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editor's view

By david ridsdale, editor-in-chief

A global affair

SOLAR AND PV TECHNOLOGY has reached a point of no return and will continue its global path of growth as a key and growing part of the delivering the energy needs of the species. While much of the focus of renewable energy production is on the returns and impact in industrialised nations, the growth of solar technology has also meant that the idea of ensuring every human has access to electrical energy is a real possibility. All of the ground work developed in rural and developing areas lays the groundwork for prosperous growth in emerging regions with a positive attitude to renewable energy developed in line with future growth.

Ease of communication and connectivity on a global scale has fed the appetite for energy but without sustainable options growing with the hunger, the current energy methods would unlikely keep up to scale. The general feeling amongst energy experts around the world is that energy will be delivered with a mix of centralised and local energy supplies. With fossil fuels tipped to maintain dominance in energy supply until at least 2050, it is localised energy production where renewables can not only grow but increase importance to the energy mix.

This year has provided the expected consolidation and geographical changes but at a faster rate than many expected. While the consolidation is far from over there are signs that the bigger players are returning to profit, suggesting a rational balance is developing. The geographical shift in the global industry has seen manufacturing move its centre to Asia as well as hosting the fastest and largest growing new markets.

Despite the comparative discrepancies between the geographic regions, there is still strong solar market growth in most areas of the world. We will have to wait until next year plays out to see how the consolidation of the manufacturing sector impacts on the global market. With the speed of change we may not have to wait as long as imagined to see how the reduced number of players cope with supply and demand when the next over, or under, supply hits the market.

Energy will be a major topic in all regions and will impact politically and financially for the next decade or so. The traditional utilities are losing the monopoly and solar will have to fight for its place at the energy table with as much vigour as any other section of the energy community.

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Global installed PV to treble by 2020 to 414GW

THE GLOBAL CUMULATIVE installed capacity of solar PV modules will more than treble from 135.66GW in 2013 to 413.98GW by 2020, according to research and consulting firm GlobalData.

The company's latest report states that emerging economies in Asia-Pacific, South and Central America and the Middle East and Africa are expected to be the markets in the future.

Swati Singh, GlobalData's Analyst covering Power, explains, "Asia-Pacific is home to developing countries, including India and China, where substantial installations are being made. The region is also a leading area for solar energy systems production, with Japan, China and Taiwan being three of the largest solar PV cell manufacturers in the world.

"Governments in the region are promoting solar module manufacturing through various long-term policies, financial incentives, subsidies and tax benefits. This commitment to solar development has led to RandD initiatives and increased solar module production and installations, which will drive future market growth."

The analyst adds that Asian companies dominate the global PV device supplies market, with seven Chinese companies currently among the top module manufacturers worldwide.

Last year marked a turning point in the solar PV space, as China, India and Japan accounted for the majority of global annual installations. China's growth was especially remarkable, contributing around 12 GW of the world's 37-GW additions in 2013.

Singh explains, "Prior to 2013, most solar PV installations were in Europe, with Italy, Germany, Spain and France accounting for the majority of global annual installations in 2012. "Reduced solar PV

module prices, combined with European countries' Feed-in Tariff (FiT) subsidies, have supported the widespread growth of small-scale distributed capacity there.

GlobalData believes that tariffs are likely to become less generous in subsequent years, with the reduction or removal of incentives been proposed and implemented in some countries."

China can quadruple solar output by 2030

CHINA CAN increase its use of renewable energy from 13 to 26 per cent by 2030, according to a new report released today by the International Renewable Energy Agency (IRENA). The growth in renewable energy use would represent nearly a fourfold increase in the share of modern renewables between 2010 and 2030. The report, Renewable Energy Prospects: China, prepared by IRENA in association with the China National Renewable Energy Centre, also says China can expand renewables in the power sector from 20 to 40 per cent by 2030, making it the world's largest renewable energy user.

The report is part of IRENA's renewable energy roadmap, REmap 2030, which provides a plan to double the share of renewable energy in the world's energy mix by 2030 and determines the potential for China and other countries to scale up renewables. The report has acquired special significance following the major announcement by China that it intends to cap carbon dioxide emissions by 2030 and expand the share of non-fossil

energy in total primary energy supply to around 20 per cent by 2030 as part of an emission reduction deal jointly made by China and the US.

"China can continue its leadership in renewable energy by accelerating action in this area," said Mr. Amin. "If China acts now to implement more renewable energy, it can play a leading role in fighting climate change."

With current policies in place, the share of renewables in China's energy mix will only rise to 17 per cent by 2030. REmap 2030 estimates that annnual investment of USD 145 billion is needed between now and 2030 in renewable energy technologies to reach the 26 per cent renewables mark – an annual increase of USD 54 billion beyond business-as-usual. The higher renewable share will result in an annual savings of USD 55 to 228 billion by 2030 when accounting for factors like human health and reduced emissions.

"REmap 2030 shows that China can achieve the energy revolution it's aiming for – and that it can do so affordably," said Dolf Gielen, Director of IRENA's Innovation and Technology Center. "It also gives China a higher goal to aspire to, stating that an energy mix with 26 per cent renewables is achievable by 2030."

China installed more renewable energy in 2013 than Europe and the remaining Asia Pacific region combined. It is a major exporter of renewable energy technology, accounts for two-thirds of solar panel production, 90 per cent of installed biogas systems, 40 per cent of newly installed wind capacity in 2013, and provides 2.6 million jobs in its renewable energy sector.

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REC Solar announces sale to Chinese investors

REC SOLAR has reached an agreement with Bluestar Elkem Investment Co whereby Bluestar Elkem will purchase 100% of the shares in a Luxembourg company (to be established) which will own REC Solar Holdings AS and all of the assets and liabilities of REC Solar at a cash purchase price equal to NOK 108.50 per share in REC Solar.

The Transaction represents a premium of 22.6 % and 27.1% to the 1 and 3-month volume weighted average share price, respectively. The total cash consideration is NOK 4,340 million.

The Board of Directors of the Company has unanimously resolved to recommend the Transaction to its shareholders. Further, Datum AS, Ferncliff Listed DAI AS, Ferncliff TIH 1 AS, Gross Management AS, QVT Fund IV LP I, QVT Fund V LP I, Quintessence Fund LP and Dallas Asset Management AS, holding a total of 20.2% of the outstanding shares of the Company, have on certain conditions entered into undertakings not to sell any shares before the EGM and to vote in favor of the Transaction at the EGM.

Ferncliff Listed DAI AS, Ferncliff TIH 1 AS, and Gross Management AS are controlled by Øystein Stray Spetalen, a board member and primary insider of the Company and Dallas Asset Management AS is controlled by Jan Christian Opsahl.

Ole Enger, the Chairman of REC Solar, comments, "This proposed Transaction is a result of an extensive and broadly marketed process where the Company has explored opportunities to maximize value for shareholders. We are pleased that we today are in position to announce the combination of the Elkem Group and REC Solar. The Board of Directors of REC Solar views the combination as a positive outcome for the Company, its excellent workforce and other stakeholders, and we look forward to working with the Elkem Group to complete the Transaction. The Board believes that a combination with the Elkem Group will provide a strong platform to further develop REC Solar."

Helge Aasen, the CEO of Elkem AS, comments, "The Elkem Group has a strategic goal to grow its presence in the solar industry. The ambition is to establish a leading integrated PV player. The Elkem Group and REC Solar have developed a strong business relationship and there is a good strategic match between the companies ensuring that a combined entity will have a strong basis for further development of the business by leveraging REC Solar's leading global brand, strong distribution channels and reputation for quality."

The Transaction is not subject to any financing condition, but is subject to other customary conditions including all required regulatory approvals. REC Solar has undertaken not to actively solicit offers from third parties which would compete with the Transaction, and has accepted a cost coverage fee of USD 10 million if the Board of the Company changes its recommendation of the Transaction and the Transaction is not completed due to a superior offer.

The Transaction is expected to be completed in March/April 2015. The Board of Directors of REC Solar expects thereafter to delist and liquidate the Company and return all cash, net of transaction costs, to shareholders.

Nomura International plc is acting as financial advisor to REC Solar in connection with the Transaction. Cipriano AS is acting as strategic advisor to REC Solar in connection with the Transaction. Advokatfirmaet Schjødt AS is acting as legal advisor to REC Solar in connection with the Transaction.

20% of Australian houses use solar

ACCORDING to the latest data sheets from the Australian Bureau of Statistics (ABS) one in five Australian households now use solar energy. Of course the statistics also show an increase in energy usage with two in three Australians having a smart phone and three in four with air conditioning.

"We started publishing statistics on solar electricity in 2011", said Karen Connaughton from the ABS, "and back then the numbers were only about five per cent of households."

"Jump just three years, to 2014, and there are solar panels being used by fourteen per cent of all households. "Add in solar hot water heating and we're up to 19 per cent, so one in five households are now using some form of solar power.

"Three-quarters of Australian households use some form of cooling and the hot spot for cooling was the Northern Territory, where 97 % had some form of cooling.

"It was the opposite with heating, as close to 90 per cent of NT households felt they could skip heating entirely, but in the ACT it seems you'd have to pry the heater from their cold, wintery hands as only a tiny one per cent of Canberrans reported not having heating.
"On the home technology side of things, while we love our TVs - 98 per cent of households have one, you'll also find games consoles in use in every third household," said Ms Connaughton.

Trina donates modules to South African installation

TRINA SOLAR has donated 4kW of solar modules to ELDO Energy for the installation of the hybrid system SunStar also known as PharoX on top of Signal Hill in Cape Town, South Africa. The rooftop system installed beside the SunStar is storing the energy in batteries and lighting up the star during the night.

The SunStar was conceptualised by Cape Town artist Christopher Swift for the 2014 World Design Capital and will remain erected for a duration of 13 months. The hybrid installation is constructed out of the old Robben Island prison fence and is meant to create an iconic and significant installation honoring the heroes that Robben Island prison bred, creating a vision for the new South Africa in its 20th year of democracy. The installation stands for innovation, possibility, creativity, courage, strength, diversity and care for the people of SA, inspiring people to see "Beyond the fence."

The 30 meter high structure in the shape of a sphere surrounded by a frame of the sun rays resembling a star is open for educational tours, film screenings, a hub for sporting events, exhibitions and debates and public meetings. The construction will be dismantled after one year and will benefit a communal or social institution in replacing a high percentage of their energy consumption with solar energy and therefore reducing their energy costs significantly.

"Trina Solar is very happy to be part of this iconic project that does not only have symbolic value but will have a lasting benefit to several communities in Cape Town. It is a sign that solar energy has great potential in South Africa and that it can serve people in need", says Ben Hill, President of Trina Solar Europe and Africa. "Further at Trina Solar, we are committed to bringing affordable and clean energy across the globe and we look forward to developing the South African market in conjunction with our partners by offering them better and faster support from our newly opened warehouse, and expert sales team based in Johannesburg.

ELDO Energy and Trina Solar have had a strong and successful working relationship during the course of 2014. Tim Ohlsen, CEO of ELDO Group said that "the business relationship that we have with Trina Solar has been a great success. We elected to use Trina Solar as our power partner due to the quality of their solar PV panels and their leadership in the global market". Trina Solar supplied one of ELDO's key projects with their monocrystalline DC05A.08 modules for a rooftop project.

Top ten reshuffle by year's end

THE 2014 top 10 PV module suppliers are almost the same group of companies as one year ago. SunPower entered the top 10 in 2014 and was ranked joint 10th largest suppliers alongside Kyocera according to IHS estimates.

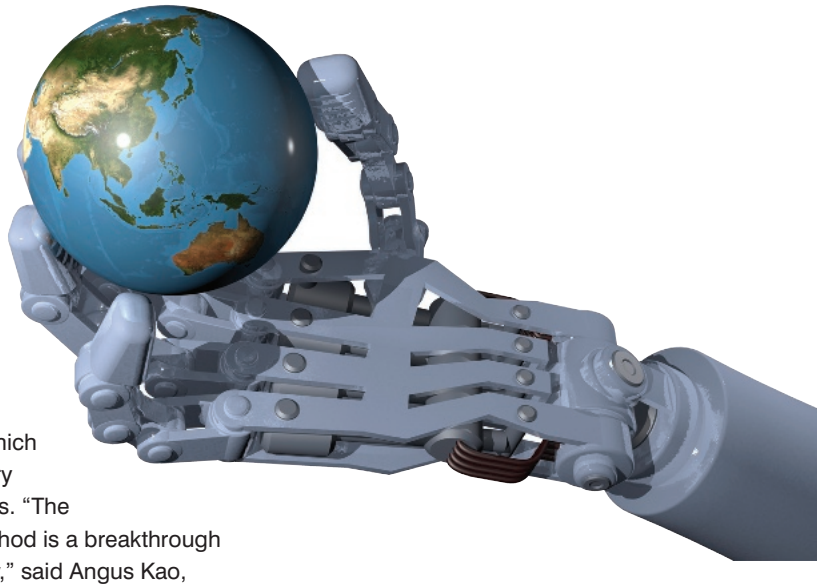
Trina Solar is expected to be ranked the world's largest PV module supplier by shipment volume for the first time. It is also expected to break industry records for both quarterly and annual PV module shipments in Q4'14. Yingli Green Energy, the holder of these previous records, is expected to be ranked the 2nd largest supplier having adopted a new strategy to prioritize profitability.

JA Solar is forecast to gain most ranking places amongst the top 10 and expected to be ranked the fifth largest supplier in 2014. Its module shipments are expected to double from 2013 level, outpacing all of the other top 10 suppliers. Such impressive growth highlights JA's transformation from a cell manufacturer into a module supplier.

China, Japan, and the US have been the largest PV markets in 2014, and were the key markets for all of the leading PV module suppliers. Japanese suppliers, Sharp Solar and Kyocera leveraged high brand awareness and acceptance in their domestic market to retain positions in the top 10 rankings in 2014.

Many of the top 10 suppliers accelerated the use of PV modules for internal solar projects in 2014, especially Trina Solar, Yingli, Jinko Solar, and JA Solar. Total unrecognized module shipments that will be used in internal projects will reach 1.4 GW in 2014 for these four companies combined, in an effort to shift towards PV project development pioneered by Canadian Solar, First Solar, and SunPower. "

Polysilicon production to lower costs for East Asia manufacturers



POLYSILICON manufacturers in Japan, China and Korea are improving their production processes in an effort to lower costs, according to EnergyTrend, a division of the Taiwan-based market intelligence firm TrendForce.

In October, the Japanese firm Tokuyama began producing polysilicon at its Malaysia plant, which has a capacity of 13,800 metric tons. Initially, Tokuyama is expected to reach 70% capacity. The South Korean polysilicon manufacturer OCI will boost capacity to 10,000 metric tons. Hanwha Chemical, another South Korean firm, will add 3,000 to 5,000 metric tons of production capacity.

SMP, a joint venture between SunEdison and Samsung Fine Chemicals, is using a new high pressure fluidized bed reactor process (HP-FBR) at its plant in Ulsan, South Korea and will increase polysilicon production from 10,000 metric tons to 13,500 metric tons. FBR is a fairly new polysilicon process through which polysilicon is deposited when monosilane gas mixes with silicon seed particles in a reactor, in a continuous process. It is an alternative to the dominant electricity-intensive Siemens method, which has been the industry standard for decades. "The FBR production method is a breakthrough for the solar industry," said Angus Kao, a research manager at EnergyTrend, adding that FBR is expected to reduce the cost of modules significantly in 2016 to 0.4/W and 0.5/W.

China-based GGL, another leading polysilicon manufacturer, will use the FBR production method to boost its production capacity to 25,000 metric tons next year.

Other Chinese manufacturers will increase their respective production capacities to 20,000 metric tons. Overall, Chinese polysilicon companies will use their cost advantages to gain market share and their total capacity is expected to reach 150,000 metric tons, Kao said.
Despite China slapping anti-dumping and countervailing duties of 53.3% to 53.7% on US polysilicon imports, Chinese manufacturers can use the OEM trading process to bring US and South Korean products into China while evading the duties. As a result, in August the China Ministry of Commerce and General Administration of Customs announced it would suspend the processing of applications for the polysilicon OEM trading business. Yet it is too early to evaluate the results of their decision.
In the meantime, the global polysilicon supply chain and prices will be affected.

SMA financial problems deepen

THE MANAGING BOARD of SMA Solar Technology has adjusted its sales and earnings forecast for 2014. For the current fiscal year, the SMA Managing Board expects sales of between EUR775 million and EUR790 million (previously: EUR850 million to EUR950 million) and a loss of up to EUR115 million excluding provisions for the planned staff reduction (previously: loss of up to EUR45 million excluding provisions for the staff reduction).

The Managing Board gives the further accelerated decline in demand in the European distribution business and project delays in Great Britain as reasons for lowering the forecast for the current fiscal year. Furthermore, earnings are impacted by additional one-time items. "Our previous forecast was based on the assumption of a strong sales upturn toward the end of the year. Unfortunately, markets in Europe have not developed as well as expected. The British government has unexpectedly extended the deadline for the grid connection of large-scale PV plants under the current subsidy regime by one year to March 31, 2016.

As a result of this, a large number of projects will be delayed until 2015.
In addition, distribution business has declined dramatically in Europe, particularly in Germany. This trend has not been reversed over the last months," said SMA Chief Executive Officer Pierre-Pascal Urbon. According to Urbon, low sales levels and one-time items resulting from the market consolidation are the main reasons for the deterioration in earnings.

The success already achieved in material cost reduction could not be recognized in earnings as planned because of effects of volume. In order to return to profitability, SMA will further intensify the measures already initiated. For example, the Managing Board is planning to reduce the development budget to EUR80 million annually by the middle of 2015.

SMA is planning to lay off at least 600 employees worldwide by mid-2015.
In addition, the Chinese subsidiary Zeversolar will be restructured. Urbon stressed that, with expected liquidity of more than EUR250 million at the end of the year 2014 and an equity ratio of approximately 50%, SMA can finance the transformation required from its own resources.

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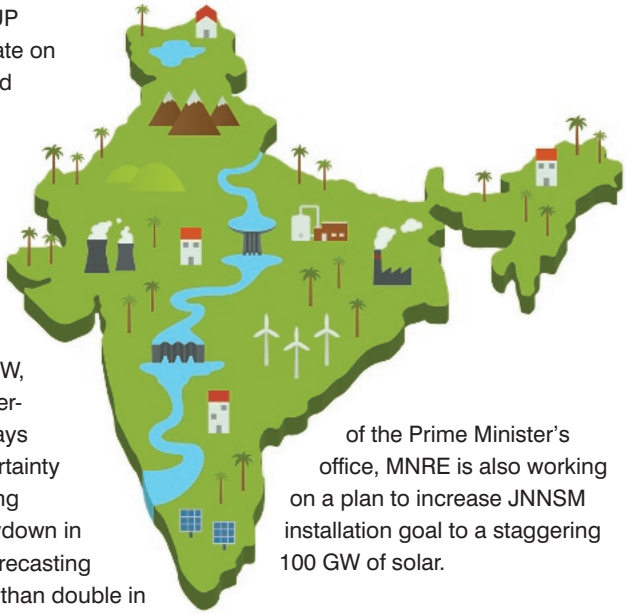
Indian solar installations to double by 2015



MERCOM CAPITAL GROUP released its quarterly update on the Indian solar market and revealed that cumulative solar installations in India crossed the 3 GW mark with 734 MW installed so far this year. However, 2014 will be a disappointment with calendar year installations forecasted at about 800 MW, a 20 percent drop year-over-year. Land acquisition delays due to elections and uncertainty caused by the anti-dumping case contributed to a slowdown in installations. Mercom is forecasting 2015 installations to more than double in 2015, reaching approximately 1,800 MW.

"The Indian solar industry is visibly upbeat since the elections and especially after getting past the anti-dumping case," commented Raj Prabhu, CEO and Co-Founder of Mercom Capital Group. "Recent cancellations of coal mining licenses by the Supreme Court amid rising coal imports and increasing costs, and continuing power shortages have all contributed to the positive momentum in the solar sector," stated Raj.

The Ministry of New and Renewable Energy (MNRE) released a new installation goal of 15 GW by 2019 via solar parks (a large area and infrastructure set aside by states to accommodate installations of 500-1,000 MW) to be set up by states in three tranches. A revised draft for Phase II, Batch 2, Tranche I Jawaharlal Nehru National Solar Mission (JNNSM) projects was released with a target of 3,000 MW.

There have been other announcements in a short period of time; a new program aimed at 'ultra mega solar projects' with a goal of installing 20 GW by establishing solar parks was announced recently. MNRE has also asked Public Sector Units (PSUs) to set up large solar projects to meet RPO obligations. At the request of the Prime Minister's office, MNRE is also working on a plan to increase JNNSM installation goal to a staggering 100 GW of solar.

By focusing exclusively on large-scale and mega solar projects, India is going in the opposite direction compared to other markets. In most major solar markets, with drop in costs, the market has shifted from large-scale projects to residential and commercial rooftop projects - closer to the end-user.

With transmission and distribution losses estimated at about 25 percent, and considering the country is severely challenged when it comes to land availability and grid infrastructure this may not be a sound long-term strategy.

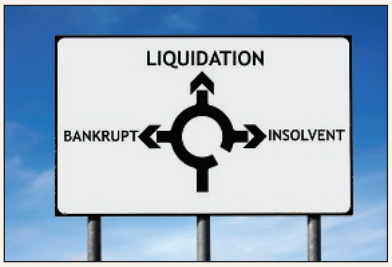
Since the inception of JNNSM in 2010, there has never been a shortage of big goals and announcements. Two primary challenges have been execution and uncertainty, due to the lack of long-term market visibility. A renewed government focus to address these challenges would give confidence to the markets, and help attract sorely needed foreign investments.

That said, prospects for the Indian solar sector have never looked better and the Modi administration's strong commitment towards solar has percolated to states, evidenced by the sense of urgency and seriousness being shown by state administrations towards solar, the likes of which we have not seen in the last five years.

Solarmax announces insolvency for struggling inverter company

EUROPEAN inverter manufacturer Solarmax has sent out an announcement that its Swiss based parent company, Sputnik Engineering has filed for insolvency.

The message states that despite management's best efforts they were unable to develop a viable solution to prevent the worsening situation.



The employees have been informed of the decisions and stopped working until further notice.

All services, including hotline, deliveries, field services, exchanges etc. will be suspended with immediate effect until further notice.

Solarmax was the 5th largest photovoltaic (PV) inverter supplier in the world in 2008, with a market share of over 4 percent. It held a share of less than 1 percent in 2013 and has had to fight to maintain that as the inverter market became crowded with new players.

European companies have suffered at the expense of rising US and Asian companies. The European market that Solarmax relied on has fallen from $5.5 billion in 2010 to $1.9 billion in 2013 and this is not expected to improve.

JV for Brazillian utility scale solar

SUNEDISON and Renova Energia, the largest renewable energy company in Brazil, have announced that they have created an exclusive joint venture to develop, own, and operate 1 gigawatt of utility scale solar photovoltaic (PV) energy which will supply the Brazilian Regulated Electricity Market. Renova and SunEdison will each own a 50% stake in the joint venture. The venture plans to build and operate four utility scale solar power plants in Bahia State, Brazil, by 2017.

The joint venture will install 106.9MW of solar by 2017 as part of contracts awarded by the Brazilian Energy Commercialization Authority, Camara Comercializadora de Energia Electrica (CCEE). The contracts were awarded in the 2014 Reserve Supply Auction (2014 LER), the first renewable energy auction in Brazil to specify a need for solar power plant capacity.

SunEdison will supply solar modules and trackers for the projects, to be assembled in Brazil, and solar plant construction will be financed by the Brazilian Development Bank (BNDES). This supply agreement guarantees access to SunEdison's world class technology at competitive pricing while mitigating supply and exchange rate risks.

