, the module has generated an excellent response amongst homeowners and installers alike, particularly in the UK. Panasonic has distributed the N285 throughout its Premium Installer Programme to its select group of MCS accredited installers.

To further raise awareness of the N285, Panasonic is engaging directly with UK homeowners through the company's virtual solar platform https://panasonic.generaytor.com/.
The service allows consumers to virtually design a solar system on their roof and in-turn, provides homeowners with a clear estimate of how much of their day-to-day needs can be powered by a solar system, the financial earnings they can expect from Panasonic solar modules, and the investment required to go solar.

Roca continues, "The purpose of launching our virtual design platform is to empower UK homeowners to see just how much they can earn and save through solar energy. The website pulls in information from neighbouring solar installations, thereby providing the users with extremely accurate estimations on how solar can power their day to day needs. Most importantly, the platform allows consumers to 'try before you buy', and therefore make an informed, independent decision of whether to go solar."

In recent years Panasonic has been involved in a variety of innovative, enterprising projects across the world to help demonstrate the different applications and benefits solar energy can offer. Among the company's most revered ventures is the much publicised solar installation upon London's Blackfriars Bridge

The company's virtual solar platform is an example of Panasonic's growing focus on consumers, fitting in well with its established brand slogan 'A better life, a better world.' This is no more evident than in the recently completed Fujisawa Sustainable Smart Town, located an hour south of Tokyo. Featuring 1,000 homes, the town is underpinned by Panasonic's solar and storage solutions making it 100 percent sustainable.

Aside from the town's high use of renewable technologies, what also sets it apart is its visionary community-lifestyle philosophy, incorporating every aspect of people's lives such as energy, security, mobility, and healthcare to create an ideal urban environment. The town has and continues to win critical acclaim and accolades across the world for its visionary concept. In recent years Panasonic has been involved in a variety of innovative, enterprising projects across the world to help demonstrate the different applications and benefits solar energy can offer.

Among the company's most revered ventures is the much publicised solar installation upon London's Blackfriars Bridge. Completed in January 2014, Panasonic worked with UK developer Solarcentury to install 4,400 HIT panels which now provide Blackfrairs Station with over 50 percent of its annual electricity demand.

Later in 2014, the company further strengthened its association visionary projects by working with Tokai University to participate and win the prestigious Carrera Solar Atacama, South America's biggest solar car race. The car was powered by a combination of the company's HIT modules and high-capacity lithium-ion batteries, covering the 1,082 km race in 15 hours, 20 minutes. Such was the success of the project, Panasonic will once again team up with Tokai to compete in this year's World Solar Challenge which will travel the length of Australia from 18th-25th October.

The World Solar Challenge will book end one of the most significant years for Panasonic as it celebrates 40 years of providing the world with solar solutions. The company used the recent Intersolar EU in Munich to mark the significant milestone, showcasing its full array of solar products and solutions, including the introduction of its lithium-ion energy storage technology for Europe.

The product mirrors the N285 in its compact design that allows it to be installed in small spaces in residential and commercial properties. Panasonic has also incorporated an emergency power function into the product, ensuring users are protected from power outages on the public network or grid.

With the company having a reputation in manufacturing high quality lithium ion batteries, they expect their energy storage solution to show strong adoption across Europe, continuing to drive the company's solar business from strength to strength in 2015 and beyond.

Perovskite
solar technology shows quick energy returns

New technology beats current solar panel technology in life-cycle energy assessment.

IN THE SOLAR POWER RESEARCH COMMUNITY, a new class of materials called perovskites is causing quite a buzz, as scientists search for technology that has a better 'energy payback time' than the silicon-based solar panels currently dominating the market. Now, a new study reports that perovskite modules are better than any commercially available solar technology when products are compared on the basis of energy payback time.

