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HAWAII: Turning away from fossil fuel power

SUNEDISION: Eying up the UK solar market

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view point

Hawaii leads the way

WHEN HAWAIIAN LEGISLATORS voted in May to end dependence on imported fossil fuels it made worldwide headlines. Hawaii derives 22 percent of its electric power from renewable resources and plans to raise that to 100 percent by 2045. This historic action will make Hawaii the first US state to de-carbonize its electric grid. The rallying cry in response has already been heard: Why can't we do this, too?

While a strong commitment is critical to change, let's realize that Hawaii's situation is unique; it didn't decide to 'go-green' on a whim. Hawaii's geography dictates electrical grids are independent from the Big Island to O'ahu. Coincidentally, that's also a great basis for adding photovoltaic power.

Second, Hawaii endured decades of dependence on expensive imported diesel fuel to generate electricity; power rates were three times that of mainland cities. In 2008 Hawaiians finally said, 'Enough!' Leaders jump-started work on wind power and solar installations.

Third, the Hawaiian Electric Company (HEC) has had a partnership with major PV solar manufacturer Enphase Energy for years. That advantage was realized publicly in February when Enphase remotely reprogrammed 800,000 microinverters with a button push. Enphase's Ameet Konhar, senior director for strategic initiatives, remarked this unique relationship is a model they hope will spread to other regions.

"We are definitely invested in Hawaii's energy future," remarked Konhar in a recent interview. "Hawaii is leading the world in how to integrate all levels of PV into the grid. Data exchanges and new storage solutions will all play a future role...to make power more predictable and reliable."

Fourth, as an archipelago Hawaii understands the global warming threat more than most. Peter Crouch, dean of engineering at the University of Hawaii, said everyone understands that Honolulu's Waikiki area could be under water by 2100 if ocean levels rise too greatly. Yet not every place in America with a substantial coastline takes Hawaii's approach. Consider Florida. The 'Sunshine State' ranks third for daily sun exposure, yet comes in between 13th and 24th for solar adoption.

The Solar Energy Industries Association asserts that Florida lags behind due to state policies. Florida also enjoys relatively inexpensive electricity. What hasn't caught fire is free enterprise leveraging the abundance of sun, along with state policies to kick-start the process.

A take-charge spirit has already manifested in Hawaii. Florida has a chance to step-up its game thanks to the growing ranks of businesspeople who see a future for solar in America's Sunshine State. But for now, it's 'Aloha time' to visit America's leading solar state.

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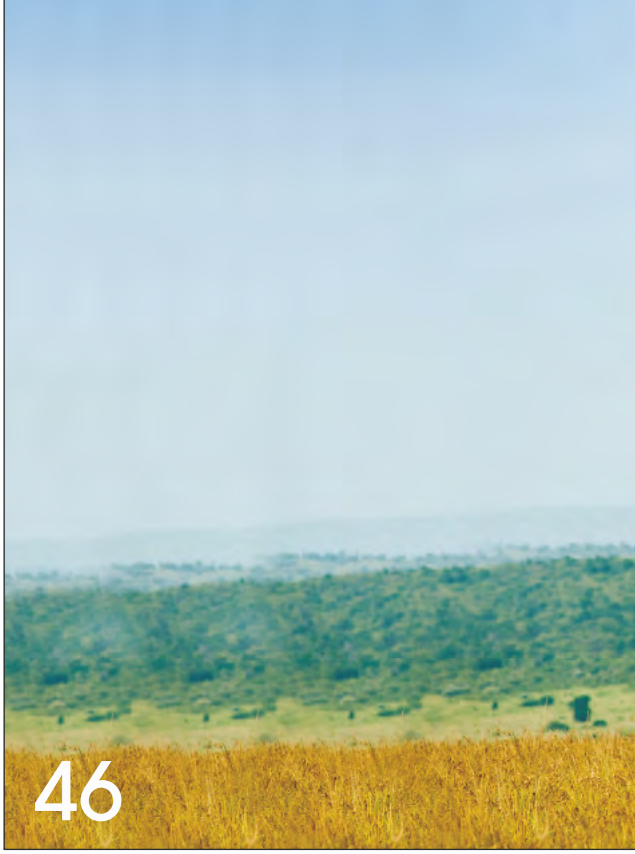

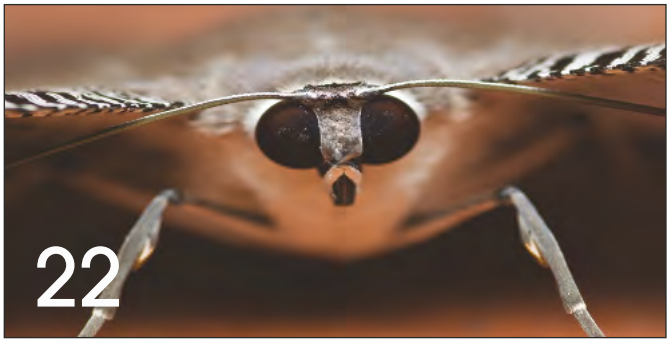

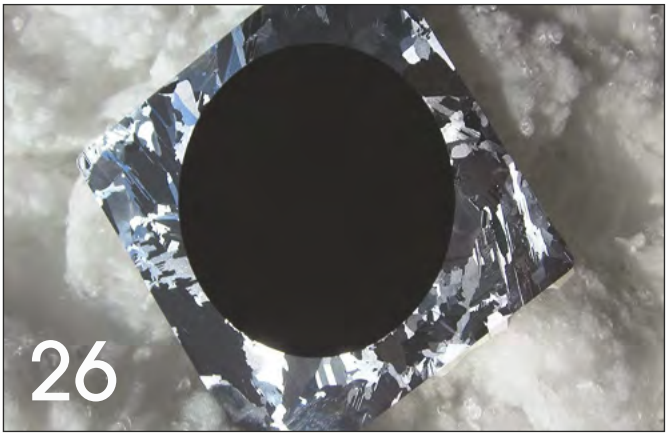

news

STATS

research

Yingli supplies Venezuela's largest solar project

YINGLI has announced that it has supplied 1.1 megawatts (MW) of solar panels for Venezuela's largest solar project, a hybrid solar-diesel power plant located in Los Roques. The 1.1 MW solar farm was developed, engineered, and constructed by Consorcio Energias Limpias

Alternativas Venezolanas (CELAV). Vico Export Solar Energy, a major regional solar product distributor, offered logistical and operational support for equipment procurement.

This power plant is Yingli's first large-scale project in Venezuela: until recently, the Venezuelan market was concentrated in off-grid systems of 25 kilowatts (kW) and smaller, typically located in isolated regions. As the country's inaugural PV power plant, it contains more than 4,400 multicrystalline YGE Series solar panels. They are expected to generate over 1,400 megawatt-hours (MWh) per year, which is enough energy to power over 400 typical Venezuelan homes. The system began operating in May 2015.

"We are pleased to partner with Yingli to bring green energy to the archipelago of Los Roques, a region that is known for its incredible natural beauty and biodiversity," commented Mr. Francisco Garcia, Project Developer of CELAV. "This new hybrid solar-diesel power plant is an ideal energy solution for Venezuela because it can reduce diesel-related logistics costs by at least 50 percent."

"We are honored to grow Yingli's presence in the Venezuelan solar market

by supplying the country's largest project, and we look forward to expanding our footprint in the country," commented Mr. Liansheng Miao, Chairman and Chief Executive Officer of Yingli. "There is significant potential for the development of more hybrid solar-diesel power plants in Venezuela, as they are an effective strategy for both increasing renewable energy production and ensuring reliable access to electricity in remote areas of the country."

IKEA Group and IKEA Foundation commit one billion euro for climate action

IKEA GROUP and IKEA Foundation are making bold new commitments to accelerate the transition to a low-carbon economy and to support the communities most at risk.

Announced today, the EUR 1 billion total is made up of an IKEA Group commitment of EUR 600 million for investment in renewable energy and a EUR 400 million IKEA Foundation funding commitment to support communities most impacted by climate change.

The announcements coincide with a key meeting in Bonn, where governments are preparing a global climate agreement to be negotiated at the COP21 meeting in Paris in December.

IKEA Group - The EUR 600 million commitment to renewable energy, announced today by the IKEA Group, builds on the EUR 1.5 billion invested in wind and solar since 2009.

The company is on track to become energy independent, producing as much renewable energy as it consumes in its buildings, and has already committed to own and operate 314 offsite wind turbines and installed 700,000 solar panels on its buildings. The majority of the new commitment (EUR500 million) will be invested in wind energy and around EUR 100 million is expected to be invested in solar up to 2020.

"Climate change is one of the world's biggest challenges and we need bold commitments and action to find a solution. That's why we are going all in to transform our business, to ensure that it is fit for the future and we can have a positive impact. This includes going 100 percent for renewable energy, by investing in wind and solar, and converting all our lighting products to affordable LED bulbs, helping many millions of households to live a more sustainable life at home." Peter Agnefjäll, President and CEO, IKEA Group.

IKEA Foundation - Building on many years of supporting children and families in some of the world's poorest communities, the IKEA Foundation also announced its own commitment of EUR 400 million through 2020 to support families and communities who are most impacted by climate change.

The IKEA Foundation funds programmes to create long term opportunities for children living in some of the world's poorest communities. In 2014, the IKEA Foundation contributed €104 million to more than forty partner organizations running programmes to benefit children in 46 countries.

Since 2009, programmes funded by the IKEA Foundation have helped more than 178 million children worldwide. The new funding will help poor communities build resilience to climate change and improve lives by adopting renewable energy technologies in homes, schools and businesses.

"We're working toward a world where children living in poverty have more opportunities to create a better future for themselves and their families. Tackling climate change is critical to achieving this goal." Per Heggenes, CEO of the IKEA Foundation

First large-scale solar plant in Kazakhstan receives EBRD backing

A LANDMARK renewable energy project in Kazakhstan will be co-financed by the EBRD and the Clean Technology Fund (CTF) with loans of well over €80 million. The EBRD President, Sir Suma Chakrabarti, said: "The EBRD has consistently supported sustainable energy projects in Kazakhstan, but Burnoye Solar is a particular landmark for the country's Green Economy agenda. It is a first in many crucial categories. It will be the first commercial-scale solar park in Kazakhstan. It will be the first privately owned renewable energy generator in Kazakhstan. And it is the first use of a new project finance structure that will open the door to more private investment in renewables in the future."

The EBRD will lend 14.06 billion tenge (€70 million equivalent), and the CTF will lend €13.8 million to the project which is pioneering the use of a non-recourse project finance structure.

The financing will be extended to Burnoye Solar-1 LLP, a project company founded by a joint Kazakh-UK venture, Samruk-Kazyna United Green LLP.

The venture is owned by UK-based United Green Energy Limited and Samruk Kazyna Invest LLP, the investment arm of Kazakhstan's sovereign wealth fund. Work on the Burnoye Solar project started following the adoption in 2014 of the Renewables Law on which the EBRD – the largest renewable energy investor in its region - cooperated closely with the Kazakh government. Burnoye Solar will be located in the energy-deficit Zhambyl region in south Kazakhstan, in an area close to Western Europe-Western China highway.

The project was implemented jointly by local and European contractors, with the advantage of ensuring a transfer of technology into the country. Taxes from the plant will be paid into the local budget. "The sun and wind of south Kazakhstan can be harsh, but they are perfect as they provide the powerful sunlight that can power up our 192,000 European-made solar panels all year round and the airflow that naturally cools them down." said Albrecht Frischenschlager, Member of the Supervisory Board, who signed the project on behalf of Burnoye Solar -1. Burnoye Solar was one of several project agreements signed by the EBRD President, Sir Suma Chakrabarti, during his working visit to Kazakhstan where he co-chairs the Foreign Investors Council with President Nazarbayev.

The EBRD is expecting to again increase its annual investments in Kazakhstan in 2015, after reaching a record US$ 700 million last year. So far this year, the EBRD has committed US$ 400 million to various projects there, including Burnoye Solar. The total EBRD lending to date in Kazakhstan is over US$ 7 billion.

Canadian Solar closes £35 million solar project financing with Investec

CANADIAN SOLAR INC has announced that on May 7th 2015 it closed a GBP35 million ($53 million) project financing facility with Investec Bank plc ("Investec"), for a portfolio of four solar power plants with an installed capacity totalling 40.2 megawatts.

Located at four different locations across England, the installations have been built under the Renewables Obligation regime and became operational in March 2015.

Dr. Shawn Qu, Chairman and Chief Executive Officer of Canadian Solar, said: "The UK market is an important component of our strategy to build and own solar power plants that we plan to drop into a YieldCo vehicle in the months ahead. Our goal is to continue investing in the UK and we look forward to continue working with Investec to support our growth."

Olivier Fricot, Head of Power and Infrastructure Lending, Investec, said: "Investec supported Canadian Solar in its first ROC based project financing. It further endorses the expertise of our team in the UK renewables sector.

This transaction represents a significant deal with one of the leading global solar energy players, and we look forward to further developing this relationship in a number of geographies where our respective organizations operate." Investec acted as sole mandated lead arranger on this transaction.

Investec has a growing presence in the UK solar market, having funded in excess of 350MWp to date.

Meyer Burger wins photovoltaic order with a value of CHF 16.5 million

MEYER BURGER has been selected by Lerri Solar Technology to supply MB PERC upgrade cell solution and innovative PV measurement technology.

The order volume is around CHF 16.5 Million. Lerri Solar Technology Co. Ltd., a leading manufacturer of high-efficiency mono crystalline cells and modules, is expanding along the PV value chain into high performance cell technology. The industrially proven MAiA 2.1 equipment platform with the mass production scalable MB PERC technology as well as the latest wafer and module measurement technologies and additional upgrade technologies from Meyer Burger have been chosen by Lerri for an initial production expansion phase.

Meyer Burger Technology Ltd (SIX Swiss Exchange: MBTN) today announced the successful signing of a strategically important technology contract with Lerri Solar Technology Co. Ltd. Meyer Burger will support Lerri in its goal to expand its focus from high quality mono crystalline solar wafers to become a leading producer of high performance mono crystalline solar modules and achieve significantly increased production within the next five years. In this initial step, Meyer Burger will supply industrially proven MAiA 2.1 equipment with MB PERC technology as well as innovative wafer and module measurement technologies and additional upgrade technologies. The total order volume is around CHF 16.5 million.

With its experience, technological capability and focus, Lerri plans to reduce the cost for mono crystalline wafers and modules to the multi crystalline level and make a major contribution to further reducing the cost of solar energy. Meyer Burger CEO Peter Pauli stated that: “The strategies of both Meyer Burger and Lerri are very complementary to one another which will contribute to a visible change in the market and further increase the share of mono crystalline in photovoltaics.”

“Meyer Burger’s focus on mono crystalline high performance and upgrade technologies ideally positions the company as our long term partner with whom we can fully realise our growth and development plans”, commented Mr. Zhong, Head of Lerri Solar Technology Co. Ltd.

Enphase Energy announces completion of Nigerian microgrid project

ENPHASE ENERGY, INC has announced the completion of its initial Clinton Global Initiative (CGI) Commitment to Action. Enphase partnered with Beacon Power Services to provide a clean and reliable energy alternative for Future Kids in Lagos, Nigeria, through piloting an innovative solar energy microgrid system.

“We are proud to accomplish our Clinton Global Initiative commitment to address some of the energy challenges in Nigeria,” said Raghu Belur, co-founder and vice-president of Enphase Energy. “Our project illustrates through modern solar PV energy, the citizens of Nigeria can gain access to a clean, reliable energy source that does not carry the same environmental footprint as diesel generators.” Electricity grids in developing nations such as Nigeria operate inconsistently. According to the 2015 U.S. Energy Information Administration report on Nigeria, the country has one of the lowest rates of net electricity generation per capita in the world. Electricity generation falls short of demand, resulting in load shedding, blackouts and a reliance on private generators. The combination of an unstable grid and polluting diesel generators is not a scalable, sustainable model for energy generation.

“We are pleased to partner with Enphase to manage the local training and installation of the Enphase microinverter system, as well as provide ongoing support for the project,” said J.S. Roy, vice president of solar at Beacon Power Services. “The goal of the site is to establish a model that can scale for future solar projects in Africa.”

Future Kids, a private nursery and primary school, had relied on diesel generators for its energy, and through an innovative project delivered by the Enphase Energy and Beacon Power Services partnership, design resources, technology and best practices for installing, operating and maintaining the solar system in a location where grid qualities are unstable were introduced. Through this pilot program, the system’s performance data is made available to the public via Enlighten, Enphase’s integrated and intelligent web-based monitoring software.

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Yingli Green Energy and Borrego Solar sign 40 MW supply agreement

YINGLI GREEN ENERGY has entered into a solar panel supply agreement with San Diego-based Borrego Solar.

Under the terms of the agreement, Yingli Americas expects to supply Borrego Solar with up to 40 megawatts (MW) of solar panels in 2015.

Borrego Solar plans to install Yingli's high-performing multicrystalline panels in commercial and utility solar projects across the United States. Since the two companies entered into their first supply agreement in 2008, Borrego Solar has installed 114 MW of Yingli Solar panels.

Last year, Borrego Solar completed several high-profile solar energy systems using Yingli panels, including the Anaheim Convention Center project (Anaheim, Calif., 2.4 MW dc); the First Wind Warren projects (Warren, Mass., 17.0 MW dc); and the Seneca project (Victorville, Calif., 8.3 MW dc).

"This supply agreement with Yingli allows us to continue providing our commercial and utility customers with the quality and cost competiveness they've come to expect," said Mr. Aaron Hall, president of Borrego Solar. "We source from a variety of technology vendors so that our engineers can design a system that is optimized for energy production and affordability. Our decision to continue working with Yingli is based on a strong six year track record and our confidence in their technology and operational support."

Mr. Robert Petrina, managing director of Yingli Green Energy Americas, commented, "Since its inception, Yingli Americas' strategic priority has been the development of long-term customer relationships with proven partners such as Borrego Solar. Our teams are closely aligned and we are determined to provide lasting support to benefit U.S. business owners and utilities."

Mr. Liansheng Miao, chairman and chief executive officer of Yingli Green Energy, commented, "We are happy to bring green jobs and clean power to the U.S. in partnership with Borrego Solar.

We've had a chance to get to know their team since their beginning, and we are proud partners." Yingli Green Energy recently announced that it reached more than 13 gigawatts (GW) of cumulative global solar panel deliveries by the end of the first quarter of 2015.

The Company's global fleet can now produce approximately 16 billion kilowatt-hours (kWh) of clean solar electricity each year, which is almost enough energy to meet the city of Beijing's residential power consumption in 2014. In total, the energy produced by all deployed Yingli Solar panels can offset nearly 9 million tons of carbon emissions each year, which is equivalent to taking about 1.7 million cars off the road.

SolarWorld AG increases revenue by 50 percent in Q1 2015

IN THE FIRST QUARTER of 2015, SolarWorld AG increased group wide shipments of solar power modules and kits by 44 percent to 202 (Q1 2014: 140) MW. The company achieved strong growth above all in the United States, where SolarWorld boosted shipments by 170 percent to 116 (Q1 2014: 43) MW.

This market had a share of 57 percent of total shipments of modules and kits. In Japan, Australia and South Africa, SolarWorld managed to grow, too. While export business outside the euro zone benefited from the low rate of the euro, the European market including Germany decreased. Thus, the foreign quota of shipments further increased to 90 (Q1 2014: 81) percent.

Consolidated revenue in Q1 2015 grew by 50 percent, thus increasing disproportionally compared with shipments to EUR 149 (Q1 2014: 99) million.

Consolidated earnings before interest, taxes, depreciation and amortization (EBITDA) rose to EUR 3 (2013: 1.6) million. This positive trend can be attributed among other factors to operative measures to improve efficiency and the cost structure at all locations. EBITDA of previous year's first quarter included positive one-off effects amounting to EUR 136 million which resulted from the initial accounting of the acquisition of the solar activities from Bosch Solar Energy AG. Including this one-off effect, EBITDA in Q1 2014 amounted to EUR 137 million.

A new opportunity for European cell manufacturers

A NEW EUROPEAN research project that goes by the name Sharc25 is setting out to make an extremely efficient thin-film solar cell for the next generation of more cost-effective solar modules. Its objective is to achieve up to 25 percent efficiency in thin-film solar cells made by the coevaporation of copper indium gallium (di)selenide, or CIGS for short. That kind of performance would top the previous best mark by just over three percentage points.

The Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) is coordinating the project. Eleven research partners from eight countries are on board. Launched in May, the project will run for 3.5 years and get €4.6 million in EU funding sourced from the research framework program Horizon 2020. The Swiss government is providing another €1.6 million.