SunEdison and Renova fully support the development of solar energy in Brazil, a country that has fully embraced renewable energy sources. Brazil recently adopted a full regulatory framework for solar energy, and is making great strides towards incorporating solar energy as a definitive part of the country's energy supply.

"Renova's JV with SunEdison positions us as the best entity to serve the needs of the Brazilian renewable energy market," said Mathias Becker, President of Renova. "This opportunity to enter the solar energy market has been two years in the making, and we're excited to see the tremendous support from the Brazilian local and state authorities in developing this and other opportunities for utility scale solar."

India announces 22.1GWs of projects

INDIA'S MINISTRY of New and Renewable Energy (MNRE) has made a number of announcements on its official site that outlines 25 large projects the country plans to roll out over the next five years. The combined total of these so called 'Ultra Mega Solar Power Projects' is now at 22.1GW and each project will be a minimum of 500MW.

Jammu and Kashmir is the state that has scored the largset project that will have a capacity of a massive 7.5GW Andhra Pradesh will host the next largest which although much smaller will still come in at 2.5GW. Rajasthan picked up three 1GW projects and another one at 700MW.

The rest of the projects are spread across the states and the government has set strict guidelines as to how much the projects can cost with the Central Electricity Regulatory Commission (CERC) determining that capital costs cannot exceed 6.91 crore INR per MW.

With a government predisposed to solar expansion the hope is that this programme can begin to seriously tackle India's energy shortages across rural areas and finally move the country's solar plans forward. With previous plans thwarted at the policy level there is a need to improve investor relations in the region.

Jinko supplies Indian project

JINKOSOLAR has announced that it supplied 21.4MW of solar PV modules to Harsha Abakus Solar, for a ground mounted solar PV project in Gujarat, India.

Located in Charanka, Gujarat, which is one of the highest solar irradiation zones in India, the project deploys seasonal tracking technology to improve plant performance.

The project is expected to generate approximately 34.24 million kWh of electricity and remove 30,000 tons of CO2 annually. Once connected to the grid, the solar plant will be one of the first solar parks commissioned under the Jawaharlal Nehru National Solar Mission Phase II Batch I with a fixed PPA rate. The project will be jointly owned by Gujarat State Electricity Corporation Limited and Gujarat Power Corporation Limited.

"With over four decades of operations in Gujarat, Harsha Abakus has sound operational track record," commented Mr. Xiande Li, Chairman of JinkoSolar. "JinkoSolar is selected as a partner due to our solid brand reputation and excellent product quality.

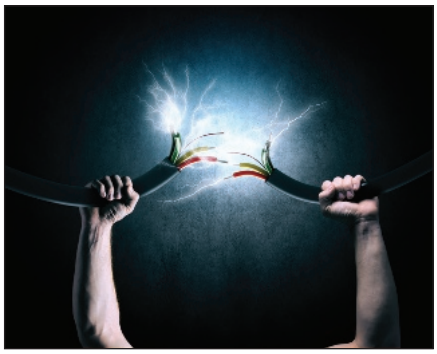
We share a common commitment to developing clean energy with Harsha Abakus, and view this project and the local Indian Government's support as a tremendous opportunity for us to grow our business in India and help diversify the country's energy mix."

Europe's first PV plant with high voltage reserve

BELECTRIC has connected a state-of-the-art, cost-effective battery storage system, called the Energy Buffer Unit, at the solar power plant Alt Daber in Brandenburg. It is the first solar power plant in Europe capable of providing operating reserve at high-voltage level comparable to conventional plants.

The innovative lead-acid storage device with a capacity of 2,000 kWh is intended for use in both renewable energy and conventional power plants. The storage device lends greater flexibility to the plant's service provision and actively stabilizes the energy grid. With its long service life and low cycle costs, Belectric GmbH's Energy Buffer Unit sets a milestone in the cost-effective and sustainable provision of system services.

"In the future, solar power plants will take over the functions of the most sophisticated network control," explains Bernhard Beck, CEO of Belectric GmbH. "In conjunction with storage devices, they make an important contribution to the adaptation of the energy supply and grid stability to the requirements of the energy transition."



Connected to an Energy Buffer Unit "Made in Germany," solar and wind farms become hybrid plants in which volatile energy sources assume responsibility for the system and contribute to fluctuation compensation. The must-run capacities of conventional power plants can be reduced and replaced by renewable energies equipped with the Energy Buffer Units.

Decentralized energy systems in conjunction with storage solutions can also reduce the need for expanding transmission and distribution networks and thereby reduce the costs of the energy transition. Belectric GmbH's energy storage device is thus paving the way towards a renewable future.

The energy storage device will be marketed by Vattenfall on the primary operating reserve market. Vattenfall thereby emphasizes its pioneering role in the integrated marketing of renewable and conventional power plants and storage technologies. "Storage devices will be an essential component of the energy transition," says Alfred Hoffmann, Vattenfall's Vice President of Portfolio Management. "They support our goal of ensuring a perfect market integration of renewable energies."

The development of the Energy Buffer Unit was supported by the Brandenburg Ministry for Economic Affairs as part of the Energy Storage Initiative. The storage device is an easily transported turnkey solution manufactured in series for energy providers. "It is another important step on the path towards being able to reliably provide power from renewable energies," explained Albrecht Gerber, Minister for Economic Affairs of the State of Brandenburg.

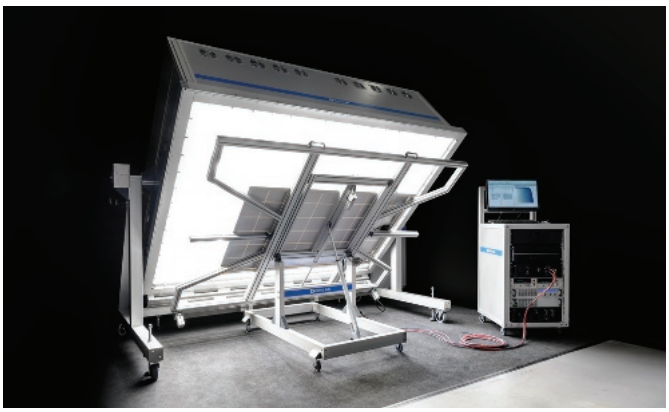
"The development of storage technologies is a central prerequisite for the success of the energy transition. Further research is urgently needed. With our Energy Storage Initiative, we seek to encourage the testing of storage technologies."

Eternal Sun raises two million in financing

ETERNAL SUN B.V. has announced that it has closed a €2 Million ($2.5 Million) Series A financing from Belgian investment firm Vermec N.V. The investment will be used to expand international sales and service operations of the Delft based high-tech company that is specialized in solar simulation technology.

Leading research institutions, solar module manufacturers as well as certification authorities rely on Eternal Sun's solar simulation systems for testing the quality of solar modules and materials. Chokri Mousaoui, Founder and CEO of Eternal Sun comments: "In an era of continuous improvement of solar modules, our solar simulation systems are in high demand with customers that aim to accurately test the performance and reliability of their solar technology. This capital injection will be used to meet this growing demand."

Mousaoui adds: "We are delighted to have Vermec as an investment partner. The founders of Vermec are successful entrepreneurs, and they invest their own money in other entrepreneurs. As a team, they have a proven track record



in scaling up businesses in a fast paced environment and are seasoned in managing growth." Michel Verhaeren, CEO of Vermec: "We are excited about Eternal Sun because the company focuses on the intersection of the solar industry and quality assurance, both of which are gaining importance worldwide. We are glad to engage with this talented team, and look forward to the upcoming period of development and growth."

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Fraunhofer announces new spin off company

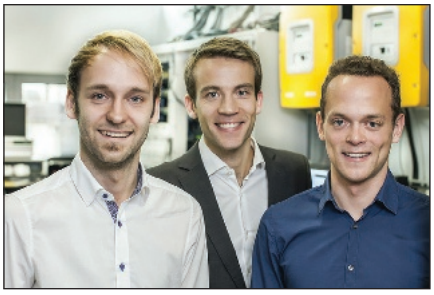
Enit Energy IT Systems GmbH is the latest spin-off of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. The new company will develop and market monitoring and control systems for decentralized energy systems, suc as combined heat and power plants, photovoltaic systems or industrial consumers. These systems help customers gain more transparency with their electricity, heat and gas consumption. In addition, the company's products enable intelligent system control and more efficient operation.

The internally developed technology, called OpenMUC, adapts itself to the customer's system and remains flexible for any adaptions in the future. Since September 1, 2014 the company Enit Systems has been set up in Freiburg.

"Our customers are industrial firms, energy supply companies and direct marketers," says Hendrik Klosterkemper, CEO of ENIT Energy IT Systems. "They receive highly efficient control technology, which is customized to fit their specific needs. Our company's expertise is based on more than five years of technology development and research in Smart Grids." Enit Systems, which emerged from the Department of Intelligent Energy Systems at Fraunhofer ISE, presently employs six engineers.

The founding team consists of Hendrik Klosterkemper, CEO; Pascal Benoit, CTO; and Simon Fey, Specialist for Communications Architecture and Smart Grid Protocols. Contact with its university roots continues with Prof. Dr. Christof Witter, Dr. Robert Kohrs and Stefan Feuerhahn, the founding partners of the company at Fraunhofer ISE. The technology transfer between the two is maintained and encouraged.

The start-up was sponsored by the Federal Ministry of Economic Affairs and Energy (BMWi) in cooperation with the Center for Renewable Energy (ZEE) of



the University of Freiburg within the EXIST Transfer of Research program. It was received support from the Climate-KIC Accelerator program of the European Institute for Technology and Innovation. At this year's competition "Startinsland Ideen Wettbewerb Südwest," Enit Systems won first place in the category "Science" and also picked up the special prize of "Green Economy" that was awarded by the Institute.

Image: Founding team of Enit Energy IT Systems GmbH: Pascal Benoit (CTO), Hendrik Klosterkemper (CEO) and Simon Fey (f.l.t.r.). Foto: dominikprobst.de

African bank okays over US$200 million solar boost

THE BOARD OF DIRECTORS of the African Development Bank Group has approved one loan of €100 million and another of US $119 million for phase II of the Ouarzazate solar complex project (the NOORo II and NOORo III power stations), the former from the Bank's own resources and the latter from the Clean Technology Fund (part of the Climate Investment Funds) in its capacity as executing agency. This second phase of the project aims to develop two new power stations with a total capacity of around 350 MW and average estimated cumulative production of over 1,100 GWh per year.

"The project is one of the innovative developments in the energy sector supported by the Bank, based on the technology used and the financial arrangements with the support of the Climate Investment Funds, namely a public-private partnership supported by several donors. The Bank's participation in this second phase will support its position as a leading partner in the

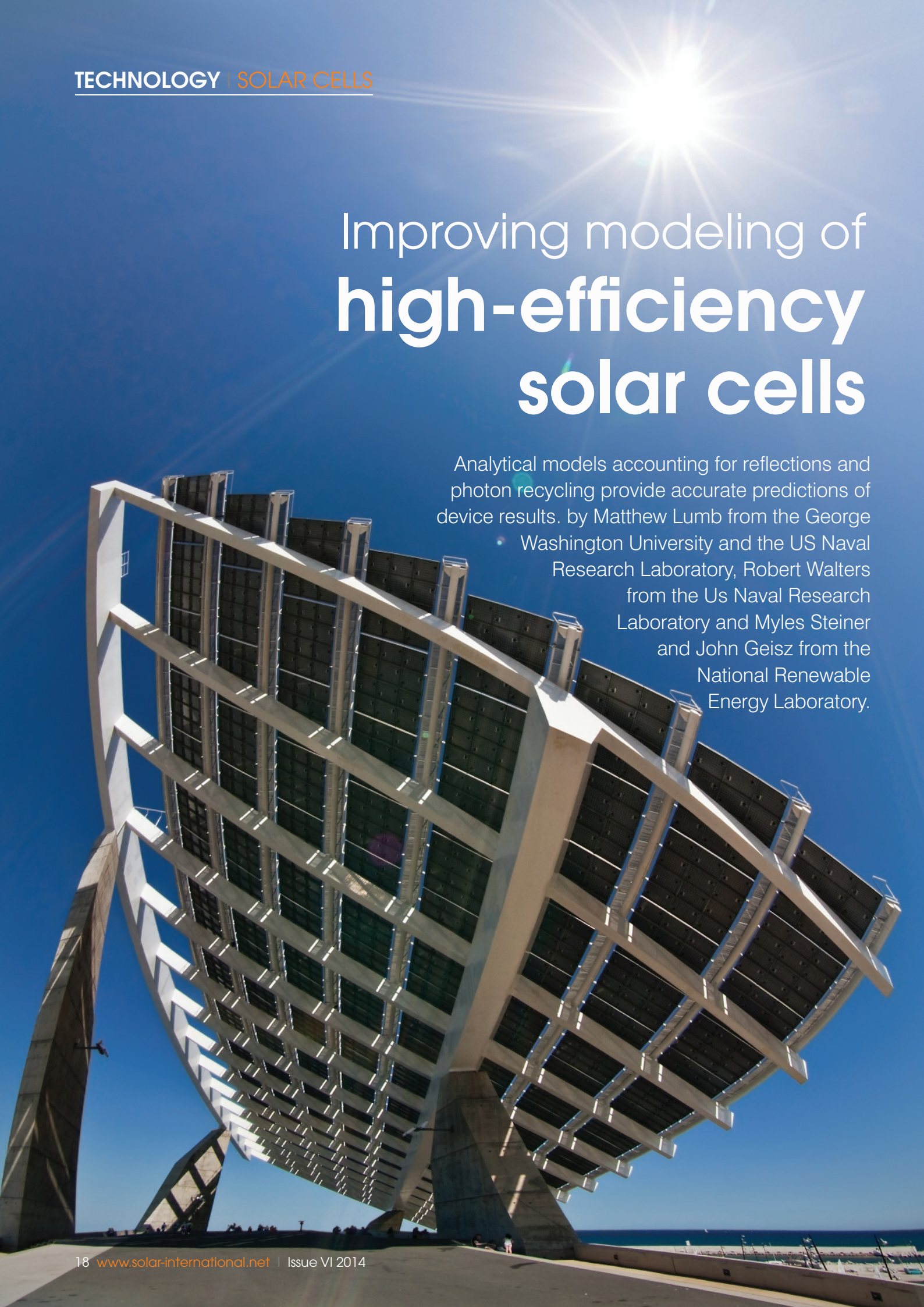
development of Morocco and strengthen its role in combatting the effects of climate change," explained Alex Rugamba, Director of the AfDB Energy, Environment and Climate Change Department.

The project is part of the Moroccan Solar Energy Programme (NOOR), which aims to develop minimum capacity of 2,000 MW by 2020 in order to secure power supplies for the population and productive sectors of the economy. Morocco currently depends on external sources for 95% of its primary energy needs. The country's energy consumption increased by an average of 7.2% between 2002 and 2012. Looking ahead to 2030, Morocco's demand for primary energy is expected to triple, whilst demand for electricity is set to quadruple. The country has made securing its power supply a priority for its new energy strategy for 2010 to 2030; one of its aims is to diversify sources of production and generate value from the potential of renewable energy sources, to increase its share of electricity production to 42% by 2020.

The project will bring socioeconomic benefits at a local level to Ouarzazate province, which has an estimated population of 583,000 inhabitants and a poverty rate of around 23%. At a national level, in addition to its positive impact on the balance of trade, it will contribute to: (i) reducing CO2 emissions by around 522,000 tonnes a year; ii) providing a reliable electricity supply to businesses, helping them to improve their competitiveness; and iii) promoting a new industrial sector producing solar equipment, which will create jobs.

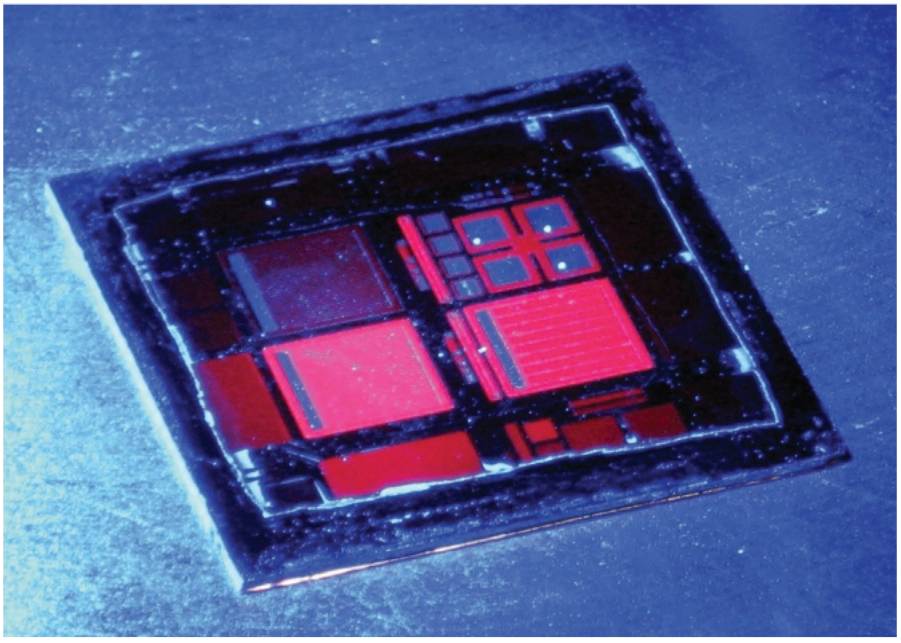
Improving modeling of high-efficiency solar cells

Analytical models accounting for reflections and photon recycling provide accurate predictions of device results. by Matthew Lumb from the George Washington University and the US Naval Research Laboratory, Robert Walters from the Us Naval Research Laboratory and Myles Steiner and John Geisz from the National Renewable Energy Laboratory.



MANY RESEARCHERS in the solar sector are pursuing the same goal – to come up with a technology that increases photovoltaic efficiency. It's a worthwhile aim, because if a cell can extract more electrical energy from the sun's rays, solar power may become more affordable, leading to increased sales and better economies of scale.

Several approaches are available for developing higher efficiency cells. One option is to design and evaluate a new architecture in the lab, and an alternative approach is to model new device designs to see if they are superior. In practice, a mix of both these approaches tends to work best, with measurements on real devices verifying the capability of a new cell design that produces promising results in modeling efforts.



A GaInP cell that is luminescing under blue light, a result of substantial photon recycling enhancement due to the back reflector.

Whatever materials are used to build a conventional solar cell, ultimately efficiency is limited by a fundamental process: radiative recombination. It follows from the reciprocity of absorption and emission processes that if all other loss mechanisms are entirely suppressed, the resulting, perfect solar cell would also, in fact, be a perfect LED.

This relationship between a faultless LED and a solar cell has been known for many, many years, and in the 1950s it was employed by Nobel-prize-winning physicist William Shockley and co-worker Hans-Joachim Queisser to derive the efficiency limit for a solar cell. This model, which accounts only for band-to-band radiative recombination of electron-hole pairs, assumes that all other processes are ideal. It is widely used by researchers in the photovoltaics community today, and one of its strengths is that it is able to express the potential of competing technologies in the simplest terms. However, real world solar cells are seldom close to ideal. Efficiency is impaired by optical losses, non-radiative recombination and electrical losses, which usually combine to make the Shockley-Queisser limit a gross overestimation.

Models that can provide a more realistic value for efficiency are highly desired, because they can aid efforts to improve solar cells. This need is particularly acute for III-V cells, which come closer than many other material systems to reaching their fundamental limit, thanks to advances in epitaxy, processing and optical management. In space, these cells are united with those made from germanium to power satellites, and in sunny climes these cells lie at the heart of power generation systems featuring mirrors or lenses that focus the sun's radiation by factors of several hundred or more.

In the 1970s, Harold Hovel and Jerry Woodall introduced a more sophisticated model that is better at capturing the performance of single-junction cells.This pair of researchers, who were working at IBM Research Laboratory in Yorktown Heights, New York, developed an analytical drift-diffusion model that contains all the real world losses (see "The Hovel and Woodall model" for details).

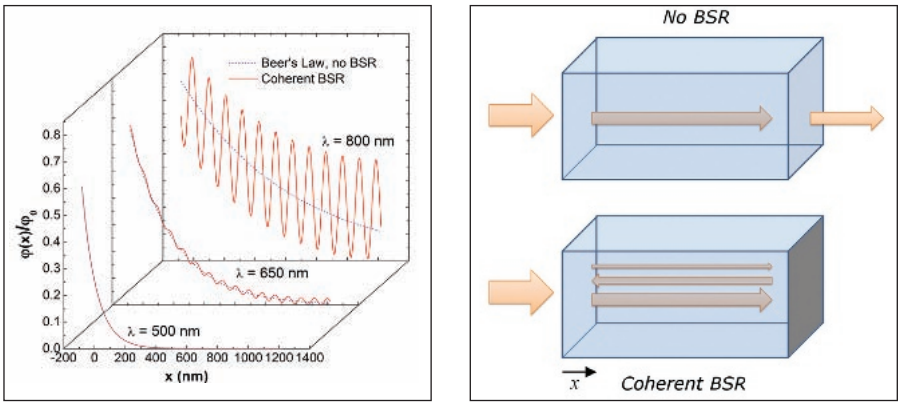


Figure 1. A generation function accounts for optical effects in a cell. A modified form of this function is used when a gold mirror is added to the cell's backside to create a coherent back-surface reflector (BSR).

However, this approach is far from perfect, because it fails to account for the contribution to energy generation that occurs in cells employing a high reflectivity back mirror, which increases absorption within the cell and enhances photon recycling. A more complete model would include coherent and incoherent optical effects, such as contributions from back surface reflectors, which increase the probability of photon absorption; and it would account for photon recycling, a process where photons spontaneously emitted by the material through radiative recombination are reabsorbed by it.

Previously, numerical methods have been employed to construct a fully numerical drift-diffusion model that accounts for all these effects. Including them all is essential for accurate modeling of today's best devices, which are coming very close to the fundamental efficiency limit.

Strengths of these numerical models include their flexibility and precision. But these merits have to be weighed against several downsides, which can be addressed by turning to an analytical model that includes the additional optical effects – which is an approach that has been pioneered by our team from the US Naval Research Laboratory, George Washington University and the National Renewable Energy Laboratory (NREL).

One of the virtues of our analytical model

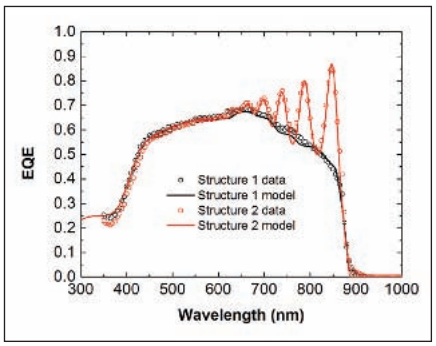


Figure 2: Modeled and experimental values of the external quantum efficiency of two GaAs solar cells of the same 1 μm thickness: structure 1 has no back reflector, whereas structure 2 has a high reflectivity gold back reflector. Note that the external quantum efficiency is a measure of the spectrally resolved probability of an incident photon being captured and converted into an electron in an external circuit.