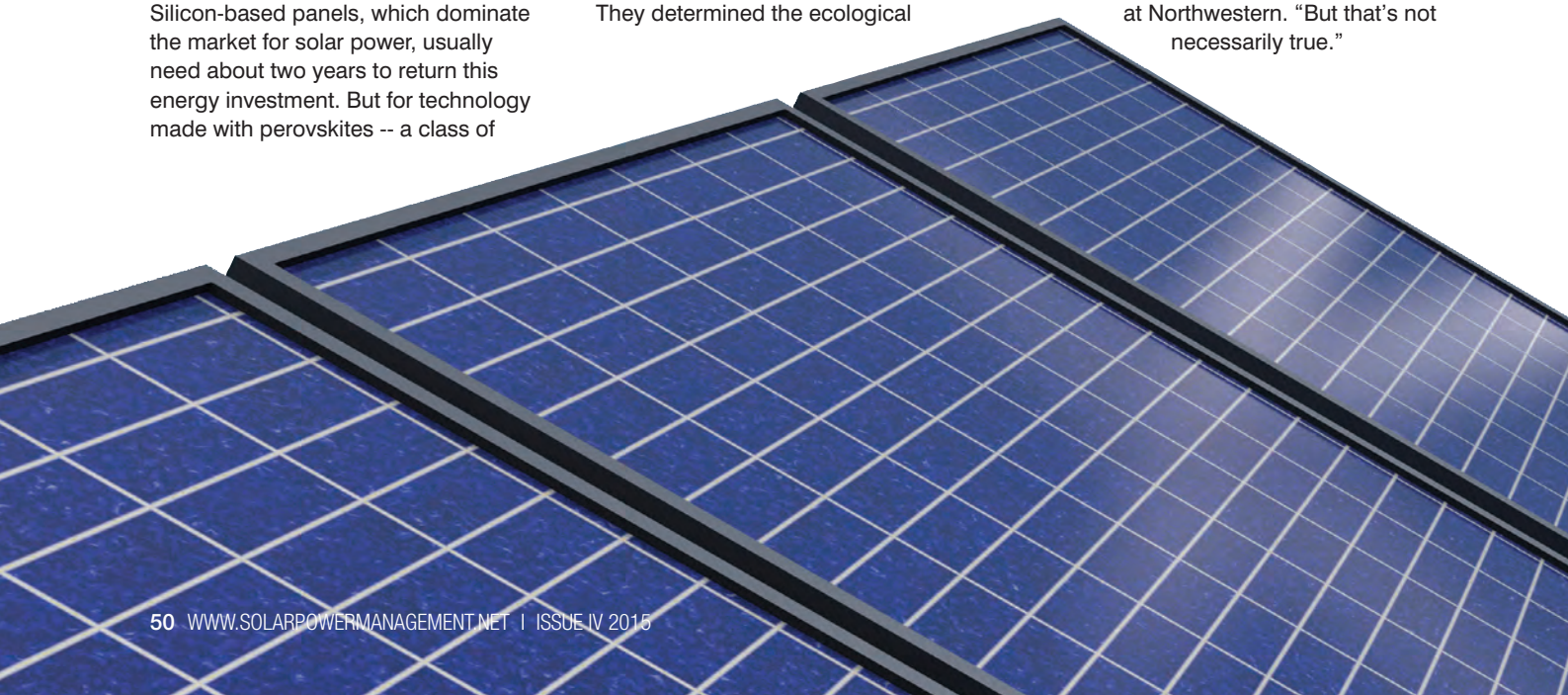
Solar panels are an investment -- not only in terms of money, but also energy. It takes energy to mine, process and purify raw materials, and then to manufacture and install the final product.
Silicon-based panels, which dominate the market for solar power, usually need about two years to return this energy investment. But for technology made with perovskites -- a class of materials causing quite a buzz in the solar research community -- the energy payback time could be as quick as two to three months.

By this metric, perovskite modules are better than any solar technology that is commercially available today.
These are the findings of a study by scientists at Northwestern University and the U.S. Department of Energy's Argonne National Laboratory.

The study took a broad perspective in evaluating solar technology: In what's called a cradle-to-grave life cycle assessment, scientists traced a product from the mining of its raw materials until its retirement in a landfill. They determined the ecological impacts of making a solar panel and calculated how long it would take to recover the energy invested.

Perovskite technology has yet to be commercialized, but researchers everywhere are excited about the materials. Most projects, however, have been narrowly focused on conversion efficiency -- how effectively the technology transforms sunlight into useable energy.

"People see 11 percent efficiency and assume it's a better product than something that's 9 percent efficient," said Fengqi You, corresponding author on the paper and assistant professor of chemical and biological engineering at Northwestern. "But that's not necessarily true."



A more comprehensive way to compare solar technology is the energy payback time, which also considers the energy that went into creating the product. This study looked at the energy inputs and outputs of two perovskite modules. A solar panel consists of many parts, and the module is the piece directly involved in converting energy from one form into another -- sunlight into electricity.

Perovskites lag behind silicon in conversion efficiency, but they require much less energy to be made into a solar module. So perovskite modules pull ahead with a substantially shorter energy payback time -- the shortest, in fact, among existing options for solar power. "Appreciating energy payback times is important if we want to move perovskites from the world of scientific curiosity to the world of relevant commercial technology," said Seth Darling, an Argonne scientist and co-author on the paper.