The results of this project could well give the European solar industry a boost. ZSW's partners in this endeavour are the EMPA (Swiss Federal Laboratories for Materials Science and Technology), the universities of Luxembourg (LU), Rouen (F), Parma (I) and Aalto (FIN), the IMEC (Interuniversitair Micro-Elektronica Centrum VZW in B), the HZB (Helmholtz-Zentrum Berlin für Materialien und Energie in D), the International Iberian Nanotechnology Laboratory INL (P), Flisom AG (CH), and Manz CIGS Technology GmbH (D). The idea behind this EU project is to pool these eleven organizations' multidisciplinary skills in a bid to develop better cells.

The performance of thin-film solar cells based on chalcopyrite has improved markedly in recent years. Able to achieve 20.4 percent efficiency, CIGS solar cells on plastic foil are almost on par with multicrystalline solar cells.

CIGS cells on glass topped that mark for the first time in 2013 and increased their lead by 1.3 percentage points to 21.7 percent in 2014. These two world records were achieved by two partners of the Sharc25 project: EMPA holds the record for the foil substrate and ZSW for glass.

Sharc25, an acronym for 'super high efficiency Cu(In, Ga)Se2 thin-film solar cells approaching 25 percent,' aims to raise the bar even higher. The five research institutes, four universities and two companies are pursuing three strategies to achieve this goal: Improve the absorber material, harness the power of new designs for more efficient surfaces and interfaces, and optimize light management to raise the efficiency threshold another few notches. An increase of about three percentage points to 25 percent efficiency would be quite the leap in performance.

An improvement on this scale would challenge the dominance of multicrystalline solar cells from Asia, and the newfound competitive edge could give the European thin-film PV industry a decisive boost.

Conergy and Sungrow collaborate

CONERGY AND SUNGROW have announced a strategic partnership in which Conergy will purchase inverters from Sungrow for many of its global commercial and utility scale projects over the next year.Conergy selected Sungrow after a rigorous evaluation process, which included multiple other candidates. The first project under this partnership is a 5MW PV solar ground-mount system situated in the center of the United Kingdom. The project will be equipped with Sungrow's SG60KTL, with class leading 99% efficiency, apparent power of 66kVA and weighing only 55kg per unit.

"As one of the world's leading downstream solar companies, with an over 3.4GW pipeline, our target is to work with best-in-class global suppliers to ensure the sustainability and quality of our solar systems," said Oliver Schweininger.

Solaredge collaborates with Tesla Motors on PV storage solutions

SOLAREDGE TECHNOLOGIES, INC has announced its collaboration with Tesla Motors ("Tesla") to provide an inverter solution that will allow for grid and photovoltaic integration with Tesla's home battery solution, the Powerwall. The joint development by SolarEdge and Tesla builds on SolarEdge's DC optimized inverter solution and Tesla's automotive-grade energy storage technology to enable more cost-effective residential solar generation, storage, and consumption for the global market.

"Tesla's collaboration with SolarEdge unites leading organizations in two rapidly-growing Industries—solar energy and energy storage—to bring homeowners a more cost-effective and integrated energy generation, storage, and consumption solution," said JB Straubel, CTO of Tesla. "SolarEdge's commitment to improving the value of PV systems through product innovation, combined with more than 1.3 GW of successful deployments, makes it an ideal partner for Tesla to develop and introduce this new energy storage solution to the PV market."

The new offering is expected to present a number of benefits to homeowners, from serving as a backup power source in the event of an electrical outage, to maximizing self-consumption, and enabling energy independence.

"Like SolarEdge, Tesla recognizes the need and opportunity to develop innovative solutions designed to lower the cost of solar energy and make clean, renewable energy more feasible for customers around the world," stated Lior Handelsman, Marketing and Product VP of SolarEdge. "Tesla's industry leading battery storage technology makes it a natural fit for this endeavor.

Together, we are taking the first step towards widespread adoption of integrated solar energy generation and storage in the residential market."

Designed to manage both functions with just one SolarEdge DC optimized inverter, the solution will allow for outdoor installation and will include remote monitoring and troubleshooting to keep operations and maintenance costs low. The solution will also support upgrading existing SolarEdge systems with the storage solution.

For enhanced safety, the solution is designed to employ SolarEdge's SafeDC architecture, which enables safe voltage levels in the event of inverter or grid disconnection to safeguard workers, homeowners, and firefighters. Additionally, the system will feature integrated rapid shutdown functionality, in full compliance with the National Electrical Code 2014, 690.12 (1) through (4). The SolarEdge solution is expected to be available by the end of 2015.

Imec presents perovskite module with 8 percent efficiency

At the Intersolar Europe exhibition in Munich this week, nano-electronics research centre Imec has announced a thin-film perovskite photovoltaic (PV) module of a power conversion efficiency of 8 percent measured over an aperture area of 16cm^2.

According to Imec, the geometrical fill factor of more than 95 percent for this size of module, demonstrates the potential of scaling up this novel thin-film PV technology from cell to module level. It also says the achievement is an important breakthrough in realising a marketable thin-film solution for applications such as building integrated photovoltaics (BIPV). 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 results demonstrate the achievement of both factors of perovskite-based solar cells.

"Not only is Imec improving the perovskite material, but it is also adjusting the cell and module structure to enhance the conversion efficiency of perovskite solar cells and modules by more than 20 percent," said Tom Aernouts, R&D manager for thin-film photovoltaics at imec. "The rapid progress that we are making is based on our strong background and track record in traditional organic photovoltaics."

Imec develops a platform for glass-based perovskite modules and collaborates with the Dutch joint thin-film PV research initiative Solliance to develop foil-based processes. 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.

SMA announce rebate program in US

SMA has rolled out a rebate program for its Sunny Boy 240-US micro inverter. Installers can now receive $10 cash back for each Sunny Boy 240-US purchased in the United States through December 31, 2015, with no quantity limitations.

Redeeming the rebate is simple and can be completed in two easy steps. First, installers must purchase the Sunny Boy 240-US from a participating SMA Authorized Distributor.
Then, they must submit purchase information along with the receipt to SMA before the end of the following calendar month.

Once that is received, SMA will mail a rebate check within 90 days directly to the installer."With each purchase of the Sunny Boy 240-US, installers will receive SMA's legendary reliability, American-assembled quality and more cash back in their pockets," said Henry Dziuba, president and general manager of SMA America. "These benefits translate into significant short-term margins and long-term O&M savings."

The Sunny Boy 240-US is ideal for residential systems and rooftops with complex, shaded situations. It boasts an improved cabling concept that eliminates the need for a trunk and branch cabling scheme, increasing flexibility.

Solar Frontier and NEW to develop 100 MW solar plants

SOLAR FRONTIER EUROPE has entered into an agreement with New Energy for the World (NEW) to develop and sell up to 100MW of CIS solar power plants in the UK. The agreement marks the continued global expansion of Solar Frontier's partnership approach in the large project segment.

Atsuhiko Hirano, CEO of Solar Frontier, said: "Solar Frontier is going global as part of our long-term growth strategy and the UK is a key market for us. We already have a strong standing in the residential, commercial and utility segments in Europe, and are now proud to introduce new and broader market solutions also in the UK. We look forward, together with our partner New Energy for the World, to develop, build, and commission turnkey CIS solar power solutions in the UK with the same level of commitment and service that differentiates Solar Frontier in Japan, a market recognized for demanding the highest quality in solar solutions."

Construction of the first project of the 100MW pipeline is expected to begin in the third quarter of 2015. Land and grid connection have already been secured, and first talks are now underway with investors regarding the sale of the first designated solar power plants. Projects will be closely based on the successful implementation approach of a previous 7.15 MW project by Solar Frontier and NEW in Banwell.

SolarCity introduces affordable new energy storage services across the U.S.

IN AN IMPORTANT STEP toward the distributed electricity grid of the future, SolarCity will make more affordable battery storage available to residential, business and government customers across the U.S., and remote communities around the world. SolarCity Co-founder and Chief Technology Officer Peter Rive provided additional detail about the rollout tonight in a post on the company's blog.

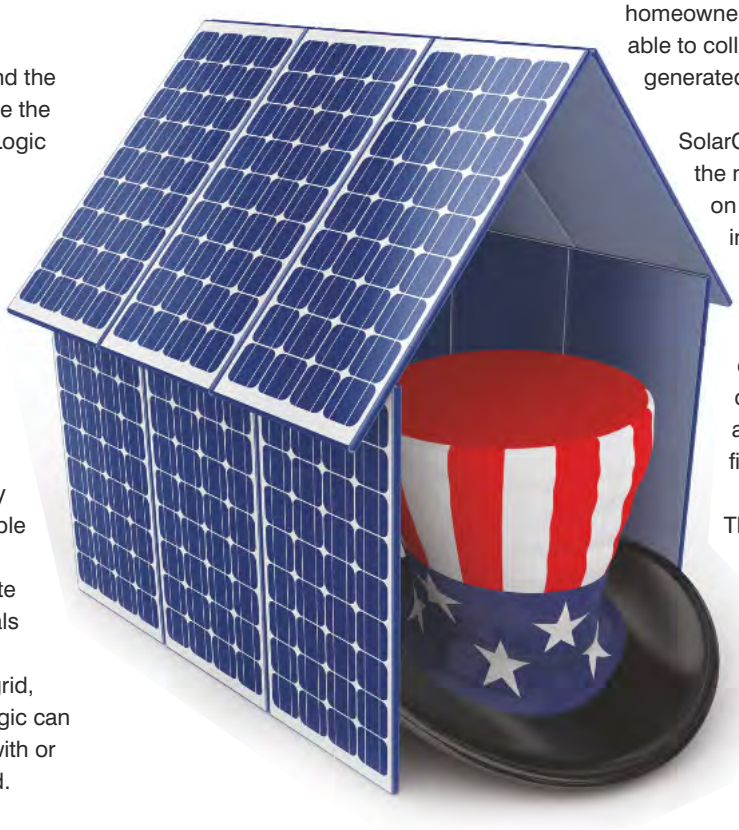
For businesses and government organizations, SolarCity will incorporate the new Tesla battery into its DemandLogic energy storage system to significantly increase the utility cost savings customers can realize from using stored solar electricity. DemandLogic, which is being adopted by several of the largest retail, biotech and Internet companies in the U.S., allows businesses to reduce energy costs by using stored electricity to reduce peak demand, and can also provide backup power during grid outages. DemandLogic's management software automates the discharge of stored energy to optimize savings on utility demand charges for customers.

For remote communities around the world, SolarCity will incorporate the new Tesla battery into its GridLogic microgrid service. GridLogic combines distributed energy resources—solar energy systems, batteries and controllable load—to enable a cleaner, more resilient and more affordable way of providing power.

SolarCity's microgrid service will ensure that any community anywhere in the world vulnerable to power outages and high energy costs—including remote or island communities, hospitals and military bases—can have dependable, clean power off-grid, when the grid is down. GridLogic can operate either in conjunction with or independently of the utility grid.

For residential solar customers, SolarCity will provide a turnkey battery backup service that includes permitting, installation and ongoing monitoring. Equipment includes Tesla's home battery, the Tesla Powerwall, which consists of an advanced hybrid solar/battery, inverter and monitoring and control systems. The fully-installed system stores electricity generated from the solar power system, using that power to automatically provide backup power during utility grid outages.

SolarCity's battery backup service replaces noisy, dirty fossil fuel generators with zero-emission storage technology. Roughly the size of a suitcase, the sleek, enclosed pack can be easily mounted on indoor or outdoor walls. When a power outage occurs, the control system immediately begins feeding power to the home from the solar system and the battery to continue operating the most commonly needed, eligible circuits selected by the customer, including the refrigerator, lighting, computer, alarm system and electrical outlets. When the battery is depleted, it can be recharged by solar power even if the outage continues for multiple days.



Incorporating Tesla's new battery technology, SolarCity is now able to configure a solar system (along with other energy management technologies) as a stand-alone, off-grid power supply. SolarCity plans to first offer these off-grid systems to eligible Hawaii customers that might otherwise be prevented from using solar power.

The combination of solar power generation and battery storage will make the utility grid safer and less susceptible to service interruptions, and will also lower the cost to expand and maintain the grid. SolarCity's energy storage rollout supports efforts already underway in multiple states to integrate aggregated storage capacity with existing grid resources. A distributed network of solar power systems and energy storage devices can also make renewable energy available on demand to utilities and their customers. In the future, distributed solar and storage resources are likely to become marketable assets, and homeowners and businesses may be able to collect revenues by providing self-generated, clean energy to others.

SolarCity will begin taking orders for the new energy storage systems on May 1st and expects to begin installing customers in October. SolarCity will initially make its battery backup options available only to new solar customers in the company's current service area, and will accommodate customers on a first-come, first-served basis.

The company plans to make the battery backup system available to its existing solar customers later this year. Off-grid solutions offered in Hawaii are expected to become available in the first half of 2016.

Azuri, Oasis Africa Resources and Ministry of Power lead the charge to provide off-grid home solar in Ghana

AZURI TECHNOLOGIES has announced at the Solar & Off-Grid Renewables West Africa Event today its partnership with energy company Oasis African Resources to bring affordable, pay-as-you-go solar power to 100,000 off-grid homes in Ghana in the next 2 years. The project is supported by the Ministry of Power, and aligns with the Government's current efforts to bring reliable, renewable power to Ghana at scale.

The deployment plan will focus on cocoa farming regions, and be distributed in association with agricultural co-operatives and women-based organisations. The large-scale roll-out builds on previous pilot deployments in Ghana, which have proven the success of this solution for rural Ghanaians over the last 18 months. While the energy crisis in Ghana has been intensifying, discussion has mainly focused on the business and urban residential populations, who are now experiencing rolling blackouts of 24 hours or more. However, these recent debates obscure the pre-existing challenges for those Ghanaians, predominantly in rural regions, living permanently off the grid. Data available indicates that about 80 percent of Ghana's population have access to the grid, however there are about 5 million people in rural Ghana most of whom are not likely to be connected in the foreseeable future.

Azuri Technologies' internationally acclaimed home solar systems bring top class European design with high quality components to provide enough clean and reliable power for daily home lighting and mobile phone charging. The project will deploy Azuri's flagship product Quad, and include 4 high quality LED lamps, mobile phone charging and a Radio/MP3 player. Crucially, instead of an upfront cost, the system can be purchased through a Pay-As-You-Go model. This model allows the customer to use the system while paying for it incrementally by the regular purchase of top-up credit, typically costing less than the lighting costs and phone charging fees being replaced.

The Minister for Power, Dr. Kwabena Donkor commented, "This initiative supports the Government's commitment to fully incorporate renewable energy into our energy supply mix, as outlined by the President during his State of the Nation's Address. The Ministry of Power is pleased to support this project for rural households, and will also explore other avenues with Oasis, Azuri and other renewable energy partners to establish solar as a significant and reliable power source for micro enterprises in both rural and urban communities."

Mr Isaac Kodom, CEO of Oasis added, "Oasis has a vision to become a leading private power solutions company that delivers outstanding, innovative products to meet the demands of today's energy provision. We are committed to developing long-term relationships with strategic partners in the energy sector – we are very excited by Azuri's innovation and the Government's commitment towards this initiative."

Simon Bransfield-Garth, CEO of Azuri, concluded, "Azuri is delighted to be helping bring high quality domestic solar power to rural Ghana. Azuri's Quad solar home system brings affordable power to rural households and provides the starting point for families to embrace clean renewable power and ultimately to access power for economic gain."

Fast, efficient switching, thanks to HiPoSwitch

Power converters use power transistor switches as key components. Lightning-fast semiconductors switches able to operate converters far more efficiently than before have now been developed in the recently completed EU group-project called HiPoSwitch.

Electrical power comes out of wall sockets, of course. But hardly any electronic device can take normal line voltage. Computers, smartphones, LEDs, and chargers for instance cannot use electrical energy in that form -- the line voltage must be converted from AC to DC, for example.

The reverse conversion (DC"AC) is also commonly used, such as in solar panel inverters. Power converters use power transistor switches as key components to accomplish this. Lightning-fast semiconductors switches able to operate these kinds of converters far more efficiently than before have now been developed in the recently completed EU group-project called HiPoSwitch.

Eight European institutional and industrial project partners led by the Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH) have successfully developed prototype power transistors that use gallium nitride (GaN) in enhancement mode.

Power converters using these novel gallium-nitride transistors have less than half the losses of existing technologies and make conversion efficiencies of over 98% practical. A great deal of primary energy consumption can be saved with their widespread use.

"More than 3000 terawatt-hours of power are generated in Europe annually," explains Joachim Würfl, head of both the HiPoSwitch project and the GaN Electronics Business Area at FBH. "If you only converted a quarter of the electricity produced annually in Europe to a different level and increased the efficiency level by two percentage points, you can turn off at least two coal-fired plants," says Würfl.

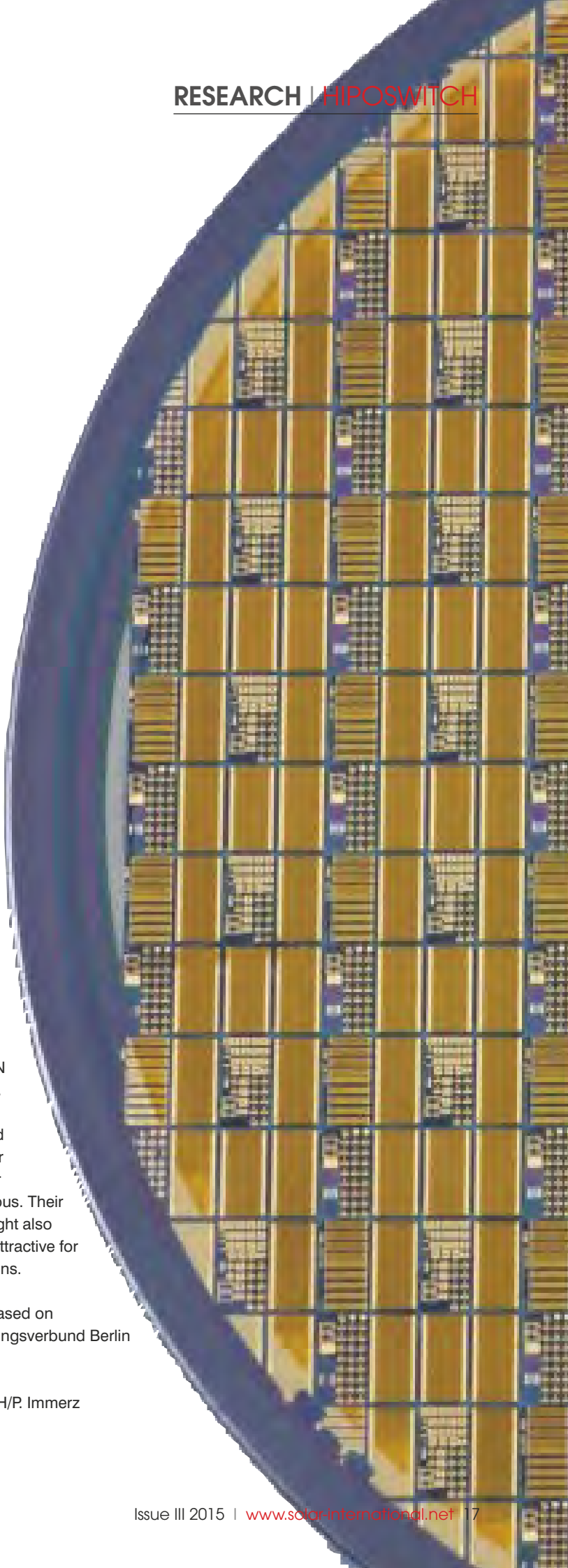
Hand-in-hand: from high-performance materials to mass-production techniques

Gallium nitride possesses ideal physical properties for a semiconductor. "GaN components are therefore very efficient and very fast power switches. And this is because of their low on-state resistance with negligible losses," Würfl emphasizes.

At the same time, higher switching frequencies mean that passive elements of the power converter, i.e. the inductive coils and capacitors, can be considerably smaller in size -- a definite improvement on the systems side. GaN has already been utilized in microwave transistors for a long while and applied in thin layers mostly on silicon carbide (SiC) substrates. This technology has been further developed by FBH over the last few years for 600 volt-rated power transistor switches. "This works well, but it is too expensive for mass markets. As an alternative, the processes developed for SiC can be transferred to considerably more cost-effective, but technologically more challenging silicon substrates," Würfl explains.