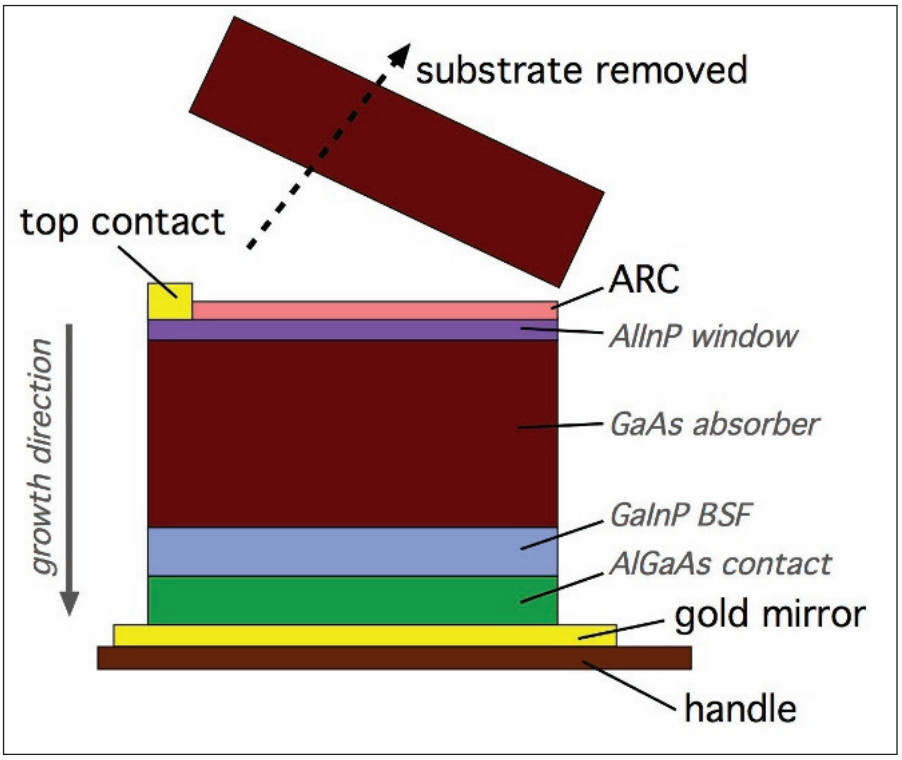


Figure 3. An inverted growth process enables a mirror to be positioned directly beneath the cell, enhancing light absorption. Another benefit of this approach is that it allows re-use of the substrate.

is that it avoids the need for advanced numerical techniques for solving boundary value problems on a mesh grid, resulting in a model that is easy to develop. What's more, the analytical model provides an excellent intuitive understanding of the inner workings of a solar cell, due to separate treatment of different regions within the device. All this is possible while delivering comparable accuracy to the numerical model, so long as we can meet the assumptions upon which the model is based. To date, our work has been restricted to the modeling of single-junction devices. However, it should be possible to extend this effort to multi-junction variants. This will require modification of the model to include luminescent coupling, which occurs when the emission from the top cell generates photons in the cell beneath.

Handling multiple reflections…

To account for the multiple reflections inside the cell when a back mirror is present, we have added a generation function to the drift-diffusion model. It is possible to determine a compact analytical expression for this function at every point in the solar cell by summing the fields of the multiple reflected beams in the absorbing region. This expression can then be incorporated into the drift-diffusion calculations, and solved in an analogous way to the original Hovel and Woodall model. Note that this approach can be applied to both coherent and incoherent reflections from the back surface reflector.

We can illustrate this approach by considering the simple case of a GaAs absorber with a coherent gold back reflector (see Figure 1). At short wavelengths GaAs is strongly absorbing, so the generation function resembles that of Beer's law – this states that as light passes through a substance, its intensity decreases exponentially. For wavelengths near the bandgap of GaAs, this law is not valid, and the generation function deviates significantly as GaAs becomes semi-transparent. In this wavelength region, the solar cell acts like a Fabry-Perot cavity, with the forward and reverse propagating fields interfering to produce an overall enhancement in the photon density absorbed by the GaAs. This leads to an increase in photocurrent. Adding a

gold mirror to the thin GaAs homojunction solar cell leads to a significant increase in its external quantum efficiency (see Figure 2, which shows that modeling can replicate experimental measurements by capturing coherent optical effects arising due to the back surface reflector). However, these demonstration devices were fabricated without a front side anti-reflection coating, leading to losses of approximately 30 percent at the front surface. Therefore, the mirrored cell in this example has not reached the realms of ultra-high efficiency.

> “When a cell is generating power, there are actually a great number of recombination events happening simultaneously, with photons emitted in all directions inside the absorber. Ideally, most of those photons are recycled into new electron-hole pairs.”

Production of these cells begins with MOCVD growth of the epitaxial layers on a GaAs substrate. During post-growth processing, if an external back metal contact is deposited on the rear side of the substrate, the thick absorbing substrate will act as a photon sink to any internally emitted radiation (this is the case for structure 1 in Figure 2). It is possible to insert a highly reflective back contact by removing the substrate and depositing the mirror directly on the rear side of the epitaxial layers. An innovative way to do this, pioneered at NREL in 2007, begins with the growth of the solar cell in an inverted configuration, with the front layers grown first and the back layers grown last.

Layers are then re-orientated during post-growth processing to create a structure where the rear surface of the actual solar cell is immediately accessible. A highly reflective metal or dielectric-metal mirror can then be deposited on the growth surface (this is the case for structure 2 in Figure 2, and the device that results from this approach is shown in Figure 3).

Fabrication of this type of cell is completed by bonding the epistructure to a handle wafer, such as silicon or a flexible plastic, and then removing the native substrate – wet chemical etching is one way to do this, though other techniques have been developed that allow the substrate to be preserved and reused. Epilayers are then processed into individual solar cell devices with front contacts.

… and photon recyling

In addition to multiple reflections, the other significant improvement of our analytical model over that developed by Hovel and Woodall is the inclusion of photon recycling. In a perfect cell, all of the solar radiation that impinges on the front surface will be absorbed. Then, in order to generate power from the device, some radiative recombination must occur.

This is an inescapable loss, but in an ideal cell all the non-radiative processes are negligible, and all of photons generated by radiative recombination can only escape the device through its front surface. When a cell is generating power, there are actually a great number of recombination events happening simultaneously, with photons emitted in all directions inside the absorber. Ideally, most of those photons are recycled into new electron-hole pairs (see Figure 4).

Progress towards this goal is possible with a back surface reflector, which suppresses photon escape through the rear surface of the cell and thus improves the external radiative efficiency.
One of the consequences of photon

The Hovel and Woodall model

IN THE 1970s, Hovel and Woodall made an important scientific contribution to solar cell efficiency modeling with the introduction of an analytical drift-diffusion model for single-junction solar cells.

This model capitalizes on the fact that simple p-n homojunction solar cells typically operate in the low-injection regime and have carrier populations well-described by Boltzmann statistics. Under these approximations, the diffusion problem for minority carriers in the quasi-neutral absorber regions can be solved analytically. Optical generation in the cell is described by Beer’s law, which is a good approximation for an optically thick homojunction. By coupling this model with accurate values in the literature for optical constants, semiconductor band parameters, minority carrier transport properties, non-radiative lifetimes and interface recombination rates, it is possible to make remarkably accurate predictions of solar cell performance.

However, the model fails to capture two significant effects related to photon management, both of which are crucial in devices approaching the fundamental limit: coherent and incoherent optical effects, such as back surface reflectors to improve the probability of photon absorption; and photon recycling, where the photons spontaneously emitted by the material through radiative recombination are reabsorbed by the material.

recycling is a cut in the net rate of radiative recombination. This can also be stated in another way – as photon-recycling increases, the radiative lifetime of minority carriers increases until the external radiative efficiency limit is reached. However, if photon recycling is to deliver a performance improvement, it is paramount that the internal radiative efficiency of the material – that is, the fraction of recombination events that are radiative – approaches unity. When this happens, the net lifetime of minority carriers increases due to photon recycling, which leads to an increase in their diffusion length.

In III-Vs cell made today, material quality is exceptionally high, enabling cells to operate at very high internal efficiencies. In these devices, the voltage produced by a solar cell provides an excellent indicator of photon recycling, which impacts the recombination rate and therefore the dark current. Our efforts at capturing photon recycling in our model (see "Including photon recycling in an analytical model") have helped us to appreciate the importance of maximizing the external radiative efficiency of solar cells. Motivated by this, members of our team at NREL have developed an important modification to conventional homojunction solar cells: the thick emitter concept.

The traditional architecture for a high efficiency III-V cell includes a thin, highly doped n-type (emitter) layer atop a thick, lower doped p-type (base) layer. Short wavelength light, with a short penetration depth, is predominantly absorbed in the emitter layer and longer wavelength light in the base layer. In contrast, our new design features a thick, moderately doped n-type emitter layer atop a thin p-type base layer, giving rise to a high external radiative efficiency. There are several reasons why a thickening of the emitter boosts performance. First, so long as the diffusion length of minority carriers significantly exceeds the thickness of the quasi-neutral regions (which is required for efficient minority carrier extraction in solar cells), a structure with a thick, low doped n-type layer can achieve a lower diffusion current than an analogous structure containing a thick, low doped p-type layer due to the lower diffusivity of minority holes to minority electrons. Another reason why our novel architecture increases efficiency is that almost all the photocurrent in the thick emitter structure is produced from the emitter, so device performance is very sensitive to the minority carrier lifetime in this layer. It is possible to optimize the emitter doping concentration to ensure high quality material with a close-to-unity internal efficiency, and a long enough diffusion length to provide efficient minority carrier collection.

When the thick emitter is included in a structure with efficient photon recycling – such as a device with very high internal efficiency and a high-reflectivity, back-surface reflector – this can lead to significant voltage enhancements. In contrast, in a conventional, thin-emitter structure, the dark current and photocurrent contributions of the solar cell are distributed more evenly among the emitter, depletion and base regions of the solar cell, making it more difficult to design a device with both high performance and high sensitivity to photon recycling effects.

Our modeling and experimental efforts have determined the significant increase in voltage output that results from the inclusion of a gold back mirror on our thick emitter GaAs cells (see Figure 5). This device delivers a conversion efficiency of 27.8 percent, within 3 percent (relative) of the current world record for a single-junction solar cell. The performance of this device approaches the fundamental, thermodynamic limit for an ideal GaAs cell.

We have used a variety of models to predict the performance of this thick-emitter, single-junction cell. Calculations based on the model by Hovel and Woodall underestimate performance, due to a failure to capture the optical enhancement that arises due to the multiple reflections from the back surface reflector, and the suppression of radiative recombination due to photon recycling. Slight improvement results from the inclusion of a more realistic generation function that incorporates multiple reflections from the back mirror and the concomitant increase in the short-circuit current density. However, this model still assumes bulk lifetime values with no

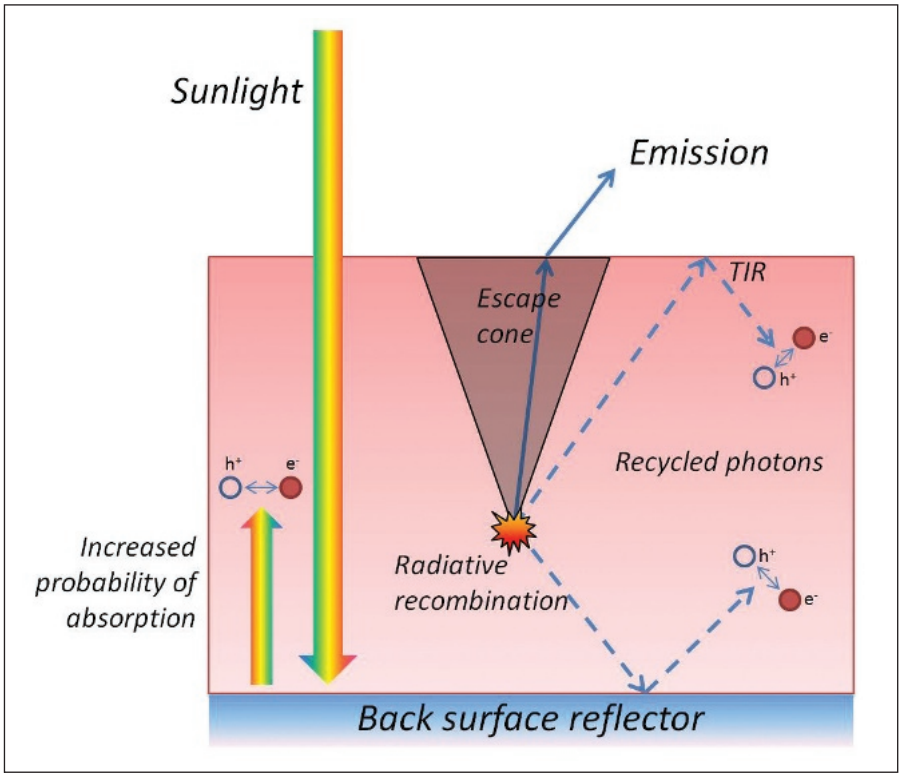


Figure 4. If photon recycling is ideal, the only photons that are able to escape the absorber pass through the front surface; all other photons are recycled to generate new electron-hole pairs. The inclusion of a back surface reflector improves the probability that incident sunlight is absorbed within the device.

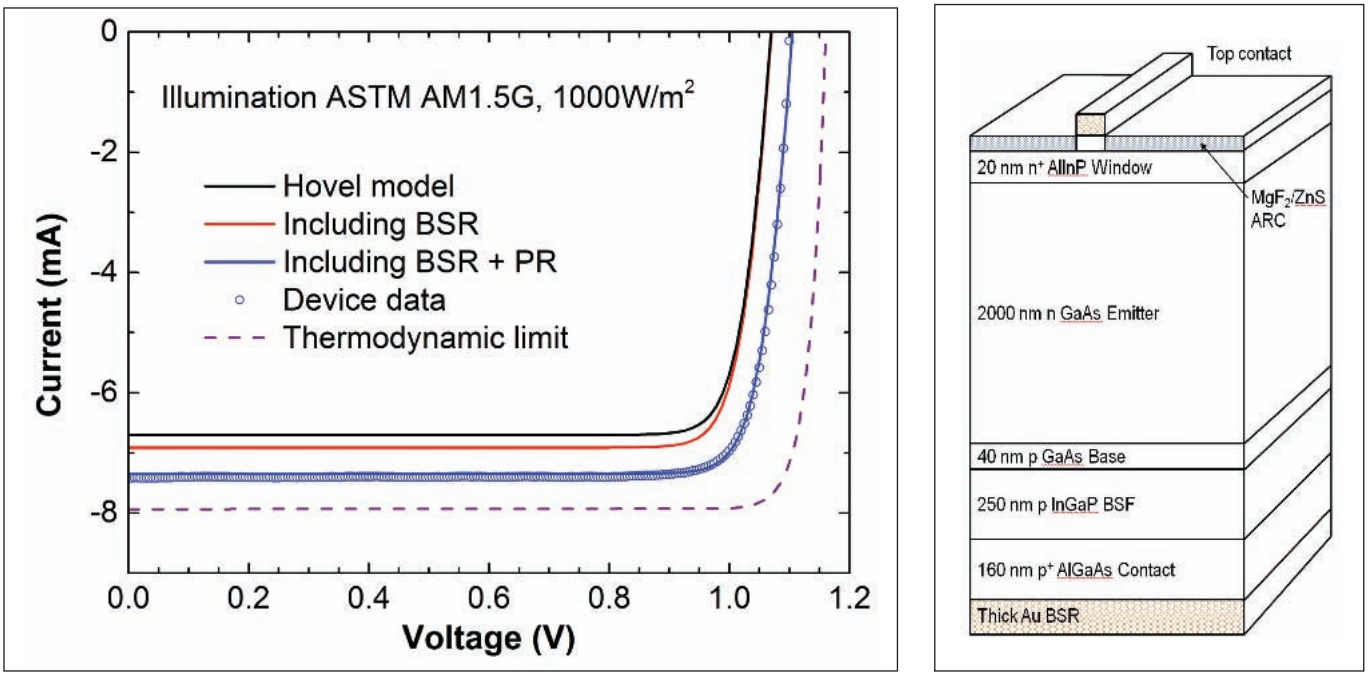


Figure 5. A variety of models have been used to try and capture the performance of the thick-emitter, single-junction cell that incorporates a reflecting gold mirror at the bottom of the device. The model by Hovel and Woodall fails to accurately reproduce the experimental data. Incorporating multiple reflections from the gold mirror, which is also known as a back surface reflector (BSR) improves the calculation, but both BSR and photon-recycling contributions are required to replicate the experimental results.

photon recycling, giving a diffusion length of 4.3 μm for minority holes in the emitter.

When photon recycling it taken into account, the diffusion length increases to 17.1 μm and the minority carrier lifetime increases. Our model can then capture the increase in photocurrent extraction efficiency and reduction in dark current. Both these improvements impact the light-current-voltage curves, where it is possible to note increases in short-circuit current density and open-circuit voltage. This voltage exceeds that predicted by the Hovel and Woodall model and highlights the need for modeling that includes photon management strategies, which allow solar cells to get even closer to their fundamental performance limit.

The authors would like to thank Dr. I. Vurgaftman, Dr. A. Hanbicki of the Naval Research Laboratory, J. Adams, V. Elarde, G. Hillier and the R&D team of Microlink Devices Inc., and D. Friedman, I. García and S. Kurtz of NREL for helpful discussions relating to this work. Research at NREL was supported by the U.S. Department of Energy under Contract No. DE-AC36-08GO28308 and funded in part by the Foundational Program to Advance Cell Efficiency.

Accounting for photon recycling in an analytical model

BY MAKING A FEW simplifying assumptions it is possible to capture the physics of photon recycling with an analytical model. The key principle that we need to consider is the reciprocity relation linking the absorbed and emitted radiation.

Under voltage bias, we assume that the quasi-Fermi level separation in the device is equal to the applied bias at all points within it – this is a very good approximation for a typical homojunction solar cell under low-injection conditions. Under this assumption, the rate of radiative recombination is uniform throughout the cell; and the photon current escaping the solar cell, which is related to the internal photon current, is determined from the generalized Planck equation and the absorbance of the structure. The absorbance is the total probability of a photon incident on the cell from outside being absorbed, which is straightforward to compute for a multilayered medium. The fraction of the total photon current in the absorber unable to escape the solar cell is known as the photon recycling factor [see, for example, Asbeck, J. Appl. Phys. **48** 820 (1977)], which determines the average reduction in the net radiative recombination rate for the electron-hole pairs in the cell.

This number is a function of the particular geometry of the cell and, in conjunction with the lifetimes of competing non-radiative processes, enables calculation of the overall minority carrier lifetimes in the absorber layers of the cell. The final simplifying assumption that we make is to assume that the net recombination rate at a given bias in the dark is equivalent to that in the light. This is the often used principle of superposition in solar cells.

Scoring industry sustainability

The Silicon Valley Toxics Coalition (SVTC) has released its Fifth Annual Solar Scorecard, which ranks manufacturers of solar photovoltaic (PV) modules according to a range of environmental, sustainability and social justice factors. Seven PV companies responded in detail to this fifth annual SVTC survey, with the remainder of the information gathered from publicly available documentation.

THE SOLAR PV INDUSTRY has seen rapid growth in recent years, particularly in the contract manufacturing segment, which now accounts for more than 25 percent of the global PV supply. The seven companies that responded to the 2014 Solar Scorecard today represent just 25.2 percent of the total PV module market share.

"Although the solar market has expanded six-fold since 2009, the market share of companies committed to reporting environmental practices has declined," said Sheila Davis, executive director of Silicon Valley Toxics Coalition. "The rise of 'white box' solar manufacturers has the potential to drive a race to the bottom. SVTC is concerned that companies who offer cheap products and hide their environmental footprint may be rewarded by the market."

Consistent responders

SVTC recognized two companies, SolarWorld and Yingli, for responding to the Solar Scorecard survey every year since 2010, demonstrating a consistent commitment to environmental stewardship despite significant disruptions in the solar industry. In addition to this recognition, SolarWorld has achieved the highest overall score across all five Solar Scorecards to date.

Mukesh Dulani, president of SolarWorld Americas noted, "We are committed not only to renewable energy, but to transparency and responsible production, including independent verifications, such as SVTC's Solar Scorecard. We encourage all of our competitors in this industry to embrace that same commitment."

The PV manufacturers included in the 2014 Solar Scorecard comprise approximately 75 percent of the industry.

Top details

Key findings from this year's solar scorecard and SVTC's research throughout the last five years included that Trina (92), SunPower (88) and Yingli (81) earned the top scores in 2014. SolarWorld (73) and REC (71) remain among the top tier of industry environmental leaders. Ten PV manufacturers of the 37 scored by SVTC post annual hazardous chemical reduction targets on their websites or in sustainability reports.

Three PV manufacturers (Trina, Yingli and Up Solar) have written letters to the Solar Energy Industries Association (SEIA) seeking action on recycling for PV modules in the United States. Over the past three SVTC surveys, 14 companies have said they would support public policy for an EPR scheme for PV modules (Aleo, Avancis, Axitec, Eurener, First Solar, REC, SolarWorld, Solon, SoloPower, SunPower, Suntech, Trina, Up Solar and Yingli). Four PV manufacturers (SolarWorld, Yingli, REC and Sharp) conduct extensive chemical emissions disclosure and reporting (although REC has not updated its 2013 data).

Thirteen companies (one less than in 2012) reported one or more categories of emissions (hazardous waste, heavy metals, air pollution, ozone depleting substances, landfill disposal). SunPower achieved a Cradle to Cradle Silver Certification for some of its PV modules, which required extensive evaluation and reporting on manufacturing practices.

> No companies could provide documentation to verify that their supply chains do not contain conflict minerals based on the due diligence guidelines set by the OECD. Twelve companies are engaged in or have started the process of due diligence to determine if conflict minerals are present in their supply chains

Lacking verification

No companies could provide documentation to verify that their supply chains does not contain conflict minerals based on the due diligence guidelines set by the OECD. Twelve companies are engaged in or have started the process of due diligence to determine if conflict minerals are present in their supply chains. "It's critically important for companies to collect and report chemical use and emissions data," said Assistant Professor Dustin Mulvaney of San Jose State University, SVTC's science advisor. "The more transparency there is on this issue, the more likely it is that companies will be able to compete to reduce their emissions per PV module."

Green leadership

As for next steps, SVTC plans to use the Solar Scorecard as the basis for a new environmental leadership standard for solar PV modules. SVTC will partner with renewable energy and green procurement leaders, as well as the nonprofit Green Electronic Council (GEC), to expand the Scorecard into a standard that meets the criteria of the American National Standards Institute (ANSI).

"Environmental procurement is greatly simplified when performance criteria are codified in credible leadership standards," said Robert Frisbee, GEC's CEO. "SVTC's hard work on the Scorecard and its intention to launch development of such a standard are commendable. We look forward to helping engage relevant stakeholders in the development process."