To get a complete picture of the environmental impacts a perovskite panel could have, the researchers also analyzed metals used for electrodes and other parts of the device.

One of the modules tested includes lead and gold, among other metals. Many perovskite models have lead in their active layer, which absorbs sunlight and plays a leading role in conversion efficiency. People in the research community have expressed concern because everyone knows lead can be toxic, Darling said.

Surprisingly, the team's assessment showed that gold was much more problematic. Gold isn't typically perceived as hazardous, but the process of mining the precious metal is extremely damaging to the environment. The module in this study uses gold in its positive electrode, where charges are collected in the process of generating electricity. The harmful effects of gold mining, an indirect impact of this particular perovskite technology, is something that could only be uncovered by a cradle-to-grave investigation, said Jian Gong, the study's first author and a Ph.D. student in You's research group at Northwestern.

The team hopes that future projects use this same zoomed-out approach to identify the best materials and manufacturing processes for the next generation of solar technology -- products that will have to be environmentally sustainable and commercially viable.

"Soon, we're going to need to produce an extremely high number of solar panels," You said. "We don't have time for trial-and-error in finding the ideal design. We need a more rigorous approach, a method that systematically considers all variables."

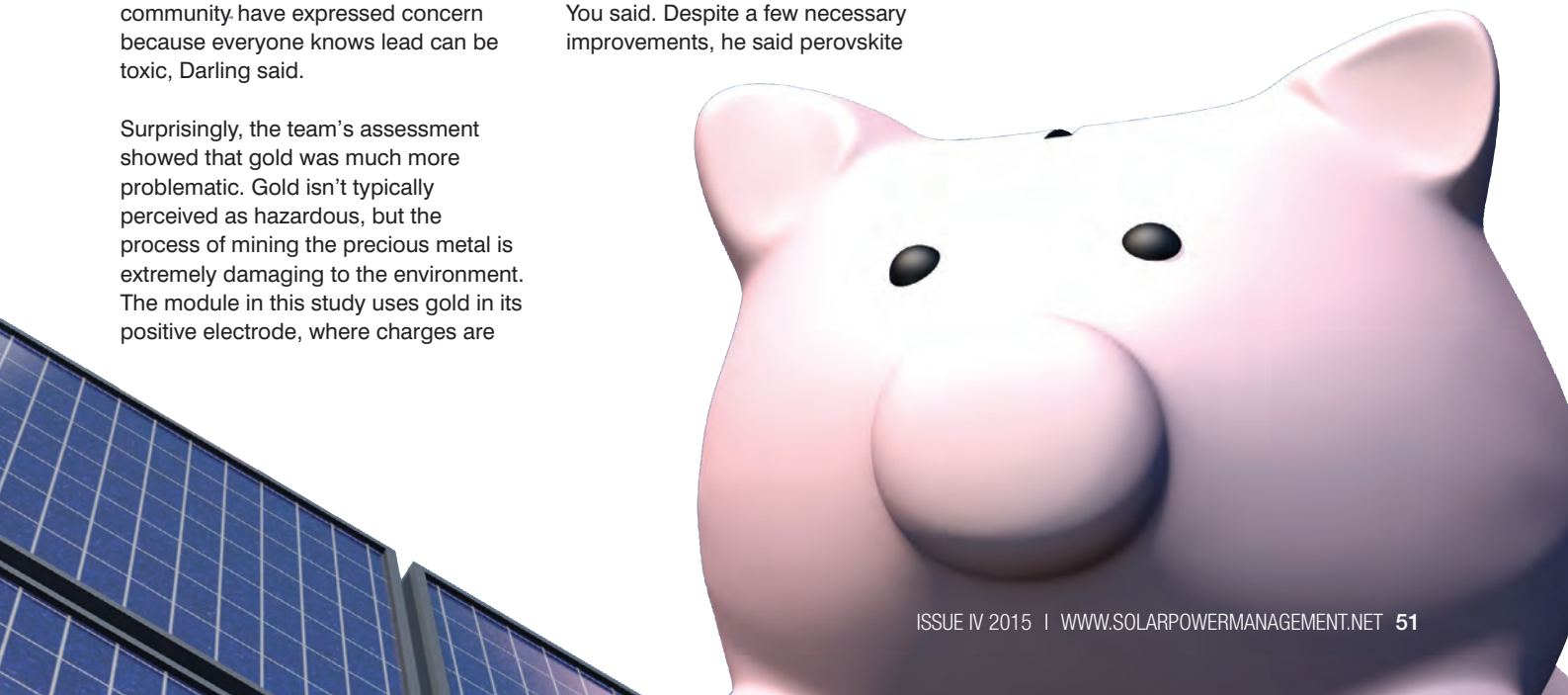
While this paper featured a thorough environmental assessment of different solar power options, further studies are needed to factor in economic costs. Before putting a perovskite panel on the market, scientists will likely have to replace gold and other unsustainable materials, for both environmental and economic reasons, Darling said.