The advances made in the HiPoSwitch project fit hand-in-glove with FBH's collaboration partners. Among other accomplishments, FBH was so successful in optimizing the processing of GaN switching transistors on SiC and silicon (Si) that nearly ideal components became feasible. Among others, comprehensive investigations of drift and degradation effects carried out by University of Padua and University of Vienna provided the foundation for this.

The finished transistor chips were finally assembled into low-induction ThinPAK housings by Infineon in Malaysia. "The single transistor measures only 4.5 x 2.5 mm and is optimized for switching 600 volts. It has an on-resistance of 75 milliohms and handles a maximum of 120 amperes. We are the only ones in Europe who can manufacture these kinds of



normally-off transistors at present," says Würfl.

The Belgian company EpiGaN together with facility manufacturer Aixtron moved the epitaxy to Si -- so that the manufacturing costs for the substrates drop by more than a factor of ten. At the same time, the wafer diameter increased to 6" or even 8," a necessary step towards cost-effective industrial production.

Chip-manufacturer Infineon matched up the newly developed GaN technology with a Si process line for industrial production of power semiconductors at their Austrian location in Villach.

Part of the project possessed a decidedly "exploratory character," as Würfl puts it, due to the completely new techniques and processes for implementing GaN power transistors that had never before been tried. Promising ideas for producing semiconductors were successfully tested together with colleagues at the University of Vienna and the Academy of Sciences in Bratislava, Slovakia.

The Austrian company Artesyn is positioned at the end of the value-added chain as a systems-level partner. They developed a 3-kW rectifier for tele-communications applications including cellular base stations.

This unit converts line voltage to DC with an efficiency of 98 percent. A specialized switching topology was developed and implemented that is matched to the properties of the GaN switching transistors.

Thanks to their broad usage, the market for energy-saving power converters is enormous. Their smaller size and weight also makes them highly attractive for aerospace applications.

The above story is based on materials by Forschungsverbund Berlin e.V. (FVB).

Picture: Credit: ©FBH/P. Immerz

Charged holes in graphene

increase energy storage capacity

Engineers have discovered a method to increase the amount of electric charge that can be stored in graphene. Research may provide a better understanding of how to improve energy storage.

ENGINEERS at the University of California, San Diego have discovered a method to increase the amount of electric charge that can be stored in graphene, a two-dimensional form of carbon. The research, published recently online in the journal Nano Letters, may provide a better understanding of how to improve the energy storage ability of capacitors for potential applications in cars, wind turbines, and solar power. Capacitors charge and discharge very fast, and are more useful for quick large bursts of energy, such as in camera flashes and power plants. Their ability to rapidly charge and discharge is an advantage over the long charge time of batteries. However, the problem with capacitors is that they store less energy than batteries.

How can the energy storage of a capacitor be improved? One approach by researchers in the lab of mechanical engineering professor Prabhakar Bandaru at the Jacobs School of Engineering at UC San Diego was to introduce more charge into a capacitor electrode using graphene as a model material for their tests. The principle is that increased charge leads to increased capacitance,

which translates to increased energy storage.

Rajaram Narayanan, a nanoengineering graduate student at UC San Diego Jacobs School of Engineering and lead author of the Nano Letters paper.

How it's made

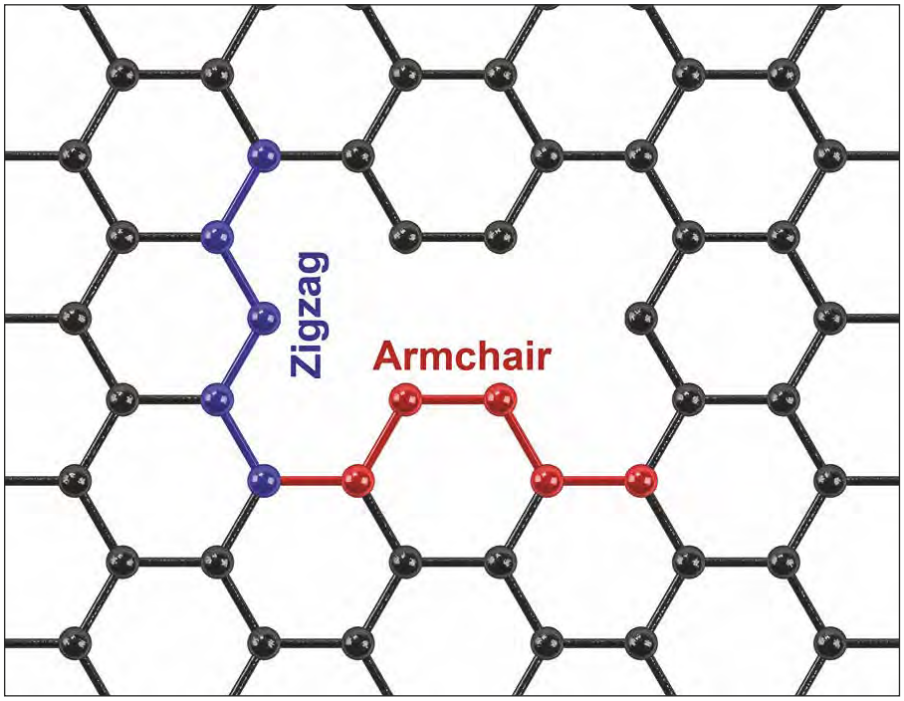
Making a perfect carbon nanotube structure -- one without defects, which are holes corresponding to missing carbon atoms -- is next to impossible. Rather than avoiding defects, the researchers in Bandaru's lab figured out a practical way to use them instead.

"I was motivated from the point of view that charged defects may be useful for energy storage," said Bandaru.
The team used a method called argon-ion based plasma processing, in which graphene samples are bombarded with positively-charged argon ions. During this process, carbon atoms are knocked out of the graphene layers and leave behind holes containing positive charges -- these are the charged defects. Exposing the graphene samples to argon plasma increased the capacitance of the materials three-fold.

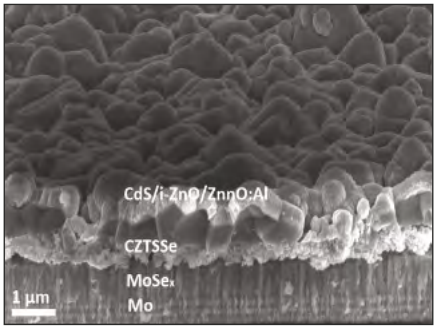
"It was exciting to show that we can introduce extra capacitance by introducing charged defects, and that we could control what kind of charged defect we could introduce into a material," said Rajaram Narayanan, a graduate student in professor Bandaru's research group and first author of the study.

Using Raman spectroscopy and electrochemical measurements, the team was able to characterize the types of defects that argon plasma processing introduced into the graphene lattices. The results revealed the formation of extended defects known as "armchair" and "zigzag" defects, which are named based on the configurations of the missing carbon atoms.

Additionally, electrochemical studies helped the team discover a new length scale that measures the distance between charges. "This new length scale will be important for electrical applications, since it can provide a basis for how small we can make electrical devices," said Bandaru.



Zigzag and armchair defects in graphene.



Electrochemical studies helped the team discover a new length scale that measures the distance between charges. "This new length scale will be important for electrical applications, since it can provide a basis for how small we can make electrical devices

Inkjet printing process for kesterite solar cells

A research team has developed an inkjet printing technology to produce kesterite thin film absorbers. Based on the inkjet-printed absorbers, solar cells with total area conversion efficiency of up to 6.4 percent have been achieved. Although this is lower than the efficiency records for this material class, the inkjet printing minimizes waste and has huge advantages for industrial production.

THE DROP-ON-DEMAND inkjet printing is a promising approach allowing patterning of materials with negligible materials waste; hence, significant reduction of raw materials cost can be achieved.

Furthermore, inkjet printing can be easily adapted to a roll-to-roll process, which is suitable for large scale production. From the industrial application perspective, both of these two features of the inkjet printing technology are of great interest. A critical requirement for using inkjet printing is to develop a suitable ink in terms of viscosity and stability which leads to compact and homogeneous films.

Tuning the molecular ink

Dr. Xianzhong Lin from the Institute for Heterogeneous Material Systems of HZB used a molecular ink which was originally developed for spin coating technologies. The ink is produced by dissolving Cu, Zn, Sn metal salt and thiourea in dimethyl sulfoxide solvent. Lin tested its suitability for inkjet printing. He found that the viscosity of the ink can be tuned by adjusting the ink concentration and the ink composition can also be easily controlled by adding or reducing the amount of each chemical added.

The CZTSSe absorbers were formed by annealing the inkjet-printed Cu-Zn-Sn-S precursor film under an atmosphere containing Selenium.

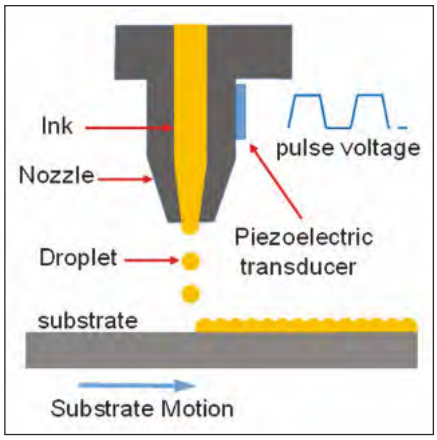


Illustration of the working principle of inkjet printing. Credit: HZB

Economical process

Initial optimization of the processing conditions such as ink composition and printing parameters have already yielded solar cells with efficiencies up to 6.4 percent. The huge advantage of inkjet printing versus spin coating to obtain thin film absorbers is the lesser amount of waste: Whereas with spin coating, a large quantity of the ink material is wasted, the inkjet printing is very economical: For example, less than 20 microliter ink is needed to build up a micrometer CZTSSe thin film absorber on an inch by inch substrate in this study.

Cross sectional scanning electron microscopy of a complete device. The Kesterite layer (CZTSSe) is printed on top of a Molybdenum substrate.

Low toxicity and low waste

"Although the solar cell performance is still far below the record efficiency of 12.7 percent for CZTSSe based solar cells, the great advantage of our approach is the low toxic and low material wastage process," Prof. Martha Lux-Steiner explains.

The team is now working on the optimization of processing conditions for the kesterite absorbers to further improve the solar cell performance and on the deposition of buffer and TCO layers by inkjet printing. The goal is to print a complete device with high efficiency without relying on expensive vacuum technology. This work opens up a promising route for the fabrication of kesterite thin film solar cells.

Journal Reference:

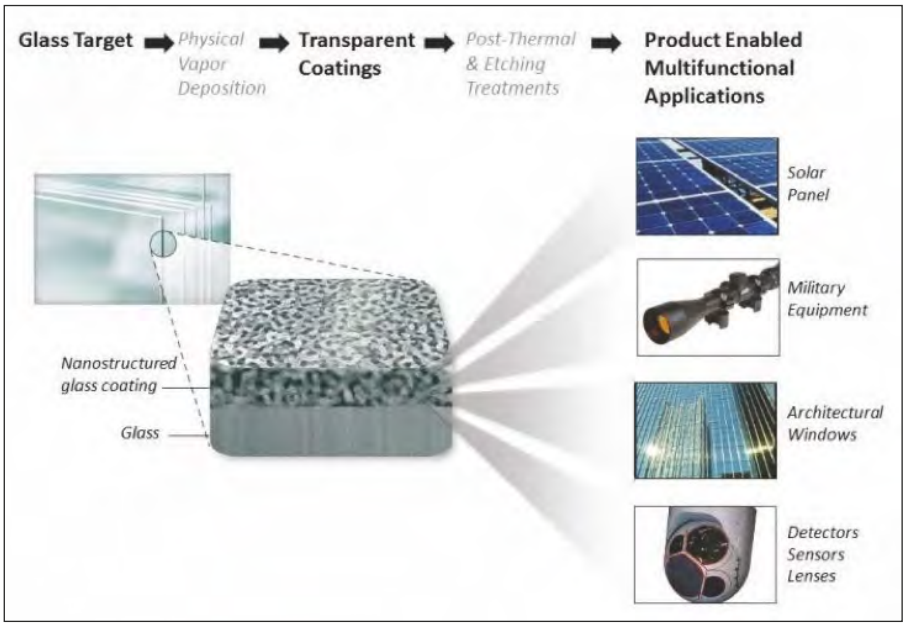
Xianzhong Lin, Jaison Kavalakkatt, Martha Ch. Lux-Steiner, Ahmed Ennaoui. Inkjet-Printed Cu2ZnSn(S, Se)4Solar Cells. Advanced Scienc e, 2015; DOI: 10.1002/advs.201500028

Superhydrophobic glass coating offers clear benefits for solar

A moth's eye and lotus leaf were the inspirations for an antireflective water-repelling, or superhydrophobic, glass coating that holds significant potential for solar panels, lenses, detectors, windows, weapons systems and many other products.

THE DISCOVERY by researchers at the Department of Energy's Oak Ridge National Laboratory, detailed in a paper published in the Journal of Materials Chemistry C, is based on a mechanically robust nanostructured layer of porous glass film. The coating can be customized to be superhydrophobic, fog-resistant and antireflective.

"While lotus leaves repel water and self-clean when it rains, a moth's eyes are antireflective because of naturally covered tapered nanostructures where the refractive index gradually increases as light travels to the moth's cornea," said Tolga Aytug, lead author of the paper and a member of ORNL's Materials Chemistry Group. "Combined, these features provide truly game-changing ability to design coatings for specific properties and performance."



Credit: ORNL

This is a schematic representation of the coated product and applications.

To be superhydrophobic, a surface must achieve a water droplet contact angle exceeding 150 degrees. ORNL's coating has a contact angle of between 155 and 165 degrees, so water literally bounces off, carrying away dust and dirt. This property combined with the suppression of light reflection from a glass surface is critical for improved performance in numerous optical applications, Aytug said. The base material -- a special type of glass coating -- is also highly durable, which sets it apart from competing technologies, according to Aytug, who described the process.

"We developed a method that starts with depositing a thin layer of glass material on a glass surface followed by thermal processing and selective material removal by etching," he said. "This produces a surface consisting of a porous three-dimensional network of high-silica content glass that resembles microscopic coral." The fact the coating can be fabricated through industry standard techniques makes it inexpensive to scale up and apply to a wide variety of glass platforms.

"The unique three-dimensionality interconnected nanoporous nature of our coatings significantly suppresses Fresnel light reflections from glass surfaces, providing enhanced transmission over a wide range of wavelengths and angles," Aytug said. The Fresnel effect describes the amount of light that is reflected versus the amount transmitted. Where solar panels are concerned, the suppression of reflected light translates into a 3-6 percent relative increase in light-to-electricity conversion efficiency and power output of the cells. Coupled with the superhydrophobic self-cleaning ability, this could also substantially reduce maintenance and operating costs of solar panels. In addition, the coating is highly effective at blocking ultraviolet light. Other potential applications include goggles, periscopes, optical instruments, photodetectors and sensors.

In addition, the superhydrophobic property can be effective at preventing ice and snow buildup on optical elements and can impede biofouling in marine applications. Aytug emphasized that the impact abrasion resistance of the coating completes the package, making it suitable for untold applications.

"This quality differentiates it from traditional polymeric and powder-based counterparts, which are generally mechanically fragile," Aytug said. "We have shown that our nanostructure glass coatings exhibit superior mechanical resistance to impact abrasion -- like sand storms -- and are thermally stable to temperatures approaching 500° C."

Other ORNL authors of the paper, titled "Monolithic Graded-Refractive-Index Glass-based Antireflective Coatings: Broadband/Omnidirectional Light Harvesting and Self-Cleaning Characteristics," were Andrew Lupini, Gerald Jellison, Pooran Joshi, Ilia Ivanov, Tao Liu, Peng Wang, Rajesh Menon, Rosa Trejo, Edgar Lara-Curzio, Scott Hunter, John Simpson, Parans Paranthaman and David Christen. The work was supported by the Laboratory Directed Technology Innovation Program. STEM research was supported by the DOE Office of Science Basic Energy Sciences. Research was also conducted at the Centre for Nanophase Materials Sciences, a DOE Office of Science User Facility. PV device measurements were done at the University of Utah.

Journal Reference

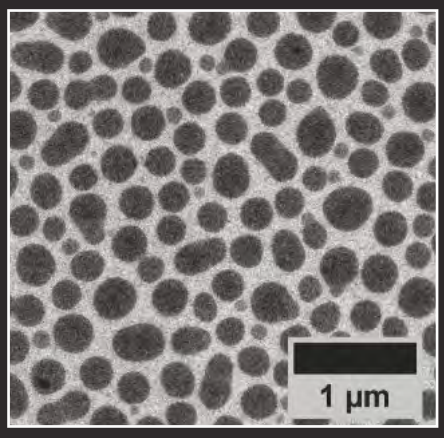
Tolga Aytug, Andrew R. Lupini, Gerald E. Jellison, Pooran C. Joshi, Ilia H. Ivanov, Tao Liu, Peng Wang, Rajesh Menon, Rosa M. Trejo, Edgar Lara-Curzio, Scott R. Hunter, John T. Simpson, M. Parans Paranthaman, David K. Christen. Monolithic graded-refractive-index glass-based antireflective coatings: broadband/omnidirectional light harvesting and self-cleaning characteristics. J. Mater. Chem. C, 2015; DOI: 10.1039/C5TC00499C

Why 'baking powder' doubles or triples efficiency of plastic solar cells

The efficiency of plastic solar cells can be doubled or tripled if an extra solvent is added during the production process. Exactly how this works has been unclear – but now researchers have come up with the answer.

THE EFFICIENCY of plastic solar cells can be doubled or tripled if an extra solvent is added during the production process, comparable with the role of baking powder in dough mixture. Exactly how this works has been unclear for the last ten years. But now researchers at Eindhoven University of Technology (TU/e) have come up with the answer in a publication in Nature Communications.

This new understanding will now enable focused development of plastic solar cells.



Plastic solar cells, also referred to as organic solar cells, use polymers instead of the usual silicon to convert the energy from sunlight into electricity. The use of plastic as basic material reduces the cost and weight of these solar cells, and makes them flexible. But their efficiency of around 10 percent still remains below that of commercial silicon solar cells, which reach efficiencies of between 15 and 20 percent.

Chance discovery

Around ten years ago, it was found by chance that the efficiency of plastic solar cells was increased by a factor of two to three times by adding an extra solvent ('co-solvent') during the production process. "These co-solvents are now used in all plastic solar cells," says TU/e professor René Janssen. "But nobody knew exactly why they have such a favourable effect on the efficiency."

Morphology

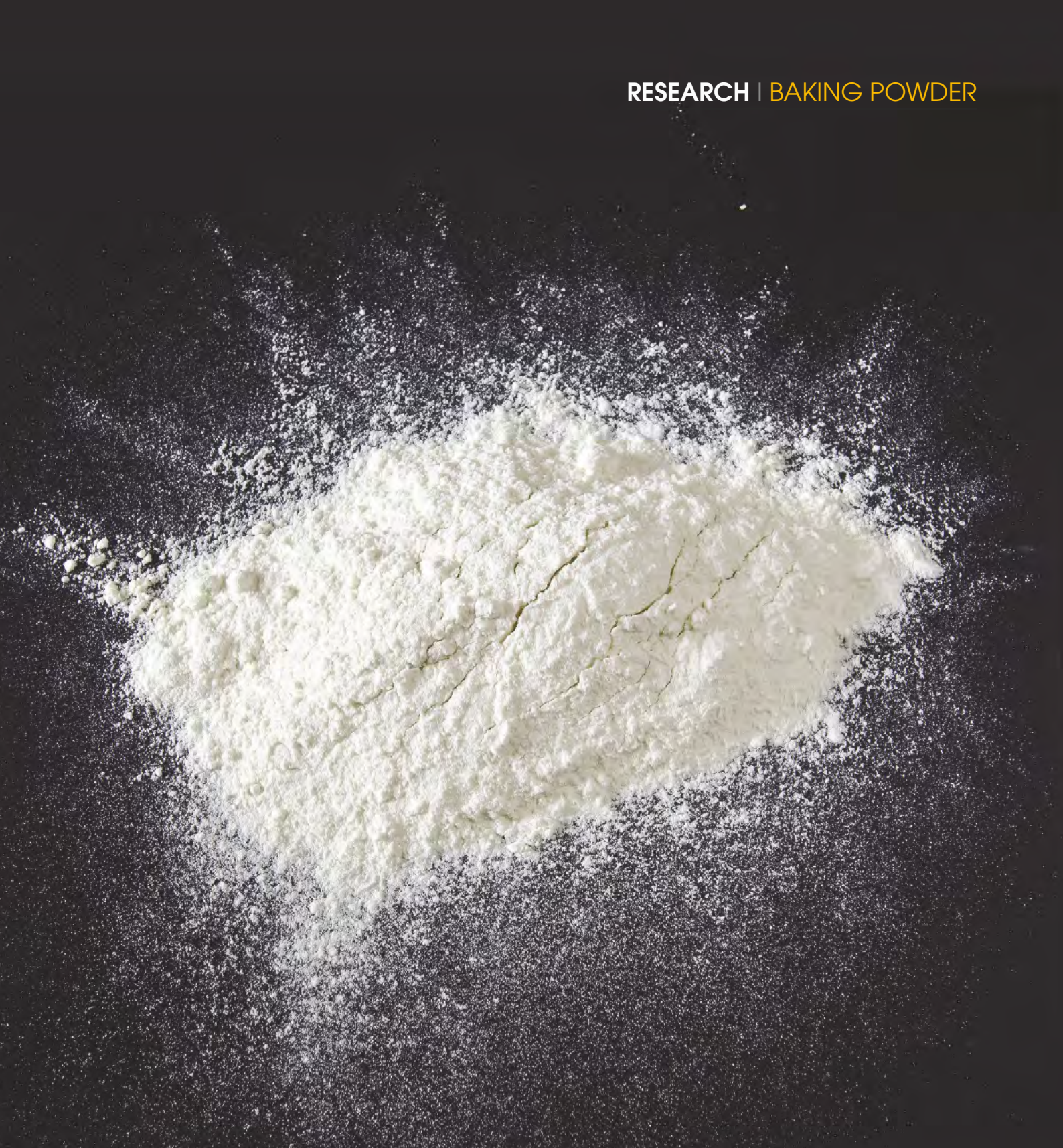
It was known that there was a connection with the 'morphology' of the solar cell, in other words the exact structure of two mixed plastic components in the cell between which electrons move under the influence of sunlight.