SOLAR SCORECARD 2014

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	Company	EPR	Emissions Transparency	Chemical Reduction Plan	Worker Rights, Health, Safety	Supply Chains	Conflict Materials	Module Toxicity	High Value Recycling	Prison Labor	Biodiversity	Water	Energy & GHGs	2014 Total Score
	Maximum Score	20	10	5	15	10	5	10	5	5	5	5	5	100
2014 LEADERS	Trina	17	10	5	15	8	3	10	4	5	5	5	5	92
	SunPower	14	10	5	15	8	3	10	4	5	4	5	5	88
	Yingli	16	2	5	13	10	3	10	4	5	5	3	5	81
	SolarWorld	12	10	5	12	10	3	0	4	5	2	5	5	73
	REC	7	6	5	15	10	0	10	2	3	5	3	5	71
ABOVE AVERAGE	Suntech	9	0	0	14	8	0	10	4	3	5	0	5	58
	First Solar	12	6	5	9	7	3	0	4	3	0	2	5	56
	Axitec	9	0	0	12	10	3	10	2	3	5	0	1	55
	Up Solar	15	2	5	5	0	3	10	3	0	5	0	2	50
	Avancis	8	0	0	8	7	3	10	0	3	5	0	0	44
	Mitsubishi	4	4	0	2	7	0	10	0	0	5	5	5	42
	Renesola	2	0	0	5	7	0	10	4	3	5	0	1	37
	LDK	4	0	0	7	0	3	10	3	3	5	0	0	35
	Panasonic	2	7	5	0	0	3	0	0	0	5	5	5	32
BELOW AVERAGE	Aleo	10	0	0	6	0	0	0	4	3	5	0	3	31
	Sharp	0	10	5	0	0	3	0	0	0	5	3	5	31
	Calyxo	12	0	0	0	7	0	0	0	3	5	0	0	27
	Solon	9	0	0	7	0	0	0	2	3	5	0	0	26
	China Sunergy-Csun	5	4	5	2	0	0	0	1	0	5	3	1	26
	Astronergy	3	0	0	2	5	0	0	2	0	5	2	0	19
	Samsung	0	4	0	0	0	0	0	0	0	5	5	5	19
	Eurener	9	0	0	2	0	0	0	0	3	5	0	0	19
	Solar Frontier	4	0	0	0	0	0	10	0	0	5	0	0	19
	Kyocera	2	4	0	0	0	0	0	0	0	5	2	5	18
	Solopower	5	0	0	0	0	0	0	2	3	5	0	0	15
	Motech	4	0	0	0	0	0	0	0	3	5	0	2	14
	Canadian	4	0	0	2	0	3	0	0	0	5	0	0	14
	Hanwha SolarOne	0	0	0	1	0	0	0	0	3	5	0	5	10
	JA Solar	2	0	0	0	0	0	0	0	0	5	0	0	10

Industry Average = 31

Industry Leadership = 70

LAGGARDS

Companies with a score below 10:

Hareon Solar
Hyundai
Jinko
Gintech
Miasole
NBSolar
Suniva
Andalay Solar

Ultra-fine line double printing

Achieving lower cost and higher cell efficiencies is the goal for every manufacturer when they approach technology changes. Yi Yang, Yi Zhang, Karl Wilhelm, and Weiming Zhang from Heraeus; Alessandro Voltan and Marco Galiazzo from Applied Materials, Italy discuss how ultra-fine line double printing is one solution meeting the manufacturers' needs.

MANUFACTURERS of photovoltaic cells and modules are on the quest to increase the output and conversion efficiency of their products while lowering their cost per watt. Over the years, gains have been achieved through improved materials, better manufacturing processes and a variety of cell design architectures.

One concept that is consistent in most advanced cell designs is to maximize the available active surface area of crystalline solar cells to improve the cell's efficiency. Finger line double printing is a technique many industry insiders support for improving cell efficiency.

Conceptually, double printing gives cell manufacturers the ability to print very narrow line widths without compromising line quality by printing finger lines on top of each other. This can be a technology challenge. A cell manufacturer must have access to the proper combination of screens and metallization pastes to print relatively narrow lines with good line geometry characteristics during the print stoke. The screens themselves must be matched for the second print stroke. And the cell manufacturer must have equipment that can accurately align finger lines within microns for the second pass.

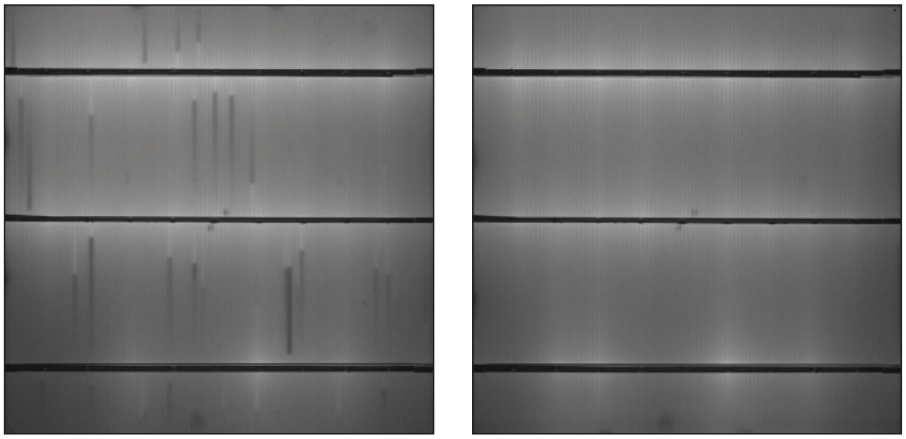
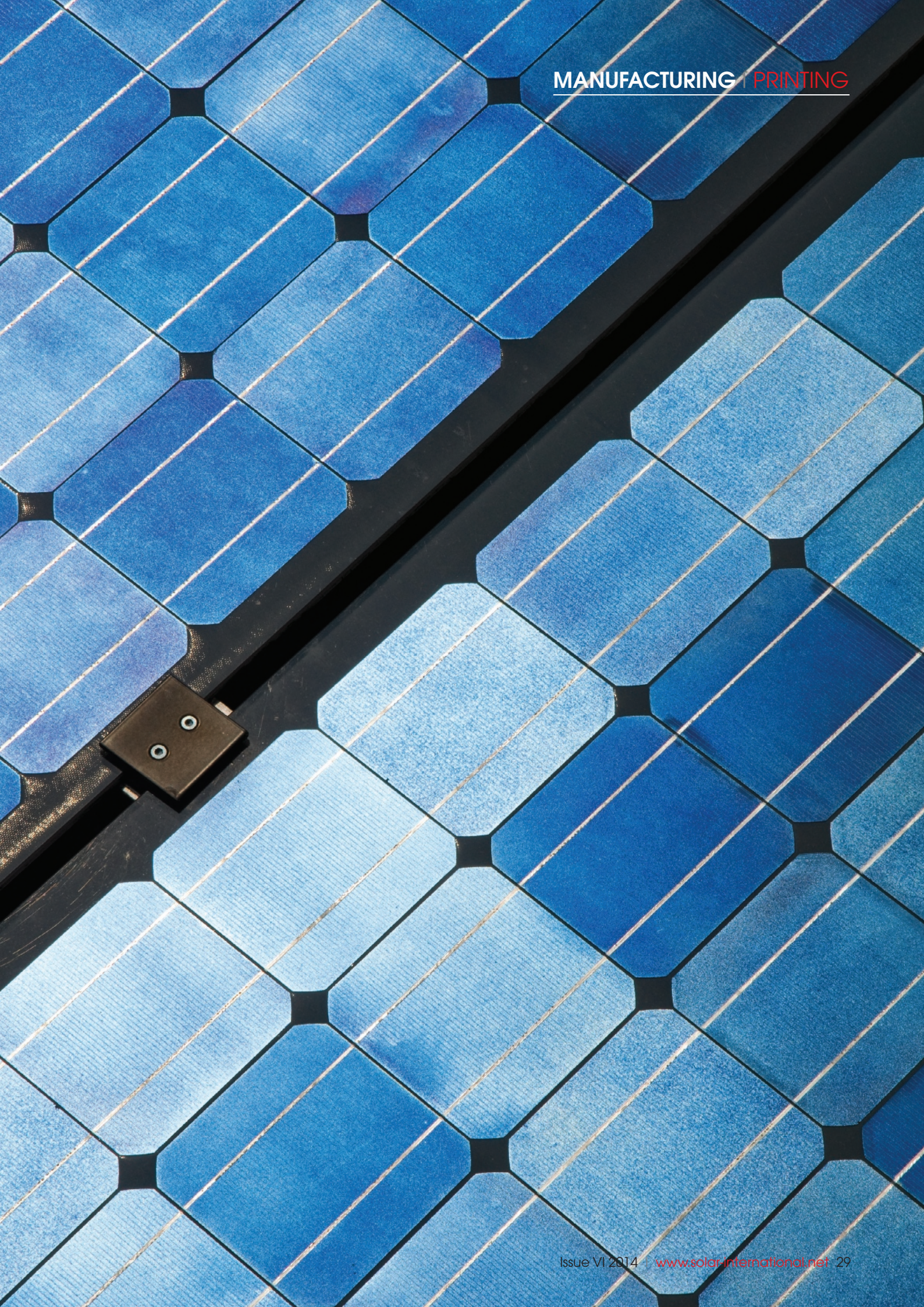


Figure 1: The electroluminescence [EL] image of the single print cell (left)[Test ID 2014-0092-8] was printed with 35 micron openings and 105 finger lines. The EL image of the double print cell (right) [Test ID: 2014-0092-4] was printed with 25 micron line openings for both print strokes and 105 finger lines. Note the improvement in the final print of the double print cell.

The Heraeus Photovoltaics Business Unit using their SOL9621 Series of front-side metallization pastes, in conjunction with Applied Materials and their Esatto Technology™ screen printing system, have demonstrated the ability to employ double printing technology to reduce finger-line widths, lower paste usage per cell and improve cell efficiency. The collaboration reduced finger line widths by 12 micron (25% width reduction), lowered pastes usage per cell by 17 milligrams (13.6% paste saving) and increased the absolute cell efficiency by greater than 0.2% compared to single printing technology.

Improved finger line quality

Paste printability is critical to cell performance. As line widths become narrower, paste formulations, screen designs and screen printing must be improved accordingly. Accurate double printing actually improves the final print of the finger line relative to single printing. When printing through extremely narrow screen openings, there is always the possibility of line breaks and necking.



Printing Parameters	Single Printing	Double Printing	Comment
Wafer	Monocrystalline	Monocrystalline	Same wafer
Screen			
Screen Opening	35 Micron	25 Micron for first and second print	10 micron difference
Number of Finger Lines	105	105	Same number of finger lines
Paste Used	Heraeus SOL9621 Series	Heraeus SOL9621 Series	Same paste
Average Finger line width	48 Micron	36 Micron	12 Micron difference
Average Finger line height	16 Micron	18 Micron	2 Micron difference
R_a (relative to height)	1.1 Micron	2.0 Micron	0.9 Micron difference
Busbar height	8 Micron	6 Micron	2 Micron difference
Front-side paste usage	125 milligrams	108 milligrams	17 milligram difference

Table 1: Printing parameters of single printing versus double printing

By double printing, line imperfections and breaks from the first stroke can be corrected during the second print stroke.

Applied Materials performed experiments comparing single printing and double printing of crystalline solar cells, both optimized for efficiency, using Heraeus' newest front-side silver paste, the SOL9621 Series.

The results from the optimized single printing method used a 35 micron screen opening, demonstrating finger lines with an average width of 48 microns and a height of 16 microns. In the double printing process, a 25 micron screen opening was used, and finger line widths of 36 microns with a height of 18 microns were obtained.

Figure 1 shows the improved final print result of the double print cell relative to the single print cell. These results are achieved even though the double print screen openings are 10 microns narrower than the single print screen openings.

The improved finger line quality of double printing provides production cost savings to cell manufacturers. Cell manufacturers have adopted automatic inspection systems in their production lines. When cells begin to show multiple line breaks, this will trigger an automatic stop in production to resolve the problem. This down time is significantly reduced due to the second stoke "repair" [if necessary] of the double printing process.

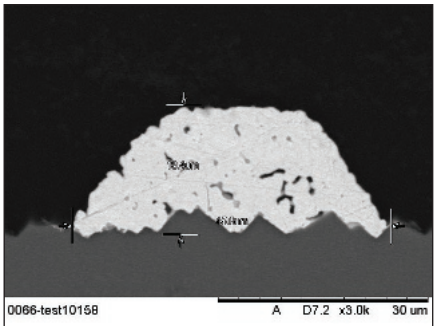
Ultra-fine finger lines with higher aspect ratio

Because of the improved line quality from the double printing process, ultra-fine lines printing with screen openings less than 35 micron can be realized at a higher success rate in manufacturing. Another benefit from double printing is the lower line resistance due to the improved finger line geometry with an increase in the minimum finger line height relative to single printing.

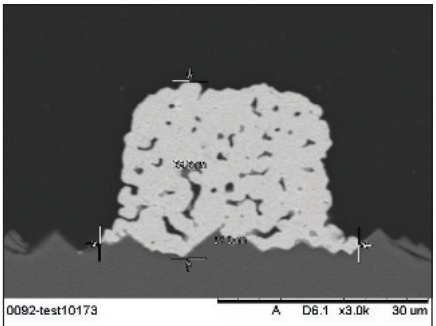
In the finger line cross section shown in Figure 2, double printing provides a narrower, taller finger line resulting in a higher aspect ratio. Assuming single print and double print use the same number of finger lines, the ultra-fine lines of double printing increase the available solar cell wafer surface area to capture light. The increased height of the ultra-fine finger, resulting in a larger cross-sectional area increases the current flow capacity. For example, in Figure 2, the cross-sectional area of the double print finger line is about 12% greater than the single print finger line. By improving the geometry of the finger lines thereby reducing the necking, the line resistance is reduced. This is one of the factors that contribute to the higher efficiency of double printing relative to single printing. The improvement in electrical performance will be highlighted later.

Reduced paste usage

Double printing has the ability to reduce paste usage as demonstrated by work done by Applied Materials with Heraeus SOL9621 paste. Table 1 shows the parameters that were used for testing. Using the parameters shown in table 1, single printing required 125 milligrams of front side metallization paste. However, for double printing a deposition of 108 milligrams of front side paste was required. This 13.6 % reduction in paste



Fine line Single Printing Finger Line



Ultra Fine line Double Printing Finger line

Figure 2: SEM images show double printing generates a narrower and higher aspect ratio finger line than single printing

usage represents a 13.6 % reduction in silver usage, which is approximately 0.2¢/Wp. For these experiments, the process was optimized for lower cost while maintaining adhesion well above the recommended standard specification.

Improved electrical performance

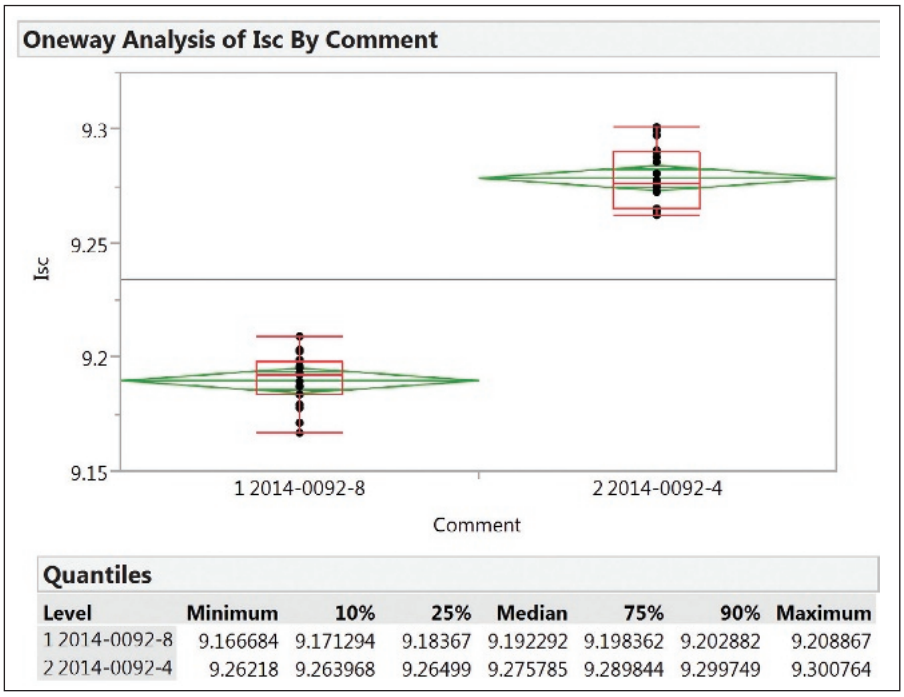
Due to the narrower finger lines, higher aspect ratio, improved printability and the precision screen printing, the electrical performance of double printed cells exceeds that of single printed cells using the same front side paste. Figure 3 highlights the 80 mA improvement in short circuit current of double printing relative to single printing. Using single printing as the benchmark, double printing had an efficiency improvement of 0.2% absolute. This correlates to an improvement of 0.048 watts per cell (or 2.9 watts for a 60 cell module).

If we are assuming the average price of monocrystalline cells are $0.40/W, then a gain of 0.048 watts per cell would produce an additional gain in revenue of about $0.02 per cell. This improvement in higher cell output, reduced down time and lower paste usage has the ability to provide cell manufacturers value in their investment.

Variation in double printing

The tests and results discussed above use a process called an A+A paste deposition, where the paste used in the first print stroke is the same as the paste used in the second paste stroke. However, there are other two-step screen printing technologies on the market that can reduce the laydown of silver paste.

An alternative double print process utilizes an A+B paste deposition method, where two different pastes are used for the front side metallization and each are optimized for different performance parameters. For example, the paste used for the first print stoke can be optimized for contact. The paste used for the second print stoke can be optimized for adhesion and Voc. The design of the screens and pastes can be tailored to use less pastes while improving performance. Preliminary A+B internal results from Heraeus have shown 1N greater adhesion, 2 mV greater Voc and up to 10% reduction in paste usage compared to the A+A paste deposition



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1 2014-0092-8	9.166684	9.171294	9.18367	9.192292	9.198362	9.202882	9.208867
2 2014-0092-4	9.26218	9.263968	9.26499	9.275785	9.289844	9.299749	9.300764

Figure 3. Test ID 2014-0092-4 (double print) shows a 80mA improvement in short circuit current compared to Test ID 2014-0092-8 (single print)

method. Further improvements are expected with additional collaboration.

Another version of a two-step screen printing methods is dual printing. Here the fingers and busbars are deposited in separate printing steps. The fingers are deposited in a single stroke, instead of two strokes as in double printing process. The high aspect ratio of double printing will not be achieved using conventional mesh screen and there is no 'repair system' for necking and line breaks. But the busbar can now be printed with an optimized screen and even an optimized paste, resulting in a minimal total paste laydown with a possible paste saving of >20 mg. Optimized busbar paste would also provide greater adhesion and possible improvement in Voc.The overall PV market continues to seek higher efficiency and materials advantages to improve a cell's cost per watt. Paste contact quality and printability continue to improve which opens new opportunities for advancement.

There are trends towards four or more busbars per cell, which can redefine conductivity requirements of individual fingers. With so many factors to consider, it is not clear which deposition technology will dominate, but our expectation is that several technologies will find a future market success.

Conclusion

There are several technologies that manufacturers are investigating to improve the performance of solar cells. Even within a technology category, there are options. Experiments have shown and manufactures are proving that double printing is a viable option to increase manufacturing precision, reduce materials cost and improve PV electrical output.

Suppliers to cell manufacturers are developing new pastes, screens, and deposition technologies. There are also other two-step paste deposition technologies that are demonstrating success in labs today and will no doubt become exciting alternatives to advance PV cell manufacturing and efficiency. In a collaborative effort among PV suppliers, these advances should enhance the appeal and value of solar/PV systems to commercial and retail customers.

A special acknowledgement to Larry Wang, Li Yan and Vineet Dua from Heraeus PV R&D

Energy is a **global** concern

Signs of stress in the energy sector must not be ignored, IEA warns in its new World Energy Outlook. The Agency warns the energy sector must tackle longer-term pressure points before they reach breaking point.

EVENTS OF THE LAST YEAR have increased many of the long-term uncertainties facing the global energy sector, says the International Energy Agency's (IEA) World Energy Outlook 2014 (WEO-2014). It warns against the risk that current events distract decision makers from recognising and tackling the longer-term signs of stress that are emerging in the energy system.

In the central scenario of WEO-2014, world primary energy demand is 37% higher in 2040, putting more pressure on the global energy system. But this pressure would be even greater if not for efficiency measures that play a vital role in holding back global demand growth.

The scenario shows that world demand for two out of the three fossil fuels – coal and oil – essentially reaches a plateau by 2040, although, for both fuels, this global outcome is a result of very different trends across countries. At the same time, renewable energy technologies gain ground rapidly, helped by falling costs and subsidies (estimated at $120 billion in 2013). By 2040, world energy supply is divided into four almost equal parts: low-carbon sources (nuclear and renewables), oil, natural gas and coal.

Renewable hope remains

The report sees a positive outlook for renewables, as they are expected to account for nearly half of the global increase in power generation to 2040, and overtake coal as the leading source of electricity. Wind power accounts for the largest share of growth in renewables-based generation, followed by hydropower and solar technologies.

However, as the share of wind and solar PV in the world's power mix quadruples, their integration becomes more challenging both from a technical and market perspective.

In a focus on nuclear power, WEO-2014 sees installed capacity grow by 60% to 2040 in the central scenario, with the increase concentrated heavily in just four countries (China, India, Korea and Russia). Despite this, the share of nuclear power in the global power mix remains well below its historic peak. Nuclear power plays an important strategic role in enhancing energy

security for some countries. It also avoids almost four years' worth of global energy-related carbon-dioxide (CO2) emissions by 2040.

However, nuclear power faces major challenges in competitive markets where there are significant market and regulatory risks, and public acceptance remains a critical issue worldwide. Many countries must also make important decisions regarding the almost 200 nuclear reactors due to be retired by 2040, and how to manage the growing volumes of spent nuclear fuel in the absence of permanent disposal facilities.

"As our global energy system grows and transforms, signs of stress continue to emerge," said IEA Executive Director Maria van der Hoeven. "But renewables are expected to go from strength to strength, and it is incredible that we can now see a point where they become the world's number one source of electricity generation."

Global realities

World oil supply rises to 104 million barrels per day (mb/d) in 2040, but hinges critically on investments in the Middle East. As tight oil output in the United States levels off, and non-OPEC supply falls back in the 2020s, the Middle East becomes the major source of supply growth. Growth in world oil demand slows to a near halt by 2040: demand in many of today's largest consumers either already being in long-term decline by 2040 (the United States, European Union and Japan) or having essentially reached a plateau (China, Russia and Brazil). China overtakes the United States as the largest oil consumer around 2030 but, as its demand growth slows, India emerges as a key driver of growth, as do sub-Saharan Africa, the Middle East and Southeast Asia.

"A well-supplied oil market in the short-term should not disguise the challenges that lie ahead, as the world is set to rely more heavily on a relatively small number of producing countries," said IEA Chief Economist Fatih Birol. "The apparent breathing space provided by rising output in the Americas over the next decade provides little reassurance, given the long lead times of new upstream projects."

Demand for gas is more than 50% higher in 2040, and it is the only fossil fuel still growing significantly at that time. The United States remains the largest global gas producer, although production levels off in the late-2030s as shale gas output starts to recede. East Africa emerges alongside Qatar, Australia, North America and others as an important source of liquefied natural gas (LNG), which is an increasingly important tool for gas security. A key uncertainty for gas outside of North America is whether it can be made available at prices that are low enough to be attractive for consumers and yet high enough to incentivise large investments in supply.

Future trends

While coal is abundant and its supply relatively secure, its future use is constrained by measures to improve efficiency, tackle local pollution and reduce CO2 emissions. Coal demand is 15% higher in 2040 but growth slows to a near halt in the 2020s. Regional trends vary, with demand reaching a peak in China, dropping by one-third in the United States, but continuing to grow in India.

The global energy system continues to face a major energy poverty crisis. In sub-Saharan Africa (the regional focus of WEO-2014), two out of every three people do not have access to electricity, and this is acting as a severe constraint on economic and social development. Meanwhile, costly fossil-fuel consumption subsidies (estimated at $550 billion in 2013) are often intended to help increase energy access, but fail to help those that need it most and discourage investment in efficiency and renewables.

Reaction times

A critical "sign of stress" is the failure to transform the energy system quickly enough to stem the rise in energy-related CO2 emissions (which grow by one-fifth to 2040) and put the world on a path consistent with a long-term global temperature increase of 2°C. In the central scenario, the entire carbon budget allowed under a 2°C climate trajectory is consumed by 2040, highlighting the need for a comprehensive and ambitious agreement at the COP21 meeting in Paris in 2015.

Panel manufacturing greener in Europe

A recent study has suggested that solar panels produced in Europe carry a lesser carbon footprint than those made in China. With growing interest and concern of environmental impact of PV, the report points to changing global dynamics.