In addition, extending the lifetime of perovskite modules will be important in order to make sure they are stable enough for long-term commercial use, You said. Despite a few necessary improvements, he said perovskite technology could be commercialized within two years if researchers use comprehensive analysis to optimize the selection of raw materials and manufacturing. One of the motivations for this study, according to the authors, was the need to improve technology so that solar energy can be scaled up in a big way.

Global energy demand is expected to nearly double by 2050, and Darling said there's no question that solar power must contribute a significant fraction. The real question, Darling said, is "How quickly do we have to get a technology to market to save the planet? And how can we make that happen?"

This research was conducted in part at the Centre for Nanoscale Materials, a DOE Office of Science User Facility supported by the DOE's Office of Basic Energy Sciences.

Journal reference
Jian Gong, Seth B. Darling, Fengqi You. Perovskite photovoltaics: life-cycle assessment of energy and environmental impacts. Energy Environ. Sci., 2015; 8 (7): 1953 DOI: 10.1039/C5EE00615E



New storage cell for **solar energy storage**

Materials science and engineering team has developed a new energy cell that can store large-scale solar energy even when it's dark.

A University of Texas at Arlington team have developed an all-vanadium photo-electrochemical flow cell that allows for efficient and large-scale solar energy storage even at nighttime. The team is now working on a larger prototype.

The innovation is an advancement over the most common solar energy systems that rely on using sunlight immediately as a power source. Those systems are hindered by not being able to use that solar energy at night or when cloudy conditions exist.

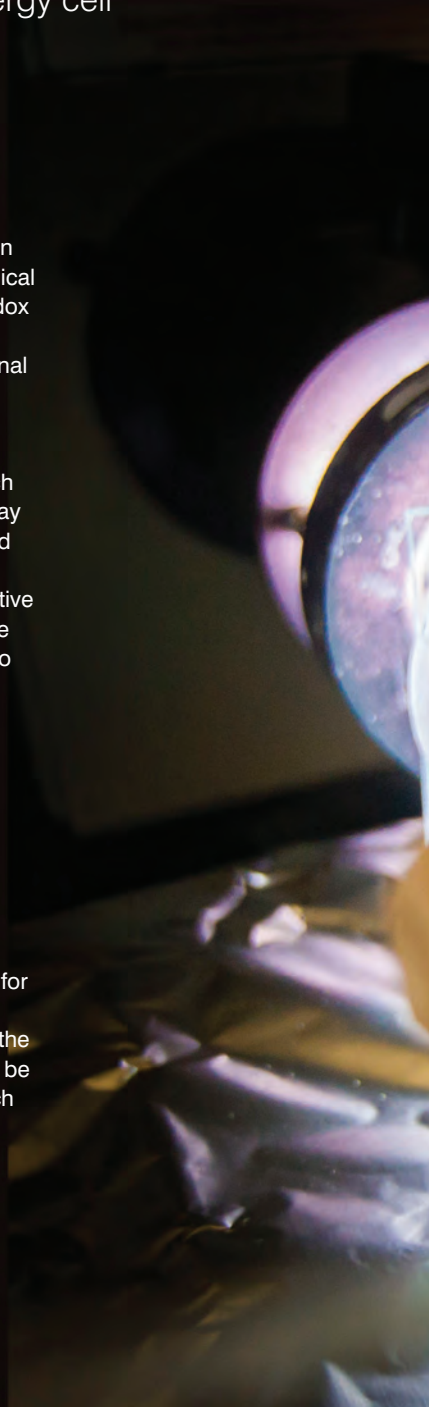
"This research has a chance to rewrite how we store and use solar power," said Fuqiang Liu, an assistant professor in the Materials Science and Engineering Department who led the research team. "As renewable energy becomes more prevalent, the ability to store solar energy and use it as a renewable alternative provides a sustainable solution to the problem of energy shortage. It also can effectively harness the inexhaustible energy from the sun."