These components -- both of them organic materials -- are dissolved during the production process, after which they evaporate and harden. The mysterious co-solvent is always added to the solvent before evaporation.

Droplet size

The Eindhoven researchers led by René Janssen used a combination of optical technologies to find a definitive explanation. They say that if they did not add a co-solvent, they found that large droplets were formed during the hardening of the plastic mixture.

These have an adverse effect on the electron transport -- and as a result on the efficiency of the solar cell. "The more co-solvent you add to the solution, the smaller the bubbles turn out to be, until they disappear completely when a specific content is reached," says Janssen.



'Folding' and evaporating

They also found the reason for that. "There are two effects that arise during the hardening process," says Janssen. "On the one hand the solution evaporates, and as well as that polymers take on a 'folded' structure. We saw that the co-solvent makes this 'folding' process start at a much earlier stage, which means the bubbles are ultimately no longer formed at all." In this way the co-solvent acts as a kind of 'baking powder': it improves the structure of the mixture, but the agent in itself is not enough.

More effective

The researchers hope their findings will make the development of plastic solar cells more effective. "Up to now it was mainly a question of trial-and-error," says Janssen. "But now we can predict much more accurately what is likely to work, and what isn't."

Journal Reference

Jacobus J. van Franeker, Mathieu Turbiez, Weiwei Li, Martijn M Wienk, René A.J. Janssen. A real-time study of the benefits of co-solvents in polymer solar cell processing. Nature Communications, 2015; 6: 6229 DOI: 10.1038/ncomms7229

Efficiency record for **black silicon** solar cells jumps

Aalto University's researchers improved their previous record by over three absolute percents together with Universitat Politècnica de Catalunya.

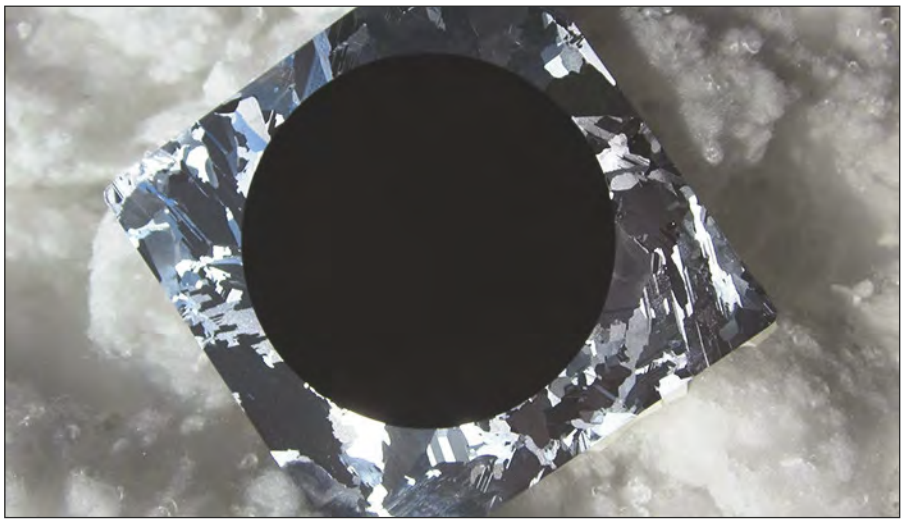
THE DEVELOPMENT of the cells fabricated last year will continue in the upcoming "BLACK" project in which Professor Savin together with her team will develop the technology further in cooperation with industry.

The researchers have obtained the record-breaking efficiency of 22.1 percent on nanostructured silicon solar cells as certified by Fraunhofer ISE CalLab. An almost 4 percent absolute increase to their previous record is achieved by applying a thin passivating film on the nanostructures by Atomic Layer Deposition, and by integrating all metal contacts on the back side of the cell. The surface recombination has long been the bottleneck of black silicon solar cells and has so far limited the cell efficiencies to only modest values.

The new record cells consists of a thick back-contacted structure that is known to be highly sensitive to the front surface recombination. The certified external quantum efficiency of 96% at 300nm wavelength demonstrates that the increased surface recombination problem no longer exists and for the first time the black silicon is not limiting the final energy conversion efficiency.
The results were published online in Nature Nanotechnology.

For Nordic conditions

The energy conversion efficiency is not the only parameter that we should look at,



explains Professor Hele Savin from Aalto University, who coordinated the study. Due to the ability of black cells to capture solar radiation from low angles, they generate more electricity already over the duration of one day as compared to the traditional cells.

This is an advantage particularly in the north, where the sun shines from a low angle for a large part of the year. We have demonstrated that in winter Helsinki, black cells generate considerably more electricity than traditional cells even though both cells have identical efficiency values, she adds.

In the near future, the goal of the team is to apply the technology to other cell structures – in particular, thin and multi-crystalline cells.

Our record cells were fabricated using p-type silicon, which is known to suffer from impurity-related degradation. There is no reason why even higher efficiencies could not be reached using n-type silicon or more advanced cell structures, Hele Savin predicts.

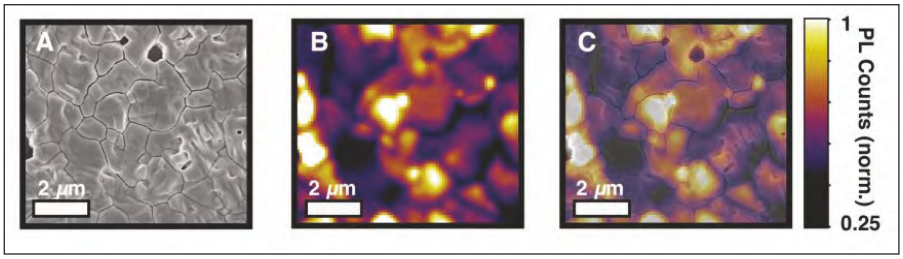
The development of the cells fabricated last year will continue in the upcoming "BLACK" project, supported by the European Union, in which Professor Savin together with her team will develop the technology further in cooperation with industry.

The surface area of the best cells in the study was already 9 cm2. This is a good starting point for upscaling the results to full wafers and all the way to the industrial scale.

Engineering a better solar cell

A new study demonstrates that perovskite materials - superefficient crystal structures - contain flaws that can be engineered to improve solar cells and other devices even further.

ONE OF THE fastest-growing areas of solar energy research is with materials called perovskites. These promising light harvesters could revolutionize the solar and electronics industries because they show potential to convert sunlight into electricity more efficiently and less expensively than today's silicon-based semiconductors.



UW researchers used microscopy to identify inefficient regions in perovskite materials used in solar cells, as evidenced by dark areas in C. Credit: University of Washington.

These superefficient crystal structures have taken the scientific community by storm in the past few years because they can be processed very inexpensively and can be used in applications ranging from solar cells to light-emitting diodes (LEDs) found in phones and computer monitors. A new study published online April 30 in the journal Science by University of Washington and University of Oxford researchers demonstrates that perovskite materials, generally believed to be uniform in composition, actually contain flaws that can be engineered to improve solar devices even further.

"Perovskites are the fastest-growing class of photovoltaic material over the past four years," said lead author Dane deQuilettes, a UW doctoral student working with David Ginger, professor of chemistry and associate director of the UW's Clean Energy Institute.

"In that short amount of time, the ability of these materials to convert sunlight directly into electricity is approaching that of today's silicon-based solar cells, rivaling technology that took 50 years to develop," deQuilettes said. "But we also suspect there is room for improvement."

The research team used high-powered imaging techniques to find defects in the perovskite films that limit the movement of charges and, therefore, limit the efficiency of the devices. Perovskite solar cells have so far have achieved efficiencies of roughly 20 percent, compared to about 25 percent for silicon-based solar cells.

In a collaboration made possible by the Clean Energy Institute, the team used a technique called confocal optical microscopy, which is more often used in biology, and applied it to semiconductor technology. They used fluorescent images and correlated them with electron microscopy images to find "dark" or poorly performing regions of the perovskite material at intersections of the crystals. In addition, they discovered that they could "turn on" some of the dark areas by using a simple chemical treatment. The images offered several surprises but also will lead to accelerated improvements in the materials' uniformity, stability and efficiency, according to corresponding author Ginger, the Alvin L. and Verla R. Kwiram Endowed Professor of Chemistry and Washington Research Foundation Distinguished Scholar.

"Surprisingly, this result shows that even what are being called good, or highly-efficient perovskite films today still are 'bad' compared to what they could be. This provides a clear target for future researchers seeking to improve and grow the materials," Ginger said. The imaging technique developed by the UW team also offers an easy way to identify previously undiscovered flaws in perovskite materials and to pinpoint areas where their composition can be chemically altered to boost performance, Ginger said. deQuilettes, who spearheaded the project as a Clean Energy Institute graduate fellow, estimates there are more than a thousand laboratories around the world currently researching the semiconducting properties of perovskite materials. Yet there is more work to be done to understand how to consistently make a material that is stable, has uniform brightness and can stand up to moisture without degrading.

The UW research offers new ways for people to think strategically about how to improve the materials and how to extend their applications to high performance light-emitting devices such as LEDs and lasers. "There are so many of us focusing on perovskites, so hopefully this technique will offer some new direction and steer us toward the places we can look to optimize their energy-capturing and emitting potential," deQuilettes said.

Co-authors of the study are Sarah M. Vorpahl, Hirokazu Nagaoka and Mark E. Ziffer of the UW and Samuel D. Stranks, Giles E. Eperon and Henry J. Snaith at Oxford. Funding for the research was provided by the state of Washington through the UW Clean Energy Institute.

New shortcut to solar cells

Scientists find gold electrodes can serve as catalysts to make black silicon for solar cells. The discovery could streamline the manufacturing process.

RICE UNIVERSITY scientists have found a way to simplify the manufacture of solar cells by using the top electrode as the catalyst that turns plain silicon into valuable black silicon. The Rice lab of chemist Andrew Barron disclosed the research in the American Chemical Society journal ACS Applied Materials and Interfaces.

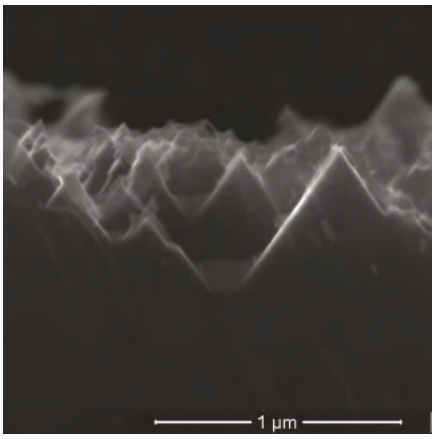
Black silicon is silicon with a highly textured surface of nanoscale spikes or pores that are smaller than the wavelength of light. The texture allows the efficient collection of light from any angle, at any time of day. Barron and his team have been fine-tuning the creation of black silicon for some time, but an advance in the manufacturing technique should push it closer to commercialization, he said. Barron noted the new work led by Rice postdoctoral researcher Yen-Tien Lu has two major attractions. "One, removing steps from the process is always good," he said. "Two, this is the first time in which metallization is a catalyst for a reaction that occurs several millimeters away."

Barron said the metal layer used as a top electrode is usually applied last in solar cell manufacturing. The new method known as contact-assisted chemical etching applies the set of thin gold lines that serve as the electrode earlier in the process, which also eliminates the need to remove used catalyst particles. The researchers discovered that etching in a chemical bath takes place a set distance from the lines. That distance, Barron said, appears to be connected to the silicon's semiconducting properties. "Yen-Tien was doing the reaction with gold top contacts, adding silver or gold catalyst and getting these beautiful pictures," he said. "And I said, 'OK, fine. Now let's do it without the catalysts.' Suddenly, we got black silicon -- but it was etching only a certain distance away from the contact. And no matter what we did, there was always that distance.

"It told us the electrochemical reaction is occurring at the metal contact and at the silicon that's a certain distance away," Barron said. "The distance is dependent upon the charge-carrying capacity, the conductivity, of the silicon. At some point, the conductivity isn't sufficient for the charge to carry any further."

Barron said an extremely thin layer of gold atop titanium, which bonds well with both gold and silicon, should be an effective electrode that also serves for catalysis. "The trick is to etch the valleys deep enough to eliminate the reflection of sunlight while not going so deep that you cause a short circuit in the cell," he said. He said the electrode's ability to act as a catalyst suggests other electronic manufacturing processes may benefit from a bit of shuffling.

"Metal contacts are normally put down last," Barron said. "It begs the question for a lot of processes of whether to put the contact down earlier and use it to do the chemistry for the rest of the process."



Credit: Barron Group/Rice University

An electron microscope image from earlier research shows the nanoscale spikes that make up the surface of black silicon used in solar cells.

Journal Reference:
Yen-Tien Lu, Andrew R Barron. In-situ fabrication of a self-aligned selective emitter silicon solar cell using the gold top contacts to facilitate the synthesis of a nanostructured black silicon anti-reflective layer instead of an external metal nanoparticle catalyst. ACS Applied Materials & Interfaces, 2015; 150513075346000 DOI: 10.1021/acsami.5b01008

> "The distance is dependent upon the charge-carrying capacity, the conductivity, of the silicon. At some point, the conductivity isn't sufficient for the charge to carry any further."

Solar cells: Increased pressure creates a happy union

By tailoring the interface between the two sections of a solar cell, researchers have produced a high-performance solar cell from the abundant and cheap materials of copper (II) oxide and silicon. By tailoring the interface between the two sections of a solar cell, A*STAR researchers have produced a high-performance solar cell from the abundant and cheap materials of copper (II) oxide and silicon.

FOR SOLAR ENERGY to become environmentally friendly and cost effective, the two main components of 'heterojunction' solar cells – the n- and p-type layers – need to be fabricated from nontoxic, abundant materials. Copper (II) oxide, also known as cupric oxide, holds promise as a p-type semiconductor since it meets both these criteria and also has an ideal bandgap for absorbing sunlight and a high light absorption.

On paper, copper oxide and silicon are a perfect pair for producing high-performance solar cells. In practice, however, their performance has been disappointing because of the tendency of holes and electrons to recombine in them – a process known as charge recombination. This recombination limits the production of electricity in a solar cell since it reverses the generation of electrical charges from light. One cause of this problem is the poor quality of the interface between copper oxide and silicon as the result of silicon oxide on the silicon surface.

Now, Goutam Dalapati from the A*STAR Institute of Materials Research and Engineering at Singapore and co-workers have used conventional procedures to produce high-performance solar cells that employ cupric oxide as the p-type material and silicon as the n-type material. They realized this by increasing the pressure during the deposition stage of fabrication, which they found enhances both the crystal and interface quality, thereby reducing the charge recombination rate.

Using a sequence of analytical techniques -- Raman spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy and high-resolution transmission electron microscopy -- they showed that the interface quality was limited by the formation of a copper-rich oxide layer as well as by the production of a silicon oxide layer on silicon surface. Dalapati explains that the team were surprised by the formation of this copper-rich layer as the cupric oxide target contained an equal mix of copper and oxygen. But the scientists also discovered that they could minimize this layer by increasing the pressure during deposition and the annealing time. Using this tactic, the team successfully produced a high-quality solar cell that had a low charge recombination rate.

Dalapati notes that "to develop cost-effective, environmentally friendly photovoltaic devices using Earth-abundant nontoxic cupric oxide, it is essential that we can increase the efficiency further." This is possible, he adds, "by reducing, or even eliminating, the copper-rich interfacial layer and the silicon oxide insulating layer."

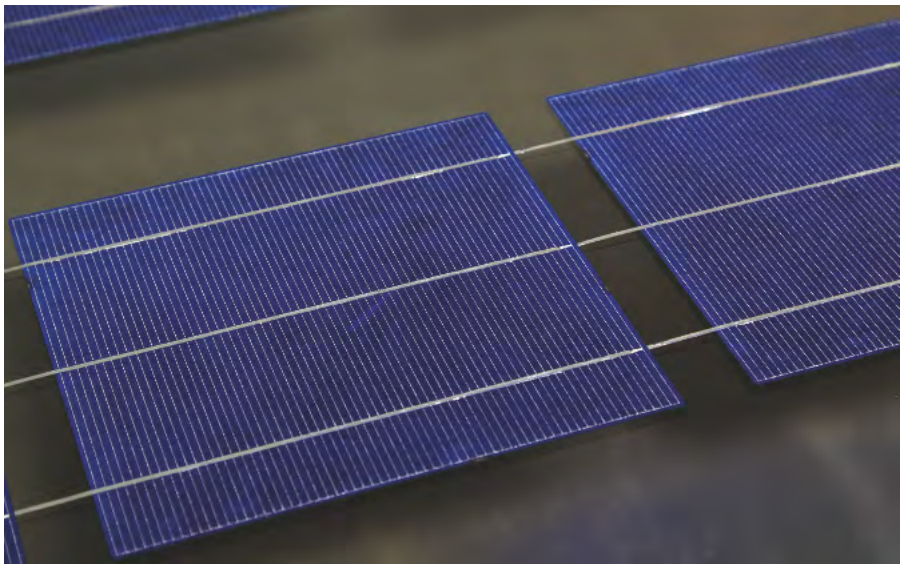
Journal Reference:
Saeid Masudy-Panah, Goutam Kumar Dalapati, K. Radhakrishnan, Avishek Kumar, Hui Ru Tan, Elumalai Naveen Kumar, Chellappan Vijila, Cheng Cheh Tan, DongZhi Chi. p-CuO/n-Si heterojunction solar cells with high open circuit voltage and photocurrent through interfacial engineering. Progress in Photovoltaics: Research and Applications, 2014;
DOI: 10.1002/pip.2483

Breakthrough in solar cell material reported

Researchers from Wake Forest University and the University of Utah are the first to successfully fabricate halide organic-inorganic hybrid perovskite field-effect transistors and measure their electrical characteristics at room temperature.

A GROUNDBREAKING PAPER on hybrid perovskites, one of the hottest solar cell and LED materials, has just been published in MRS Communications, a flagship journal of the Materials Research Society.

First created in 2012, perovskite solar cells have shown great promise in recent years as an affordable alternative to other solar technologies, such as photovoltaic cells typically used in solar panels. Now scientists from Wake Forest University and the University of Utah have described the very first example of field-effect modulation in perovskites (i.e. their use in transistors), with potentially far-reaching implications.



Until now, researchers have been unable to fabricate field-effect transistors to measure the charge transport of the materials. Necessary prerequisites for a material that forms an efficient solar cell are strong optical absorption and efficient charge carrier transport. With these first generation transistors, researchers from Wake Forest and Utah were able for the first time to directly measure the ability of hybrid perovskites to transport charge, widening the spectrum of possible applications of these materials.

