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editor's view

By david ridsdale, editor-in-chief

Globally optimistic, locally cautious

Analysts seem to be in agreement that 2014 is going to develop into an excellent year for the global solar and PV markets with strong growth leading to renewed expansion from the larger manufacturers. While all this may be true from a global perspective the impact of such news will generally only be felt by the international companies large enough to be represented in enough markets to absorb the good with the bad. For more localised businesses the year's success will be all about location, timing and luck.

Global growth indicators tell us very little about local situations and it is no surprise that some areas will do better than others. What the global growth figures do tell us is the speed at which markets are ramping up and then consolidating. A cursory look at analysts predictions over the last few years points to the need for new markets to be constantly developed. Europe's stalwart markets of the last decade are slowing down in terms of year on year growth. The high end growth continues to occur in regions with the best government financial supports. Much of the growth that the analyst figures aims to identify comes with high end returns.

Global data still does not provide enough detail to determine regional success. Japan is tipped to be one of the strongest markets over the next couple of years but the Asia Pacific region is tipped to experience only modest improvements. Other regions focus on the percentage increase of installations but this is bound to appear impressive at the start of an industry and the benchmark is near zero.
The financial returns of PV and solar is what drives analysts and investors to focus on the larger global movements but

fails to acknowledge the continual growth in areas that may be decreasing the financial support. The reduction in support is indicative of a strong industry that in some areas is already receiving less support than the comparable fossil fuel producers in the region. Germany may be reducing its financial supports and returns may not be as high as previously possible but the country is expected to be the number one market in Europe again by 2015. The industry there is strong and growth steady and consistent.

So while there is room for optimism at the global growth numbers that will inspire manufacturing expansions that will in turn encourage growth along the value chain of tool and material suppliers, there also remains caution at the local level where companies are realising their success is too often tied into local government policy decisions based on issues not always relevant to the local region.

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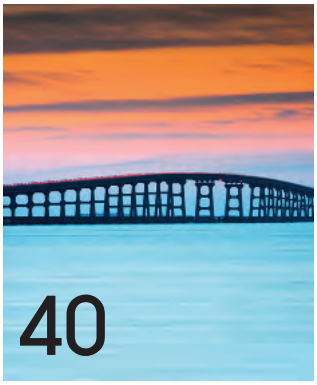

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First Solar passes 20% to break CdTe record

FIRST SOLAR has announced it has set a world record for cadmium-telluride (CdTe) photovoltaic (PV) solar cell conversion efficiency, achieving 20.4 percent conversion efficiency certified at the Newport Corporation's Technology and Applications Centre (TAC) PV Lab and confirmed by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). The record-setting cell was constructed at the company's Perrysburg, Ohio factory and Research & Development Centre.

This certified result bests the previous record of 19.6 percent conversion efficiency set by GE Global Research in 2013. Last April, First Solar and GE announced a solar technology partnership in which First Solar acquired GE's CdTe solar intellectual property and secured a collaborative research partnership with GE's R&D team. The partnership was formed to accelerate innovation in PV technology and accelerate solar module performance at manufacturing scale.

"This record marks another achievement in our mission to unlock the industry-changing potential of CdTe PV," said Raffi Garabedian, First Solar's Chief Technology Officer. "We are demonstrating improvement in CdTe PV performance at a rate that dramatically outstrips the trajectory of conventional silicon technologies, which have already plateaued near their ultimate entitlements. The synergy realized in our partnership with GE also demonstrates the value of our consistent and strong investment in R&D. The advanced technologies and processes we developed for this record-setting cell are already being commercialized and will positively impact performance of our future production modules and power plants."

First Solar's new CdTe research cell conversion efficiency matches the research cell efficiency record of multicrystalline silicon, another technology used in the PV solar market.

First Solar has continued to transfer its success in the R&D lab into its commercial modules, increasing its average production module efficiency to 13.4 percent in the fourth quarter of 2013, up 0.6 percent from 12.9 percent in the fourth quarter of 2012. The company's lead line was producing modules with 13.9 percent average efficiency at the end of 2013.

Global demand for polysilicon to surge 25 percent

Demand for polysilicon used in solar and semiconductor applications is expected to rise sharply to 282,000 metric tons in 2014, up 25 percent versus last year.

According to the latest NPD Solarbuzz Polysilicon and Wafer Supply Chain Quarterly report, the growth in demand for polysilicon is being driven by the rapid increase in end-market solar photovoltaic (PV) module shipments, which are now expected to reach approximately 49 gigawatts (GW) this year.

Polysilicon used for semiconductor applications typically requires very high purity of 11N (99.999999999 percent) and very low levels of contaminants. Semiconductor polysilicon is a high value-added segment, but future demand growth in this mature market is only expected to be modest. Solar PV-grade polysilicon has less stringent purity requirements, but it has the potential for very high growth, when solar panel demand is strong; however, the growth trajectory in polysilicon supply and end-market demand is not always directly correlated.

It may take three to six months after polysilicon is produced for it to be converted into wafers and cells, and then shipped as finished modules through distribution channels for installation. This lag time can push polysilicon demand higher than module demand, in a rapidly expanding market.

"Conversely, the amount of silicon required per watt at the module level has been declining steadily each year," said Charles Annis, vice president at NPD Solarbuzz. "Solar supply chain companies have lowered the number of grams-per-watt by reducing wafer thickness and kerf loss, increasing yields in all manufacturing steps, reducing module loss, and continuously raising panel efficiency." Between 2005 the end of 2014, the average amount of silicon used in a solar module will fall by 55 percent, to approximately 5 grams-per-watt.

This trend is expected to continue, though at a slower rate, as many of the material reduction steps implemented to decrease polysilicon consumption have now been exhausted.

Robust end-market solar-PV demand continues to drive polysilicon production levels. This, in turn, raises module efficiencies and reduces costs, which will remain important priorities across the entire solar-PV supply chain, in order to increase profitability in 2014 and stimulate increased end market demand in future years.

Indian PV forecast raised to 1GW

INDIAN SOLAR installations are forecast to be approximately 1,000 MW in 2014, according to Mercom Capital Group, a global clean energy communications and consulting firm. Solar installations in India totaled 1,004 MW in 2013 compared to 986 MW in 2012. In line with Mercom's forecast, there was very little growth in installations year-over-year. The firm's detailed survey of the market revealed that growth in installations might be elusive again in 2014 with numbers forecast to be similar to 2012 and 2013.

According to Mercom, there are several factors behind the slow solar growth. With a few exceptions, there are no Jawaharlal Nehru National Solar Mission (JNNSM) PV projects expected to come online until at least mid-2015.

Most CSP projects have stalled, state policies are all over the map, and as the company has warned for some time, India is now in a trade dispute with the U.S. in the World Trade Organization (WTO).

"It is time for developers to go directly to consumers, there is a large power-starved market waiting to be served that looks better and better every day as diesel prices keep climbing," commented Raj Prabhu, CEO and Co-Founder of Mercom Capital Group.

The United States recently announced its request for WTO dispute settlement consultations with India regarding the Domestic Content Requirement (DCR) in JNNSM Phase II projects. The United States claims that DCR rules discriminate against U.S.-manufactured solar cells and modules. In Phase II, India has extended DCR rules to include thin film technology.

In addition to difficulties with project economic viability stemming from reverse auctions that have pushed down project margins, state policies have been delayed frequently, there is no real Renewable Purchase Obligation (RPO) enforcement in place, and national elections are fast approaching adding more uncertainty to India's solar market which could result in a slowdown in large-scale solar project installations.

Nevertheless, Mercom stressed that India's solar market potential remains as large as ever, even in a slower-growing economy. As power shortages continue, peak shortage is a critical problem that has stifled industrial growth, and back-up generation is becoming increasingly expensive.

The government of India announced partial deregulation of diesel prices in January 2013, by incremental price increases of ~ 0.50 (~$0.008)/month for retail customers, as the government tries to get subsidized diesel to a market-based price.

This rise has resulted in a ~15 percent increase in diesel prices over the last 13 months, making solar a very attractive option. Meanwhile, coal has not been the answer to the country's energy problems with its own supply shortage issues, and coal power plants are increasingly dependent on imports as prices continue to climb.

"The case for solar in India will remain strong as long as the relevant policy goals address power shortages that affect millions of Indians, businesses, industries, and agriculture," added Prabhu.

Concentrating solar power market to shrink

THE OPENING of the Ivanpah CSP plant has brought renewed interest in the technology. The crash of PVmodule prices will cause the CSP market to decline from 2.45 GW in 2013 to 2.0 GW in 2018. The technology has the potential to bounce back and beat multicrystalline silicon in LCOE, according to Lux Research.