SOLAR PANELS made in China have a higher overall carbon footprint and are likely to use substantially more energy during manufacturing than those made in Europe, said a new study from Northwestern University and the U.S. Department of Energy's Argonne National Laboratory. The report compared energy and greenhouse gas emissions that go into the manufacturing process of solar panels in Europe and China.

"We estimated that a solar panel's carbon footprint is about twice as high when made in China and used in Europe, compared to those locally made and used in Europe," said Fengqi You, assistant professor of chemical and biological engineering at Northwestern and corresponding author on the paper.

"While it might be an economically attractive option to move solar panel manufacturing from Europe to China, it is actually less sustainable from the life cycle energy and environmental perspective—especially under the motivation of using solar panels for a more sustainable future," he said.

Entire life cycle

The team performed a type of systematic evaluation called life cycle analysis to come up with these hard data. Life cycle analysis tallies up all the energy used to make a product—energy to mine raw materials, fuel to transport the materials and products, electricity to power the processing factory, and so forth.

This provides a more accurate picture of the overall energy consumed and produced and the environmental impact of making and using a solar panel.

Assuming that a solar panel is made of silicon—by far the most common solar panel material—and is installed in sunny southern Europe, a solar

panel made in China would take about 20 to 30 percent longer to produce enough energy to cancel out the energy used to make it. The carbon footprint is about twice as high.

The biggest reason is that China has fewer environmental and efficiency standards for its factories and plants and generates more electricity from coal and other non-renewable sources, the authors said.

"It takes a lot of energy to extract and process solar-grade silicon, and in China, that energy tends to come from dirtier and less efficient energy sources than it does in Europe," said Argonne scientist and co-author Seth Darling. "This gap will likely close over time as China strengthens environmental regulations."

The study did not include the energy cost of transporting a solar panel to its final destination. Transportation would magnify the difference even further if it—like 60 percent of all solar installations in 2012—went up in Germany or Italy, Darling said.

Comparing types

The team also compared the numbers for different types of silicon solar panels. Single-crystal solar panels are better at harvesting energy than other types, but take the longest to "pay back" the energy used to manufacture them because the process is more energy-intensive. Multicrystalline panels came next, followed by ribbon silicon panels, which are easiest to manufacture but least efficient—however, their payback time was fastest.

To encourage more sustainable production of solar cells, the authors suggest a break-even carbon tariff. "This would be based on the carbon footprint and energy efficiency difference between manufacturing regions, and would be a better market- and science-based solution than a solar panel tariff," said Dajun Yue, a Northwestern graduate student in You's research group and lead author on the paper.

"The break-even carbon tariff we calculated, which is at the range of €105-129 per ton of carbon dioxide, depending on the possible carbon tax to be imposed by these two regions in the near term, is close to the reported CO2 capture and sequestration cost," You said.

Funding for this research was provided by the Institute for Sustainability and Energy at Northwestern University. The research was performed in part at the Center for Nanoscale Materials, a U.S. Department of Energy user facility.

Local energy required

Mega cities of the future will require local electricity production. Sven Lindström, CEO of Midsummer argues that solar 'roof energy' is the answer.

SEVEN BILLION PEOPLE will live and work in urban areas by 2050 and the demand for energy for all these people will be huge. Local production of energy will be needed with building-integrated photovoltaics (BIPV) key to make cities at least partially self-sufficient with energy. Rapid development in thin film solar cell efficiency strengthens the business case for BIPV, with great opportunities for suppliers of roofing materials and construction companies.

More than half of the planet's population live in urban regions today. This will grow to 75 per cent in the next 30 to 35 years. That would mean seven billion people living in more or less congested areas, all needing shelter, food – and lots of energy.

There is a growing consensus that the mega cities in the future cannot rely entirely on energy produced far away. Besides supply constraints, there are energy losses in the transport of the electricity, logistical nightmares, security issues and of course environmental concerns.

There is a very healthy debate about distributed energy generation, often defined as electricity generation from many small sources. This discussion must be encouraged. We simply cannot solve the energy challenges of tomorrow with energy solutions of yesterday.

How local is local?

The distributed energy discussion has so far mainly centred on local smaller power plants, district energy, more efficient electricity distribution, the 'smart grid' etc. That is good. But we must also talk about the potential for local production of renewable energy by the end users on a micro scale, the very individuals who consume all this energy.

What do the end users have in common? Well, they all need a roof over their heads, at home and at work. These roofs can produce renewable energy! So the building industry can play a major role in solving the mega cities' energy challenges.

Roof top solutions

Look at an aerial image of a city and you will see an area densely covered by buildings – crisscrossed by roads and the occasional recreational area. All these buildings - houses, apartment blocks, garages, offices, factories, schools and municipal buildings of all sorts – have roofs. New development in solar energy has transformed all these roofs – and even walls – into potential giant solar energy receivers.

The electricity produced by 'roof solar energy' could be used for heating, cooling, running office machinery or even fed back to the grid, earning the building owners money.

What I call 'roof energy' is of course building-integrated photovoltaics (BIPV), one of the fastest growing segments of the photovoltaic industry. Photovoltaic materials are used to replace (or are added on to) conventional building materials in not only roofs but also skylights and facades. They can be incorporated into the construction of new buildings as a principal or ancillary source of electrical power and existing buildings may be retrofitted with similar technology.

Traditional wafer-based silicon solar cells are efficient but rigid, thick and heavy, ideal for large solar parks in sparsely populated areas but not in dense cities. They are too heavy for most roofs. However, thin films solar cells made out of a copper-indium-gallium-selenium metal alloy (CIGS) 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.

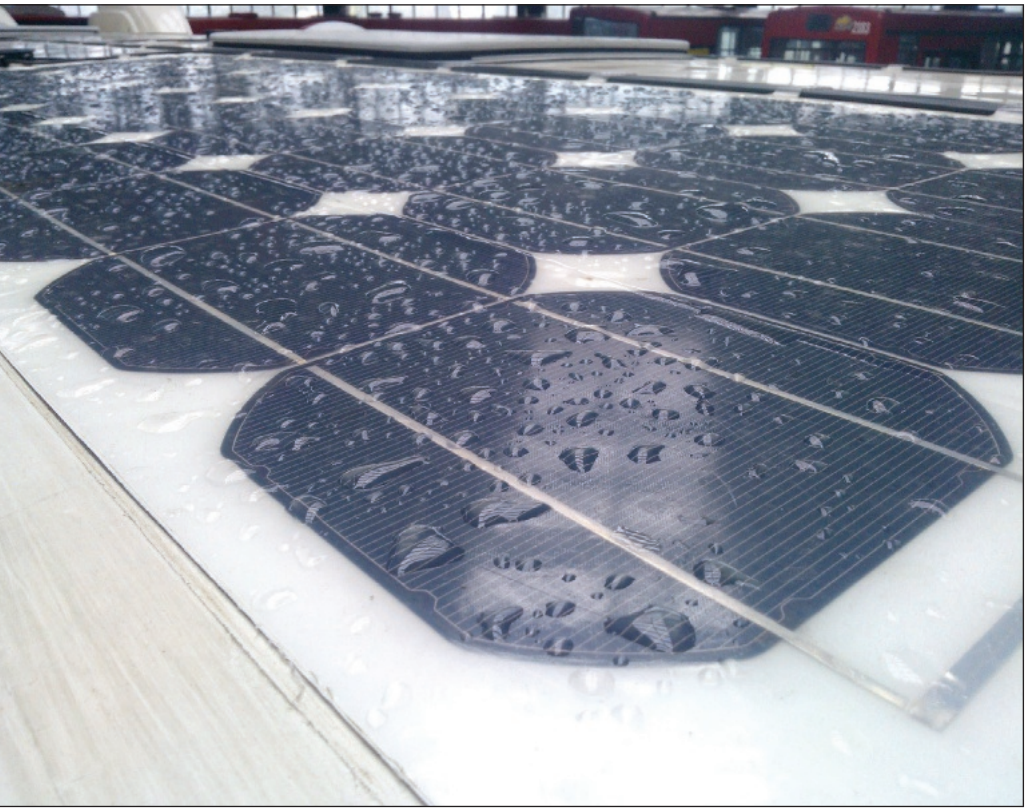
Thin film coverage

The business case for thin films solar cells are strengthening rapidly since they are becoming increasingly efficient. A Swedish supplier of thin film solar cell manufacturing equipment (Midsummer) has managed to increase the aperture efficiency (the area on the solar panel that collects energy) from six per cent four years ago to 11 per cent two years ago and a record breaking 17 per cent today by using a revolutionary all-dry, all vacuum process where all layers are deposited by sputtering.

An office, school, storage facility or factory with a flat rood in a Mediterranean country like Italy could annually yield 1,250 kWh from every kW installed, at a production cost of 5.6 euro cents (7.2 US cents). The production cost would decrease if the roof is slanted, by up to 20 per cent for an optimal 35 degree angle. The production cost would obviously be higher in colder countries and lower in countries nearer the equator. But even in Sweden the production cost could be as low as 8 cents.

A production cost of 5 to 10 cents is well below the current – not to mention the expected future – electricity prices in Europe. There are great variations in the price of electricity in Europe today, but many users pay between 10 and 30 cents per kWh (incl taxes). Commercial and residential users pay even more.

So there is already a business case for thin film solar cells on roofs, either retrofitted or new construction. The payoff time is five years for a building in Rome, nine years in Munich, 14 years in Paris and 19 years in Stockholm – well below



the 25+ years lifespan of the panels.

Healthy foundations

The $100bn global roofing material market is in a healthy state, growing at 3.7 per cent per annum and driven by an uptick in residential building construction (especially reroofing) in both developed and developing markets. Here is an excellent opportunity for architects, roofing material suppliers and construction companies to take a leading position in what is destined to be the material of choice for urban planners in the future. Concrete tiles and bituminous products dominate the roofing markets but both have disadvantages. Asphalt singles have a short life span and concrete tiles are heavy and cannot be used on flat roofs. And none of them can produce renewable energy!

Thin film BIPV solar energy solutions, on the other end, can be made light and are flexible. They can be fitted or retrofitted onto roofs without perforating the roofs and can be curved or bent. Installation is easy and cost-efficient, with no racks or ballast needed. There are no weight constraints and no access limitations (you can walk on the panels). And they can be integrated on both bitumen and TPO membranes.

Selling roofing solutions and electricity together opens up to completely new business models: suppliers can offer a discounted roofing price in combination with a stable and independent supply of electricity. Customers can secure electricity price – and get a new roof.

Municipalities and city planners in today's and tomorrow's mega cities will make efforts to make their cities greener and more sustainable. It is no wild guess that green buildings with 'roof energy' systems will get preferential treatment in public tenders, and maybe even subsidies. Building owners will like the prospect of lower energy costs.

So the question to the world's architects, roof manufacturers and construction companies is: Do you feel lucky? Do you feel confident enough to keep doing business as usual, selling traditional roofs to consumers who might sooner than expected demand energy producing and cost saving roofs and buildings? Or will you grab an unparalleled opportunity to gain market share by offering state of the art products that will change the world, or at least the way the world's urban population power their daily lives?

For me, the answer is simple: If end users can produce part of the energy consume, in a sustainable fashion, where they live and work, that would go a long way towards solving the energy and climate challenges of the future. Flexible, efficient, thin film solar cells for buildings and moving vehicles are an integral part of this solution.

Sven Lindström is co-founder, Chairman and CEO of Midsummer, a leading global supplier of production lines for cost effective manufacturing of flexible thin film CIGS solar cells. Mr. Lindström has over 20 years of experience from international business and development of high tech production equipment and vacuum deposition systems. He has over ten years of experience from the development and management of solar cell production equipment and is a firm supporter of distributed electricity production.

www.midsummer.se

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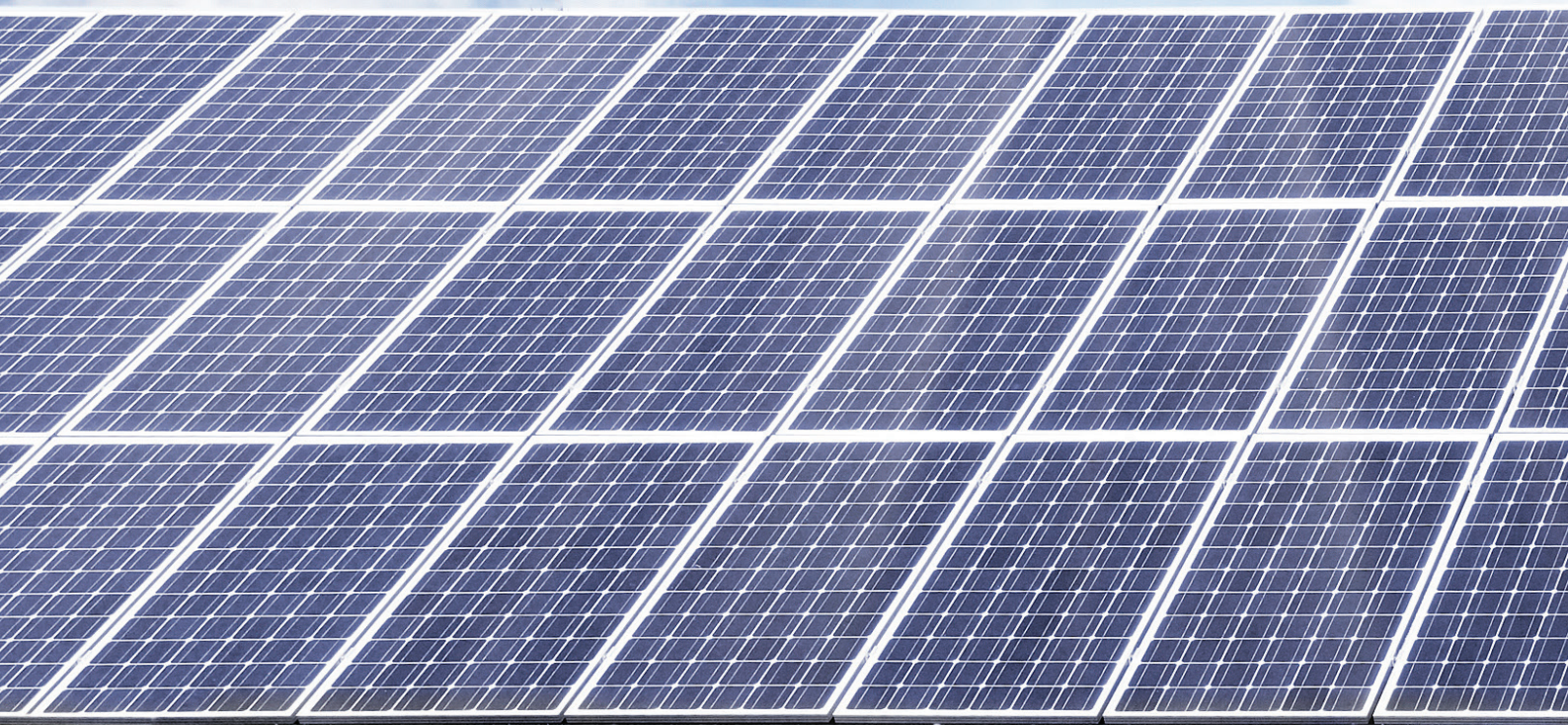
Lighting up the agri-business landscape

The UK government is providing confusing messages for solar in a rural setting. Giles Hanglin, director at Savills Energy, explains the steps which will need to be taken by farmers to make the most of the solar opportunity now, as well as suggesting the role government will need to play in commercial roll-out success.



AS THE INTERNATIONAL ENERGY AGENCY (IEA) announces that solar power could replace coal as the world's primary electricity source by 2050, it is crucial to understand how the agricultural sector will need to develop to make this prediction a reality.

Agricultural solar has certainly come under the spotlight of late, with numerous arguments between the government and shadow ministers about the potential impact of ground-mount solar installations on the livestock and crop output of our farming sector.

Indeed, while the UK government can't actually put a figure on the amount of land allegedly lost to renewables, secretary of state for the environment, Elizabeth Truss, has described solar farms as "a blight on the countryside."

In contrast, the National Farmers Union (NFU) and the Country Land and Business Association (CLA) have both argued that agricultural activity can co-exist alongside solar farms in order to produce food and energy from the same hectares.

In addition, organisations like Solarcentury, Lightsource and Kingspan have all produced data to show the benefits of ground-mount and rooftop solar for the UK's commercial and agricultural sectors. Their partnership work with numerous flora and fauna-related charities highlights the importance of biodiversity when developing a solar site on existing farmland.

Economic benefits

Looking at the issue from a wider perspective, the Solar Trade Association has suggested that home-grown UK solar will be cheaper than gas by 2018; and cheaper than wholesale electricity prices by 2028. The research into large-scale solar installations, of 10MW and above, shows that a growing supply chain in the UK and falling global component costs will bring the total required investment

down substantially over the next 15 years.

The Centre for Economics and Business Research (CEBR) thinks this parity with wholesale electricity could come even earlier, perhaps in 2024. It also suggests that solar will eventually contribute more to the UK economy than any other energy technology, providing 15% of total UK electricity consumption by 2030, supporting 50,000 jobs and adding more than £25bn to UK economic output.

Of course, for all of this to happen, it is essential that government policy is consistent and that land owners and business managers are able to access all of the facts to make a decision about whether solar is right for them. From January 2014, farmers who rent their land to ground-mounted solar panels will not be eligible for subsidies through the Common Agricultural Policy (CAP) scheme; although there is debate about how much difference this will actually make to solar take-up.

The government has also put in place an end to subsidies for new solar farms above 5MW from next April; although the Renewable Obligation grace period has recently been extended from three to 12 months. This means that extra time for accreditation will be provided for those installations which, through no fault of their own, find grid connection delays cause them to miss the 31st March 2015 application deadline.

Farmer's retort

The Farm Power coalition, led by Forum for the Future, has recently responded to the government's attacks on ground-mount solar with its own report, which suggests an untapped potential of 20GW of energy across UK farmland.

Arguing that this figure, which would go a long way towards supporting renewable energy targets, could be managed in a way that complements crop and livestock production, the coalition has identified two key obstacles: grid connection shortfall and the planning process.

Such challenges echo Savills' own findings among land owners looking to invest in the renewables landscape. Indeed, in the latest Savills Estates Benchmarking survey, 70% of landowners who responded had assessed the renewable energy potential of their estate recently, with another 12% planning to do so within a 12-month period. However, many identified grid capacity, planning requirements and energy storage as key barriers to progress.

Renewable energy has the potential to fundamentally transform the profitability of business in the rural sector. Historically, many landowners strengthened their business by spreading risk and developing multi-faceted income streams; renewable energy can be viewed in the same way. Benefits include the diversification of their portfolio, generation

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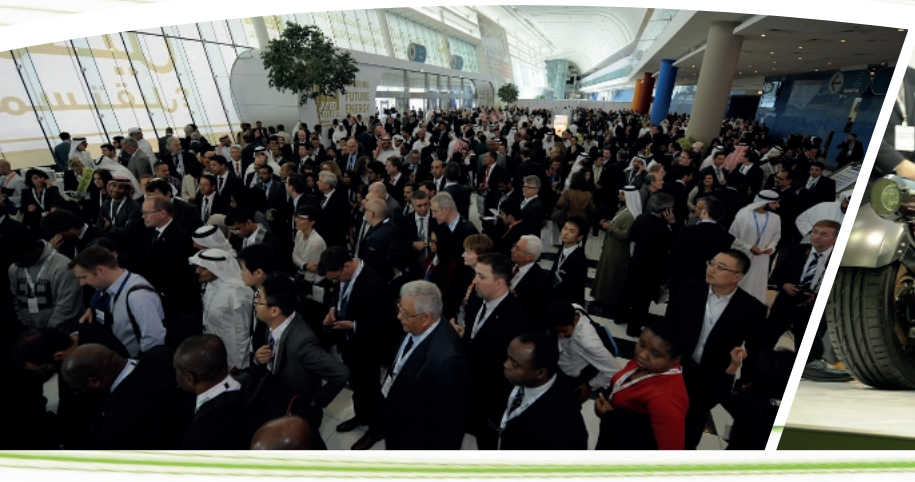

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of an additional source of income, the value of sustainability when securing contracts to supply to retailers, as well as hedging against future energy prices rises.

Rising prices, dramatic weather and supply and demand fluctuations are all adding to volatility in profits. Looking forward, the country is taking coal-fired generators offline over the coming years, with some predictions suggesting that this will take national generation capacity below the minimum strategic requirement. While many businesses have installed back-up generating schemes over the past few years, many more have not. Managed correctly, these factors come together to provide opportunities for land and property owners.

Opportunity not to be lost

The potential benefits of solar for the British economy are phenomenal and the UK is currently at the forefront of innovation when it comes to establishing the most appropriate solutions for solar installations.

While ground-mount is currently under fire, the Department for Energy and Climate Change (DECC) has placed its support firmly behind rooftop solar. With a target of commercial and industrial roofs to support around a third of the UK's future solar mix, the opportunity for agricultural and commercial property owners to exploit rooftop spaces for energy generation will be a major platform for growth over the next five to ten years.

Indeed, agricultural and commercial organisations continue to be driven by the need to push out cost from the supply chain and one of the key areas to do so is around energy. For many circumstances, the pay-back for solar, regardless of the current FiTs environment, is just too great to ignore. With a return on investment of as much as 15% on a commercial rooftop for both the owner and tenant, if applicable, the opportunity to 'green-up' the portfolio while addressing the challenges of energy

costs and energy efficiency is substantial. It is frustrating that solar has come in for a bit of a beating of late due to the various misconceptions around subsidies, perceived impact on the landscape and the debatable competition with other land uses. Indeed, for agricultural and rural commercial property owners, solar represents a real opportunity to realise commercial benefits for the long-term while making a positive environmental contribution.

As an industry, we have been talking about the benefits of solar power for a long time; however, the constant tinkering with subsidies and government policy has meant that solar has not always seemed like the most straight-forward choice. This has put off both land owners and potential investors who may have otherwise seen significant returns.

Energy close to home

It is not just about the solar installation itself. On-site power generation is at its most effective when combined with other smart technology within the agricultural business. For example, solar systems can work in conjunction with other renewable technologies to contribute towards the heating, cooling and daylighting of almost any building.

Rising electricity prices are one of the big unknowns for businesses, while there is an increasing imperative for organisations to invest in efficiency measures. Rooftop solar represents a real opportunity for commercial property owners and tenants to address the dual challenge of energy costs and environmental performance, while realising genuine commercial benefits for the long-term.

Of course, solar is not right for everyone and it is important that landlords engage with experienced advisors who can identify, develop and commercialise energy generation opportunities to achieve valuable commercial benefits. Many agricultural and commercial buildings have already been transformed to deliver future energy needs and we expect this trend to continue over the coming decade, especially with the government's 2020 targets in sight.

Solar ubiquity tipped for 2025

Each year Thompson Reuters puts together an outline of technologies that will affect the world. This year they have compiled a list of top ten technologies that will impact the world and solar is one of the key technologies the group has selected.

It's human nature to want to know what's coming. As far back as one can look in history, humans have tried to predict everything from the weather and rise and fall of tides to, in more recent times, stock performance and who will reign as champion in a sporting event. From Nostradamus to Toffler to Kurzweil, academics, astronomers, economists, futurists, mathematicians, scientists, sociologists, sports enthusiasts and others have contributed to the science – and art – of predicting what is to come.

Thomson Reuters focuses on innovation and has chosen to leverage those assets to forecast the future. With a scientific and intellectual property repository these predictions are a compilation of 10 innovation predictions for the world in 2025, based on research done by Thomson Reuters analysts using the company's patent and scientific literature solutions.