MRS Communications Principal Editor, Alberto Salleo from Stanford University, explains: 'Hybrid inorganic-organic halide perovskites are a new promising materials family for low-cost and even solution-processable thin film optoelectronics. Efficient solar cells and bright light-emitting diodes using hybrid perovskites have already been demonstrated, taking the thin film electronics community by storm. In spite of estimates of high mobilities and low defect densities, field-effect devices have so far not been demonstrated. Indeed, electrostatic gating, the key operating mechanism of transistors, has remained elusive. A large part of the perovskite community remains convinced that field-effect modulation is impossible in these materials, highlighting how little is known about surfaces and defects in these materials.'

'This article is the first report of the fabrication and room-temperature operation of field-effect transistors based on hybrid perovskites. In perovskite transistors, transport is ambipolar with balanced electron and hole mobilities. These results are extremely promising as they show that hybrid perovskites can be used for low-cost thin film electronic circuits that could potentially lead to integrated optoelectronic systems and electrically pumped lasing.'

This timely paper is of enormous interest to a broad range of scientists, given the recent surge in research on perovskite based solar cells. The high efficiencies and low production costs of the crystalline material have already made it the fastest advancing solar technology to date and a commercially attractive option, with start-up companies promising modules on the market by 2017.

The peer-reviewed paper - authored by Yaochuan Mei, Chuang Zhang, Z.V. Vardeny and Oana D. Jurchescu - will be freely available via Open Access from MRS Communications, a high-impact, peer-reviewed journal focusing on groundbreaking work across the broad spectrum of materials research.

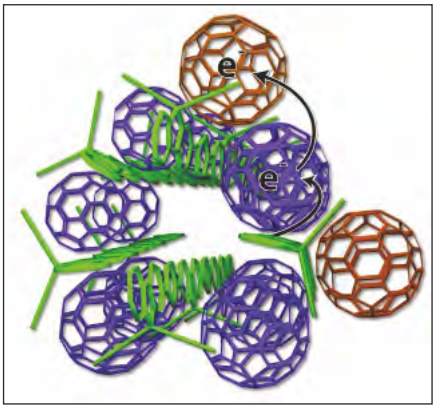
Chemists devise technology that could transform solar energy storage

Chemists have developed a major improvement to capture and retain energy from sunlight, where the stored energy can last dramatically longer than current solar technology allows -- up to several weeks, instead of the microseconds found in today's rooftop solar panels.

THE MATERIALS in most of today's residential rooftop solar panels can store energy from the sun for only a few microseconds at a time. A new technology developed by chemists at UCLA is capable of storing solar energy for up to several weeks -- an advance that could change the way scientists think about designing solar cells.

The findings were published in June in the journal Science. The new design is inspired by the way that plants generate energy through photosynthesis.

'Biology does a very good job of creating energy from sunlight,' said Sarah Tolbert, a UCLA professor of chemistry and one of the senior authors of the research. 'Plants do this through photosynthesis with extremely high efficiency.'



Credit: Courtesy of UCLA Chemistry

Pictured above are polymer donors and fullerene acceptors.

'In photosynthesis, plants that are exposed to sunlight use carefully organized nanoscale structures within their cells to rapidly separate charges -- pulling electrons away from the positively charged molecule that is left behind, and keeping positive and negative charges separated,' Tolbert said. 'That separation is the key to making the process so efficient.'

To capture energy from sunlight, conventional rooftop solar cells use silicon, a fairly expensive material. There is currently a big push to make lower-cost solar cells using plastics, rather than silicon, but today's plastic solar cells are relatively inefficient, in large part because the separated positive and negative electric charges often recombine before they can become electrical energy.
'Modern plastic solar cells don't have well-defined structures like plants do because we never knew how to make them before,' Tolbert said. 'But this new system pulls charges apart and keeps them separated for days, or even weeks. Once you make the right structure, you can vastly improve the retention of energy.'

The two components that make the UCLA-developed system work are a polymer donor and a nano-scale fullerene acceptor. The polymer donor absorbs sunlight and passes electrons to the fullerene acceptor; the process generates electrical energy.

The plastic materials, called organic photovoltaics, are typically organized like a plate of cooked pasta -- a disorganized mass of long, skinny polymer 'spaghetti' with random fullerene 'meatballs.' But this arrangement makes it difficult to get current out of the cell because the electrons sometimes hop back to the polymer spaghetti and are lost.

The UCLA technology arranges the elements more neatly -- like small bundles of uncooked spaghetti with precisely placed meatballs. Some fullerene meatballs are designed to sit inside the spaghetti bundles, but others are forced to stay on the outside. The fullerenes inside the structure take electrons from the polymers and toss them to the outside fullerene, which can effectively keep the electrons away from the polymer for weeks.

'When the charges never come back together, the system works far better,' said Benjamin Schwartz, a UCLA professor of chemistry and another senior co-author. 'This is the first time this has been shown using modern synthetic organic photovoltaic materials.'
In the new system, the materials self-assemble just by being placed in close proximity.

Credit: Image courtesy of University of Copenhagen - Faculty of Science

Copemhagen chemistry student Anders Bo Skov is getting set to save sunshine for a rainy day.

'We worked really hard to design something so we don't have to work very hard,' Tolbert said.

The new design is also more environmentally friendly than current technology, because the materials can assemble in water instead of more toxic organic solutions that are widely used today.

'Once you make the materials, you can dump them into water and they assemble into the appropriate structure because of the way the materials are designed,' Schwartz said. 'So there's no additional work.'

The researchers are already working on how to incorporate the technology into actual solar cells. Yves Rubin, a UCLA professor of chemistry and another senior co-author of the study, led the team that created the uniquely designed molecules. 'We don't have these materials in a real device yet; this is all in solution,' he said. 'When we can put them together and make a closed circuit, then we will really be somewhere.'

For now, though, the UCLA research has proven that inexpensive photovoltaic materials can be organized in a way that greatly improves their ability to retain energy from sunlight.

Tolbert and Schwartz also are members of UCLA's California NanoSystems Institute. The study's other co-lead authors were UCLA graduate students Rachel Huber and Amy Ferreira. UCLA's Electron Imaging Center for NanoMachines imaged the assembled structure in a lab led by Hong Zhou.

The research was supported by the National Science Foundation (grant CHE-1112569) and by the Center for Molecularly Engineered Energy Materials, an Energy Frontier Research Center funded by the U.S. Department of Energy (DE-AC06-76RLO-1830). Ferreira received support from the Clean Green IGERT (grant DGE-0903720).

Journal Reference:
R. C. Huber, A. S. Ferreira, R. Thompson, D. Kilbride, N. S. Knutson, L. S. Devi, D. B. Toso, J. R. Challa, Z. H. Zhou, Y. Rubin, B. J. Schwartz, S. H. Tolbert. Long-lived photoinduced polaron formation in conjugated polyelectrolyte-fullerene assemblies. Science, 2015; 348 (6241): 1340 DOI: 10.1126/science.aaa6850

Better battery
for storing solar energy?

A breakthrough may prove pivotal for technologies trying to capture the energy of the sun.

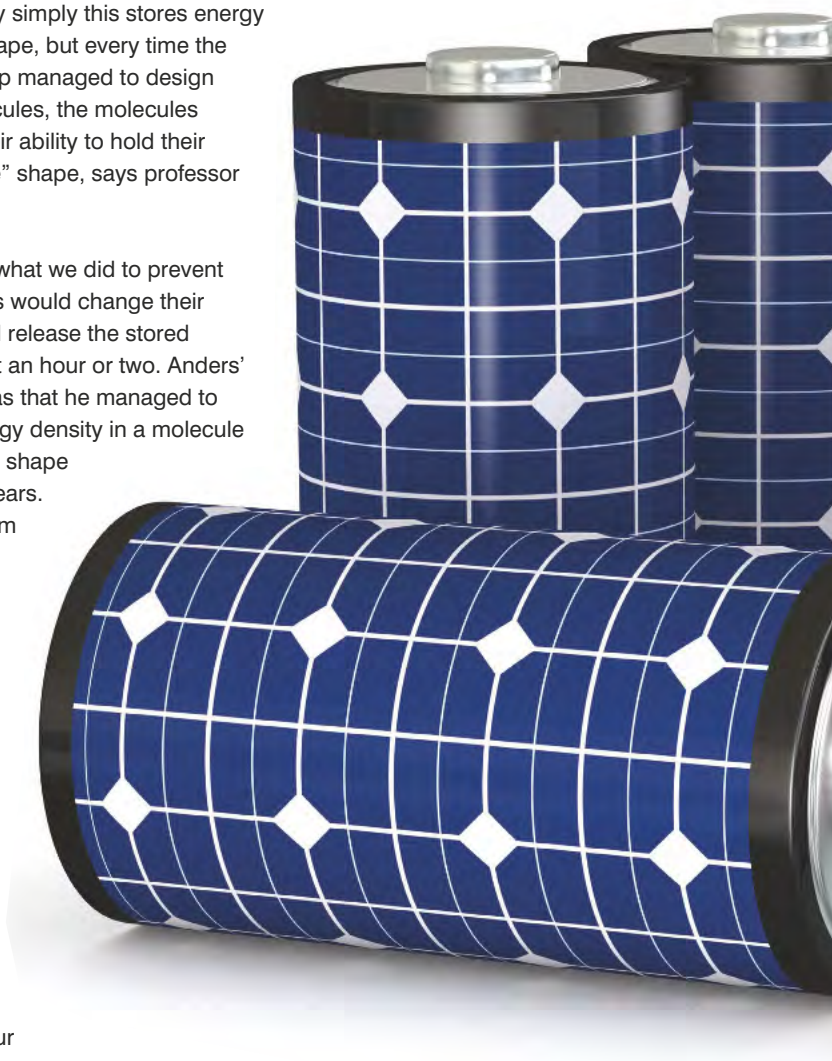
THE SUN is a huge source of energy. In just one hour planet Earth is hit by so much sunshine that humankind could cover its energy needs for an entire year if only we knew how to harvest and save it. But storing sunshine is not trivial. Now a student at Department of Chemistry, University of Copenhagen has researched his way to a breakthrough which may prove pivotal for technologies trying to capture the energy of the sun, and saving it for a rainy day.

Anders Bo Skov has recently started studying for his Master's degree in chemistry at University of Copenhagen. Together with his supervisor, Mogens Brøndsted Nielsen, he is publishing the paper "Towards Solar Energy Storage in the Photochromic Dihydroazulene-Vinylheptafulvene System" in the journal Chemistry -- A European Journal.

Professor Brøndsted is in charge of "Center for Exploitation of Solar Energy" at University of Copenhagen. Here his team is attempting to develop molecules capable of harvesting and holding substantial amounts of solar energy, storing it for significant amounts of time, and releasing it on demand. Regrettably a year of research had them butting their heads against what looked like an irksome law of nature. As the capacity of the molecules to hold energy seemed to improve, the capacity to store it over time dropped; and vice versa. The group is working with molecules known as the Dihydroazulene-Vinylheptafulvene system. Put very simply this stores energy by changing shape, but every time the Brøndsted group managed to design improved molecules, the molecules lost some of their ability to hold their "energy storage" shape, says professor Brøndsted.

"Regardless of what we did to prevent it, the molecules would change their shape back and release the stored energy after just an hour or two. Anders' achievement was that he managed to double the energy density in a molecule that can hold its shape for a hundred years. Our only problem now is how we get it to release the energy again. The molecule does not seem to want to change its shape back again," grins Mogens Brøndsted.

During his Bachelor studies Anders Bo Skov had four



months to improve Brøndsted's unstable molecule for his bachelor project. And he made it in the nick of time. Chemistry is a lot like baking. No bread is likely to come out of the oven if, for example, the flour disappears while the dough is proving. Using that analogy, Skov's "bread" persisted in disappearing between his very hands. The molecules he was working with were that unstable.

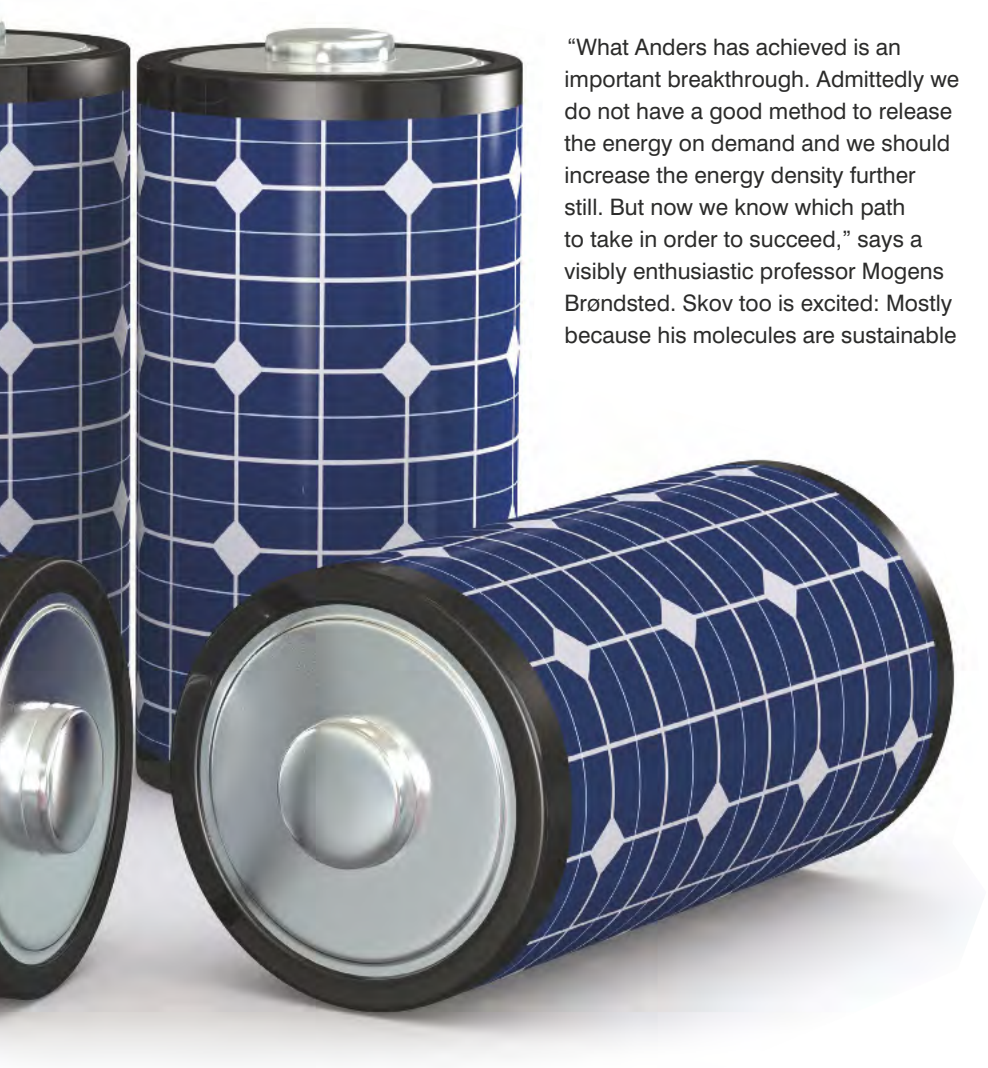
"My chemical "recipe" demanded four synthesis steps in order to work. The first three were a piece of cake. I had them working in just a month. Getting the last step in order took me three months," tells Skov. Regardless of method, when you store energy there is a theoretical limit to the energy density… And then there is reality. In theory a kilogram of the right molecules could store a megajoule of energy if they were perfectly designed. With that amount of energy you can heat three liters of water from room temperature to boiling.

A kilo of Skov's molecules can boil only 75 centilitres but it does that in just three minutes. This means that his molecules could bring to the boil 15 litres of water per hour and Skov as well as his supervisor are convinced that this is just the beginning.

"What Anders has achieved is an important breakthrough. Admittedly we do not have a good method to release the energy on demand and we should increase the energy density further still. But now we know which path to take in order to succeed," says a visibly enthusiastic professor Mogens Brøndsted. Skov too is excited: Mostly because his molecules are sustainable on more levels than just the obvious one. Not only do they harvest sustainable solar energy. They are also completely non-toxic, he relates.

"When it comes to storing solar power our biggest competition comes from lithium ion batteries and lithium is a poisonous metal. My molecule releases neither CO2, nor any other chemical compounds while working. It is "Sunlight in-power out." And when the molecule wears out one day it degrades to a colorant which is also found in chamomile flowers," explains the Masters student.

Despite all the frustrations under ways, Skov has become so excited about his bachelor project that he has brought it with him into his Master's programme. Normally Master students will start the programme by taking courses for a year, before turning to the research for their thesis. Skov on the other hand just stayed in the lab after his bachelor project. He is affiliated with the Center for Exploitation of Solar Energy in order to pursue his ideas for tweaking the sun-catcher molecule. Now he wants it to release the energy on demand. And the 25 year-old Masters student is brimming with ideas for the construction of such a compliant molecule.



Journal Reference:

Martina Cacciarini, Anders B. Skov, Martyn Jevric, Anne S. Hansen, Jonas Elm, Henrik G. Kjaergaard, Kurt V. Mikkelsen, Mogens Brøndsted Nielsen. Towards Solar Energy Storage in the Photochromic Dihydroazulene-Vinylheptafulvene System. Chemistry - A European Journal, 2015; 21 (20): 7454 DOI: 10.1002/chem.201500100

Perspective

makes all the difference in solar

More people are taking control of their energy future with solar-based systems. Mark Andrews examines contributing factors and finds that perspectives vary across international borders.

EVERY DAY seems to bring more headlines about ways worldwide energy production are changing. Facts documenting renewable energy's growing role and predictions of PV dominance by mid-century are now becoming common.

Solar energy's role has been transformed since 2008 when PV-generated energy made up far less than 1 percent of humanity's overall energy resources. In 2015, even some of the world's most conservative political and economic voices are joining the chorus pointing to a 'solar ascendency.'

Deutsche Bank in March joined others predicting that by 2030 power from solar energy systems will see a 10-fold increase over today's levels, creating $5 trillion (USD) in annual revenue. The International Energy Agency (IEA) last year predicted solar power would be the world's leading electricity source by 2050.

Deutsche Bank's voluminous report credited solar's rapid advance mainly

to declining PV panel and installation costs. Other industry watchers zero in on a combination of factors including steep declines in materials and other price drivers including market entrance by lower-cost manufactures combined with sizable efficiency increases. Other researchers have pointed to more money being made available to finance both household and utility-scale programs in combination with many types of governmental incentive programs.

Follow the money

A key reason for accelerating advances of solar within the planet's energy lineup is the fact that overall costs of installing and maintaining a PV system are reaching parity with fossil fuel generated electric power. While a desire to 'go green' with achieving energy independence are also major motivators, it very often comes down to the money—what a person or utility pays for electric power generated by burning something vs. the costs of a solar-based system with no moving parts and no imported fuels.

Globally, the unsubsidized rates for rooftop solar energy range between $0.08 and $0.13 per kilowatt hour (KWh) of capacity. That amount is about 30 to 40 percent below the retail price for electricity in many markets. The difference between how close solar-based power costs are to fossil fuel generation varies widely; it is tied to what resources a region utilizes to generate electricity – areas rich in oil, natural gas or coal typically see lower costs for generating power than do areas where fuel is imported. But these disparities are shrinking quickly as solar becomes the 'great equalizer' of energy generation.

Solar-generated electricity is still more costly in many markets, particularly those that are long-established or tied to coal-fired power plants. But this is changing as well. According to the Deutsche Bank report, the cost ratio of solar power vs. coal-based wholesale electricity to was 7:1 in 2001. That ratio on average is now less that 2:1 and could approach 1:1 over the next 12 to 18 months. Parity with coal-fired generation sometime in 2016 is not only a possibility, but a likelihood.

Going beyond cost

With economics on the side of solar in an ever-widening fashion it can be argued that now is the best time to draw a line in the sand; to commit and take the plunge. A wide range of factors have made it possible to not only reduce one's monthly electric bill but also reduce greenhouse gases and be largely independent of a regional utility's rate hikes and other negatives of centralized power generation. There is also the not-inconsiderable benefit of moving to a widely distributed power model vs. highly concentrated systems that are vulnerable to cascading transmission failures, external interference, political unrest and

all the other headline grabbing calamities which have all the more impacts in a technologically interdependent world.

So why aren't more people rushing to be part of the solar movement? First, it takes the will to change, and as anyone in the business of changing minds can tell you, disrupting human habits is challenging without a massive effort to coax, cajole or simply convince persons that 'status quo' is no longer in their best interests.