"CSP has fallen by the wayside of the solar industry after attracting huge amounts of government and investor money in 2010 and 2011. But the industry can still bring the technology back to the forefront for utility-scale, stand-alone power applications," said Ed Cahill, Lux Research Associate and the lead author of the report titled, "Turning Up the Heat on Advanced Concentrating Solar Components."

Lux Research analysts evaluated CSP technologies and economics in order to discover optimal models. Among their findings were thermal energy storage (TES) are among the top targets for cost reduction. Today's CSP system costs are 37% to 60% higher than mc-Si without TES – and 300% to 600% higher with 14 hours of TES. Storage is among the largest portions of the system cost stack, and will be a primary target for system components.

Advanced power towers will win for large projects. Supercritical steam systems are the most likely to come to fruition by 2020. The next step for power towers will likely be toward Air Brayton and supercritical CO2 systems that can beat mc-Si's LCOE by 31% and 33%, respectively. Fresnel reflector systems are best for small projects. Linear Fresnel reflectors with molten salt heat transfer fluid can undercut mc-Si's LCOE by 6% and have the most potential to dominate smaller CSP projects and alternative applications like integrated solar combined cycle (ISCC), industrial heat and enhanced oil recovery (EOR).

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World's largest solar thermal plant begins operations

NRG SOLAR has announced that the Ivanpah Solar Electric Generating System is now operational and delivering solar electricity to California customers. At full capacity, the facility's trio of 450-foot high towers produces a gross total of 392MW of solar power, enough electricity to provide 140,000 California homes with clean energy and avoid 400,000 metric tons of carbon dioxide per year, equal to removing 72,000 vehicles off the road.

Ivanpah is a joint effort between NRG, Google, and BrightSource Energy. Bechtel is the engineering, procurement, and construction contractor on the project. The project received a $1.6 billion loan guarantee from the US Department of Energy's Loan Programs Office.

The facility achieved commercial operation on December 31, 2013. NRG will be the plant's operator.

Ivanpah, which accounts for nearly 30 percent of all solar thermal energy currently operational in the US, is the largest solar project of its kind in the world. The project is the first to use BrightSource's solar power tower technology to produce electricity, which includes 173,500 heliostats that follow the sun's trajectory, solar field integration software and a solar receiver steam generator.

Since breaking ground in October 2010, the project has created thousands of jobs and, at the peak of construction, employed nearly 3,000 site workers who completed more than 8.35 million man-hours. A total of approximately $650 million in salaries for construction and operations is expected to be paid over the next 30 years.

"Cleantech innovations such as Ivanpah are critical to establishing America's leadership in large-scale, clean-energy technology," said Tom Doyle, president, NRG Solar. "We see Ivanpah changing the energy landscape by proving that utility-scale solar is not only possible, but incredibly beneficial to both the

economy and in how we produce and consume energy. "

"Achieving commercial operation is a result of a well-coordinated effort between the Ivanpah project affiliates and Bechtel," said Toby Seay, president of Bechtel's power global business unit. "Consistent teamwork with a focus on safety and quality is key to executing a project of this size and complexity."

The solar energy harnessed from Ivanpah's Units 1 and 3 are being sold to Pacific Gas & Electric under two long-term power purchase agreements, while the electricity from Unit 2 is being sold to Southern California Edison under a similar contract.

"Congratulations to the Ivanpah team for achieving commercial operation," said Rick Needham, Google's director of energy and sustainability. "At Google we invest in innovative renewable energy projects that have the potential to transform the energy landscape and help provide more clean power to businesses and homes around the world. Ivanpah is a shining example of such a project and we're delighted to be a part of it."

"This is a culmination of many years of hard work by all of our partners at Ivanpah. The completion of this project is a watershed moment for solar thermal energy. With all three units now delivering power, BrightSource has demonstrated its technology at scale," said David Ramm, chairman and CEO of BrightSource Energy. "This is a great kickoff to 2014, as BrightSource focuses increasingly on international markets and applications for our solar steam technology."

EU WEEE directive is only law in two countries despite deadline

THE OFFICIAL 18-month transition period for transposing the revised WEEE Directive into national law has ended. Originally launched in 2003, the Waste Electrical and Electronic Equipment Directive (WEEE) regulates the treatment of electrical and electronic waste at the end of their life cycle. The directive has been amended twice in 2008 and 2012, resulting in many new additional products. PV modules were introduced in the latest revision of 2012.

"Waste management has been a reality for a vast majority of the European PV market since 2007. Including PV modules in the enlarged scope of the recast WEEE Directive has simply created a mandatory framework for every PV actor putting PV modules on an EU market for the very first time", explained Jan Clyncke, Managing Director of Europe's leading take-back and recycling scheme for PV module waste.

With entry into force on January 1, 2014, the UK and Bulgaria were the first countries to transpose the new text into national law. So far, no other EU Member State has implemented their national version of the EU directive. Although key PV markets like Germany, Italy, France and Spain are yet to incorporate iit into national laws, WEEE will remain relevant to the PV sector in 2014 and beyond.

$30 million to arpa-e projects for hybrid solar energy technologies

US ENERGY SECRETARY Ernest Moniz has announced $30 million in funding to 12 ARPA-E projects to develop transformational hybrid solar energy technologies that deliver cost-effective power when the sun is not shining.

These projects will help advance solar energy beyond current photovoltaic (PV) and concentrated solar power (CSP) technologies to drive lower-cost, reliable solar energy deployment.

In the State of the Union address, President Obama highlighted the US growing role in solar as demonstrated in a new industry report which recently found that U.S. utility-scale solar set a record with 2.3 gigawatts installed in 2013.

"The United States is becoming a global leader in solar and we're seeing more and more Americans rely on affordable, clean solar energy to power their homes and businesses." said Secretary Moniz. "The Energy Department is working across the industry to help our country's top engineers, scientists and entrepreneurs bring new solar innovations to market faster. The ARPA-E projects announced are exactly the type of innovative technologies we need to keep breaking through barriers – advancing lower cost, highly efficient solar power."

As part of the announcement, Secretary Moniz will award $30 million to 12 projects through ARPA-E's Full-Spectrum Optimized Conversion and Utilization of Sunlight (FOCUS) program, which is aimed at developing new hybrid solar energy converters and hybrid energy storage systems that can deliver low-cost, high-efficiency solar energy on demand.

Under the FOCUS program Sharp Labs of America will receive about $4 million to develop a hybrid solar converter that could enable utilities to provide on-demand and low-cost solar electricity.

MicroLink Devices will receive about $3.6 million to develop high-efficiency solar cells that can operate at temperatures above 750°F and can extract the most energy possible from sunlight when the panels are integrated with hybrid solar converters.

Australian solar industry ready for review

THE RENEWABLE ENERGY INDUSTRY in Australia has welcomed the start of the Federal Government's review of the Renewable Energy Target, saying the scheme's low cost and massive benefits could now be decisively demonstrated and critics' misleading claims debunked.

"The clean energy industry is keen to show the huge positive impact of a stable target, delivering 41,000 gigawatt hours of large-scale renewable energy and millions more solar households and businesses by 2020," Clean Energy Council Chief Executive David Green said today.

"We relish the opportunity to demonstrate the $18 billion value that the existing Renewable Energy Target represents for our economy, and also for the nation to show current and future investors that Australia is open for business.

"Prime Minister Tony Abbott obviously appreciates all this, saying today that 'Renewable energy makes a lot of sense', while also acknowledging the government's need to avoid creating sovereign risk by respecting decisions businesses have made 'in good faith'."

Contrary to claims from some Renewable Energy Target opponents, it contributes only a small amount to power bills – yet has already supported many billions of dollars of investment in Australia's economy along with 30,000 jobs, Mr Green said.

Respected analysts including the Australian Energy Market Commission have estimated the cost of the Renewable Energy Target at just 3 to 5 per cent of power bills.

"Every review of the Renewable Energy Target to date has shown that it is doing what it is meant to – delivering clean energy such as solar, wind, bioenergy and hydro at the lowest possible cost to consumers, while providing thousands of jobs and significant investment across Australia.

"This is all the more important when we consider the main alternative – gas – is predicted to triple in price this decade, according to the Australian Industry Group. Without renewables, these price hikes will flow onto the power bills of Australian businesses and households."

Mr Green said the Renewable Energy Target had been one of Australia's most frequently-scrutinised policies, as legislation currently requires a review of the policy every two years.

"The industry is looking forward to proving its case on the benefits of the current Renewable Energy Target so the two-yearly review requirement is removed, providing investors with the confidence they need to support clean energy projects."