In some cases, the analysts found a growing body of work that gave additional credence to the prediction. In others, the topic was still emerging. In all instances, they followed a trail of current research and innovation activity to connect the dots and make these innovation predictions.

Methodology

The aim of the project was to identify 10 technologies of tomorrow that will be in use in 2025 based on research and development currently identifiable in the literature of today – both scientific literature and published patents. The innovation predictions were discovered using solutions from the IP & Science business of Thomson Reuters.

First, broad fields were identified from recently published data (over the last two years) using Thomson Reuters Web of Science and InCites, for scientific and scholarly literature, and Thomson Reuters Derwent World Patents Index and Thomson Innovation, for patents. Analysts scoured the array of information to identify the themes of emerging importance from 2012 and 2013 using citation rankings, most cited papers, hot topics and research fronts, beginning in InCites.

The most active research fronts were identified by ranking the number of citations per paper and assessing the number of core papers per front.

A similar approach was used to identify the top 10 fields in patent literature, by locating the highest publishing fields and then drilling down into the essentials within these fields. Derwent Manual Codes were used to identify the patent fields with the highest number of inventions with a priority date of 2012 and onward.

Broad fields from scientific literature and patents were then merged and compared to identify the most impactful areas. From these areas and based on further analysis of data in each field, the analysts were able to make the 10 predictions of innovation in 2025.

In 2025 solar is the largest source of energy

Methods for harvesting, storing and converting solar energy are so advanced and efficient that it becomes the primary source of energy on our planet. Thanks to improvements in photovoltaic technology, chemical bonding, photocatalysts and three-dimensional nanoscale heterojunctions, the use of the sun as the world's primary source of energy is no longer for the environmentally conscious select; it is for the masses.

The sun's energy will be harvested much more efficiently. Its energy will be stored and used when needed. And the conversion of solar power will be much more efficient. Solar thermal and solar photovoltaic energy (from new dye-sensitized and thin-film materials) will heat buildings, water, and provide energy for devices in the home and office, as well as in retail buildings and manufacturing facilities.

Chemical bonds, a photosynthetic process, will make solar energy available when needed. Increased efficiency of energy conversion will be realized through new materials such as cobalt-oxide and titanium-oxide nanostructures, photocatalysts and 3D nanoscale heterojunctions; while new methods

using mesoscopic oxide films sensitized by dyes or quantum dots will contribute to improving the 2014 solar conversion efficiency rate of less than 10 percent.

FAST FACTS

- "Fabrication of novel heterostructure of CO304-Modified TIO2 nanorod arrays and enhanced photoelectrochemical property" most highly cited paper (last two years)
- "Design rules for donors in bulk-heterojunction solar cells – towards 10-energy-conversion efficiency" most highly cited paper (more than 1,600 times)

The rest of the top ten...

In 2025 dementia declines

Understanding of the human genome and genetic mutations leads to improved detection of, and prevention methods for, the onset of neurodegenerative diseases such as dementia and Alzheimer's.

Analysis and understanding of the human genome will have far-reaching effects in 2025. As Baby Boomers begin to reach their 80s, more and more scientific research funds will be directed toward afflictions they may encounter. Current neurodegenerative disease research is focused on identifying pathogenic chromosomes that influence the onset of diseases. This work is vital to understanding human genetic variations and will enable scientists to begin to fix genetic malfunctions, such as those impacting dementia patients.

In 2025 type I diabetes is preventable

A human genome engineering platform is a reality, paving the way for the modification of disease-causing genes and helping to prevent certain metabolic conditions. Type 1 diabetes and other metabolic conditions such as muscular dystrophy will be preventable in 2025.

Advancements in ribonucleic acid-guided (RNA-guided) engineering used for specialist sequence synthesis will be so much more sophisticated that a human genome engineering platform will exist. The pillar biological molecules of life on earth: RNA, DNA and proteins, and the roles they play, will be understood much more clearly in the next decade.

In 2025 food shortages and food price fluctuations are things of the past

Advancements in lighting technologies and imaging techniques, coupled with genetic crop modification, provide an environment ripe for successful indoor crop growth and detecting diseased foods.

Simultaneous revolutions in both lighting technologies and imaging techniques will have far reaching effects in the next decade. Advancements in Organic Light Emitting Diodes, LCD and plasma technologies, alongside three-dimensional displays coupled with hyperspectral imaging, will improve year-round crop growth, helping feed the world's eight billion people and overcoming environmental changes that will affect traditional farming.

In 2025 electric air transportation takes off

Light-weight aerospace engineering coupled with new battery technologies power electric vehicle transportation - on land and in the air.

Getting from point A to point B will be significantly different in 2025 from how it happens today. Cars and airplanes will still exist, but they will be smarter, battery-powered, able to travel longer distances and more light-weight. Advancements in non-carbon-basedfuel sources, including lithium-ion batteries, reversible hydrogen storage options, nanomaterials in fuel cells and thin-film batteries will all contribute to this reality.

As these new planes will be able to take off and land in much smaller spaces, getting a pilot's license could become the new right-of-passage to adulthood in the 21st Century.

In 2025 digital everything... everywhere

From the smallest personal items to the largest continents, everything, everywhere will be digitally connected, and responsive to our wants and likes.

The digital world as we know it today will seem simple and rudimentary in 2025. If you think we're electronically dependent now, you haven't seen anything yet.

Thanks to the prevalence of improved semiconductors, graphene-carbon nanotube capacitors, cell-free networks of service antenna and 5G technology, wireless communications will dominate everything, everywhere.

From cars and homes that respond to your every wish and want, to appliances that think for themselves, to interconnected geographies – from the most remote farmlands to bustling cities – we will all be digitally directed. Imagine the day when the entire continent of Africa is completely, digitally connected. That day will happen in 2025.

Carbon nanostructures, and carbon-based nanocomposites in particular, are part of the driving force behind this transformation, and are poised to take center stage in high-energy density and power-density applications. Carbon nanocomposites can be used as supercapacitive electrodes, either in two-or-three-dimensional structures, with high surface area. And, these supercapacitors will be able to store infinitely more energy for later release.

Petroleum-based packaging is history; cellulose-derived packaging rules

Bio-nanocomposites based on nanocellulose make 100% fully biodegradeable packaging pervasive.

Petroleum-based packaging products will be no more. Research is emerging focused on the use of bio-nanocomposites and nanocellulose for packaging. In 2025, these materials will be staples of choice.

Nanocellulose is material comprising nano-sized cellulose fibrils with a high length/ width ratio. In layman's terms, it is pseudo-plastic. Bio-nanocomposites are derived from bio matter, whether biomass or some other plant matter. Advancements in the use of these elements will, in 2025, provide packaging materials that are fully biodegradeable.

Toxic plastic-petroleum

packaging that litters cities, fields, beaches and oceans, and which isn't biodegradable, will be nearing extinction in another decade. Thanks to advancements in the technology related to and use of these bio-nano materials, petroleum-based packaging products will be history.

Cancer treatments have very few toxic side effects

Drug development is so much more precise, binding to specific proteins and using antibodies to give exact mechanisms of action, that the debilitating effects of toxic chemicals on patients is significantly reduced.

Just as Big Data is enabling companies to deliver personalized customer experiences, so too is life sciences moving from broad-brush drugs to very accurate and targeted treatments that result in significantly improved patient experiences.

This personalized medicine movement is not new. For several years the pharmaceutical community has been working on therapies that target specific molecules and perform targeted functions. Many drugs are now developed from biotechnology and are aimed at treating specific forms of a disease.

The impact of these advancements will be that patients in 2025 will have much more targeted drug treatments that result in fewer toxic side effects.

DNA mapping at birth is the norm to manage disease risk

The evolution of micro-total analysis systems (singlecell analysis) and advancements in nanotechnology, coupled with more widespread Big Data technologies, make DNA-mapping at birth the norm, as well as part of one's annual physician exam.

As the volume of matter which can be manipulated in the lab gets smaller and smaller, greater possibilities for precise medical screening emerge. Blood tests potentially become a thing of the past, as nano-probes will be inserted into a patient to gather data over longer periods of time and provide greater accuracy.

Micro-total analysis systems will be much closer to providing the sensitivity and selectivity required to make in vivo measurements for diagnosis.

Single-cell analysis, currently in the research phase, will be mainstream and set to replace traditional flow cytometry for the isolation, purification and separation of cells in immunology testing.

Big Data will be embedded in society in the next decade, allowing medical researchers and physicians to use it to their advantage. In 2025, humans will have their DNA mapped at birth and checked annually to identify any changes that could point to the onset of autoimmune diseases.

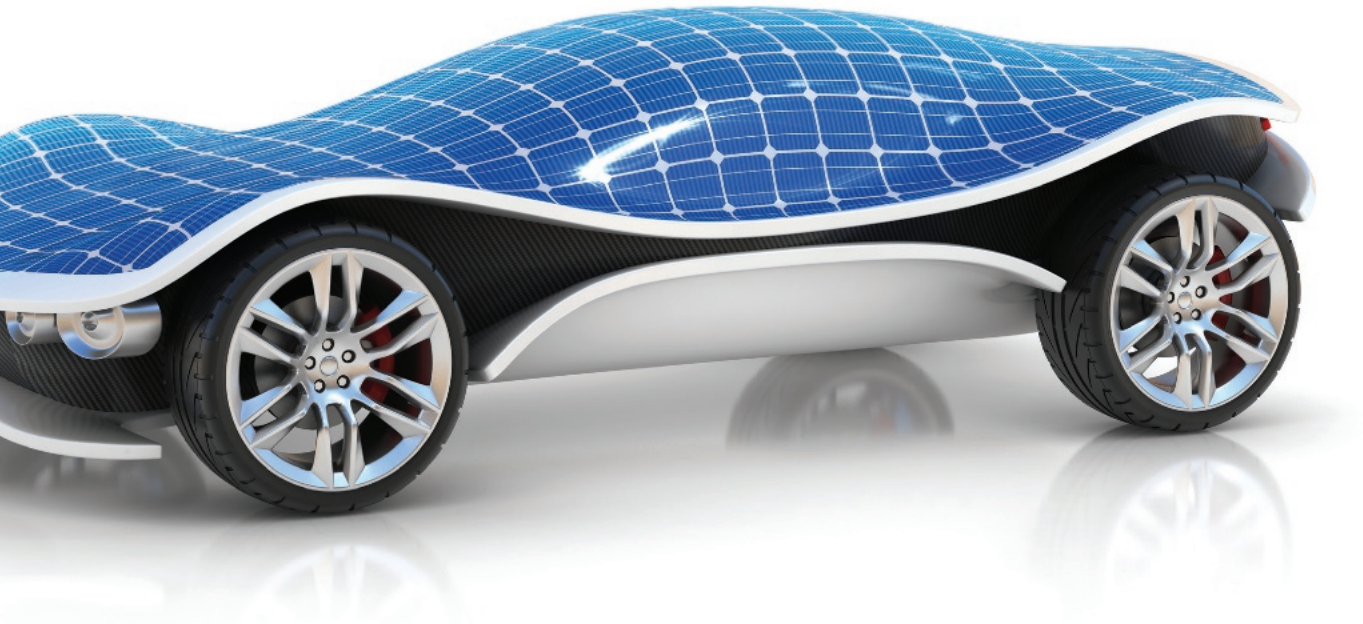
In 2025 teleportation is tested

Kinematical techniques used to understand the Higgs Boson particles generated in the Large Hadron Collider advance such that quantum teleportation is more commonplace. The frequent request heard on Star Trek will not be such an abstract concept as we move through the 21st Century.

Since the 2013 success at the CERN's Large Hadron Collider (LHC), research related to the Higgs Boson particle has increased. In fact, papers on this topic have been the most prevalent in fundamental physics in 2014.

Measurement techniques developed to understand the particles generated in the LHC were ground breaking through the use of new kinematical techniques. Kinematics is a form of classic mechanics that studies the motion of points, objects and groups of objects regardless of the impetus for motion.

We are on the precipice of this field's explosion; it is truly an emerging research front. Early indicators point to a rapid acceleration of research leading to the testing of quantum teleportation in 2025. Although in 2025 we as humans won't yet be able to teleport through space, a significant investment in and testing of quantum teleportation will be underway using other forms of matter.



Opening new avenues in organic solar cell research

Manufacturability is delivered by repetitve excellence. Olympus discuss how a new confocal laser scanning microscope (CLSM) is enhancing both accuracy and efficiency of research into organic solar cells.

Moving towards a sustainable manufacture of photovoltaics, Dr Manuela Schiek's research group at the University of Oldenburg, Germany has discovered how the quick and non-destructive nature of the Olympus LEXT OLS4100 high-resolution analysis and stitching function capabilities have enhanced their research.

Current solar cell manufacture processes are quite hazardous and energy consuming in contrast to the 'green' intentions of the end products. Dr Schiek's research focuses on alternative materials for solar cell manufacture that are non-hazardous and readily available, including the use of organic semiconductors and a transparent electrode system formed from a silver nanowire mesh.

Surface analysis

With its complex multi-layered structure, surface analysis techniques provide vital insights into the workings of a solar cell. Combining the ability to generate detailed, true-colour optical images with the non-contact capabilities of laser scanning technology, the LEXT 3D CLSM enables exceptional high precision optical profilometry and metrology. In Schiek's work, the LEXT was employed to accurately measure the thickness of organic semiconductor materials in the energy-capturing active layer of solar cells as this can critically affect their efficiency. The LEXT was found to be faster, more efficient and more accurate than stylus-based techniques through its non-contact capability to measure soft or adhesive surfaces at high-resolution.

Stitching solution

The expanded field of view offered by the rapid and intuitive stitching function of the LEXT also markedly improved the efficiency of surface roughness evaluation in comparison to Atomic Force Microscopy (AFM). The LEXT enabled viewing of a more representative sample of silver wire mesh on the transparent electrode surface and this combined with the wide magnification range helped to identify regions of unwanted aggregation that would otherwise have been missed. Dr Schiek commented, "The LEXT has been a great asset in our work. As well as being much faster than AFM, the area that you can inspect is a lot larger, with true colours and a 3D height profile for more insightful analyses".

Focus on South Australia

SOUTH Australia made headlines around the world when it was announced that the state - 'a place with the population of West Virginia' - had been powered by 100% renewable energy for an entire working day.

MANY INDUSTRY COMMENTATORS took the recent news that South Australia had achieved 100% renewable coverage as proof that a fully renewable future is possible. South Australia, moving against the wider trends in Australia, is the poster child for that future.

The news certainly gives credence to the 2009 announcement from Mike Rann, the state premier at the time, laying out the plan to turn South Australia in to a clean energy hub for the eastern seaboard of Australia.

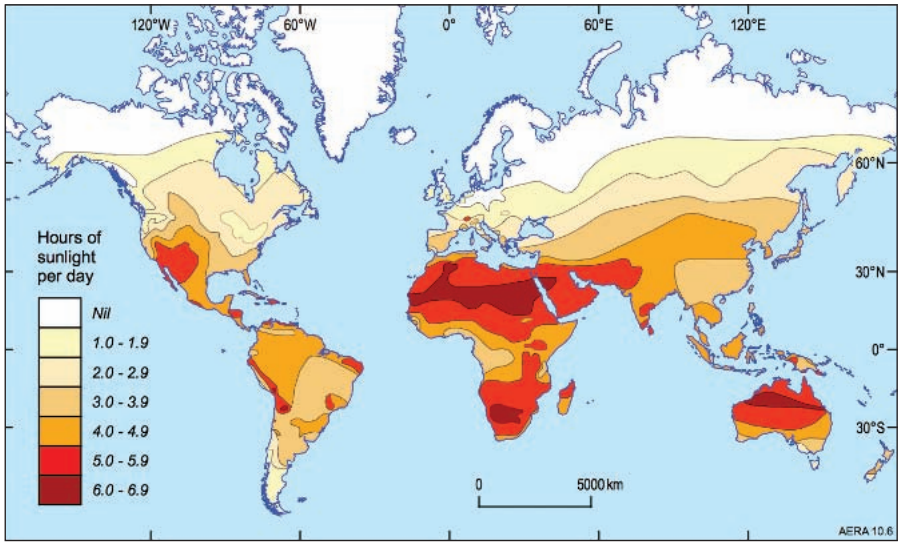
On that date the government announced a target of 33 per cent renewables in South Australia by 2020. The state just about reached that goal in September of this year, six years ahead of schedule. Current premier, Jay Weatherill, increased the target to 50 per cent by 2025 - a goal some argue will be reached with government assistance or not.

South Australia is an energy-blessed state. Olympic Dam in the outback north of the state is the biggest single deposit of uranium on earth - harbouring 30 per cent of the world's total resource - even though Australia has no nuclear energy facilities. Gas and oil are plentiful, and there's low-grade coal to be found.
Moreover, the land is awash in solar and wind energy ready to be tamed. It also boasts potential in the novel applications of geothermal and wave energy.

The State of Solar

Nearly a quarter of houses in South Australia have installed rooftop solar panels, making it one of the highest penetration rates in the world. Solar power makes sense on a continent where, according to the Federal Government's Australian Renewable Energy Agency (ARENA), "solar energy is a vast and largely untapped resource. Australia has the highest average solar radiation per square metre of any continent in the world."

Australia experiences more daylight hours than much of the world and South



Hours of sunlight per day, during the worst month of the year on an optimally tilted surface

Australia is well positioned to take advantage of many of those hours.
Its solar dominance started when the Rann government introduced feed-in tariffs and subsidies in 2008 for households installing panels and solar hot water systems.

Combined with high energy costs - which according to the Australian Energy Market Operator (AEMO) where "largely driven by transmission and distribution network price increases," - it was the perfect storm for solar uptake in the state.
GRAPHIC - Solar Installation.
Caption: Installations over time: from almost nothing to massive spikes in demand, the solar revolution in South Australia created an industry overnight and drastically changed power production. The lower amount of recent installations correlates with the end of the feed-in tariff program in 2013.

Record breaking activity

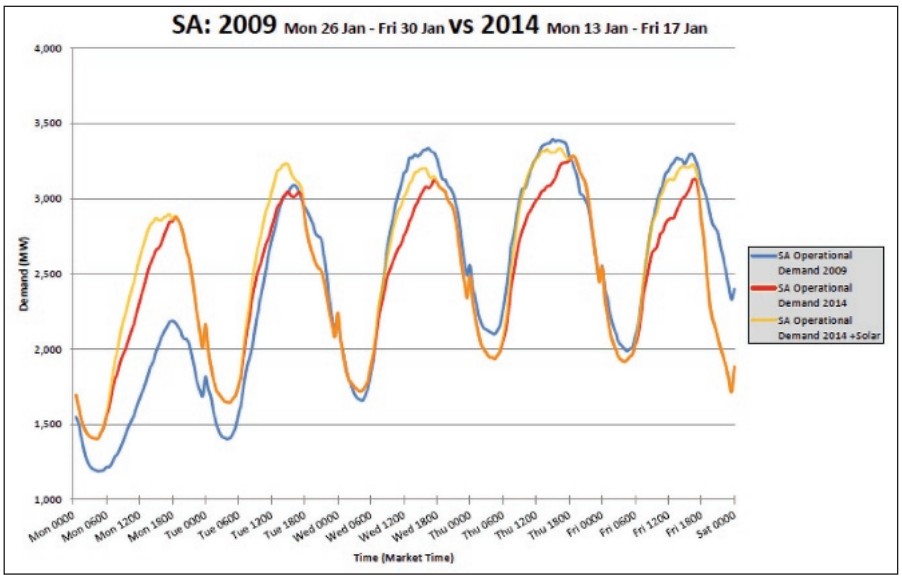
The state government also funded large solar infrastructure works, including a 1 MW solar array on the roof of the historic Adelaide Showgrounds. The array is big enough to power some 200 homes.

It was the largest rooftop photovoltaic (PV) array in the country at the time. It has more than 9,200 metres2 of panels and is more than five times larger than Australia's next biggest at Melbourne's Victoria Markets. The array is so large, in fact, that the Showgrounds are registered as a power station.

Currently, rooftop PV accounts for 5.2 per cent of the state's demand over the course of a year - 704 GWh per annum out of 12,855 GWh demand in 2013-2014. Solar's outlook is far more impressive during peak hours. On average, some 13.7% of peak demand is met by solar, though that can reach up to a quarter on certain days.

Solar proves even more useful during South Australia's summer heatwaves, when the grid is ill equipped to meet demand from energy-eating air conditioners and failing infrastructure. In perhaps the biggest shift in the state's energy outlook, solar scales up ahead of demand during these blazingly hot conditions, shifting and cutting peaks in the grid.

The AEMO released a report after the January 13-17 2014 South Australian heatwave. It recorded the first ever five-day period above 42 °C, the hottest five-day maximum temperature on record, the hottest maximum five-day average temperature (at 43.6 °C) and the fourth



The blue represents demand during a 2009 heatwave, before solar was widespread. The red line represents demand during the 2014 heatwave. The gold line shows solar power ramping up and feeding in to the grid slightly ahead of the rise in demand in 2014 - pushing the peaks later in to the day and cutting their length.

hottest day measured in South Australia (45.1 °C).

Network relief

Spark Infrastructure, which owns SA Power Networks, agreed that rooftop PV reduced stress on the network and introduced stability to the grid during the heatwave.

A decentralised network of power supply also means there's some failsafe during extreme conditions - another admission was that many of the traditional power generators were in high-risk fire areas during the heatwave.

It comes with a social payoff too. A lower risk of blackouts ensures that the state's most vulnerable citizens during a heatwave, such as the elderly, are kept cool and healthy.

The general social benefits of solar extend to low-income earners as well. They're much more likely to install panels than wealthier families, earning a degree of energy independence that buffers them from outside forces.

For one, the relative importance of power bills is much higher in these households. Spikes in the wholesale price of energy no longer put the crunch on solar generating homes, and the state's focus on renewables would also have taken the sting out of Australia's soon to be defunct Carbon Tax.

Sustainable Industries

Industries in South Australia have strongly taken to renewable energy - partly in thanks to the feed-in tariffs and payback that homes enjoyed but also for the green credentials that comes with a strong environmental profile.

That point runs especially true for agricultural food and produce exporters. 'Premium Food and Wine from our Clean Environment' is a South Australian tagline and one of the state's priorities.

Export markets such as China and Europe are increasingly prepared to pay more for the benefit of sustainable, cleanly sourced food and products. Australia can't be the food bowl of Asia, but it can find significant opportunities in supplying premium products to its growing middle class.

Jacob's Creek Winery in the Barossa Valley have heavily invested in low-waste practice and renewable energy. Their visitor's centre is flanked by two large solar arrays that produce all the energy the winery requires, selling the excess back in to the grid.

Brett McKinnon, Global Operations Director at Pernod Ricard Winemakers, owners of Jacob's Creek, said that the panels are part of their responsibility as a business.

"Environment has always been a big focus for at the site. These particular solar panels have a 40% higher output than standard fixed panels - they have the capacity to generate an impressive 220kWh per day," McKinnon said.

"We're a responsible business and have a commitment to minimising the impact we have on the environment we're operating in. Whether it's the solar panels used at the visitor centre, optimising our supply chain, or looking at our waste strategy, we're constantly looking for new ways to optimise the way we work.

"People often have their pictures taken next to them and we always hear visitors talking about them when they visit us. The solar panels are one of the first things people see when they enter the Jacob's Creek Visitor Centre - and we find it's also one of their lasting memories."

South of Adelaide, Softfoot Alpacas are a leading light in the livestock trade and one of the state's top export studs is also ahead of the curve on renewables.

Gary and Sandy Retallick purchased their farmland in the late 1990s. It was in dreadful condition due to overgrazing by sheep. Having got in to the alpaca game - in part due to the fact they're considered some of the most environmentally friendly livestock available - they turned the property around, Manager Ben Schmaal explains.