While widely accepted on anecdotal evidence, the good people at Plymouth University (UK) recently released a study showing that adults across all socio-economic levels have misconceptions about energy saving behaviours and are often loathe to change their habits. On average, many people also mistake the effectiveness of certain tactics to cut consumption so they won't do what's most effective while embracing what feels good. In many instances people have no idea how the price they pay for energy compares to prices they could pay if they were energy independent. The study even showed that many felt energy conservation might not be needed despite ample evidence of its long-term necessity.

"Energy use affects every aspect of contemporary life, and energy saving is a crucial part of our response to climate change and fossil fuel depletion. But despite a range of energy-related behaviour change initiatives in education and public life, 'energy literacy' among citizens remains patchy. Studies have in

fact shown that environmental concerns in some countries are at a 20-year low, and without strong motivation for changing behaviours, there is limited potential for energy consumption to be further reduced," said Professor Debby Cotton, the report's lead author.

An interesting outcome of the study pointed to the fact that while people collectively embrace the desire to be responsible custodians of energy and other resources, personal behaviour varies widely. In other words – we say one thing but do another.

Despite 200 years of staggering technological advances, humans very often choose to keep on doing whatever it is they find comfortable. It's as if they collectively agreed to believe, "There is no reason to change. Everything is just fine."

Governments' role

Despite individuals' change-resistant behaviors, moving away from fossil fueled electricity has been taking place faster than ever. Many perspectives factor into reasons behind this move, but the most important determinant behind large-scale change is the fact that visionary national governments have found it in their best interests to be energy independent. Those leaders, sometimes with public consensus and at other times charging ahead of opinion polls, have supported solar research, subsidized PV and other renewable conversions, and have made long-term commitments to shake off dependence on resources that are finite, polluting, dangerous or in the hands of unreliable international neighbors.

"Energy use affects every aspect of contemporary life, and energy saving is a crucial part of our response to climate change and fossil fuel depletion. But despite a range of energy-related behaviour change initiatives in education and public life, 'energy literacy' among citizens remains patchy"

Looking back at the Plymouth University report, we can see that self-interest remains firmly in the driver's seat of human behaviour. In that light, is it surprising to find that countries with large petroleum, coal or natural gas reserves tend to be the least aggressive in adopting technologies that will render those resources less valuable? Not at all. But even countries with large fossil fuel reserves can see the inevitable. Namely, that any energy resource that doesn't require massive amounts of work to create and distribute, not to mention that is virtually immune to mishandling or sabotage, is going to eventually be the resource most people chose.

What about the US?

The evolution of solar energy in the United States is at its infancy compared to other nations that have pursued policies to become independent through renewable energy sources during the 21st century. Even though the role solar holds in the US energy budget grew by more than 100 percent between 2014 and 2013, it still makes up less than 1 percent of the country's total energy consumption.

The US Energy Information Administration (EIA) in a recent report cited that utility-scale solar projects in 2014 generated 12,303 GWh compared to 6,048 GWh in 2013. The agency cited a number of reasons for the doubling, including many large-scale projects coming online, continuation of the Investment Tax Credit, continuing increases in technological innovations that lower costs, and a pro-solar US president. The same report said it expected growth to be robust the rest of 2015, but warned that unless the current 30 percent ITC is extended growth could fall-off dramatically starting in 2016.

What's at stake if the US fails to pick-up the solar adoption pace compared to its neighbors? In reality it could find itself at odds with its own best interests and long-term growth potential. Imagine a country trying to compete on the world stage when it pays double (or more) to generate power compared to other competitors?

The group Environment America recently made the case that the US could and should establish a goal to obtain at least 10 percent of its electricity from solar by 2030. Deutsche Bank in its March report stated that the rest of the world's major energy-using nations are on track to meet or beat the 10 percent goal by that same year. Their report stated that, "we believe the solar industry is going through fundamental change and the opportunity is bigger than it has ever been before," said Deutsche Bank analyst Vishal Shah.

Germany knows a bit about solar energy success. It set a goal to achieve energy independence, phase- out nuclear power and lead with technological innovations that would benefit the country's citizens as well as its corporations. It is well down the road to getting there. In the first quarter of 2014 it generated about a quarter of its domestic energy from renewable resources in the depths of winter. By 9 June 2015 it generated more than 50 percent of its power using solar. A combination of pro-renewable national policies helped sustain this revolution including feed in tariffs (FIT) and a range of policies that have made investing in solar technology citizen and investor friendly.

While Germany achieves 50 percent solar capacity, the US strives to cross the 1 percent threshold. But it's simplistic to not consider the differences between these two. Beyond size and geography there is a major difference in how modern oil and coal-fired industrializations of the 19th and 20th century played a role in the US's emergence as a global economic power. While Germany's oil and gas resources are practically non-existent and its coal reserves are largely depleted, the US still has vast quantities of coal, oil shale and petroleum within national waters.

Its home-grown hydraulic fracturing technology quickly led the US to leap-frog as the number-one natural gas producer. As we've seen elsewhere, it is hard for solar to thrive when there are entrenched systems for delivering low cost electricity using resources a country can directly control.

National vs. Regional energy policies

Energy policy is complicated and perspectives about what should be a

priority vary from country / region to region—individualism drives opinion and shapes perspective. But even while the US managed to affect world oil prices with new-found fossil fuel technologies, not every corner of the country is all about 'Oil Patch' politics.

The US-based National Renewable Energy Laboratory (NEWL) released a study recently that examined why some US states are much more successful than others in encouraging private and public renewable energy investments. The 10 US states with the largest solar economies are responsible for 90 percent of the entire country's solar energy investment.

The NEWL report found that there are two major factors that determined how successfully a state grew its solar base. First, governmental policy was just as important in US states as it has been on national stages across Europe and Asia.

For example, there had to be sets of clear and understandable policies and regulations for interconnection to the electricity grid including net metering to work. Policies that enabled local utilities to compensate PV system owners through a simple billing mechanism were critical. Second were the non-policy issues including the relative amount of sunlight available for solar generation (PV is bigger in California than North Dakota, for example); community interest and the cost of competing grid electricity were additional drivers.

This new report concluded that in addition to having a growing economy, state regulations needed to be simple and building/installation permit processes needed to be simple. In fact, easy paperwork and a strong local economy went far toward overcoming relatively low sunlight winter months in northern locations. Analysts found this was true in Maryland, North Carolina and Delaware. These states far outpaced solar investment levels in Florida that has a clear geographic advantage in terms of average hours of good solar exposure throughout any given year.

> "Energy policy is complicated and perspectives about what should be a priority vary from country to country / region to region—individualism drives opinion and shapes perspective"

Too late to change? Not so fast...

While the US may be behind other countries that have achieved high solar adoption rates in the past 10 years, it can catch-up and is making strides. The Solar Energy Industries Association (SEIA) said in a recent report that a slow start does not preclude a good finish.

"In 2004 there were only two states with 10 MW of installed solar capacity, yet 10 years later 35 states have topped that threshold, and 20 states have more than 100 MW. But here's the best news of all: we expect to double our total capacity in the next two years alone," said SEIA president and CEO Rhone Resch.

Like the NERL report stated, public policy is a huge driver along with the willingness of citizens who recognize that changing energy priorities is not only needed, but essential to long-term personal and national economic success.

In this regard, Hawaii is now America's number-one solar champion. Hawaii in May became the first state to vote for generating 100 percent of its energy from renewable resources by 2045. Hawaiian lawmakers voted 74-2 in favor of the proposition as it seeks to rely totally on solar, wind and geothermal resources, with an interim goal of 30% by 2020. Hawaii generated about 22 percent of its energy through renewable resources in 2014.

"Through this process of transformation Hawaii can be the model that other states and even nations follow. And we'll achieve the biggest turnaround in the country, going from 90 percent dependence on fossil fuels to 100 percent clean energy," said Hawaiian State Senator Mike Gabbard.

Hitting the mental reset button

As we've seen, change isn't easy. It's not human nature to head where things are unknown if it means leaving a comfortable and secure location. But as many people and nations have seen, relying on other countries for key resources when there are feasible and cost-effective alternatives at home leaves them at risk to whomever controls fuel or technological resources.

An effective and self-sufficient energy policy isn't only possible, it's in everyone's best interests. Even the most conservative believe industrialized nations with large populations that have long depended upon fossil-fueled energy systems will convert to solar or other renewable energy resources, though it will take time and investments. Some say sizeable change will occur by 2030, others by 2050. But change is inevitable by either reckoning.

The question remains whether to lead or play catch-up in the move to solar independence. Leaders are the innovators who control future markets and set prices. Where would you rather be and what is your perspective in the solar energy equation? It really is about the money, and so much more.

Shining a light on metal nanoparticles

Researchers at the University of Surrey have had a breakthrough using the polymer-wrapped nanotubes as a replacement for an existing polymer layer used to transport charge to the electrodes of the plastic solar cell. The work led to the development of a composite material with exceptional semiconducting properties. Professor Ravi Silva explains.

THE ADVENT OF the concept of flexible electronics, which was closely followed by the development of printed electronics, there has been a strong drive towards the integration of light-weight active components that can conform to nearly any form factor. Among the technologies that were predicted to be heavily influenced by this new concept of flexible electronics was the photovoltaic (PV) market.

One of the earliest material technologies that was quickly adopted in the field of flexible electronics and PV was amorphous silicon with initial products appearing on the market as early as the 1970s. However, the disordered nature of amorphous silicon meant poorer performance when compared to the conventional crystalline silicon used in solar panels.

The requirement for low cost supports, such as plastics, for flexible electronics meant that high temperature treatments that could improve the quality of the silicon were also out of the question. It is at this point that researchers under the direction of Professor Ravi Silva at the Advanced Technology Institute (ATI), University of Surrey, began investigating the possibility of using a class of high powered lasers, called excimer lasers, which could crystallise the silicon without damaging the underlying plastic.

"The use of excimer lasers, where the energy is delivered in a very short time period of around 25 nanoseconds, allowed us to overcome the potential damage to the underlying substrate whilst crystallising the top surface of the upper silicon layer," explained Professor Silva. However, the use of amorphous silicon had other problems. While the technology was widespread, it was based on vacuum-based production techniques which require the use of energy intensive equipment, a technology that the flexible electronic industry was looking to distance itself from.

During the same period that the ATI's work on laser crystallised solar cells was developing, Professor Alan Heeger, (one of the Nobel Prize winner for Chemistry in 2000 for the discovery of conducting polymers) and his team at the University of California, Santa Barbara, discovered an efficient charge transfer between electrically conducting plastics (known as semiconducting polymers) and football-shaped carbon molecules (called fullerenes, first discovered by Sir Harry Kroto, who was one of the recipients for the Nobel Prize in Chemistry for the discovery of fullerenes). The advantage of this class of materials was the ability to make ink solutions that could be coated in thin films onto a surface.

"Here was a dream material system that had the potential to revolutionise not only the printed electronics industry, but also provided a launch-pad towards a low cost technology for renewable energy generation."

While the initial phase in the development of this technology was slow, and filled with inconsistent and inaccurate measurement techniques, there was enough potential to drive the imagination of dedicated researchers in pushing the technology further. However, much like the amorphous silicon technologies, the disordered nature of the thin films produced with these inks meant poorer performance. While other groups worldwide focused on improving the characteristics of the semiconducting polymer, Professor Silva and his group chose to follow a different direction.

"Back then, tubes of interconnected hexagons of carbon atoms were thought to be an ideal electronic material that had the potential to revolutionise the electronics industry. First discovered in 1992 by Kavali Prize winning physicist Sumio Ijima, these 'carbon nanotubes' were found not only to be stronger than most other available materials, but also transported electrical charge much faster than most many of the available materials.

All of a sudden, there was the tantalising possibility of pushing the boundaries of our polymer solar cells by adding a tiny fraction of carbon nanotubes, and consequently vastly improving the collection of electrical charge"

Unfortunately, these nanotubes had one problem: in their pure form, they did not form good inks. Typically, the carbon nanotubes would stick together and fall out of solution.

It was at this point that Professor Silva's group came up with the idea of attaching small groups to the nanotube that would help them to be dispersed in the solvents used for making the semiconducting inks other groups were already investigating. Boosted by funding from the energy giant E.ON, a three year project was initiated to investigate the effect of adding low cost "multi-walled" carbon nanotubes (nanotubes with multiple layers similar to a rolled newspaper) into plastic solar cells.

While there was the possibility of investigating the use of "single-walled" carbon nanotubes, with only a single tube of carbon atoms, the link between the electrical conductivity and the inherent carbon structure meant that their fantastic properties would be degraded by the addition of solubilising chemical species through the breaking of the bonds on the tube surface.

Such an affect would be mitigated in the multi-walled structure as there would be several concentric tubes which would help preserve the electrical properties, and only the outer tube would lose electrical conductivity as the solubilising groups were attached. While the initial investigations into the addition of carbon nanotubes into organic solar cells produced interesting characteristics, researchers at the ATI discovered that adding the nanotube creates a new material interface within the solar cell

where extra charge can be generated. "It's almost as if two people were working on a project together with a certain efficiency, and along comes a third who shows them another way of improving their output."

While this work on multi-walled carbon nanotubes was being pursued, other researchers at Surrey then started focusing on single walled carbon nanotubes for use in plastic solar cells. This was principally driven by the availability of single walled carbon

nanotube samples that, to a higher percentage than multi-wall carbon nanotubes, were semiconducting in nature. The researchers asked the question, "what if instead of breaking the bonds on the nanotube surface, could we wrap a nanotube with a polymer that allows us to make ink solutions, but is compatible with use in solar cells?" The answer was resoundingly positive. "The wrapping of carbon nanotubes with polymers were already being aggressively investigated by other groups in places like Oxford and Rice University (USA), however, very few had given thought to adding them to the plastic solar cells. The breakthrough came through using the polymer-wrapped nanotubes as a replacement for an existing polymer layer used to transport charge to the electrodes of the plastic solar cell. Working with a new semiconducting polymer, the Surrey researchers soon reported the best performing plastic solar cells containing carbon nanotubes. The work led to the development of the composite material with exceptional semiconducting properties and the ability to produce inks for printing onto a chosen surface.

According to Professor Silva, "this material, which has been patented, is groundbreaking and can find use in numerous practical applications in printed electronics, ranging from infrared detectors and solar cells to transistors." Other than developing carbon nanotubes for plastic solar cells, Professor Silva's group also specialises in utilising metal nanoparticles that can help the solar cell capture more light.

"This work initially began as a study on using our laser facilities to make small nanoparticles. The excimer laser allowed us to develop a process for producing metal nanoparticles on plastics that can play a major role in manufacturing printed solar cells using roll-to-roll techniques". The knowledge of laser processing of nanoparticles led directly to the group participating in a 4-year European Union 7th framework project (SMARTONICS, grant number 310229) aimed at developing a roll-to-roll pilot plant integrating smart machines and systems for the production of organic electronics devices.

Other than focusing on the active semiconducting layer itself, Professor Silva's group also focuses on alternate transparent conductors. Currently, indium tin oxide (ITO), a material in demand by the electronics industry but whose supply is subject to fluctuations, is the material of choice for one the electrical contacts for the organic PV modules. However, the ATI has been turning its attention towards alternate conductors, such as carbon nanotube films that can be spray coated onto any given substrate or metal grids, which can match the performance of the ITO contacts.

However, the scope of the investigations of Prof Silva's group into organic solar cells extends even further. They are now looking at new electrically conducting layers that can be integrated into the device architecture that improve performance, but conform to the requirement of solution processability. "There is a huge interest in developing new interlayers that significantly improve device performance and lifetime. We at the ATI have been focusing on developing hybrid nanostructures to further improve the device performance".

One of the success stories has been the integration of graphene, together with metal oxide nanoparticles, into one of the layers of plastic solar cells. While a majority of groups have looked to add graphene, Professor Silva's group is one of the few who have achieved this using solutions of graphene derivatives.

"Most institutes tend to use a derivative of graphene on a specific contact of these plastic solar cells while others tend to rely on the cumbersome chemical vapour deposition grown graphene. What we have achieved in the ATI is to start off with a graphene derivative that is stable in an environmentally friendly solvent and then either use it as it is, or integrate it with metal nanoparticles to improve the overall PV device performance".

With for the development of organic PV technology, Professor Silva's group is now focussing on widening the applicability of organic PV technology for other applications. For example, they have recently looked to develop new hybrid PV technologies for hydrogen generation and x-ray detection and harvesting.

FREE ONLINE WEBINAR

PROCESS SOLUTIONS FOR GaN AND SiC POWER SEMICONDUCTOR DEVICES

Wednesday 8th July 2015 at 16:00 GMT +1

The potential energy efficiency savings from the adoption of wide band gap power semiconductor devices based on GaN or SiC has led to significant research and development that is now beginning to be realised in commercially available devices. Many technical challenges have been addressed but further research is still on-going into higher performance lower cost devices

In this webinar the first talk will address process solutions available today and the second talk will outline research into addressing the challenges of the next generation of devices. This webinar will be of interest to all those researching into this growing field of interest

Who should attend?

Process and device fabrication researchers and engineers in wide band gap devices

Talks:

Plasma etch and deposition processes for GaN and SiC power semiconductor devices
Speaker: Chris Hodson, Product Manager Power Semiconductor and ICT devices, Oxford Instruments

Silicon Compatible GaN Power Electronics
Speaker: Professor Iain Thayne, Professor Ultrafast Systems (Electronic and Nanoscale Engineering) University of Glasgow

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Bridging the gap between projects and funding in Africa

Last month Access Infra Africa ('Access'), a developer, owner and operator of power assets in Africa, launched the Access Co-Development Fund ('ACF'), a US$ 5 million competition designed to bridge the gap between early stage renewable energy projects in Africa and the expertise and funding they require to come to operation. Solar International spoke to the Program Director, Karim Megherbi Megherbi to find more about the program.

Q What is the ACF?

A ACF is a platform which provides both technical assistance and funds to finance the development costs of renewable energy projects until financial close. Access will then arrange the financing, in equity and debt, of the projects which were successfully developed under the ACF program. This means that developers that are selected under the ACF program will focus on the development of their project, the financing being handle by ACF and Access, while they benefit at the same time of the support of the full team of Access.

Q Who launched the ACF and why?

A ACF was launched by Access, so this is a fully private initiative. We believe that there is a lot of interesting projects on "stand by" in Africa, many motivated developers lack the necessary funds to achieve their goal. But the money is clearly not the only issue. To successfully develop a power project in Africa you need an extensive range of expertise, a strong team which has experience in structuring such projects. In particular the legal and financial schemes, as well as the risk management during the development phase, are challenging. This is where we come in: our goal is to transform the most interesting projects/ concepts initiated by local developers into a reality. This will be an exciting journey for all of us.

Q Why does early stage development in Africa matter?

A The early stage development money is the most difficult to raise and the most difficult to manage. On one hand, only few people are interesting in your project at first, essentially because nobody is willing to loose time on something which is uncertain. So at the beginning, the most common reaction you see is "come back when you are more advanced" – which means that you still need to spend money and make studies before coming back. On the other hand, when you were able to raise some funds at the beginning, the use of it is very strategic: it should be spent appropriately in order to build a strong case which will lead you to the next level and basically increase the probability of success of your project. ACF will address both issues.

Q Explain the partnership with the Africa Energy Forum?

A As you know the AEF has been growing extensively in the recent years, proving high quality of organization as well as

enlisting growing interest of investors in the Africa Energy market. We are very pleased to be collaborating with the AEF on this initiative. There will be a plenary session dedicated to ACF at this year's AEF in Dubai, where the 5 shortlisted developers will be able to present their projects to an expert panel at the AEF. This will be really exciting and novel.

Q Who can apply and what are the criteria?

A Everybody can apply. We wanted the competition to be as wide as possible. All commercial power generation projects are welcomed, as long as it is based on the African continent and that it uses renewable or hybrid technologies. The scoring will be based on technical, commercial and environmental and social aspects.

Q How do projects apply to be considered for the ACF?

A We wanted the process to be as simple as possible, so there is only one form to fill with documents to attach, if any. Interested applicants can download the form and guidelines from at http://access-power.com/access-co-development-fund-acf-launched/. The documentation package is sent to the ACF email address (ACF@access-power.com) and the application will be taken into account immediately. All enquiries should be directed to same email.

Q Who is judging and what are they looking for?

A There will be two steps in the process: first Access's team will review the proposals and will make a shortlist of 5 projects based on the criteria and methodology described in the guidelines. Then the final decision on who can benefit from the 5M USD budget will be made by the expert panel made up of senior representatives of IFC, FMO, Trinity LLC, Eren, and Access. I guess we can say that what everybody is looking for are projects that make sense, are commercially viable and that will improve the environment, supported by a team which will be able to work closely with Access' team.

Q What are the expected benefits of the ACF?