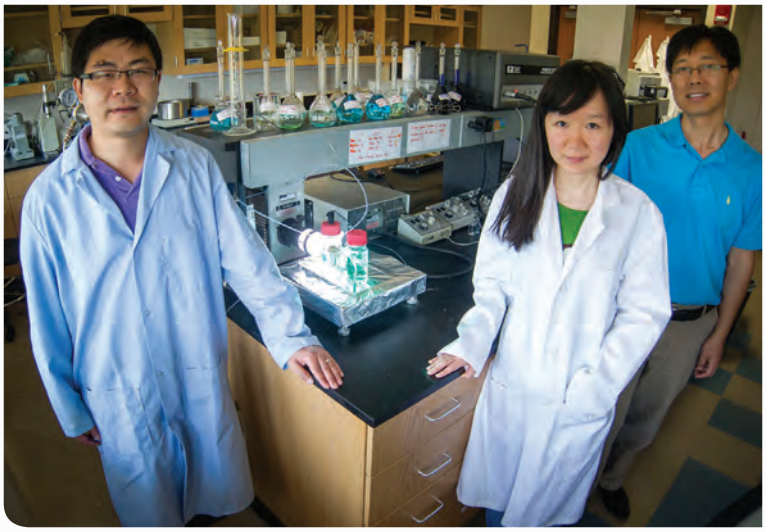
The work is a product of the 2013 National Science Foundation $400,000 Faculty Early Career Development grant awarded to Liu to improve the way solar energy is captured, stored and transmitted for use. Other members of the team included lead author Dong Liu, who recently defended his UT Arlington Ph.D. dissertation in 2015, and Zi Wei, a UT Arlington doctoral candidate.

The research is detailed in "Reversible Electron Storage in an All-Vanadium Photoelectrochemical Storage Cell: Synergy between Vanadium Redox and Hybrid Photocatalyst," in the most recent edition of the American Chemical Society journal ACS Catalysis.

Khosrow Behbehani, dean of the College of Engineering, said the groundbreaking research has the potential to positively impact on the way we generate and consume energy. "Dr. Liu and his colleagues are working to help us shape a more sustainable future and are taking innovative steps to improve our ability to harness and use one of the larger sources of energy available to us – the sun," Behbehani said.
Dong Liu, lead author of the paper, said a major drawback of current solar technology is the limitation on storing energy under dark conditions.

"We have demonstrated simultaneously reversible storage of both solar energy and electrons in the cell," Dong Liu said. "Release of the stored electrons under dark conditions continues solar energy storage, thus allowing for unintermittent storage around the clock."
Wei, another co-author of the paper, said that the research should allow solar energy storage to be done in a much higher capacity and on a much larger scale.





Dong Liu (left), Zi Wei (cantre) and Fuqiang Liu, an assistant professor in the UT Arlington Materials Science and Engineering Department.

azymuth

PV Module Cleaning: Does it pay?

MANY PHOTOVOLTAIC PLANTS IN GERMANY are exposed to heavy soiling. This ranges from PV plants that are located next to very busy streets exposed to extreme pollution or bird droppings. Pollution causes yield losses and in some cases irreversible damage to the modules if the contaminants are not frequently removed. From a technical perspective cleaning of PV modules makes a lot of sense in most cases, but does it calculate for the PV owner?

There are numerous reasons which are responsible for the contamination and the self-cleaning during rainy days will not remove all dirt in most cases. And the effect of self-cleaning is highly dependent on the slope of the modules – the smaller the angle of the slope, the less the effect will be. Further, the design of the modules also plays a crucial role. For example when you look at frameless PV modules the running water leaves less sediments at the edge the module. If PV modules are exposed to one or more of the following reasons of soiling, a regular cleaning should be considered:

- Organic substances from ventilation systems of cattle sheds
- Exhaust air from smokestacks
- Exhaust from nearby roads and industry
- Feed dusts from agriculture
- Bird droppings
- Leaves and flowers from trees
- Growth of plants like lichen, algae and moss