"Softfoot was originally set up as an environmentally conscious retreat for Gary and Sandy from their plastics manufacturing business in Adelaide. As Softfoot grew and they spent more time on the property, it became obvious that diesel generators were not an environmentally sound form on energy," Schmaal said.

"Due to the distance from the nearest point on the grid, renewables were the

only real option. Self tracking solar banks, as well as 40 panels were installed along with a wind turbine to offer a broad power profile to suit most conditions."
Their operation - including the farm, their residence and a guest facility - now sources all of its energy from wind and solar, with a battery bank that stores enough energy for any downtime.

Having rejuvenated the wetlands that once existed on the property, and planting 50,000 trees, Softfoot now runs as a carbon positive business. The Retallicks have also decided to connect to the grid in order to feed in their excess energy over the summer.

Manufacturing support

Agriculture isn't the only industry calling all in on renewable energy. One of the state's largest industry infrastructure projects, the Tonsley advanced manufacturing precinct, is also becoming one of the greenest.

Premier Jay Weatherill announced it would potentially become the largest solar installation in the state to date, putting out a tender for up to 25,000 square metres of solar panels to line the distinctive saw-tooth roof of the old plant.

"The rooftop of the main assembly plant has the capacity to generate the equivalent of electricity required to power up to 770 South Australian homes a year," Premier Weatherill said in a statement. There are hundreds, if not thousands of SA jobs in the renewable energy sector – these are the growth areas we should be supporting, not undermining."

The award winning Sustainable Industries Education Centre.

Built on the bones of the old Mitsubishi automotive plant, the Tonsley cluster is both a symbolic and literal revival of the state's struggling manufacturing industry as a cleaner, smarter activity.

"Tonsley is already a world leading example of sustainability and innovation in urban renewal and the announcement represents the next step forward in its commitment to design excellence and energy efficiency," the Premier said in a statement.

The project's green credentials expand beyond renewable energy. The Tonsley TAFE Sustainable Industries Education Centre won the Creative Re-Use Category at this year's World Architecture Festival Awards in Singapore for reusing 90% of the original steel structure.

ZEN Energy Systems are one of Tonsley's first major tenants. The solar installer and tech company recently received a $200,000 grant to ease their move in to the facilities. Richard Turner, CEO of ZEN, says that the potential for industry to collaborate with educational institutions is unprecedented.

"This is one of the first setups in the country that has enabled collaboration on campus. We're in the heart of the Sustainable Industries Education Centre.

Right above us is the renewable energy school, right below is the electrical school, next to us is the plumbing and solar thermal school, behind us is a carpentry school that is building houses and want to integrate our technology in to those," Turner said.

"People who come here, from all over Australia and overseas, they just go 'wow' - they can't believe what has been achieved here. The space and the technology and the scope for us to grow quickly from this base is incredible. It's all part of the long term vision."

An artists impression of the finished Tonsley precinct.

Part of Tindo's advanced manufacturing facility.

ZEN Energy has installed over 250,000 panels since they started in the business. Turner thinks there's still room to grow in the solar market, even though almost a quarter of South Australian homes are penetrated by the technology.

"Let's say overall we're 20% penetrated across the country. There's still another 40% in the middle there. That middle will be largely a finance based market. There are interesting models around paying for your system that effectively don't cost you anything - rental models, loan models, power purchase agreements.They revolve around the system paying for itself over time out of its own savings. I've been contacted by nearly every major financial institution in the last 12 months. They're all waking up together saying 'Okay, we understand solar is no longer in the realm of weird science.' This is real technology."

ZEN are currently searching for strategic partners that could take their business and brand to a wider national audience very quickly.

Solar boom

The solar sector is a major growth area in the state. Suntrix, a South Australian owned and operated solar installation company, was recently named one of the country's fastest growing companies by Business Review Weekly.

Suntrix's inclusion - due to its 66% growth in the past year - follows their 2013 Telstra South Australian Business of the Year award. Managing Director Jenny Paradiso was also named South Australia's Entrepreneur of the Year for 2014.

She believes that the residential market is becoming a tougher sell for solar installers, but there's still plenty of potential in commercial and utility scale solar.

"I wouldn't say solar has reached its saturation point. But all of the easy-pickings, so to say, are gone. We're still selling residential. In regards to the solar industry, residential is just such a small part of our business," Paradiso said.

Commercial is making up a larger portion of their business now, whether that's the local fish and chip shop or a huge 100 KW installation. Many solar companies from the early days of feed-in tariffs have also gone out of business, and Suntrix finds work maintaining and servicing their panels.

"The solar industry is going through rapid change, and we hope to see a long-term solution that respects the value that renewable energy brings," Paradiso said, referring to the federal Renewable Energy Target.

"We also want Suntrix to continue to be part of that solution. Any entrepreneur focuses on innovation to develop a competitive edge, and Suntrix is no different."

Tindo Solar are the only manufacturer of solar panels in Australia. They currently run a highly automated 60MW production line. Adrian Ferraretto, Managing Director of Tindo, believes that the ideological side of renewable energy certainly provides an incentive for potential customers - but it has to stack up financially too.

"There's definitely a desire - the vast majority of people love and believe in the idea of powering their lives with solar as opposed to burning coal and gas," Ferraretto said.

"At the end of the day it's not only an environmental product, it's a financial product, and I understand that. It needs to stack up - and it does at the moment. It's a stable market, a good market to work in."

Former Manager of People and Business at Tindo, Richard Inwood, recently stated that renewables have the capability to bolster the manufacturing industry in the state.

"Look at what's imported - this year it's about $1.4 billion in solar panels and if we replace 20% of that with an Australian made module, we're talking about 600 manufacturing jobs," Inwood said.
The Clean Energy Finance Corporation (CEFC) has recently provided them with up to $20 million in financing to build up that capability.

"The most important thing is that as we put in the extra capacity, our volume and our efficiency to manufacture is enhanced, which means our prices comes down, which means our competitiveness goes through the roof."

Wind in the sails

South Australia is the largest producer of wind energy in Australia. The state's 1.5 GW of wind energy make up almost half of the country's capability. It has changed the landscape of energy generation in the state. Of the two coal powered plants that were operating in South Australia, one has shut down and the other operates at reduced capacity for six months of the year.

During the recent 100% renewable energy working days in South Australia, wind energy was responsible for generating the majority of the state's power.
As wind supply rose over the course of that week, the wholesale price of electricity fell. That observation is backed up by a 2011 study by the University of New South Wales that shows an inverse relationship between wind generation and energy price in South Australia.

According to a submission to the AEMO from Tim O'Loughlin, former Commissioner for Renewable Energy, Its success in attracting so much wind investment is "largely the result of a confluence of factors such as: world class wind resources; a land use planning system which is regarded by investors as the most competitive in the nation; access to power lines and siting away from population centres."

Sustainable Regions

Kangaroo Island is one of Australia's most recognisable tourist destinations. Visitors are now greeted at the airport by a 50kW sun-tracking solar array.

It's part of a $500,000 project by RenewablesSA, Regional Development Australia and the Kangaroo Island council - a snapshot of what remote communities are capable of as part of the state's renewable future.

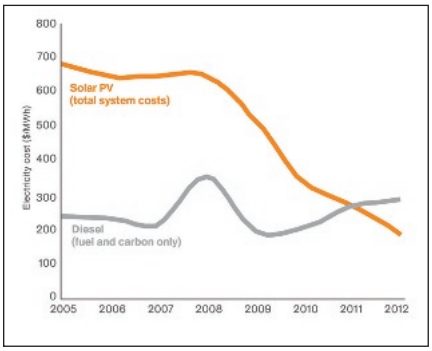
While not massive, the array offsets all electricity use by the airport and also supplies power for three electric vehicles provided by Nissan. The independence promised to remote and off-grid communities by renewable energy and infrastructure is significant. People in remote areas often suffer prohibitively high costs for energy due to fuel transport and market volatility. The natural gas and diesel mix that currently makes up much of the 15,812 GWh of off-grid electricity is the costliest electricity in the country. Richard Turner of ZEN Energy recently attended a conference on energy storage in Sydney and noted that major energy utilities were there as well.

"They're traditionally in the business of poles and wires and transport, but going forward there'll be energy storage and even solar panels come in to the mix of assets - because for a lot of the regional communities, the cost of enhancing the power grid is going to be far too much money," Turner said.

AECOM predicts the regional market's potential, fed by renewable technology suitable for remote areas, such as solar and wind, runs between $600 million to $2 billion, depending on penetration. Employment provided by manufacturing, installing and maintaining renewable technologies is huge. The Climate Institute predicts up to 5,000 jobs being created in South Australia's electricity sector by 2030, with the majority of those in renewables - and a significant slice in regional areas.

Remote assistance

The South Australian government currently provide energy to 3,400 customers in remote communities



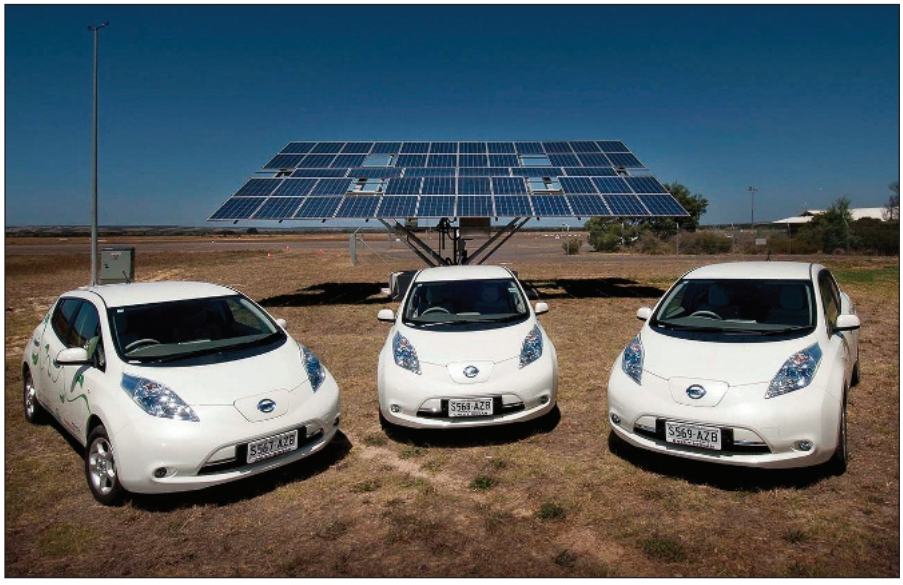
Solar vs Diesel price

through the Remote Areas Energy Supplies (RAES) scheme. These include 13 remote towns, and a number of Aboriginal communities across three Aboriginal Land Holding Authorities. Currently Parachilna is the only remote community under the RAES scheme to be powered by a hybrid solar/diesel system, where solar automatically replaces diesel generation when available, but more sites are being considered for the mix.

Industrial operations consume up to 79% of off-grid generation, with mining making up the majority of that, but they are increasingly moving towards self-generation from renewable means, growing at 6% each year. As the cost of PV generation falls, that share is likely to grow.

Battery Tech

ZEN Energy are best known for their Freedom Powerbank battery system,



The airport tracking area and three electric vehicles on Kangaroo Island.

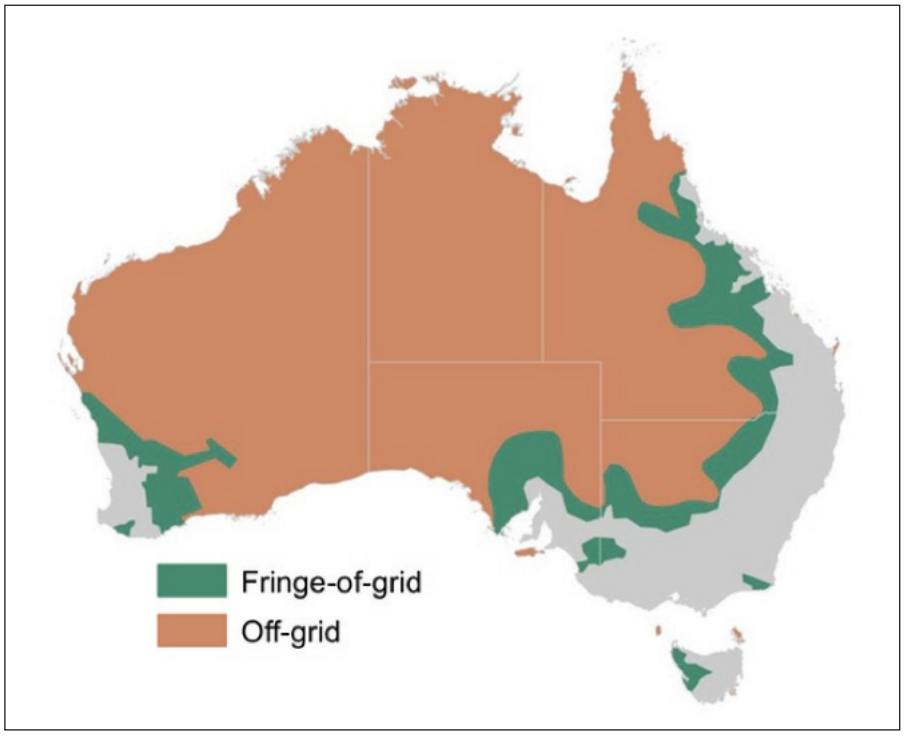
which almost doubled the effectiveness of batteries through software alone. They've received significant funding to further develop their software and technology. CEO Richard Turner believes that home energy storage will change the way we live.

"There is going to be a radical change. It's like moving from mainframe computing to PCs all over again - we're going from centralised energy generation and the grid to distributed energy generation and storage, where we generate and store and consume power where we need it," he says.

He's seen evidence that power utilities are strongly looking in to their own battery solutions and how to integrate more distributed energy production in the grid.

"It's a bit of a conundrum for them. We're part of their problem, but we're also part of the solution for them, in terms of cheaper augmentation of the power grid. Storage is a very good way of balancing and optimising because we can store power in low demand, pull it back in high demand, and actually flatten that demand curve."

ZEN sees three markets: the consumer market for people who want to go off grid, or become grid-independent, the retailer market for companies like AGL and Origin, who will be selling less power in the future as people become more self-sufficient - but will pick up the slack by selling more hardware such as solar and storage systems, and the utility market, as a partner to optimise the grid. They're not the only company at it: Tindo recently announced a collaboration with the University of South Australia to develop metal-air batteries which have the potential to increase capacity significantly.



It's also strongly in the interest of renewable energy suppliers to move in to these areas. Around 2% of Australia's population live in remote regions, yet they consist 6% of the nation's energy demand.

Tonsley during early construction. The sawtooth roof will soon be covered in a massive solar panel array.

Old graphite mines on South Australia's mineral-rich Eyre Peninsula are reopening, taking up the slack to provide resources to massive enterprises like Elon Musk's giga-factory making the next generation of batteries for electric vehicles.

South Australian mining companies such as Lincoln Minerals, Archer Exploration and Valence Industries have claims on huge deposits of some of the world's highest quality flake graphite.

"This is a commodity breakthrough starting to have tsunami-like demand dynamics," said Lincoln Minerals Managing Director Dr John Parker, about the rise of the electric car and demand for

lithium-ion batteries, of which graphite is a crucial component.

Valence Industries are also investing heavily in graphite and graphene - whether it's research or processing facilities - with a view to pursue high value markets such as battery-grade graphite. If large scale enterprises like the Nevada giga-factory succeed in pushing battery prices down for the electric car market, then technologies that South Australia already excels in, such as solar PV, will benefit from low storage costs and put further pressure on generators.

"South Australia could potentially be the first mainland state to go 100% renewables. While that figure might seem outlandish at first thought, there is modelling using actual demand, solar and wind data to suggest that renewables could supply all of the country's energy with a stable supply - even without battery storage"

The Renewable Future

South Australia's renewable future seems bright, even if recent developments in federal policy have slowed investment in the sector. The transition to renewables is a necessary development as the economic giants of the world - the United States and China - increasingly move towards clean energy themselves.

China has started imposing tariffs on dirty energy and coal imports as it declares as 'war on pollution'. Australia's growing market in the country's middle class also strongly relies on its image as a clean environment and producer.

India, though still a huge consumer of Australian coal, has also revealed plans to become a 'renewable superpower', expecting to invest $100 billion in to renewable energy within the next five years by doubling the 'clean energy' tax on coal to fund it. As the money starts to leave coal, new mineral opportunities present themselves in the graphite potential of the Eyre Peninsula. Major shifts in global investment are also proof that the world is moving away from traditional generation.

Investment bank Citigroup released a report last year warning major utilities of 'energy Darwinism': as renewables reach cost parity with coal and gas generated energy, their market share will be swept from beneath them. According to investment bank UBS, it could be economically feasible for Australian homes to jump off the grid entirely by 2018, using only solar and battery storage. Coupled with recent large profile divestments from fossil energy by the Australian National University and, more significantly, $50 billion from a Rockefeller family owned foundation, public and private perceptions are changing.

Traditional suppliers, such as Alinta Energy, are even investigating and investing in renewables. Their $2.3 million feasibility study in solar thermal generation looks like it will provide Port Augusta, with all of the regional town's energy needs.

According to the state government, South Australia passed the nation's first dedicated climate change legislation and was the first state with a greenhouse gas reduction strategy. The results of that are obvious across the board, with a booming renewables industry, a stable supply of green energy and efficiency savings across the state.

Leading light

South Australia could potentially be the first mainland state to go 100% renewables. While that figure might seem outlandish at first thought, there is modelling using actual demand, solar and wind data to suggest that renewables could supply all of the country's energy with a stable supply - even without battery storage. By following South Australia's early lead in its remarkable transition to clean renewable energy, taking advantage of the country's abundant wind and solar potential, Australia could shift from being one of the biggest OECD polluters per capita to one of the lowest.

Whatever happens, the share of renewables in the state will continue to grow. The investment that South Australia's prime export markets - places like China and India - pour in to their own renewable projects will grow too. It seems obvious that as those markets develop, so will opportunities to create new industries and break new ground.

One of the 80 kWh tracking arrays lining the road to the Jacob's Creek visitor's centre.

Australian researchers surpass 40% efficiency

University of New South Wales (NSW), led by Professor Martin Green, have achieved the highest solar efficiency for a standard solar cells recorded.

UNSW's solar researchers have converted over 40% of the sunlight hitting a solar system into electricity, the highest efficiency ever reported.

The world-beating efficiency was achieved in outdoor tests in Sydney, before being independently confirmed by the National Renewable Energy Laboratory (NREL) at their outdoor test facility in the United States.

The work was funded by the Australian Renewable Energy Agency (ARENA) and supported by the Australia–US Institute for Advanced Photovoltaics (AUSIAPV)

"This is the highest efficiency ever reported for sunlight conversion into electricity," UNSW Scientia Professor and Director of the Australian Centre for Advanced Photovoltaics (ACAP) Professor Martin Green said. "We used commercial solar cells, but in a new way, so these efficiency improvements are readily accessible to the solar industry," added Dr Mark Keevers, the UNSW solar scientist who managed the project.

The 40% efficiency milestone is the latest in a long line of achievements by UNSW solar researchers spanning four decades. These include the first photovoltaic system to convert sunlight to electricity with over 20% efficiency in 1989, with the new result doubling this performance.

"The new results are based on the use of focused sunlight, and are particularly relevant to photovoltaic power towers being developed in Australia," Professor Green said.

Power towers are being developed by Australian company, RayGen Resources, which provided design and technical support for the high efficiency prototype. Another partner in the research was Spectrolab, a US–based company that provided some of the cells used in the project.

A part of the design is the use of a custom optical bandpass filter to capture sunlight that is normally wasted by commercial solar cells on towers and convert it to electricity at a higher efficiency than the solar cells themselves ever could. Such filters reflect particular wavelengths of light while transmitting others.

ARENA CEO Ivor Frischknecht said the achievement is another world first for Australian research and development and further demonstrates the value of

investing in Australia's renewable energy ingenuity.

"We hope to see this home grown innovation take the next steps from prototyping to pilot scale demonstrations. Ultimately, more efficient commercial solar plants will make renewable energy cheaper, increasing its competitiveness."

The 40% efficiency achievement is outlined in a paper expected to be published soon by the Progress in Photovoltaics journal and be presented at the Australian PV Institute's Asia-Pacific Solar Research Conference that was held at the University of NSW.

Known as the 'Father of photovoltaics', Martin Green is a Scientia Professor at UNSW and Director of the Australian National Energy Agency-supported Centre for Advanced Photovoltaics. He was formerly a Director of CSG Solar, a company formed specifically to commercialise the University's thin-film, polycrystalline-silicon-on-glass solar cell. His group's contributions to photovoltaics are well known including the development of the world's highest efficiency silicon solar cells and the successes of several spin-off companies.

New world record for solar cell efficiency at 46%

French-German cooperation achieves record for multi-junction solar cell energy conversion.

A NEW WORLD RECORD for the direct conversion of sunlight into electricity has been established. The multi-junction solar cell converts 46% of the solar light into electrical energy and was developed by Soitec and CEA-Leti, France, together with the Fraunhofer Institute for Solar Energy Systems ISE, Germany.

Multi-junction cells are used in concentrator photovoltaic (CPV) systems to produce low-cost electricity in photovoltaic power plants, in regions with a large amount of direct solar radiation. It is the cooperation's second world record within one year, after the one previously announced in September 2013, and clearly demonstrates the strong competitiveness of the European photovoltaic research and industry.

Multi-junction solar cells are based on a selection of III-V compound semiconductor materials. The world record cell is a four-junction cell, and each of its sub-cells converts precisely one quarter of the incoming photons in the wavelength range between 300 and 1750 nm into electricity. When applied in concentrator PV, a very small cell is used with a Fresnel lens, which concentrates the sunlight onto the cell.

The new record efficiency was measured at a concentration of 508 suns and has been confirmed by the Japanese AIST (National Institute of Advanced Industrial Science and Technology), one of the leading centers for independent verification of solar cell performance results under standard testing conditions. A special challenge that had to be met by this cell is the exact distribution of the photons among the four sub-cells. It has been achieved by precise tuning of the composition and thicknesses of each layer inside the cell structure.

"This is a major milestone for our French-German collaboration. We are extremely pleased to hear that our result of 46% efficiency has now been independently confirmed by AIST in Japan", explains Dr. Frank Dimroth, project manager for the cell development at the German Fraunhofer Institute for Solar Energy Systems ISE. "CPV is the most efficient solar technology today and suitable for all countries with high direct normal irradiance."

Jocelyne Wasselin, Vice President Solar Cell Product Development for Soitec, a company headquartered in France and a world leader in high performance semiconductor materials, says: "We are very proud of this new world record. It confirms we made the right technology choice when we decided to develop this four-junction solar cell and clearly indicates that we can demonstrate 50% efficiency in the near future."

She adds: "To produce this new generation of solar cells, we have already installed a line in France. It uses our bonding and layer-transfer technologies and already employs more than 25 engineers and technicians. I have no doubt that this successful cooperation with our French and German partners will drive further increase of CPV technology efficiency and competitiveness."