A Obviously the realization of up to 5 projects and their impacts on the environment will already be a big achievement. But we think that ACF will also generate a lot of interest within the DFI world that the relationship between the development institutions and the private sector will soar higher. This could potentially leverage the fund available and their social and economic impact.

Q What is the timeline for the ACF? Where can potential applicants find more information?

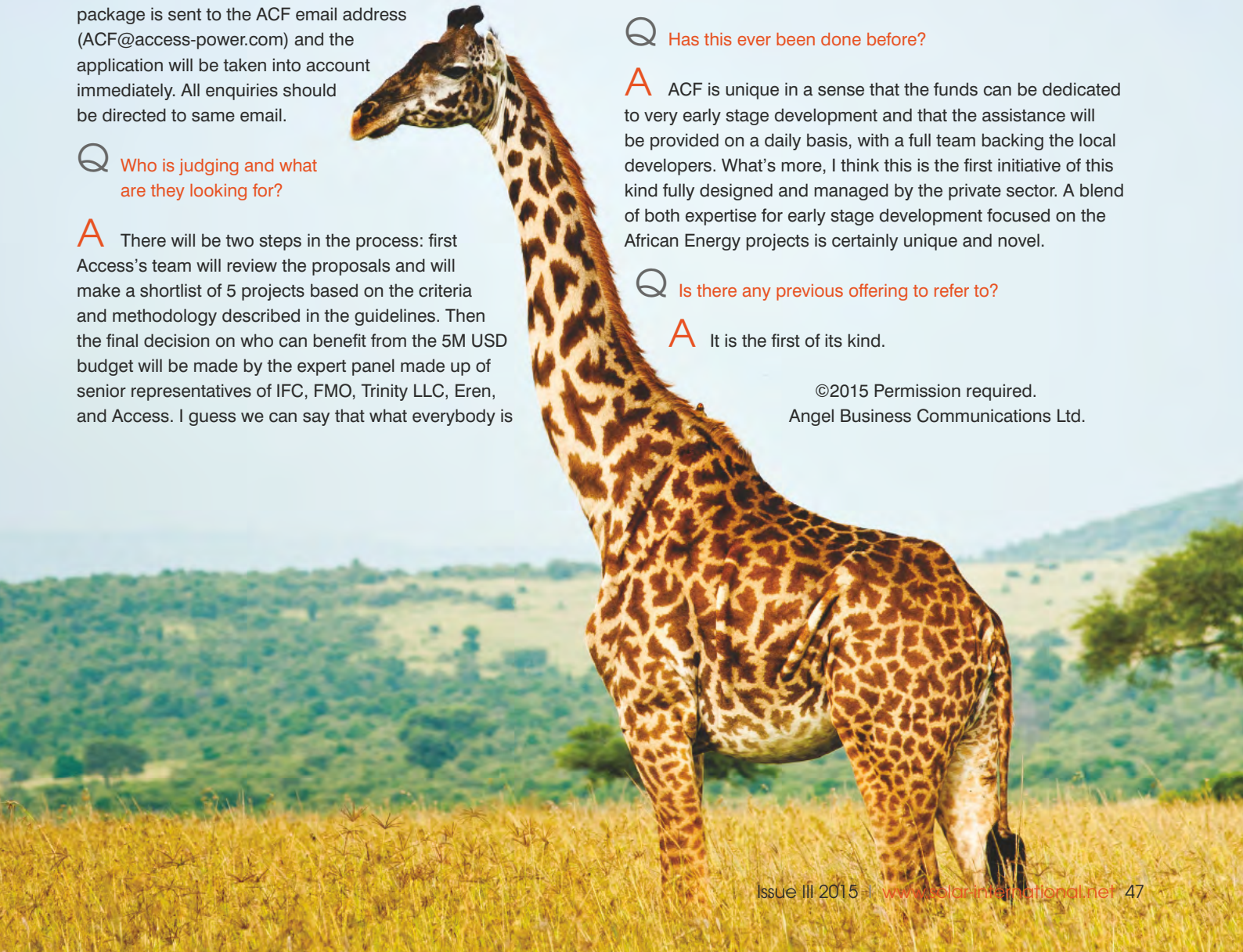
A The application period is short: from the 1st of April until the 20th of May. The shortlist will be communicated shortly after the end of the application period, together with an invitation to the AEF to the shortlisted companies. The plenary session will take place at the AEF in Dubai on the 11th of June. Applicants can find more information on Access website www.access-power.com

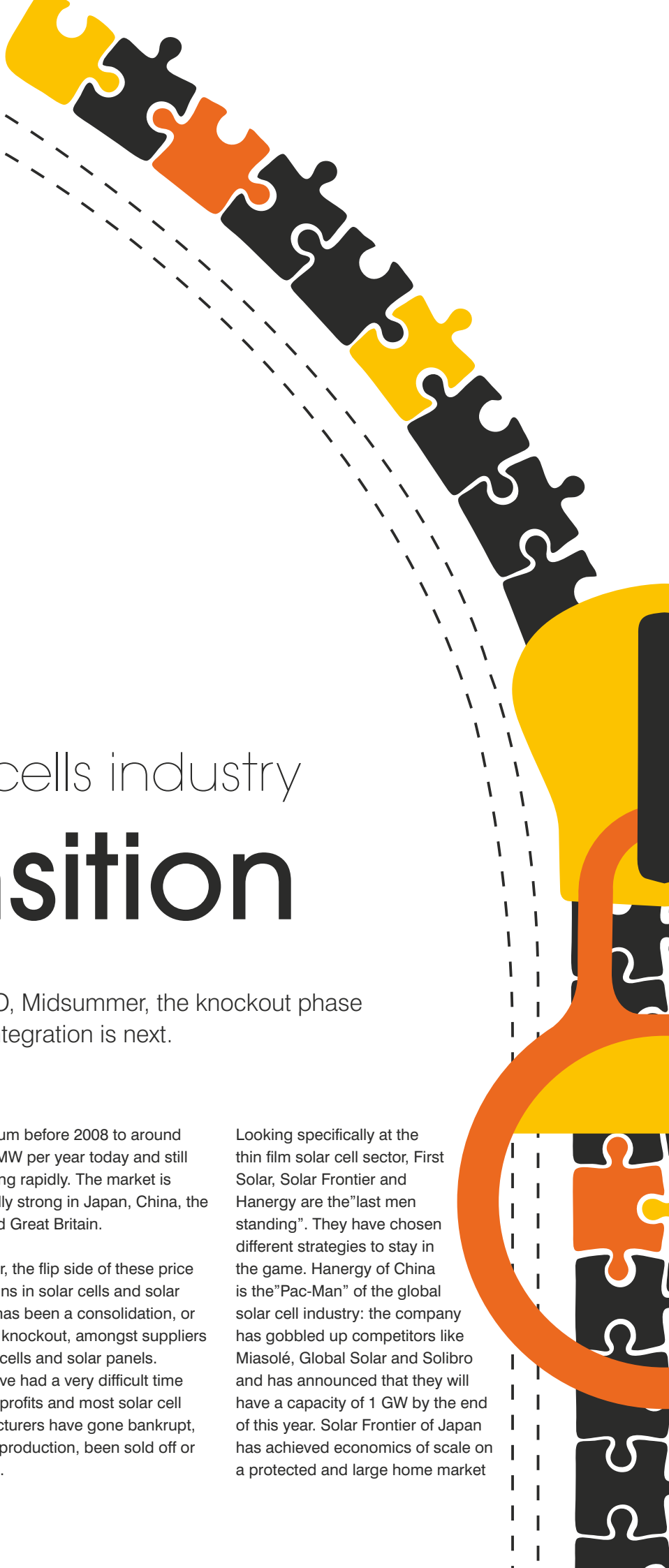
Q Has this ever been done before?

A ACF is unique in a sense that the funds can be dedicated to very early stage development and that the assistance will be provided on a daily basis, with a full team backing the local developers. What's more, I think this is the first initiative of this kind fully designed and managed by the private sector. A blend of both expertise for early stage development focused on the African Energy projects is certainly unique and novel.

Q Is there any previous offering to refer to?

A It is the first of its kind.





Thin film solar cells industry in transition

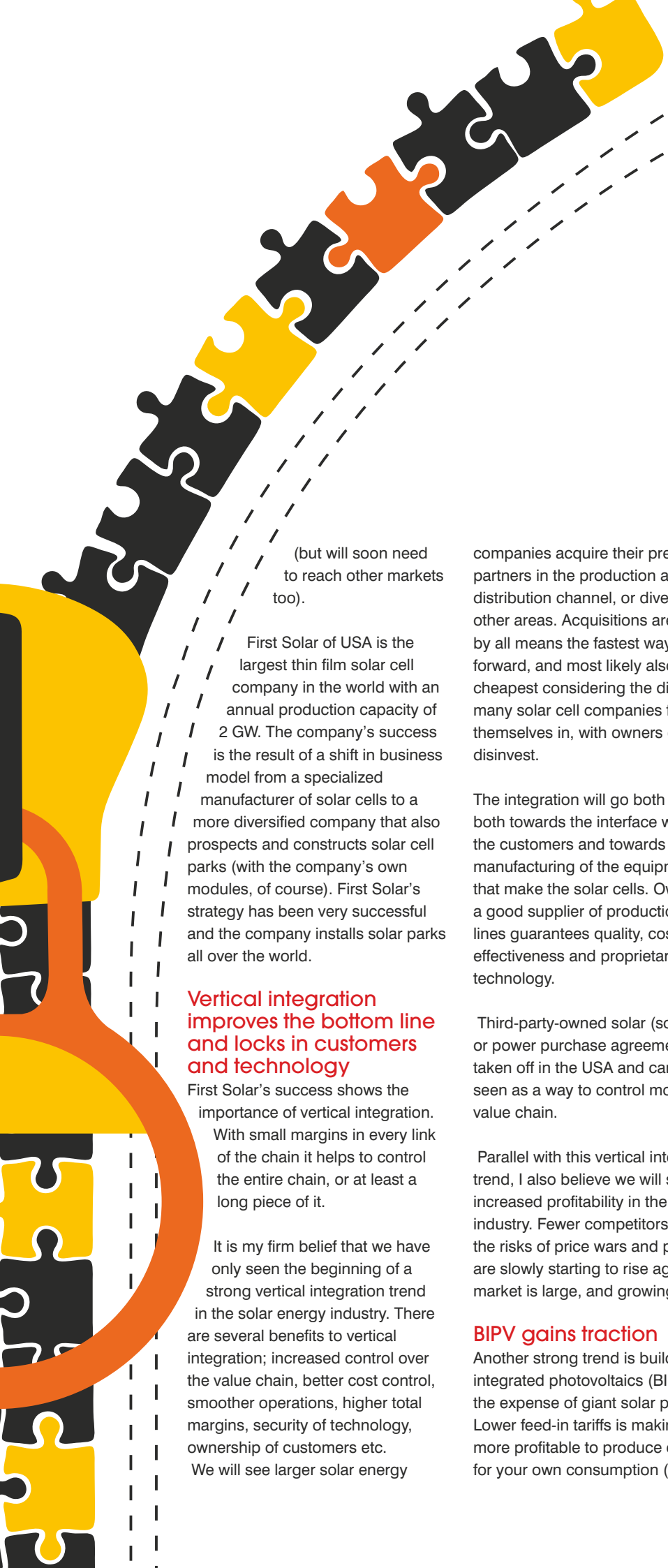
According to Sven Lindström, CEO, Midsummer, the knockout phase is over – profitability and vertical integration is next.

PRICES OF SOLAR CELLS and solar panels have fallen dramatically over the last few years. This (and state subsidies) has been good for the advancement of this amazing renewable energy source, and solar energy can today be seen as an established energy source, reliable and well distributed, cost competitive with traditional non-renewable energy sources and with a very healthy annual growth in installed solar panels.

Annual solar cell installations have rocketed from less than 5,000 MW per annum before 2008 to around 40,000 MW per year today and still increasing rapidly. The market is especially strong in Japan, China, the USA and Great Britain.

However, the flip side of these price reductions in solar cells and solar panels has been a consolidation, or rather a knockout, amongst suppliers of solar cells and solar panels. They have had a very difficult time making profits and most solar cell manufacturers have gone bankrupt, ceased production, been sold off or rescued.

Looking specifically at the thin film solar cell sector, First Solar, Solar Frontier and Hanergy are the"last men standing". They have chosen different strategies to stay in the game. Hanergy of China is the"Pac-Man" of the global solar cell industry: the company has gobbled up competitors like Miasolé, Global Solar and Solibro and has announced that they will have a capacity of 1 GW by the end of this year. Solar Frontier of Japan has achieved economics of scale on a protected and large home market



(but will soon need to reach other markets too).

First Solar of USA is the largest thin film solar cell company in the world with an annual production capacity of 2 GW. The company's success is the result of a shift in business model from a specialized manufacturer of solar cells to a more diversified company that also prospects and constructs solar cell parks (with the company's own modules, of course). First Solar's strategy has been very successful and the company installs solar parks all over the world.

Vertical integration improves the bottom line and locks in customers and technology

First Solar's success shows the importance of vertical integration. With small margins in every link of the chain it helps to control the entire chain, or at least a long piece of it.

It is my firm belief that we have only seen the beginning of a strong vertical integration trend in the solar energy industry. There are several benefits to vertical integration; increased control over the value chain, better cost control, smoother operations, higher total margins, security of technology, ownership of customers etc.

We will see larger solar energy companies acquire their previous partners in the production and distribution channel, or diversify into other areas. Acquisitions are by all means the fastest way forward, and most likely also the cheapest considering the dire straits many solar cell companies find themselves in, with owners eager to disinvest.

The integration will go both ways: both towards the interface with the customers and towards the manufacturing of the equipment that make the solar cells. Owning a good supplier of production lines guarantees quality, cost effectiveness and proprietary technology.

Third-party-owned solar (solar lease or power purchase agreement) has taken off in the USA and can also be seen as a way to control more of the value chain.

Parallel with this vertical integration trend, I also believe we will see increased profitability in the solar industry. Fewer competitors reduce the risks of price wars and prices are slowly starting to rise again. The market is large, and growing.

BIPV gains traction

Another strong trend is building integrated photovoltaics (BIPV), at the expense of giant solar parks. Lower feed-in tariffs is making it more profitable to produce energy for your own consumption (factories, offices) than to feed it into the grid. Rapid advancements in thin film solar cell efficiency has improved the business case for such solar cells and property owners and managers are beginning to take notice, as do roof manufacturers and municipalities.

The implementation of PV into buildings should not be considered an added novelty product supplementing current construction materials, but rather be seen as an integrated part of roofing and facade material that could add substantial value to building material suppliers' range.

Thin film CIGS solar cells are thin, light and flexible. They can be made frameless and can be bent and are ideal for buildings and other structures that are uneven, moving or weak. They are also becoming increasingly efficient. All the major potential investors in the solar energy industry today are looking at this particular segment.

So to summarize: the shake-out is over. Vertical integration comes next, with a focus on BIPV that will make thin film CIGS solar cells the product of choice for many players in this arena. Profitability will return to the industry. The future is indeed sunny and bright.

Solar-Tectic on course for **sapphire success**

As cheap sapphire glass production gathers pace, solar cell start-up, Solar-Tectic, has set its sights on photovoltaics, smartphone displays and more. Rebecca Pool reports.

IF SOLAR-TECTIC'S latest developments are anything to go by, 2015 looks set to be a big year for the US-based solar cell start-up.

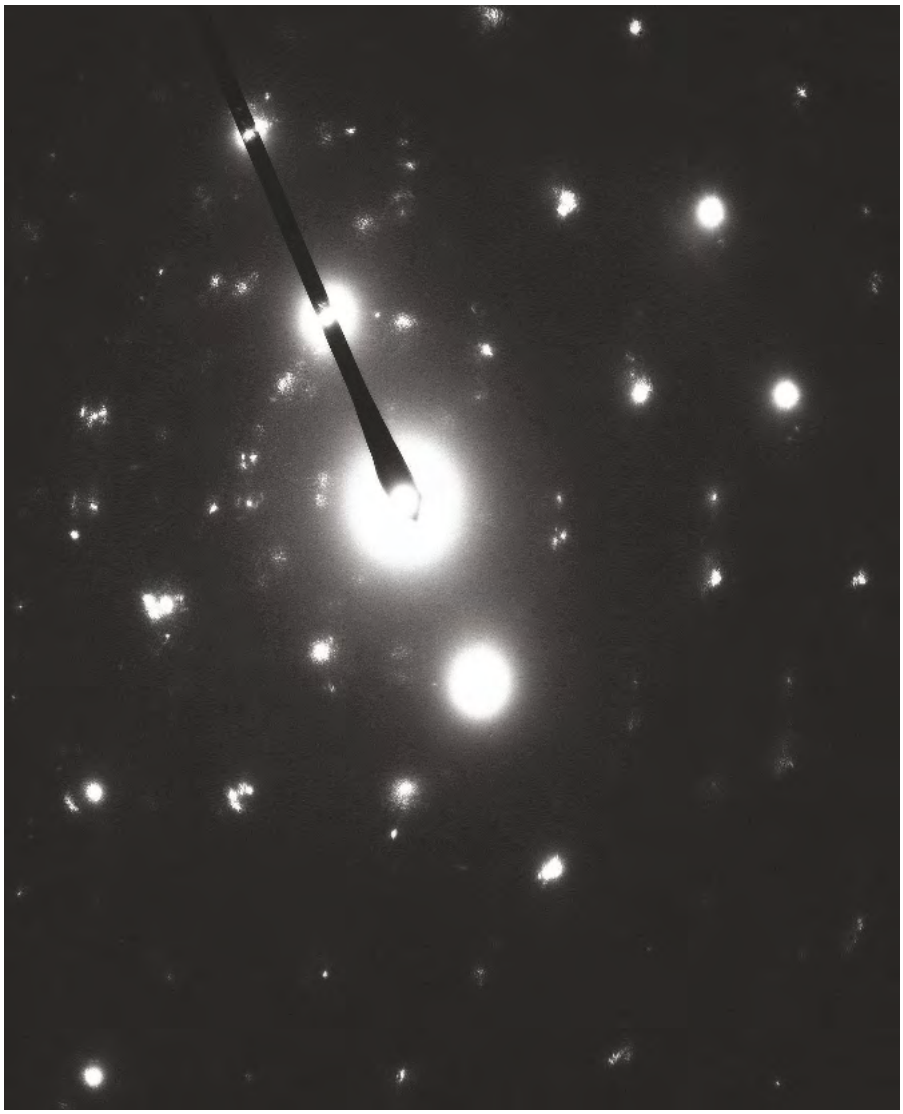
Plans to produce sapphire glass, consisting of a thin film of sapphire on MgO-buffered soda-lime glass, are well underway with smartphone covers clearly being the number one application.

What's more, company researchers have also deposited highly textured silicon films on the MgO/soda-lime glass substrate, opening the door to cheap fabrication of photovoltaics and more. And with the technology also being honed for LEDs, the future is looking bright.

Solar-Tectic was set up in 2010, to commercialise the thin film technology developed by the late Dr Praveen Chaudhari, IBM materials physicist, Brookhaven National Laboratory director and 1995 US National Medal of Innovation and Technology winner.

As his son, Dr Ashok Chaudhari, explains: "His idea for solar cells at the time was to deposit high quality but inexpensive thin films onto inexpensive substrates."

"He wanted to deposit silicon onto a cheap substrate, with the trick being to deposit a thin film of sapphire onto glass," adds Chaudhari. "If you could do this, then you have your crystalline substrate



TEM diffraction pattern of sapphire/MgO interface showing crystallinity of each. UV visible spectroscopy has also shown near perfect transparency of sapphire glass. [Chaudhari]

on which you can deposit silicon or another semiconductor film."

Five years on and the 'trick' is being put into practice. Late last year, and working alongside colleagues from thin film deposition system manufacturer, Blue Wave Semiconductors, US, the company received a US patent for its growth of single crystal semiconductor films, on inexpensive substrates, including glass.

"Soda lime glass is very cheap and that makes a big difference," says Chaudhari.

"Other researchers hadn't really thought about using this glass as it has a very low melting point," he adds. "But we can deposit thin films onto this glass at much low temperatures than other deposition processes."

<Crosshead> Traditional science

Chaudhari's success lies in the materials phenomenon, 'eutectic melting'. When two elements, such as silicon and a metal, combine to form a superlattice, known as a eutectic system, the melting point of each is lowered.

At the so-called eutectic point, both elements within the superlattice will melt at the lowest possible melting temperature. However, fix the relative compositions of each as required, and your element of choice will still melt from the superlattice at a lower temperature than if in its pure form.