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Report suggests localised grid defections in US by 2025

ROCKY MOUNTAIN INSTITUTE (RMI), HOMER Energy and CohnReznick Think Energy (CRTE) have released a report detailing the potential for appreciable customer defection from the electric grid in major markets by 2025, without incurring higher costs or lower reliability. The report shows that, as the hybrid combination of solar photovoltaic and battery storage become cost competitive with retail grid electricity rates, migration of customers away from the grid could happen well within the 30-year planned economic life of typical utility investments such as central thermal generation plants and transmission infrastructure.

In the first installment of two reports, RMI, HOMER and CRTE outline the possible scenarios in five different U.S. regions, Hawaii, California, Kentucky, Texas and New York, and identify when solar PV and storage combinations could disrupt existing utility business models. The decline of solar PV and battery storage costs, coupled with increasing retail electricity prices, has resulted in grid parity for commercial customers in Hawaii. The most optimistic projections, based on certain solar and efficiency targets being met, depict grid parity for millions of residential and commercial customers in New York and California within this decade.

Key points in the report include the fact that a considerable number of utility customers will likely see favourable defection economics within 10 years. Utilities will likely experience significant revenue decay before defection. The likelihood of favourable long-term customer defection signals the eventual demise of traditional utility regulatory models.

“Solar-plus-storage represents a fundamentally new paradigm,” said RMI Managing Director Jon Creyts, PhD. “While other distributed generation options still require some degree of grid dependence, solar-plus-storage provides an opportunity for customers to cut the cord to their utility entirely. To remain

competitive, utilities need to understand how to leverage hybrid systems within the electricity system.”

Even before total grid defection becomes a reality, utilities will see further revenue decline since solar-plus-battery systems sized to meet most of a customer’s load will become cost effective sooner. In addition, other motivating factors such as customer desire for increased power reliability and low-carbon electricity generation are driving early adopters ahead of grid parity.

“To best compete, property owners and developers will need to understand how distributed generation and storage is rapidly changing energy economics,” said CRTE Founder and President Mark Crowdis. “By assessing the impact of these new technologies and the innovative contracting approaches that support them, property owners can be at the leading edge of this new market, ensuring long term financial savings for their properties.”

The second installment of the report will offer solutions for how utilities might rethink the “threat” of such hybrid resources and unlock opportunities through new business models, within existing regulatory frameworks or under an evolved regulatory landscape, to better capture the value of distributed resources.

“As storage and control technologies improve, we have the opportunity to incorporate more and more renewable energy sources into the grid in a way that balances and optimizes those power sources,” said HOMER Energy CEO Peter Lilienthal, PhD.

Asia Pacific to experience modest growth

THE ASIA-PACIFIC (APAC) solar photovoltaic (PV) module market value is forecast to show modest growth by the end of next year, jumping from $6.7 billion in 2012 to $8.6 billion by 2015, at a Compound Annual Growth Rate (CAGR) of 7.9%, says a new report from research and consulting firm GlobalData.

According to the report, the APAC region’s solar PV installed capacity is also expected to increase over the coming years, from 19.6 Gigawatts (GW) in 2012 to 420.6 GW by 2030, at a CAGR of 18.6%. In 2013, China and Japan led the region with a combined total of 77% of capacity. APAC is also the world leader for solar energy systems manufacturing, with Japan, China and Taiwan being three of the largest solar PV cell producers.

Prasad Tanikella, GlobalData’s Senior Analyst covering Alternative Energy, said, “With favourable conditions contributing to a thriving manufacturing industry, China continued to be the world’s largest manufacturer of solar modules for the sixth consecutive year in 2013. Domestically available polysilicon, a favourable regulatory environment and an easily available and inexpensive labour force have allowed companies, such as Yingli Green Energy, Canadian Solar Inc., Trina Solar, LDK Solar and Suntech Power Holdings Co., to lead solar module production capacities.”

Solar EPC landscape consolidates

THE 30 LARGEST Engineering, Procurement and Construction (EPC) companies in the global PV industry installed 30 percent of the world's non-residential PV capacity in 2013, up a solid 5 percentage points from 2012, according to IHS Technology.

"We see integrators in the U.S. and China rapidly executing very large pipelines, which accounts for some of the notable growth last year," said Josefin Berg, senior analyst for solar demand at IHS.

In a global market where non-residential PV additions climbed 20 percent during the past year, a company like China's TBEA Sun Oasis quadrupled its installations to approximately 1 gigawatt (GW)—enough for the integrator to come in at second place. TBEA was surpassed only by No. 1 Arizona-based First Solar, which had doubled its installation capacity in non-residential markets to more than 1.1 GW.

Overall, the share of the 30 largest integrators in the non-residential solar market was up from 25 percent in 2012. Nine of the world's top 10 entities are Chinese- and U.S.-based integrators that actively pursue large utility-scale projects, mainly conducted in their home markets. Growing local opportunities will propel these leading companies to gain further market share.

The only European-based integrator among the top 10 in 2013 was Abengoa of Spain, which is pursuing opportunities in the U.S. to build up installations worth 260 megawatts (MW).

IHS predicts that this trend will continue in 2014 as China and North America maintain their momentum as the markets to watch for large utility-scale PV. The findings are contained in the report, "IHS PV EPC and Project Market Tracker," from the Power & Energy service of IHS.

Planned PV projects in US and China swell to 50 percent of global PV pipeline Currently under construction in the United States are at least 2.5 GW worth of projects larger than 20 MW, and plans for another 2.1 GW are afoot in China. Globally, 123 projects larger than 20 MW are also being built elsewhere besides the two countries, amounting to some 7.6 GW in total.

The progress of these projects will significantly impact the EPC ranking in 2014, but First Solar's current construction of 770 MW is likely to allow the integrator to keep its position within the top three.

The global PV pipeline tracked by IHS adds up to 114 GW in nearly 10,000 projects in various stages from under construction to early- phase planning. Half of this capacity is located in the U.S. and China. Of the global pipeline, 10 GW is under construction, while another 10 GW has secured power purchase agreements (PPA) or other contracts.

"The road from first planning a project to final execution is paved with challenges," Berg noted. "Even after permits have been secured, PPAs signed and suppliers identified, troubles in obtaining finance or overhauled government policies can block or delay projects. This is particularly true in emerging markets, but financing can be a challenge also in more mature European markets."

In the U.K., the highly competitive PV environment has left two major PV integrators, S.A.G. Solarstrom AG and Wirsol AG, insolvent in the midst of high ambitions. As a result, Wirsol had to sell off its 100 MW pipeline to Conergy AG. It may seem a paradox that in the midst of a booming market for utility-scale PV in the UK – a market forecast to install 1.2 GW of non-residential PV in 2014 – system integrators struggle to stay afloat. The main reason is the high financial risk that EPC suppliers take on, as the tight profit margins under the UK's trimmed ROC-scheme keep final investor risk adverse.

The system integrator is expected to cover all costs during the construction process, until the projects have been accredited for the Renewable Obligation Credits (ROC), a process that can take more than six months after project completion.

"This long process put system integrators at risk of running out of cash before the project is sold and paid for," Berg observed. "Consequently, the most successful EPC companies building PV plants in the U.K. are either backed by venture capital, or form part of larger construction groups."

In the former category is an integrator like Solarcentury; in the latter are players like Isolux Corsan, Martifer, Oskomera and Goldbeck.

TSMC CIGS branch out in the U.S.

CENTROSOLAR AMERICA and TSMC Solar, a subsidiary of TSMC, have come to an agreement for the deployment of TSMC Solar's CIGS solar modules across North America.

The agreement names Centrosolar America as the exclusive provider of the TSMC Solar CIGS technology in residential and commercial solar markets. TSMC Solar and Centrosolar America may also collaborate on utility-scale projects. Centrosolar America will distribute CIGS solar modules from TSMC Solar, whose CIGS (copper, indium, gallium, selenium) technology is cost competitive with silicon based solar modules, and differentiates itself through several key attributes.

Most importantly, the CIGS modules yield more kWh's per Watt installed over the life of the system due to a lower temperature coefficient, increased power rating due to the "Light Soaking effect" once exposed to light, and less power loss in shaded conditions due to the CIGS cell configuration.

These high performance attributes of the CIGS modules are especially important in high temperature regions, such as the Sun Belt in the United States and in Mexico and the Caribbean. In addition, the CIGS modules have an all black, sleek appearance that is aesthetically pleasing to homeowners.

"With its heritage of manufacturing excellence and as a world leader in CIGS-based solar technology, TSMC Solar is now changing the landscape of the North American solar energy market," says Ram Akella, Centrosolar America's Managing Director.

"Our robust network of installers and distributors today delivers the most cutting-edge, turn-key solutions on the market and is ideally positioned to bring TSMC Solar's new high performance CIGS technology to homeowners and commercial projects on a broad scale."