New record solar cell on a 100 mm wafer yielding approximately 500 concentrator solar cell devices. ©Fraunhofer ISE/Photo Alexander Wekkeli

Midsummer halves CIGS layer on solar cells

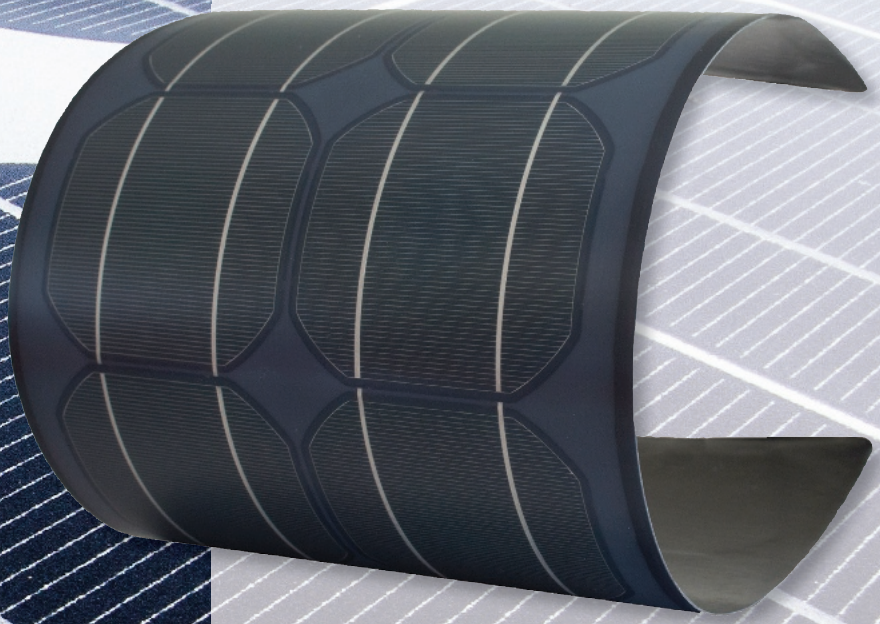
Thinner layer in flexible CIGS solar cells retain efficiency and cuts costs.

Midsummer, the Swedish maker of flexible thin film CIGS (copper-indium-gallium-selenium) solar cells, has reduced its CIGS layer thickness to 800nm. This is less than half of what other suppliers can offer, according to the company. “This puts the foundation for low manufacturing cost, which further strengthens the business case and attractiveness for Midsummer’s thin film CIGS solar cells”, said Sven Lindström, CEO at Midsummer.

Earlier this year, Midsummer announced that the company has managed to increase the efficiency of the whole solar cell to 16.2 percent aperture area of the full 156x156mm cell. Since then, Midsummer has raised the efficiency from 16.2 percent to 16.7 percent on 156x156mm aperture area. With the help of a new aggressive grading of the CIGS layer, they have also been able to thin it out to 800nm; normally the thickness of the CIGS layer is 2000nm.

Most of the light is absorbed in the first 800nm, so for productivity reasons the absorber layer can be kept thin.

A thinner CIGS layer has a number of advantages. CIGS is the most expensive layer in the solar cell; so reducing the thickness has major cost advantages. Also, if the CIGS layer is reduced, the production time is reduced which increases productivity. A thinner CIGS layer also means that it takes less energy to coat the layer. It also reduces the time during which



the substrate needs to be kept warm.

“Considering that the solar cell is made on stainless steel substrates, contains no cadmium buffer layer and that the production process is an all-dry, all vacuum process where all layers (including the buffer layer) are deposited by sputtering, this achievement by our engineers is truly impressive. By halving the thickness of the CIGS thin film solar cell the manufacturing cost will be significantly reduced, which further strengthens the business case”, said Sven Lindström, CEO Midsummer.

Midsummer’s scientists see the opportunity to reduce the thickness even further with a reflective back contact, i.e. any photons that have passed through the CIGS layer would be reflected and have the chance to do work on the way back.

“Our scientists are constantly working on reducing the thickness and they will now start to work on this opportunity. As soon as we are done we will report it. We are always aiming to increase the productivity in our machines while many of our competitors are chasing records, which means their CIGS-layers turn out to be thicker than ours”, Sven Lindström concluded.

Blu-Ray patterns enhance solar efficiency

It turns out Blu-ray discs are more useful than anticipated in the PV sector.

ALREADY one of the best ways to store high-definition movies and television shows because of their high-density data storage, Blu-ray discs also improve the performance of solar cells -- suggesting a second use for unwanted discs -- according to new research from Northwestern University.

An interdisciplinary research team has discovered that the pattern of information written on a Blu-ray disc -- and it doesn't matter if it's Jackie Chan's "Supercop" or the cartoon "Family Guy" -- works very well for improving light absorption across the solar spectrum. And better yet, the researchers know why.

"We had a hunch that Blu-ray discs might work for improving solar cells, and, to our delight, we found the existing patterns are already very good," said Jiaxing Huang, a materials chemist and an associate professor of materials science and engineering in the McCormick School of Engineering and Applied Science. "It's as if electrical engineers and computer scientists developing the Blu-ray technology have been subconsciously doing our jobs, too."

Blu-ray discs contain a higher density of data than DVDs or CDs, and it is this quasi-random pattern, perfected by engineers over decades for data storage, that, when transferred to the surface of solar cells, provides the right texture to improve the cells' light absorption and performance.

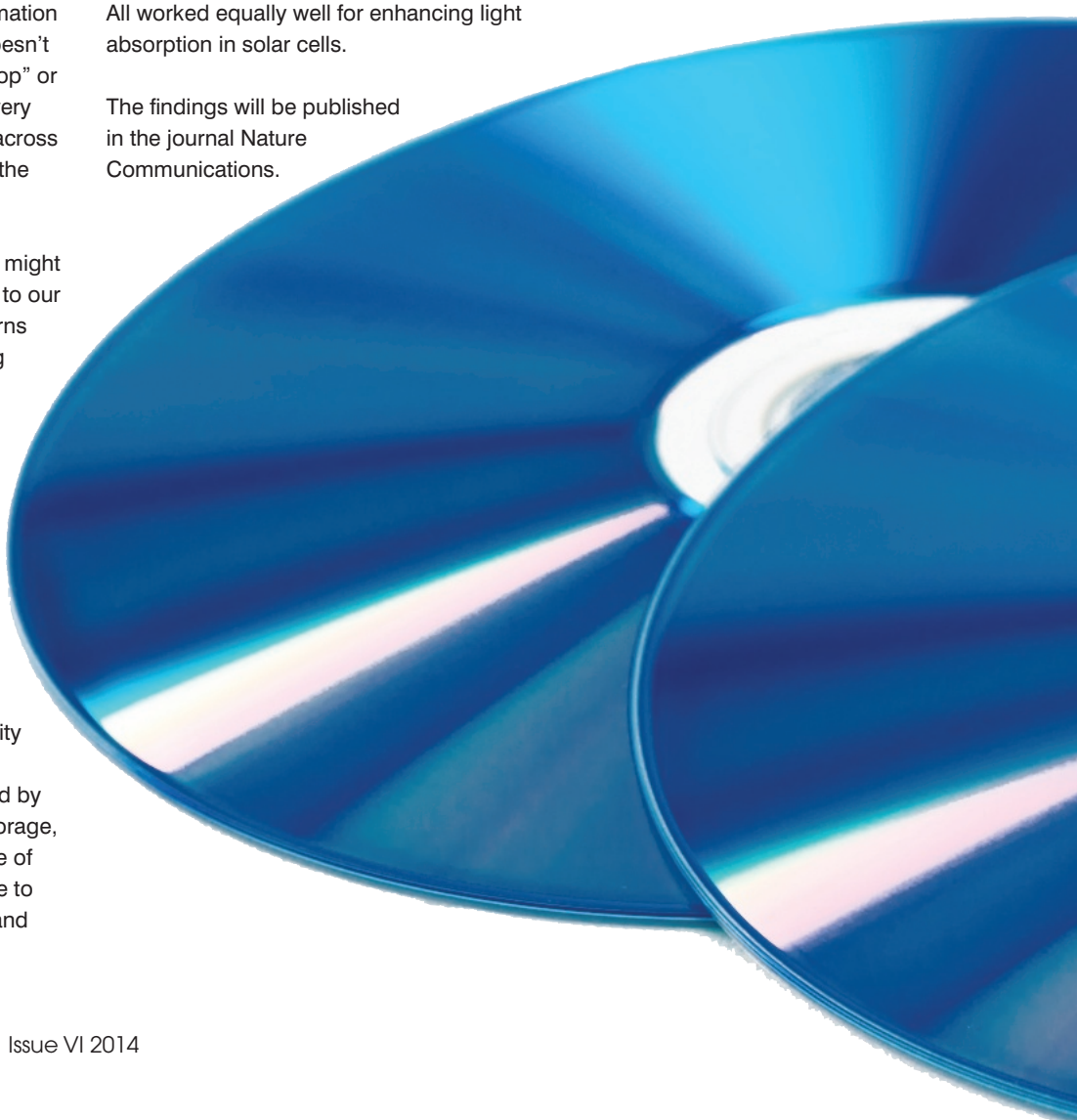
Working with Cheng Sun, an associate professor of mechanical engineering at McCormick, Huang and his team tested a wide range of movies and television shows stored on Blu-ray discs, including action movies, dramas, documentaries, cartoons and black-and-white content, and found the video content did not matter.

All worked equally well for enhancing light absorption in solar cells.

The findings will be published in the journal Nature Communications.

In the field of solar cells, it is known that if texture is placed on the surface of a solar cell, light is scattered more effectively, increasing a cell's efficiency. Scientists have long been searching for the most effective texture with a reasonable manufacturing cost.

The Northwestern researchers have demonstrated that a Blu-ray disc's strings



of binary code 0s and 1s, embedded as islands and pits to store video information, give solar cells the near-optimal surface texture to improve their absorption over the broad spectrum of sunlight.

In their study, the researchers first selected the Jackie Chan movie "Supercop." They replicated the pattern on the active layer of a polymer solar cell and found the cell was more efficient than a control solar cell with a random pattern on its surface.

"We found a random pattern or texture does work better than no pattern, but a Blu-ray disc pattern is best of all," Huang said. "Then I wondered, why did it work? If you don't understand why, it's not good science."

Huang puzzled over the question of why for some time. One day, his wife, Shaorong Liu, a database engineer at IBM, suggested it likely had something to do with data compression. That was the insight Huang needed.

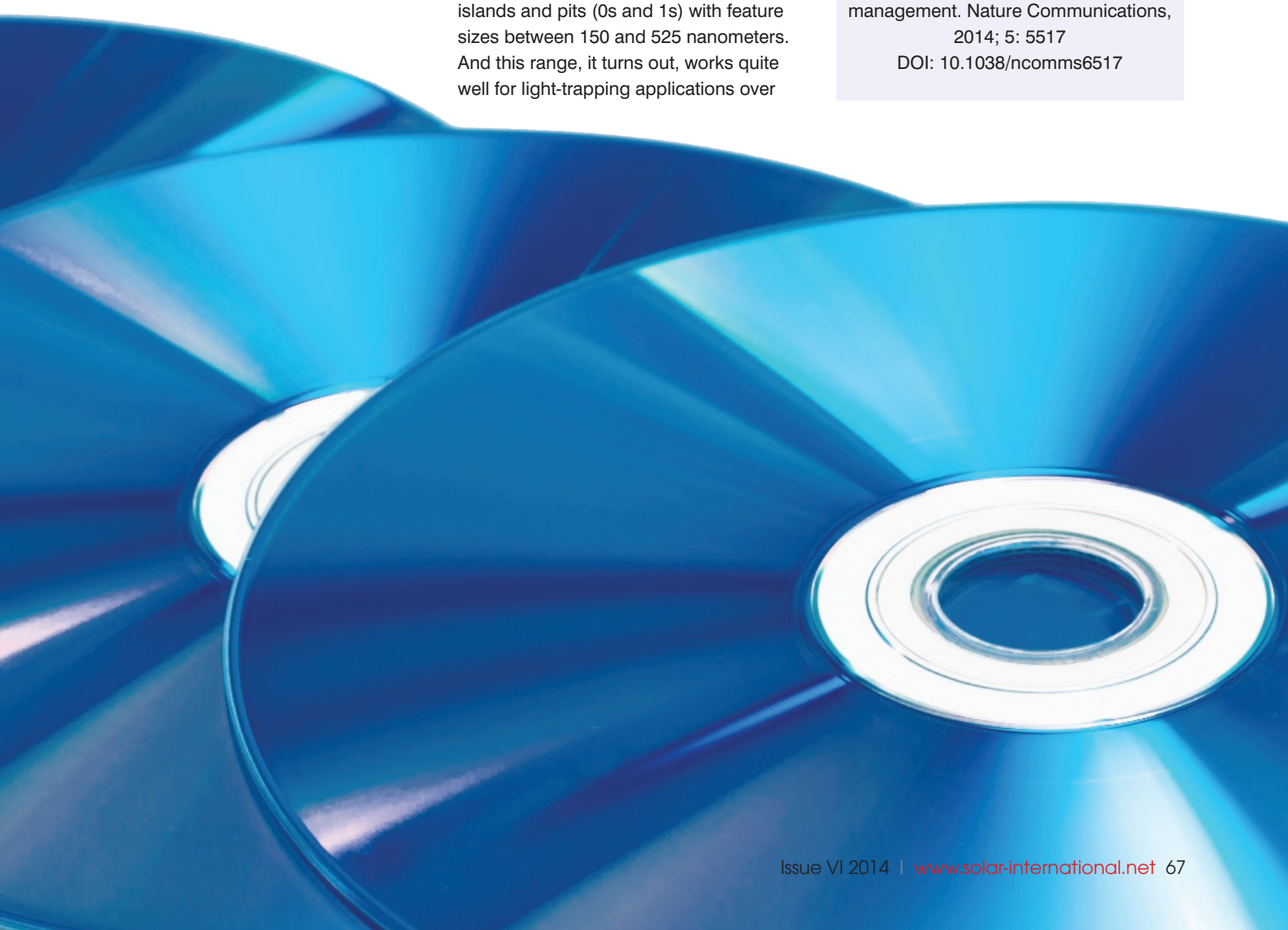
Huang and Sun then turned to McCormick colleague Dongning Guo, an expert in information theory, to investigate this idea. Guo is an associate professor of electrical engineering and computer science. The researchers looked closely at the data processing algorithms in the Blu-ray standard and noted the algorithms serve two major purposes:

Achieving as high a degree of compression as possible by converting the video signals into a seemingly random sequence of 0s and 1s; and Increasing error tolerance by adding controlled redundancy into the data sequence, which also limits the number of consecutive 0s and 1s.

These two purposes, the researchers said, have resulted in a quasi-random array of islands and pits (0s and 1s) with feature sizes between 150 and 525 nanometers. And this range, it turns out, works quite well for light-trapping applications over the entire solar spectrum.

The overall broadband absorption enhancement of a Blu-ray patterned solar cell was measured to be 21.8 percent, the researchers report. "In addition to improving polymer solar cells, our simulation suggests the Blu-ray patterns could be broadly applied for light trapping in other kinds of solar cells," Sun said. "It has been quite unexpected and truly thrilling to see new science coming out of the intersection of information theory, nanophotonics and materials science," Huang said.

Journal Reference:
Alexander J. Smith, Chen Wang, Dongning Guo, Cheng Sun, Jiaxing Huang. Repurposing Blu-ray movie discs as quasi-random nanoimprinting templates for photon management. Nature Communications, 2014; 5: 5517
DOI: 10.1038/ncomms6517



Fool's gold shows solar promise

As the installation of photovoltaic solar cells continues to accelerate, scientists are looking for inexpensive materials beyond the traditional silicon that can efficiently convert sunlight into electricity.

THEORETICALLY, IRON PYRITE, a cheap compound that makes a common mineral known as fool's gold, could do a reasonable energy conversion job in solar, but when it works at all, the efficiency remains frustratingly low. Now, a University of Wisconsin-Madison research team explains why that is, in a discovery that suggests how improvements in this promising material could lead to inexpensive yet efficient solar cells.

This lump of iron pyrite shows the characteristic cubic crystals of fool's gold. Defects in pyrite's crystal structure are an obstacle to building solar cells from the material.

"We think we now understand why pyrite hasn't worked," says chemistry Professor Song Jin, "and that provides the hope, based on our understanding, for figuring out how to make it work. This could be even more difficult, but exciting and rewarding."

Although most commercial photovoltaic cells nowadays are based on silicon, the light-collecting film must be relatively thick and pure, which makes the production process costly and energy-intensive, says Jin.

A film of iron pyrite — a compound built of iron and sulfur atoms — could be 1,000 times thinner than silicon and still efficiently absorb sunlight. Like silicon, iron and sulfur are common elements in the Earth's crust, so solar cells made of iron pyrite could have a significant material cost advantage in large scale deployment. In fact, previous research that balanced factors like theoretical efficiency, materials availability, and extraction cost put iron pyrite at the top of the list of candidates for low-cost and large-scale photovoltaic materials.

In the current online edition of the Journal of the American Chemical Society, Jin and first author Miguel Cabán-Acevedo, a chemistry Ph.D. student, together with other scientists at UW-Madison, explain how they identified defects in the body of the iron pyrite material as the source of inefficiency.

In a photovoltaic material, absorption of sunlight creates oppositely charged carriers, called electrons and holes, that must be separated in order for sunlight to be converted to electricity. The efficiency of a photovoltaic solar cell can be judged by three parameters, Jin says, and the solar cells made of pyrite were almost totally deficient in one: voltage. Without a voltage, a cell cannot produce any power, he points out. Yet based on its essential parameters, iron pyrite should be a reasonably good solar material.

"We wanted to know, why is the photovoltage so low," Jin says.

"We did a lot of different measurements and studies to look comprehensively at the problem," says Cabán-Acevedo, "and we think we have fully and definitively shown why pyrite, as a solar material, has not been efficient."

In exploring why pyrite was practically unable to make photovoltaic electricity, many researchers have looked at the surface of the crystals, but Cabán-Acevedo and Jin also looked inside.

"If you think of this as a body, many have focused on the skin, but we looked at the heart," says Cabán-Acevedo, "and we think the major problems lie inside, although there are problems on the skin."

The internal problems, called "bulk defects," occur when a sulfur atom is missing from its expected place in the crystal structure. These defects are intrinsic to the material properties of iron pyrite and are present even in ultra-pure crystals. Their presence in large numbers eventually leads to the lack of photovoltage for solar cells based on iron pyrite crystals.

Science advances by comprehending causes, Jin says. "Our message is that we understand why pyrite does not work. If you don't understand something, you must try to solve it by trial and error. You don't have to stumble around in the dark."

Journal Reference
Miguel Cabán-Acevedo, Nicholas S. Kaiser, Caroline R. English, Dong Liang, Blaise J. Thompson, Hong-En Chen, Kyle J. Czech, John C. Wright, Robert J Hamers, Song Jin. Ionization of High-Density Deep Donor Defect States Explains the Low Photovoltage of Iron Pyrite Single Crystals. Journal of the American Chemical Society, 2014; 141115145159006 DOI: 10.1021/ja509142w

Solar tree

Plans to install the "solar tree" next to the planetarium in Millennium Square as part of Bristol's European Green Capital year have been submitted to the city council.

ORDINARILY, news of a tree being planted in one of Bristol's squares wouldn't be greeted with much fanfare. But when it is made of steel and capable of catching solar energy through its multi-directional "leaves", you can understand why it is making waves.

The tree has been billed as "functional public sculpture", designed to engage people in renewable energy.

Created to mimic a natural tree, its leaves are solar panels made by recovering addicts from the Bristol Drugs Project.

If it gets planning permission and is installed in the square, the tree will serve as a hands-on exhibit. Visitors will be able to charge mobile phones for nothing and it will also act as a free wi-fi hotspot.

There will be an interactive tilting solar panel demonstrating the photovoltaic (PV) method – converting sunlight into electricity – in different light conditions. Science centre At-Bristol intends to use the energy created from the tree to help power its interactive science exhibits.

At-Bristol is a main partner in the project, which been backed by Bristol Civic Society.

A statement included with the planning application, submitted by Demand Energy Equality, said: "The sculpture will engage and inspire members of the public around the key themes of renewable energy, the science of solar PV technology and the need to reduce energy consumption.

"It will take its place as a valuable addition to the At-Bristol estate, adding to the interactive educational exhibits and resources available to the Bristol and wider public for the purpose of public science education.

"The proposal also has support from a wide variety of sources, ranging from the Bristol Green Capital Energy and Education Action Groups (in light of the Tree's prominent place in the 2015 European Green Capital Year programme), the Bristol Drugs Project, At-Bristol, assistant Bristol Mayor Gus Hoyt and the Bristol Civic Society."

The solar tree, created by Bristol artist John Packer, is set to be installed in an existing planter in the square, to replace a tree due to be removed due to its age.

A statement about the artist's approach said: "The solar panels are functional and collect the sun's rays throughout the day. The body of the tree references functional urban structures like site tower cranes and the old dock cranes near Millennium Square."

Demand Energy Equality have already funded a prototype of the tree in Brislington to provide renewable energy for a nearby Edible Futures nursery.

A letter of support from Phil Winfield, At-Bristol's chief executive, said: "The solar tree fits perfectly with the rationale behind the At-Bristol site and complements the purpose of Millennium Square, as well as playing a key role in our science education work."

Netherlands construct solar road

The first road in the world that converts sunlight into electricity is ready for use.

SOLAROAD IS A PIONEERING INNOVATION in the field of energy harvesting. It is a unique concept, which converts sunlight on the road surface into electricity: the road network works as an inexhaustible source of green power.

The SolaRoad pilot road has been opened this week. SolaRoad is a road surface that acts as a solar panel. SolaRoad was officially opened on the 12th of November by Minister Kamp. This is the first road in the world that converts sunlight into electricity. SolaRoad was developed by TNO, the Province of North-Holland, Ooms Civiel and Imtech Traffic&Infra.

The pilot road of just a hundred metres consists of concrete modules each of 2.5 by 3.5 metres. Solar cells are fitted in one travelling direction underneath a tempered glass top layer which is approximately 1-cm thick. There are no solar cells on the other side of the road and this is used to test various top layers. In time, the solar power from the road will be used for practical applications in street lighting, traffic systems, electric cars (which drive on the surface) and households. This first section of

SolaRoad is located in Krommenie, The Netherlands. For a three-year period, various measurements will be taken and tests performed to enable SolaRoad to undergo further development. The tests must answer questions such as: How does it behave in practice? How much energy does it produce? and What is it like to cycle over? In the run-up to the surface being laid, the road was tested in the laboratory to ensure that it fulfils all (safety) requirements for road surfaces.

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Editor-in-Chief David Ridsdale
T: +44 (0)1923 690210 E: david.ridsdale@angelbc.com

Director of Solar Publishing Jackie Cannon
T: +44 (0)1923 690205 E: jackie.cannon@angelbc.com
Sales Manager Shehzad Munshi
T: +44 (0)1923 690215 E: shehzad.munshi@angelbc.com
Director of Logistics Sharon Cowley
T: +44 (0)1923 690200 E: sharon.cowley@angelbc.com
Design & Production Manager Mitch Gaynor
T: +44 (0)1923 690214 E: mitch.gaynor@angelbc.com
Circulation and Subscriptions
T: +44 (0)1923 690200 E: circ@angelbc.com

Directors:
Bill Dunlop Uprichard – CEO
Stephen Whitehurst – COO
Jan Smoothy – CFO
Jackie Cannon, Scott Adams, Sharon Cowley, Sukhi Bhadal, Jason Holloway

USA Representatives: Tom Brun, Tom Brun Media,
T: 724 539-2404, E: tbrun@brunmedia.com
Janice Jenkins, Tom Brun Media.
T: 724 929-3550, E: jjenkins@brunmedia.com

Japan Representative: Katsuhiro Ishii,
Ace Media Services Inc.,
T: 81-3-5691-3335 E: amskatsu@dream.com

China Representative: Parker Xu, Unionbandy Limited,
T: 86-755-83753881, E: xp@unionbandy.net

Published by: Angel Business Communications Ltd (London Office), Hannay House, 39 Clarendon Road, Watford, Herts WD17 1JA, UK

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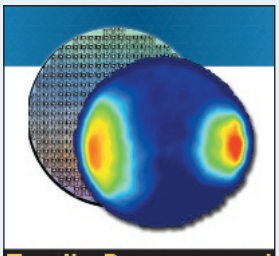

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