Chaudhari has harnessed this effect to develop his proprietary eutectic deposition method. Here, silicon films can be deposited from a metal-semiconductor system, such as an Al-Si eutectic melt, onto glass via an electron beam evaporation system between temperatures of 300 to 600°C. These growth temperatures are higher than the materials systems' eutectic point, but don't melt the glass substrate.

As Chaudhari explains: "When depositing silicon from the eutectic melt, we keep the temperature constant, above the eutectic temperature, and increase the amount of silicon until heterogeneous nucleation takes place. This allows for large grained thin film deposition."

Set to scale cheap sapphire glass production, Solar-Tectic will target solar cell, smartphone and LED applications.

So far the results are very promising. Initial X-ray diffraction of sapphire films, deposited via the electron beam evaporation system onto the Mg-buffered soda lime glass, reveals continuous highly textured Al2O3, crucial for smartphone cover applications.

At the same time, similar analyses of silicon films, deposited from an Al-Si eutectic melt, reveal a highly textured silicon film, ready for GaN deposition and, of course, LEDs. Chaudhari soon hopes to scale the process. Right now he and colleagues are working with small sample sizes, but in his words: "We don't foresee any issues for scalability here."

And crucially, the process is without a doubt relatively low-cost. As sapphire furnace maker and supplier of sapphire material for Apple's smartphones, GT Advanced Technologies, files for bankruptcy, Chaudhari claims his deposition process is 'many orders of magnitude cheaper'.

"It also consumes much less energy than the Apple-GTAT furnaces that heated sapphire to 2000°C. We only heat to 550°C and for a much shorter time," he says.

"Our process is very traditional materials science, and why neither Apple nor GTAT took this route puzzles me," he adds. "Apple is very cunning, but employees are primarily designers, not materials scientists, so maybe they just missed this traditional materials view."

So where next for the start-up? According to Chaudhari, a next step is to deposit GaN on his highly textured silicon layers. In-house work starts soon, and companies are already contacting him to collaborate and develop the technology further.

"We're a start-up and a family-run business with a limited budget," he says. "We've got great results with silicon so need a company to work with that can really take this forward."

Lights out for CPV?

What does Soitec's decision to exit CPV mean for the rest of the industry? Rebecca Pool investigates.

AS THE DUST SETTLES on Soitec's recent decision to distance itself from concentrated photovoltaics and re-focus on electronic materials, industry players are mulling the impact on the costly world of CPV.

France-based Soitec, a consistent leader in CPV development, had set a record-breaking 46 percent solar cell efficiency and was one of the sector's highest hopes for commercialisation. Its 44 MW Touwsrivier project in South Africa was one of several big wins in recent years that fuelled analysts buoyant predictions of rapid market expansion through to 2020. But, as the price of rival silicon cells has plummeted, Soitec, and the industry has struggled.

In April last year, Soitec revealed independent US energy company, Tenaska, had ditched plans to use the CPV developer's technology at its planned 150 MW California PV power plant, choosing more conventional and cheaper PV modules instead. Then, come December, US utility San Diego Gas & Electric, which had agreed to buy the power generated at the California plant, terminated its business relationship with Soitec and shares sank to an all-time low.

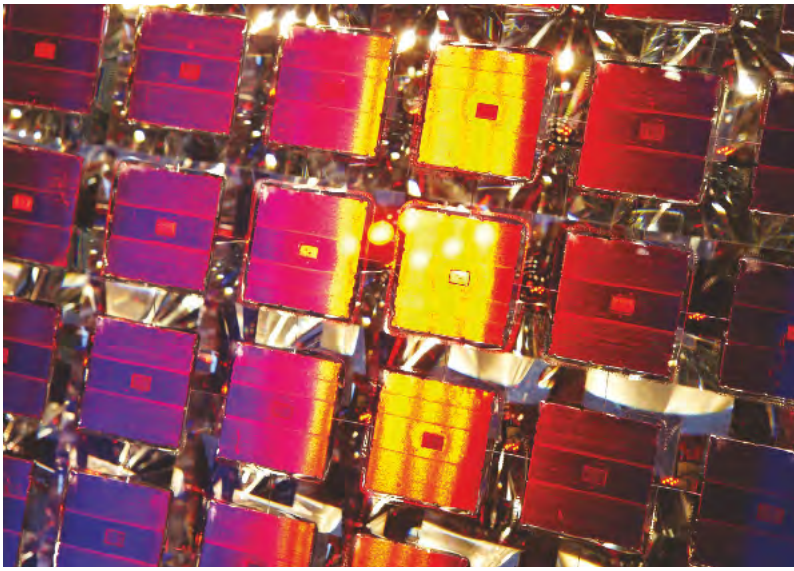
The company's latest 'strategic re-focus' not only brings job cuts at Soitec's San Diego CPV module production plant, but sees industry analysts trimming CPV industry forecasts. Just days before Soitec's New Year bombshell, US-based industry analyst firm, IHS, predicted CPV would experience accelerated growth of 37percent in 2015 bringing some 250 MW in new installations. IHS solar research analyst, Karl Melkonyan, says the news shifts his company's outlook back by around a year, as predictions had included many of Soitec's projects. But, crucially, he doesn't expect any significant long-term effects.

"Of course this announcement negatively affects our projections, and perhaps investment will slow down," he says. "But CPV is an established technology and it doesn't mean we will see any mid- or long-term damage to the industry."

Pointing to very recent market developments, such as Portugal-based MagPower tying up with France-based Heliotrop to form a European CPV consortium, he says: "The CPV market is still in its early phases of growth, and the supplier base will continue to change over the next five years."

"This alliance between MagPower and Heliotrop is a good example of this, and can help CPV technology find the path to a breakthrough," he adds.

Indeed, Melkonyan cites MagPower as just one CPV developer to watch with others including China's leading light, Suncore, Semprius, US, and Spain-based Abengoa Solar. "Progress will continue," he says. "Semprius is developing a new four-junction cell... Abengoa is ready to build CPV plant. [The sector] is depending on good orders and investment, this will come with time."



Soitec achieved a module efficiency of 32.8 percent with its highly efficient multi-junction solar cells.

But what next for Soitec? Once industry has adjusted to the company's re-focus, Melkonyan is hopeful, as he puts it: 'a company with a large balance sheet' will step in.

Pointing to partnerships between Middle East investors and CPV players, such as Enertech, Kuwait, and Morgan Solar, Canada, as well as Saudi-based KACST and Solar Junction, US, he says: "This is a good opportunity for, maybe an oil company, to either partner with Soitec or acquire [its assets]." As he adds: "Soitec's technology is established with competitive prices and good manufacturing... this could be an even better opportunity."

For its part, Soitec hasn't announced a firm plan of action. Following its initial cull of 100 employees at its manufacturing facility in San Diego, further cost-cutting and restructuring measures are expected. But in its last conference call, Soitec executives certainly emphasised that its solar cell technology is mature and ready for large-scale production, a fact that can only offer investor appeal.

And with CPV installations in 14 countries, including the 44 MW Touwsrivier project, under development, it's clearly not yet lights out for the company. "Soitec's solar [business] is still working, it hasn't shut down," asserts Melkonyan. "The company has reduced two to three of the production lines it had in the US and will complete remaining orders."

"This is still a lot of installations compared to competitors so the company must be looking for a good partnership with a larger business," he adds.

SunEdision has their eye on the prize in the UK solar market

SunEdision have seen steady growth globally and their rapid progress in the UK surprises no one. Solar International caught up with SunEdison GM for Europe, Alessandro Ceschiat to find out the secret of their success following their recent announcement of securing financing for development of 97MW in PV capacity to power 30,000 homes in the UK.

Q SunEdison seems to be reaching quite a stride in projects planned for the UK with recent news about financing for 97 MW in 8 large-scale UK projects and an earlier announcement of financing for 85.2 MW in 5 UK projects. Are there more UK projects in the works for 2015 and What locations/communities will host the 13 projects financed in the UK so far this year?

A The UK is one of the most attractive solar markets in the world and so it comes as no surprise that since entering the UK we have seen tremendous growth. The 182.2 MW of projects we are financing this year is just the continuation of SunEdison exceptional development, which has seen 375 MW connected in the last 12 months.

All these projects, which are already interconnected, are predominately located in the South England and Wales. Nonetheless, we do not view the future of UK solar as just in the South. Improving technology means that large scale solar is commercially viable in the North of England, Scotland and

Northern Ireland. Our confidence in UK solar means that we have an attractive and healthy investment pipeline for large scale solar. SunEdison is also investing and growing in other areas such as residential and commercial rooftop and the recent launch of our PPA solution is testament to that.

Q SunEdison's solar Energy Saver Plan (ESP) seems like a great alternative for homeowners who can't or don't wish to self-finance a project – How does the ESP fit into SunEdison's overall strategy for bringing renewable power to the UK and elsewhere? Does the company offer programs designed for homeowners who wish to purchase the system and utilize all the power it generates for their residential needs?

A Our solar business mirrors the UK solar future, which is residential, rooftop and utility all working together to power homes at the lowest cost. Residential will have a huge role to play in the UK and will contribute to the Government's own goal of 20GW of solar by early next decade.

Our extensive market research showed the biggest barrier for potential residential customers was upfront costs. So by removing these we are making residential solar a truly attractive option that delivers real savings. Our Energy Saver Plan solution allows clients to save up to 15% on their energy bills without any upfront investment. As people become more aware of residential solar and the lack of upfront costs involved, the sector can only grow.

The Energy Saver Plan is designed so consumers can use as much of the energy that solar produces. We encourage the practice of self-consumption so that the use of their traditional energy is lessened. The more customers self-consume, the higher the savings.

The Energy Saver Plan is set up so if the energy produced is not consumed, it goes to the grid. Based on the export tariff, a solar consumer will be benefit from the energy they give to the grid. This is deemed to be 50% of the total electricity generated from the PV System.

Q Advantages of programs like the Energy Saver Plan appear three-fold: Having a PV-based system installed with no up-front costs to the homeowner; reducing energy bills ±15% once completed; forestalling electricity rate increases or managing them to around 3.5% annually, compared to the open market that can widely fluctuate – With these factors in mind: How do residential, commercial and utility-scale projects complement one another? And will the various types of solar systems continue to get cheaper as technology, manufacturing scale and competition drive the market?

A As mentioned above, residential, commercial and utility will have an important role in UK's energy mix. And this reflected in SunEdison's business model.

The rate of technological development and declining costs has meant that solar deployment has gone from almost zero to nearly 6GW in just five years. And there are no signs of this abating.

Another important aspect of improving technology is driving down costs so utility, residential and commercial become cost competitive with fossil fuels. With a stable regulatory environment

grid parity may be possible in the next decade. Competition in the solar market is healthy as it ensures that savings that come through improving technology are passed onto the consumer. There are enough opportunities in the UK for lots of solar developers to happily co-exist.

Q In describing itself, SunEdison mentions that it is one of the few companies involved in every major aspect of photovoltaic power from manufacturing PV cells and related equipment to installation, financing and management of services from residential to utility-scale. Can you elaborate on what this means to consumers, communities and regional power requirements?

A Working across the entire chain from manufacturing, developing, designing, financing, constructing, operating and managing allows us to be a pioneer wherever we work. But it is even more than this - SunEdison, through its Yieldco Terraform Power, is also long term owner of the plants. This means that we are a real Independent Power Production Company able to supply clean energy to clients through a mix of technologies that combines solar, wind and even hydro assets. Thanks to the acquisition of First Wind in early 2015, SunEdison is no longer a solar company but the world's largest renewable energy developing company.

This can vary from developing and deploying the most cutting-edge technology, to being able to offer no upfront costs for residential or commercial customers or to being long term suppliers of clean energy to large clients through PPA agreements. All this is done with the goal of producing low carbon power at the lowest cost for the consumer. These goals do not change in any of the markets or sectors we operate in.

Q Solar electricity generation is a rapidly changing industry – Looking ahead, what technological innovations does SunEdison expect will be transformative in the UK and elsewhere?

A Our latest innovation is a technology that produces the world's most cost-effective silicon – the key ingredient for solar panels. The technology, called "high pressure fluidized bed reactor" or HP-FBR, produces high purity silicon 10 times more efficiently and uses 90% less energy than competing technologies. This will reduce the cost of the raw material needed to produce solar panels to less than $0.05 per watt peak by 2016.

Another important part of the solar story is working with other renewables or clean technologies. We have recently acquired an energy storage company – Solar Grid Storage. We are excited that we will be playing an active role in developing energy storage solutions. There is also a future for solar to work alongside wind power and other clean techs such as hydro or biomass. We recently acquired First Wind which will enabling us to create more competitive Power Purchase Agreements, which ultimately results in efficiency gains to the consumer.

Q The 'Edison' portion of SunEdison harkens back to the company's heritage in 20th century electrification and (mostly) fossil-fueled power generation. At the same time some of the earliest power plants were hydroelectric—the first renewable resources; SunEdison traces its roots to the beginning of the semiconductor industry and early growth in PV power up through the present. How does the company's diverse heritage inform its growth objectives?

A First formed in 1959, SunEdison has always been at the forefront of solar innovation and deployment. Its design utilises the latest technologies and materials to optimise solar energy and consistently bring down costs. To date we have secured more than $5billion in solar financing and conducting our own R&D and manufacturing allows SunEdison to push the industry forward.

This innovation and pioneering spirit has meant that we have broadened our horizons beyond solar. Our acquisition of First Wind, along with TerraForm, means that SunEdison is the largest renewable developer in the world. We now have diverse portfolio that includes wind, solar and energy storage. We are an energy company of the future that reflects a balanced energy mix with a combination of renewable technologies that work together to provide energy security and lower consumer bills.

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Kingdom Future Energy Summit is the world's foremost event dedicated to renewable energies, energy efficiency and clean technologies. KFES includes a world-class summit that brings together the potential stake holders, project owners, ministries, researchers, utility bodies from the renewable power and water industry.

Kingdom Future Energy Summit will be the most comprehensive gathering of renewable technologies in the region. The forum provides an unrivalled opportunity for technology manufacturers and system integrators to build relationships with industry influencers and key decision makers within Saudi Arabia and rest of GCC.

This event brings together policy makers, distinguished personnel from Utilities/Ministries and technology leaders in the business community to share their vision in order to establish the initiatives required to build the Kingdom a perfect place to invest and to explore the renewable power industry. This is achieved through a blend of in-depth real life case studies of ongoing and completed projects, keynote presentations and interactive panel discussions.

This Summit is scheduled to be held in Saudi Arabia, blessed with an abundant solar resource throughout the year and an abnormally high number of sunny cloudless days, making solar technology a perfect fit for its sunny climate.

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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.

Worldwide solar demand to trigger record high supply chain profit in 2015

IHS Inc has identified at least 89 countries with solar photovoltaic (PV) end-markets that will show growth in solar installations in 2015, which is forecast to drive a 30 percent increase in demand. IHS forecasts that this demand growth will raise PV module gross profits to $5 billion in 2015, which is more than double the profits garnered in 2014 and a four-year record.

"This year we expect a good combination of high demand in a vast number of countries, no collapsing end-markets and stabilizing prices," said Ash Sharma, senior research director for solar at IHS. "This positive market environment will cause marked improvement for the supply chain."

The surge in PV demand, coupled with a slowing in average selling price (ASP) declines and improving cost structures, will result in greater profits throughout the supply chain, according to the PV Integrated Market Tracker. In particular, gross margins for the wafer industry will increase to 20 percent this year, while module industry margins will increase to 13 percent.

Last year there were 73 countries that enjoyed year-over-year growth, but the 21 countries that declined accounted for a 5.6 gigawatt (GW) drop in demand. Demand will decline in only seven countries (0.5 GW) this year. "This year's improved PV market is not necessarily a return to the good times of 2009 to 2011, but it is certainly an industry turning point," Sharma said. "In 2015 we can expect a much healthier year for the supply chain, after two very difficult years, when incentives were pared back in several countries, over-supply continued and prices collapsed. We now see far healthier and sustainable margins for much of the industry."

The PV Integrated Market Tracker focuses on the markets for polysilicon, solar wafers, PV cells and modules, and PV installations, delivering expert analysis, market data and market forecasts.

Unprecedented solar PV boom in the UK in Q1 2015, IHS says

ACCORDING to a new report from IHS Inc, at least 110 photovoltaic (PV) projects with a combined capacity of 1.6 GW were completed in the United Kingdom in the first quarter (Q1) of 2015, prior to the end of the Renewable Obligations (RO) scheme for projects larger than 5 megawatts (MW). This latest PV push brings the total number of large solar farms to 311, with a combined capacity of 3.8 GW, which is more than half (51 percent) of the U.K.'s total installed PV capacity of 7.5 GW.

"As in markets like Germany, France and Italy, PV developers and installers in the United Kingdom try to demonstrate how fast they can build large PV plants, once the paperwork has cleared," said Josefin Berg, senior analyst for solar power at IHS. "In fact, some of these projects received their permits as late as early February of this year."

According to the IHS UK Deal Tracker report, one third of the total capacity is controlled by the three largest PV investors in the U.K. -- Lightsource, TerraForm Power and Bluefield LLP – and half of the total capacity is owned by the 10 largest developers. "Financial investors dominate the ownership landscape in the U.K., and we will see many of these newly built plants being acquired over the coming months," Berg said.

The UK Deal Tracker contains data on locations; developers; engineering, procurement and construction contractors (EPCCs); and owners for 2,403 PV projects in the United Kingdom. Of these, 831 projects are at various stages of development. "There are 500 projects in the U.K. pipeline that are larger than 5 megawatts, and which now will either have to be reduced below 5 megawatts, submitted to the highly oversubscribed Contracts for Difference tenders or scrapped entirely," Berg said.

"After this rush in the U.K., less capacity will be installed per quarter, but the market has not cooled off," Berg continued. "How policy makers will react to this market pace remains to be seen, as we will not know much before the coming elections."

azimuth

Cheap solar cells made from shrimp shells

RESEARCHERS have successfully created electricity-generating solar-cells with chemicals found the shells of shrimps and other crustaceans for the first time.

Researchers at Queen Mary University of London (QMUL) have successfully created electricity-generating solar-cells with chemicals found the shells of shrimps and other crustaceans for the first time.

The materials chitin and chitosan found in the shells are abundant and significantly cheaper to produce than the expensive metals such as ruthenium, which is similar to platinum, that are currently used in making nanostructured solar-cells. Currently the efficiency of solar cells made with these biomass-derived materials is low but if it can be improved they could be placed in everything from wearable chargers for tablets, phones and smartwatches, to semi-transparent films over window.

Researchers, from QMUL's School of Engineering and Materials Science, used a process known as hydrothermal carbonization to create the carbon quantum dots (CQDs) from the widely and cheaply available chemicals found in crustacean shells. They then coat standard zinc oxide nanorods with the CQDs to make the solar cells.

Dr Joe Briscoe, one of the researchers on the project, said: "This could be a great new way to make these versatile, quick and easy to produce solar cells from readily available, sustainable materials. Once we've improved their efficiency they could be used anywhere that solar cells are used now, particularly to charge the kinds of devices people carry with them every day.

Professor Magdalena Titirici, Professor of Sustainable Materials Technology at QMUL, said: "New techniques mean that we can produce exciting new materials from organic by-products that are already easily available. Sustainable materials can be both high-tech and low-cost."

"We've also used biomass, in that case algae, to make the kinds of supercapacitors that can be used to store power in consumer electronics, in defibrillators and for energy recovery in vehicles."

Journal Reference:
Joe Briscoe, Adam Marinovic, Marta Sevilla, Steve Dunn, Magdalena Titirici. Biomass-Derived Carbon Quantum Dot Sensitizers for Solid-State Nanostructured Solar Cells. Angewandte Chemie International Edition, 2015 (in press)

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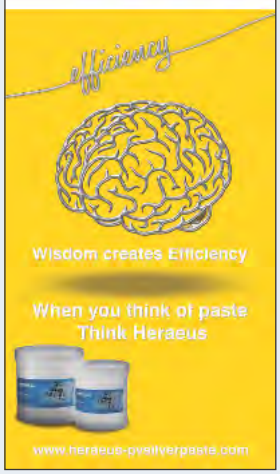

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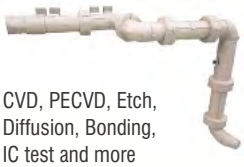

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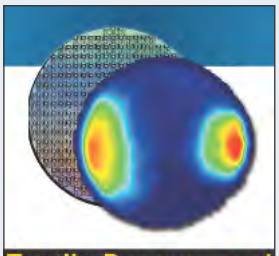

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