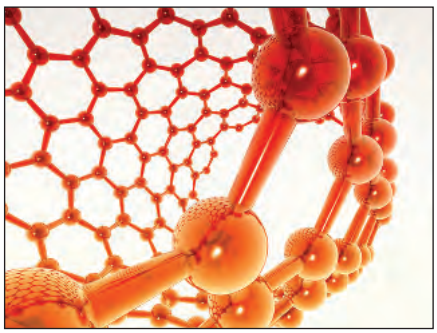
"For Centrosolar America, this partnership with TSMC Solar means expanded opportunities in serving the larger scale commercial and utility-scale markets and new ways to provide our installers with the latest technology, products and service for their customers. It means more choices in solar for the end-users and it challenges the mainstream industry to take solar to the next level," adds Akella.

Nanotechnology key to solar energy and energy storage

A NEW STUDY from the IEC (International Electrotechnical Commission) and the Fraunhofer Institute for Systems and Innovation Research ISI has found that nanotechnology will bring significant benefits to the energy sector, especially to energy storage and solar energy.

Improved materials efficiency and reduced manufacturing costs are just two of the real economic benefits that nanotechnology already brings these fields and that's only the beginning. Battery storage capacity could be extended, solar cells could be produced cheaper, and the lifetime of solar cells or batteries for electric cars could be increased, all thanks to continued development of nanotechnology.

In the study, "Nanotechnology in the sectors of solar energy and energy storage" commissioned by the IEC (International Electrotechnical Commission), the Fraunhofer Institute for Systems and Innovation Research ISI found that there is a whole range of nanomaterials which will grow in importance as technology continues to advance. A key finding of the study is that technologies where "nano" already plays



an important role will be of special interest for industry and research.

The following nanomaterial technologies will be of particular importance: "organic and printed electronics", "nano-coatings," "nano-composites", "nano-fluids", "nano-catalysts", "nanocarbons" and "nano-electrodes". These seven technology profiles form the basis for two comprehensive roadmaps in the technical report. The study found that in some areas nanotechnology may even be a key to success.

For example, through the use of nanotechnology the light and energy generation of crystalline silicon solar cells or organic solar cells can already be enabled or significantly increased. Their manufacturing also requires less material and is more cost-efficient.

Energy storage capacity will significantly improve with the use of nanomaterials for lithium-ion batteries. This is by far the most important battery technology for energy storage since the early 1990s. It is especially important in view of the constantly increasing demand for electric vehicles, whose success is also directly linked to battery performance and resulting range extension.

Large-scale application in solar power generation and energy storage
Dr. Björn P. Moller, project leader of this study at Fraunhofer ISI is convinced that everything points to its large-scale application in solar power generation and energy storage, unlike many other fields where nanotechnology has been unable to make a break-through.

Moller said, "It can be assumed that in 2035 the share of fossil fuels in global energy production will have decreased to 75 percent. It is therefore important that technologies such as solar cells are developed with the nanotechnology and that energy storage is improved."

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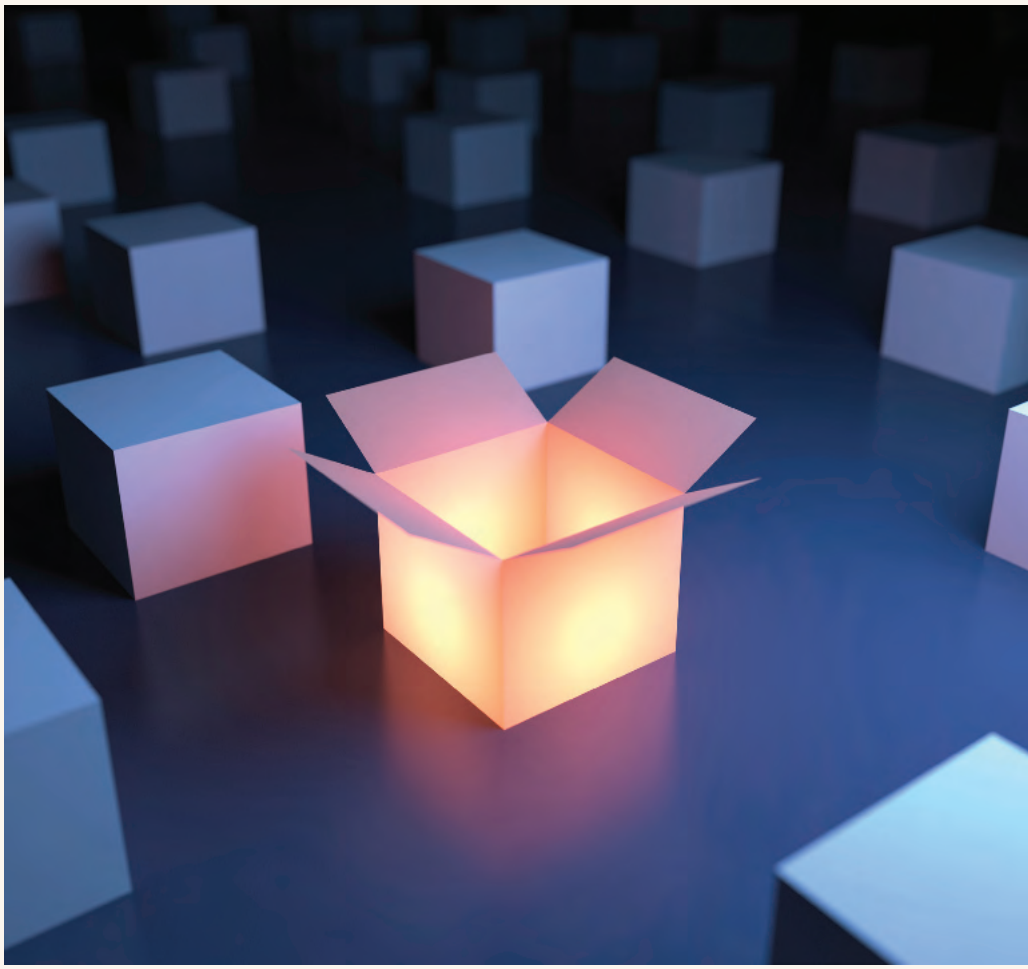


Breaking the mould

PV manufacturing technology has developed on the back of other industries, most specifically microelectronics. Many of the process and manufacturing outcomes remain legacy of other industries. Alex Savidis, Applications Manager at Solar Capture Technologies discusses how the industry can break the the mould – with alternative materials for solar PV modules.

YOU COULD BE FORGIVEN for thinking that all solar panels have to be flat, rectangular, and made out of glass, a Tedlar backing sheet and an aluminium frame. After all, that's the standard formula for domestic and commercial PV modules. And it's the traditional pattern followed by pretty much all off-the-shelf solar units available to design engineers for other applications, even if they're not really appropriate for the job. But why? Is there a good reason for the materials used to be limited in this way?

The reality is that there are plenty of alternatives that are far better suited to equipment design applications that need a different shape, size, weight, appearance or ability to cope in harsh conditions. You just need to know where to look.

A typical PV module used on house roofs, commercial buildings and solar farms is basically a laminate sandwich made up of three components - solar cells, glass and a backing sheet normally made from Tedlar – laminated together with an encapsulant. That's fine for what they need to do. But would they all be right for integration into a traffic bollard, an offshore buoy or the approach lights used to guide a helicopter onto an oil rig?

More and more solar panels are finding their way into applications where they're used for autonomously powering devices that can't be connected to the grid, or where it's too expensive to do so.

But design engineers are often frustrated by the inflexibility of the standard solar units available from catalogues, and their inability to meet the specific characteristics they need – with the risk that designs end up being seriously compromised.

Shaping for purpose

Shape is a common problem. Illuminated traffic bollards, for example, may need a special semi-circular curved shape that's designed to fit perfectly into the top of the unit. Floating buoys out at sea with flashing beacons call for a circular disc design, with the solar cells arranged into a wide ring. Neither can be achieved with standard components that can only be bolted on. But although solar cells are rigid, it is possible to combine a series of "flats" to form shapes and profiles to suit the desired design.

Weight is another common issue. Pole-mounted devices attached to street furniture for the remote monitoring of emissions can be at risk from high winds if the materials used are too heavy. Portable applications such as charging devices carried to power field equipment

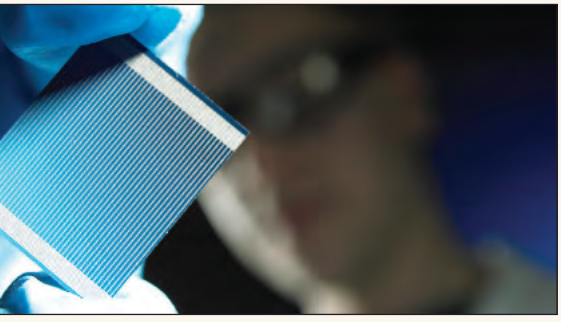
like radios or PDAs on expeditions or military excursions also need to be as light as possible. One solution can be found in the materials used to support the solar cells and give mechanical rigidity. By using aluminium or fibreglass as a substrate, much thinner solar modules can be made.