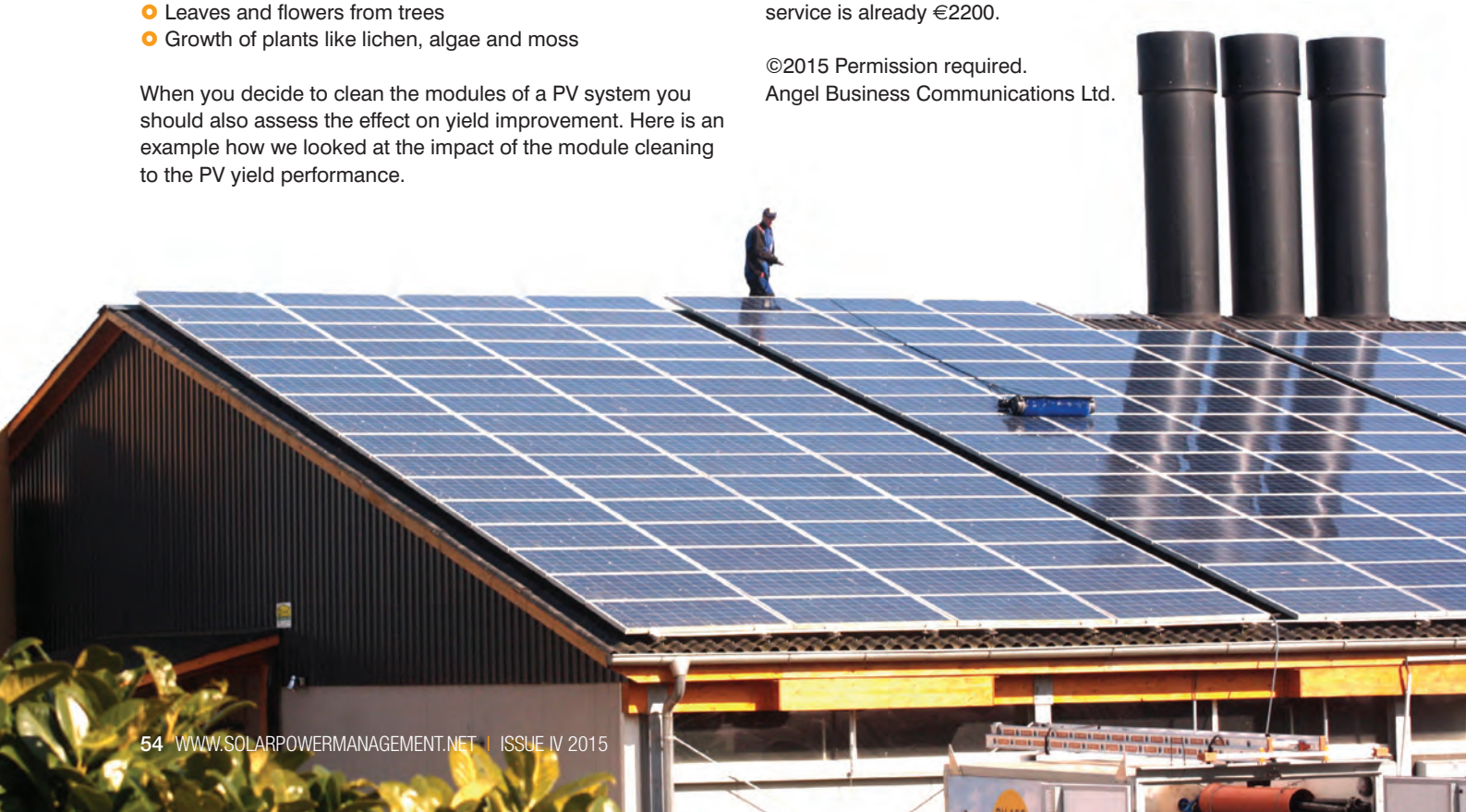
When you decide to clean the modules of a PV system you should also assess the effect on yield improvement. Here is an example how we looked at the impact of the module cleaning to the PV yield performance.

We compared:
The yield performance of a 100 kWp PV system before and after cleaning. The facility is located on the roofs of a stockyard. A nearby PV system, without particular pollution load was used as reference. Both PV systems were running without fail in the period under review.

Module cleaning
Figure 1 shows the monthly energy yield of the PV Plant (blue), the reference PV plant (red) and the prognosis for the PV Plant without cleaning. The PV plant was cleaned on the 24th of May. After cleaning a significant yield increase of more than 15 percent was measured and only two months after the cleaning the monthly yield dropped again below the reference and continuously degraded over time.

The green bars show a prognosis for the expected monthly yields if no cleaning would have been performed. The monthly yield improvement caused by the cleaning for the period from June to December adds up to 11.000kWh.

In the case of a feed-in tariff of 0.33 €/kWh, this corresponds to €3.630. The cleaning cost for the 100 kWp PV system is €1.430. The profit gained seven months after the cleaning service is already €2200.



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