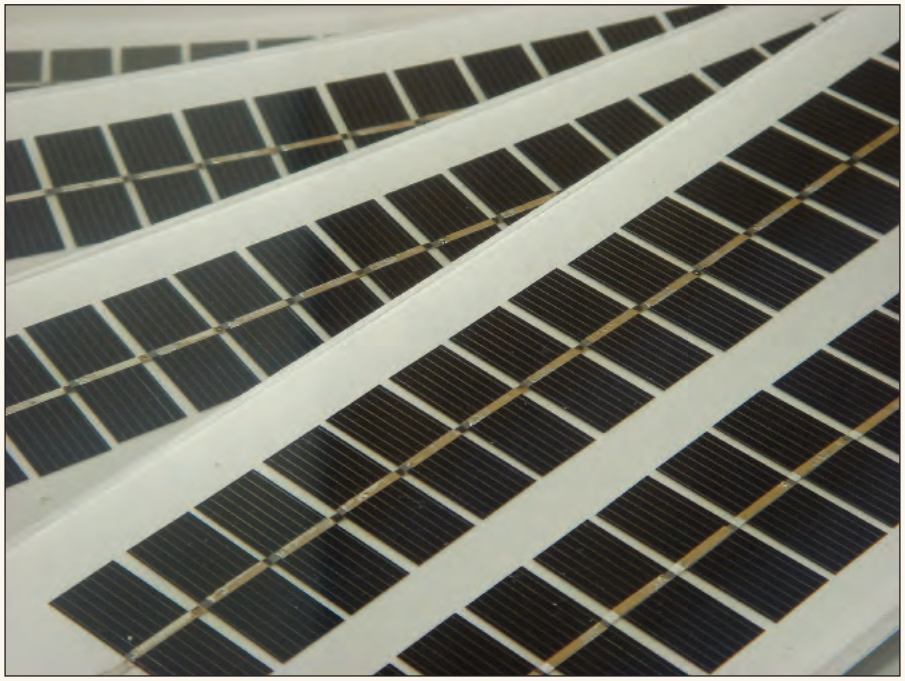
Wind uplift can be a major problem on solar modules fitted onto luxury motor homes. Off the shelf units made from glass, Tedlar and an aluminium frame have an overall depth of 30 to 40mm and have to be attached with PTFE brackets and adhesive – leaving a gap between the module and the roof that can cause aerodynamic issues. A solar module made from a combination of aluminium and Teflon, bonded directly to the roof, can achieve the necessary rigidity with a thickness of only a few millimetres, no gap, and much less risk of wind uplift.

Does my PV look good in this?

How about appearance and aesthetics? Glass can be quite reflective, and sometimes attract attention for all the wrong reasons. Solar panels used trackside for rail applications and left unattended in remote stretches are an easy target for vandalism and theft. Military back packs with solar chargers need a discreet design to avoid the risk of glare. In instances like these, a material like Teflon which is duller than glass and can be textured is far more discreet.

Another problem with conventional solar modules for this type of application is the shiny silver bus bars that are in stark contrast to the dark blue cells and light coloured substrate. By colouring the bus bars and using black anodised aluminium as a substrate with a textured Teflon cover, it's possible to make very discreet, dull looking solar panels.





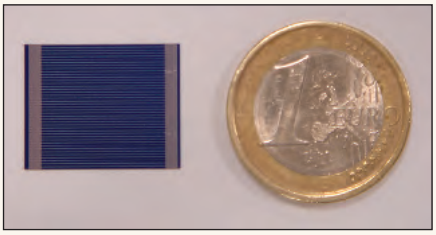
Teflon brings other advantages, too. Unlike glass, it won't shatter on impact. It has a higher light transmittance than solar glass, with improved light efficiency for higher power output from a smaller module when space is at a premium.

All that, and it's less expensive too. It's even being used on solar panels for environmental applications in remote camera systems to monitor wildlife.

The encapsulant normally used in standard solar panels is EVA (ethylene vinyl acetate) – a common polymer that's also found in everything from sunglasses to flip flops. Again this is fine for conventional domestic and commercial solar power uses. But for more especially demanding applications, other specialised encapsulants can also be used.

Expanding the options

Think about aerospace applications, for example, where solar panels fitted onto portable runway lights might be in the vicinity of 350 degree heat from the exhaust of a jet engine. Think about solar powered lights for arctic expeditions, or powering GPRS in hot and dusty deserts. For harsh applications like these (as well as many far less demanding ones),



conventional solar power units simply won't cut it. As a specialised manufacturer of PV cells and custom-made, application-specific solar modules, Solar Capture Technologies produces around 10,000 units per year – in all shapes and sizes, with appropriate electrical output, and in small to medium volumes including proof of concept demonstrations and prototyping. With past roots in NaREC and BP Solar, the business is now completely independent with its own full design and manufacturing facilities – including testing under true atmospheric conditions such as sea water, humidity, and high and low temperatures.

So if you thought that all solar panels have to be flat, rectangular, and only made out of glass, a Tedlar back sheet and an aluminium frame, it might be time to think again. The solar application that you never thought possible might be well within your reach.

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Balancing
energy and resources

Energy development is constantly locking horns with resource concerns. In a pro-active move, two US groups representing both sides have joined forces to support policies that will see continued improve the national grid whilst preserving natural resources through a shared approach to risk and benefits.

THE EDISON ELECTRIC INSTITUTE (EEI) and the Natural Resources Defense Council (NRDC) has announced a joint agreement to advance support for utility policies that enhance the electric power grid for the benefit of all electricity customers and the environment.

EEI, which represents the nation's investor-owned electric utilities, and the major environmental organization will work together to encourage state utility regulators to implement policies that balance the desire to promote innovation, while at the same time supporting fair and adequate cost recovery for maintaining the evolving grid.

The agreement urges state utility regulators to adopt a number of policies that range from employing new rate designs to ensure utilities remain financially whole when they help customers adopt distributed generation technologies and use energy more efficiently to assuring customers that costs will not be shifted unreasonably to them from other customers.

Forward looking governance

The joint statement to the regulators of the national network of state utilities discusses the evolving nature of the grid and the changing demands for both supply and consumers. With power flow in two directions there is a need to consider fair policies that will address the future needs that such changes will bring. Without customer involvement in services such as balancing, voltage support, and voluntary load management there will be issues in a two way energy business.

The EEI and NRDC have come together before and in 2008 launched a joint campaign to accelerate energy efficiency gains and encourage utilities to undertake a host of other cost-effective and clean energy resources and grid enhancements. Together, these changes have done much to promote clean energy and efficient electricity usage, but they also have highlighted the vital need for regulatory policies that will support fair and adequate cost recovery for maintaining the evolving grid.

Recovering the fixed costs of the grid is becoming more challenging. While customers are discovering new opportunities that enhance the value that the grid brings to them, policy makers should rethink how utility costs are recovered, with consideration needed for new rate designs and new approaches that balance the desire to promote innovation while still enabling recovery of the capital investment that recognizes. Traditional rate regulation can at times incentivize utility retail sales growth; in turn, utilities sometimes leverage that growth between rate cases to meet system-wide needs for cost recovery and capital investment.

With so many new energy sources entering the grid network, led by solar and other renewable energy sources, the two groups feel there is a need for legislators to take a more direct but broader approach to grid development. There can no longer be a reliance on traditional energy supliers to recoup all the costs of infrastructure.

Sharing the burden

Energy supply is not simply electricity to every door. It is the entire value chain of infrastructure that requires investment and change to meet the changing needs of the energy mix. The intermittency of renewable energies create problems for the traditional grid structure and the realities are that energy supply is changing. There is a need for balancing energy production with emissions policies so there is no question as to whether renewable sources will diminish.

The joint statement included the following recommendations aimed at creating a legislative environment to include new technologies for enhancing grid performance while lowering emissions

1. The retail electricity distribution business should not be viewed or regulated as if it were a commodity business dependent on growth in electricity use to keep its owners financially whole. Instead, utility businesses should focus on meeting customers' energy service needs. Therefore, recovery of utilities' non-fuel costs should reflect their costs of maintaining and improving the electricity grid, and should not be tied to levels of retail commodity sales.

2. Traditional rate regulation allows non-fuel revenues to grow between rate cases in proportion to growth in commodity sales, which averaged more than twice the rate of population growth between 1973 and 2000 before slowing significantly. If regulators break the linkage between cost recovery and commodity sales, they should provide for reasonable and predictable annual adjustments in utilities' authorized non-fuel revenue requirements.

3. "Net metering" programs in wide use across the United States have helped valuable "distributed" technologies such as rooftop solar power gain traction and improve performance, but additional approaches are needed now. Although such generation can reduce a grid's needs for central station generation and other infrastructure, it typically does not eliminate its owners' needs for grid services. For example, solar generation at a residence typically does not align perfectly with the occupants' energy use, requiring some use of the grid as the equivalent of a battery. When they use distribution and transmission systems to import and export electricity, owners and operators of on-site distributed generation must provide reasonable cost-based compensation for the utility services they use, while also being compensated fairly for the services they provide. Customers deserve the opportunity to interconnect distributed generation to the grid quickly and easily.

4. Utilities deserve assurances that recovery of their authorized non-fuel costs will not vary with fluctuations in electricity use. Customers deserve assurances that costs will not be shifted unreasonably to them from other customers. Rate designs will continue to develop that reward customers for using electricity more efficiently. Examples include, but are not limited to, real-time pricing and variable demand charges that take advantage of digital meter capabilities where available.

5. It is appropriate to consider expanding investor-owned utilities' earnings opportunities to include performance based incentives tied to benefits delivered to their customers by cost-effective initiatives to improve energy efficiency, integrate clean energy generation, and improve grids. In general, business models should include profit opportunities linked to utilities' performance in delivering safe, reliable, affordable, and clean energy services.

6. We will work together to ensure that energy efficiency services reach underserved populations, including the increased deployment of utility programs focused on affordable multi-family housing.

7. We reaffirm our goal of "helping electricity users take advantage of all cost-effective energy efficiency opportunities through an integrated combination of financial incentives to customers and minimum standards governing the performance of buildings and equipment," and we rededicate ourselves to the five key elements of that campaign.

8. We also reaffirm our call to state regulators, when presented with a reasonable business case by utilities, to "support significantly enhanced utility investment in 'smart meters' and a 'smart grid' that focuses on delivering new energy management tools to customers, enabling increased energy efficiency, supporting efficient new technology such as plug-in electric vehicles, and reducing the cost of integrating renewable energy generation with variable output into resource portfolios."

"The electric power industry's mission is to provide safe, reliable, affordable, and increasingly clean electricity. Today utilities are partnering with customers, regulators and all stakeholders to transform the way they generate and deliver electricity. This agreement helps chart a path to success," said EEI Executive Vice President David Owens. Ralph Cavanagh, co-director of NRDC's energy program, added, "This path-breaking agreement steers us toward new and innovative ways to increase and speed the deployment of clean energy resources. NRDC has long advocated for the increased integration of energy efficiency and renewable energy into the nation's electric grid."

Owens and Cavanagh announced the agreement during a joint presentation to the National Association of Regulatory Utility Commissioners, which meets in Washington. NARUC's chief objective is to serve the consumer interest by seeking to improve the quality and effectiveness of public regulation in America.

How much does renewable energy cost?

There is a great deal of confusion and conjecture about the real costs of electricity production. The Fraunhofer Institute for Solar Energy Systems ISE has released their analysis of renewable costs compared to traditional costs and solar shines a positive light for a renewable future.

A STUDY FROM the Fraunhofer Institute for Solar Energy Systems ISE compared the present costs for conversion of different energy forms into electricity and gives a prognosis for the further cost development up to 2030. The scientists in Freiburg analysed both the levelized cost of electricity (LCOE) from renewables as well as from conventional energy technologies.

They present comparative figures for new power plants constructed in Germany, which are based on solar, wind energy and biogas as well as brown coal, hard coal and gas. The study shows that the LCOE from renewables has decreased rapidly over the last years and has even caught up with the generation costs from conventional power plants. Forecasts for Germany indicate that the costs to produce electricity from PV and wind will be less than fossil fuel plants by 2030.

Conventional versus renewable

The scientists analysed photovoltaic (PV) systems in Germany at locations with a global horizontal irradiance between 1000 and 1200 kWh/(m²a). Their conclusion is that cost-efficient open field PV plants, installed during 2013 in southern Germany, can achieve LCOE of about 0.08 euro/kWh.

Even small roof-installed PV systems in northern Germany produce electricity today for less than 0.14 euro/kWh and therefore lie well below the average electricity price of 0.29 euro/kWh for households.

With respect to wind farms, the study shows electricity from onshore wind costs less to produce than it does from hard coal, combined cycle gas power plants. Today, the LCOE from onshore wind ranges between 0.05 and 0.11 euro/kWh.

Offshore wind, on the other hand, has much higher electricity generation costs of 0.12 to 0.19 euro/kWh, despite the fact that it has more full-load operating hours. The offshore wind technology still shows a potential for cost reductions, whereas onshore wind has nearly reached its limit.

The ambient conditions such as the solar radiation and the wind availability as well as the financing costs and the risk premium for new power plants all influence the results substantially. Only by including these factors in our study are we able to realistically compare the levelized cost of electricity from the different technologies and thus convincingly present the cost-competitiveness of renewables

Levelized electricity generation costs from biogas, dependent on load and fuel type, range from 0.14 to 0.22 euro/kWh.

"The cost of electricity generation is not the only decisive factor in determining the competiveness of renewable and conventional energy sources. The upstream and downstream costs also play a major role," says Christoph Kost, project head at Fraunhofer ISE. "The ambient conditions such as the solar radiation and the wind availability as well as the financing costs and the risk premium for new power plants all influence the results substantially. Only by including these factors in our study are we able to realistically compare the levelized cost of electricity from the different technologies and thus convincingly present the cost-competitiveness of renewables."

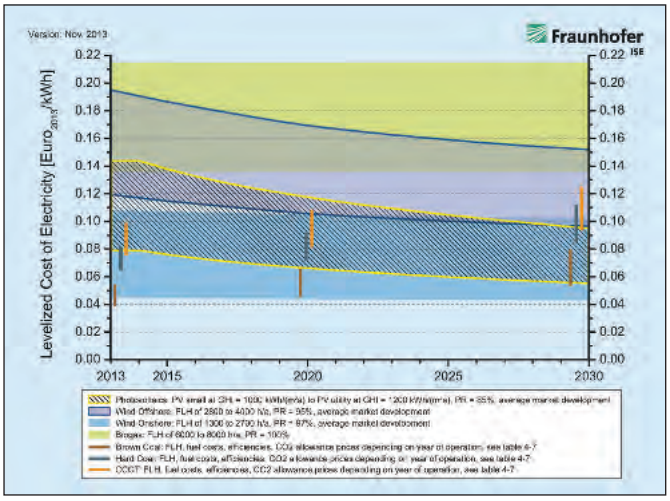
The study uses the LCOE of new conventional power plants for brown coal, hard coal and natural gas as reference values. Dependent on the number of full load operating hours assumed, of the fuel price and of the price of carbon credits, the levelized cost of electricity from brown coal presently extends up to 0.053 euro/kWh, from hard coal up to 0.080 euro/kWh and from combined cycle gas power plants up to 0.098 euro/kWh respectively.

The analysis is extended by an outlook on the LCOE of oil-fired power plants in the Middle East. Under the assumption of oil prices from the world market, oil-fired power plants show generation costs in the range of 0.13 - 0.17 euro/kWh compared to PV with an LCOE of around 0.08 euro/kWh.

Outlook and Forecast 2030

After evaluating and comparing all of the data, the scientists at Fraunhofer ISE presented the following outlook.

"By 2030 the electricity generation costs from PV will decline down to 0.06 - 0.09 euro/kWh. At this value, even small roof-installed PV systems will be able to compete with onshore wind and also with the higher generation costs in the future from brown coal, hard coal and combined cycle gas power plants," says Prof. Eicke R. Weber, director of Fraunhofer ISE.



Prognosis of electricity generation costs from renewables and conventional power plants in Germany up to 2030, based on a learning curve analysis. "Electricity Generation Costs from Renewable Energies" (Fraunhofer ISE, November 2013) Graph: ©Fraunhofer ISE

Onshore wind will experience a decrease in the electricity generation cost, as compared to conventional power plants. At the latest, this technology will be competitive with brown coal in 2020, since with the progressing energy transformation, the number of full load operating hours will decline and the price of the carbon credits could increase. Upon comparing different renewable technologies, the results show that, in the future, the costs of PV and onshore wind will lie well below 0.10 euro/kWh.

Within the available renewable options that are being considered for the future mix of electricity production it is these two technologies that appearing to be winning the race towards cost leadership as the energy industries begin to choose what renewable sources they want in their future energy mix.

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Power reform
needed for Asia Pacific

The Asia Pacific region is tipped as a high growth area for the solar and PV markets but they are only part of the energy needs and changes in the region. A new report from Frost and Sullivan suggests that implementation of power sector reforms are essential to drive investments in 2014.

BUOYANT PEAK POWER DEMAND, favourable coal prices and a resurgent Southeast Asian economy are likely to drive investments in the Asia Pacific power generation industry for 2014. The rising electricity demand is likely to augment power generation in the Asia Pacific (APAC) region by 4.1% in 2014. As per the International Monetary Fund (IMF)'s outlook, Indonesia, Malaysia, The Philippines, Thailand and Vietnam are forecasted to register a combined GDP growth of 5.7% in 2014. The growth will be driven by rising domestic consumption, credit expansion and rising middle class income.

"Coal will remain the fuel of choice even in 2014, due to a combination of low prices and abundant availability. Furthermore, the low natural gas prices in the US have led to a rapid increase in US coal exports to Asia," noted Ravi Krishnaswamy, Vice-President for the Energy & Environment Practice, Frost & Sullivan Asia Pacific. "Indonesia and Vietnam are expected to ride the demand wave for coal-fired power plants mainly due to the vast capacity additions they intend to achieve to bridge the power deficit," he added.

Traditional support waning

The U.S. Export-Import (Ex-Im) Bank and the European Bank for Reconstruction and Development have announced in late 2013 that they will stop financing coal power projects abroad. "In 2012 and 2013, carbon emissions in Japan increased sharply due to the country's heavy reliance on fossil fuels for power generation in the aftermath of the 2011 Fukushima

Daiichi disaster. Hence to improve its current energy situation and to reduce emissions, Japan is most likely to seriously consider options to restart its nuclear power projects," noted Krishnaswamy.

Similarly, South Korea which is heavily dependent on nuclear power for almost one third of its power generation is currently facing questions on its safety of nuclear projects. In 2014, the country is likely to vigorously work on addressing the safety issues and include nuclear power in their planned installed capacity growth in the coming years. The government is likely to launch a revised nuclear policy in early 2014. Southeast Asia's nuclear ambition is set to begin with Vietnam taking the lead. Vietnam's first nuclear power plant's construction which was scheduled to start in 2017 might commence earlier subject to the outcome of political discussions in the next few months.

FiT for purpose

Many nations in the Asia Pacific region have recently introduced Feed-in-Tariff (FiT) schemes for different renewable sources of electric power in the last two years and many have brought favourable changes to their already existing tariff schemes. Introduction of FiT for solar photovoltaics (PV) in Japan in 2012

had a great impact on the market and it led to the explosive growth of the sector in 2013. In 2014, similar market trend is likely to continue as the solar PV rates are likely to remain stable and the electricity tariffs are already very high. In 2013, Indonesia had revised its FiT rates which are likely to encourage the start of numerous geothermal, biomass and many other renewable energy (RE) projects in the country.

"Thailand plans to add 1000 MW of solar PV by the end of 2014. The growth of RE projects has been impressive in Thailand since the introduction of the FiT policy in 2006," said Krishnaswamy. "However, the FiT was only limited for a period of 10 years. In a radical change from the old policy, Thailand's National Energy Policy Commission (NEPC) has approved new FiT for both ground mounted and rooftop solar PV with a FiT validity of 25 years. Such a policy change is likely to stir-up the growth of RE in Thailand in 2014," he added.

The RE developers in The Philippines are not satisfied with the FiT rates implemented by The Philippines' Energy Regulatory Commission for wind, hydro, solar and biomass. However, in 2014, some biomass, small hydropower and wind projects are likely to make a headstart. In Vietnam, UK firm Tortech and Malaysian firm CHE group are undertaking construction of twenty 10MW biomass fired power plants. The firms have said that they have been encouraged by the lucrative FiT schemes in the country. In Malaysia, the SEDA (Sustainable Energy Development Authority) is likely to introduce wind power under the FiT scheme in 2014.

Leading the way

Japan's electricity sector is poised to experience a turnover as government has passed the electricity bill to bring reforms in the sector that has been the first priority of the Prime Minister Shinzo Abe after the nuclear accident of 2011. The establishment of a national grid and liberalisation of the power market are the key agendas of this reform. The liberalisation of utilities is expected to end the monopolistic market.

The Prime Minister has said that approximate investments of US$299 billion are required till 2020 for the transformation of the power sector. Two coal-fired thermal power plants and twelve gas-fired plants are likely to be completed by end of 2014 and their supply of electricity will replace the oil-based power by approximately 20% of its current generating capacity.
In Malaysia, the New Energy Plan 2011- 2015 initiated by the government focuses on the de-regulation of electricity prices and reduction of subsidies. This step will encourage higher investments in all the three sectors of power industry – generation, transmission, and distribution. Regulations will provide incentives for the use of energy efficient equipment at both individual and utility level.

"Implementation of several of the proposed power sector reforms in the Asia Pacific countries will accelerate investments and lead to harmonisation of the regional electricity markets," concluded Krishnaswamy.

Efficient use of energy

Rising electric bills is a greater part of US business' operating expense. Energy usage is as big a part of the overall energy picture as production. Renewable energy will play a part moving forward but must form part of an overall view of energy.

Vic Shao, CEO of Green Charge Networks, looks at the rise and fall of energy efficiency initiatives and suggests the next energy savings frontier will be power efficiency.

ENERGY HAS BEEN THE FOCUS for much of the past four decades for efficiency initiatives. We have changed light bulbs, swapped out old appliances, insulated our buildings, and added solar systems. The efficiency gains have slowed, however, and the next savings frontier will come from Power Efficiency. Through a combination of distributed energy storage and sophisticated software, our society can control power more efficiently and increase utilization of trillions of dollars of grid assets already in place. Intelligent energy storage can reduce the stress on our electric grid while helping businesses save money on their monthly electric bills.

The oil crisis of 1973 brought the idea of energy efficiency into the American consciousness. The implementation of which has been a tremendous success by all accounts. Economists estimate that the adoption of efficient products and services is responsible for 60 – 75% of the increase in energy productivity since 1970[1]. Despite supersized homes, vehicles, and newer comforts, energy use per capita has actually decreased from 1970 to 2010[2]. However, after four decades of replacing light bulbs, wall insulations, and inefficient appliances, most of the low-hanging fruits are gone. It is increasingly difficult to eke out more savings on the energy side, and the solutions are becoming complex and costly.

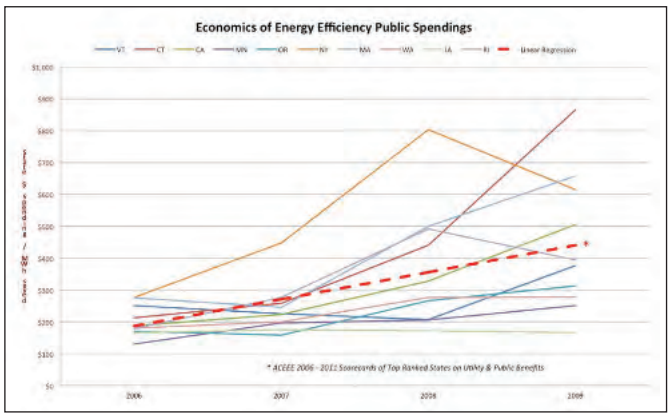
Rising cost of efficiciency

The American Council for an Energy-Efficient Economy (ACEEE) publishes an annual scorecard by State on policy efforts, and it provides quantitative data on dollars spent and energy saved. According to ACEEE's Scorecards between 2006 – 2011, the top 10 U.S. States spend an average 30% more year over year in energy efficiency measures to achieve the same kWh savings. This trend is distressing for businesses looking to the future.

The price of energy (kWh) that businesses pay has historically held steady or decreased, even in traditionally expensive markets such as California due to efficiency savings. Prices have maintained due to domestic production, racking and deregulated competition. In effect the US throws money at maintaining efficiency savings despite the solution becoming less enticing (economically speaking) over time. Energy efficiency will continue to be a driving force, but the pace is slowing and it has reached a point of diminishing returns.

The problem is power (kW), not energy (kWh)

Consolidated Edison of New York, a regulated utility, provides electric service in New York City and Westchester County. According to its 2012 annual report[3], it spent $2.27 billion in



Graph 1: Economics of energy efficiency public spending

operation and maintenance costs on its electric operations, an increase of 11.3% from 2011. In fact, over the course of the past 5 years, its electric O&M budget has increased year over year by 4 – 13%. It further maintains a construction expenditures budget around $2.5 billion per year to keep up with rising demands on the distribution grid. Considering that Con Edison is just one out of thousands of electric utilities across the country, altogether distributing over 4 million GWhs of energy annually, the cost to upkeep the electric grid runs into hundreds of billions of dollars. This massive and growing capital expenditure is a strain on the US economy and is the focus of the Smart Grid movement.

But let's examine the problem in more details. Currently, much of the capital is spent on hardware equipment – bigger transformers, cables, and power gear to sustain growth. The challenge is not energy but power; it is the maximum throughput of energy at a given time through the grid infrastructure. Power spikes create a grossly inefficient use of capital, as can be observed in graph 2.

This graph shows the historic all-time-high loading on the distribution grid in Con Edison service territory of 13,189MW, which occurred on July 22, 2011. But for the entire 2011 calendar year, the grid was above 12,000GW for only 36 hours or 0.4% of the time, and above 11,000GW for 156 hours or 1.8% of the year. Yet, utilities spend billions to upgrade distribution grid infrastructure by brute force – essentially by installing more copper in the ground. Think of it this way: the grid has to be capable of handling the maximum demand. If a factory never ran all year except for one day when it did a highly electricity intensive process, we would still have to build the grid infrastructure to accommodate that level of use. Extrapolate this requirement across America and you have an electric grid that is built for a small number of high-use moments. This cost burden is then passed onto commercial and industrial ratepayers in the form of increasingly excessive demand charges.

Programming a way forward

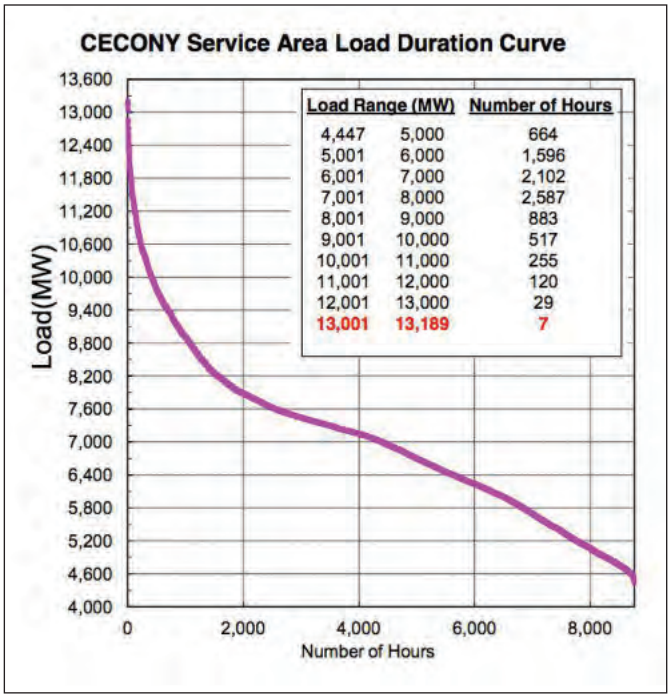
The past decade in California saw ¢/kWh drop by 4% a year but $/kW has risen by 7% year on year[5] (refer to graph 3).

Energy (kWh) is no longer the cost driver for commercial and industrial electric ratepayers; power (kW) is where the pain lies. Many ratepayers pay 50% extra a month on power demand in California and have had no way out. They can buy energy on the open market at competitive rates, but power distribution is still monopolised by the local utility. As most rate designs only assess demand charges for commercial and industrial (C&I) ratepayers and not for residential customers, the cost burden for infrastructure O&M is increasingly shouldered by businesses. To level the playing field, commercial and industrial customers need a new class of solutions that addresses today's reality – we call this paradigm "Power Efficiency".

Imagine demand response without the hassles and manual interventions, and a solution with higher savings than solar. The Smart Grid has brought intelligence into the utility operators' control centres, but so far it has done very little to help business owners reduce cost. Power Efficiency is the new Energy Efficiency; it is the next frontier in efficiency savings.

Power efficiency requires sophisticated software, predictive algorithms, and distributed energy storage; but if done right, it holds the promise of using software instead of copper to keep up with rising electric demands on the grid at 3X – 10X less than current costs. We can now use utility and weather data to predict demand and store energy locally. In doing so, we can significantly reduce stress on the electric grid and the amount of peak energy consumed.

By using power more efficiently, we can extend the utilization of existing grid infrastructure -- making the grid more secure, resilient, and responsive. Most importantly, Power Efficiency



Graph 2: Service area load duration curve

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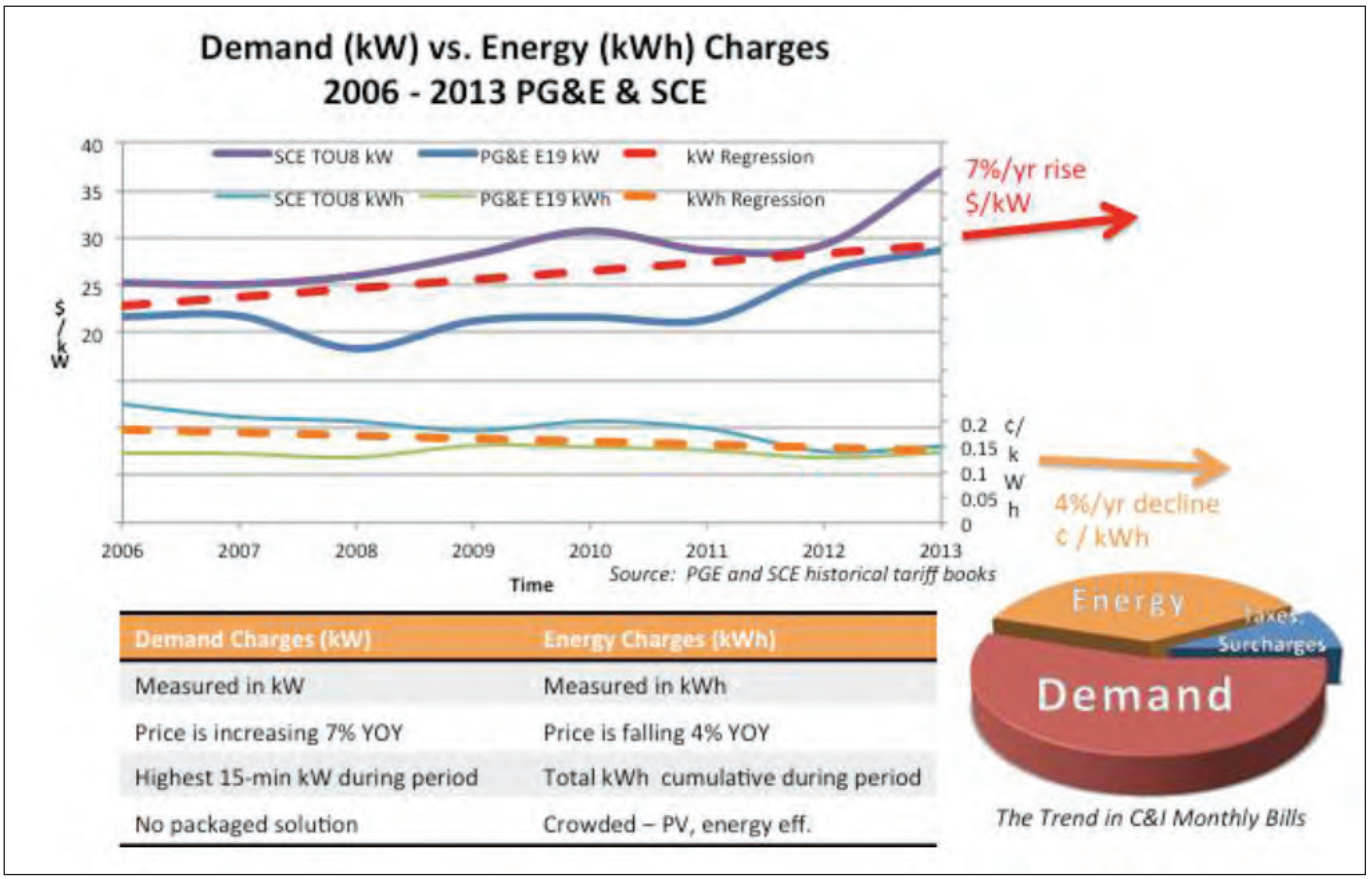

Graph 3: Demand (kW vs. Energy (kWh) charges. 2006-2013 PG&E and SCE

solutions monetize savings for commercial and industrial businesses where the Smart Grid implementation has not yet achieved. The ROI-driven approach promotes grassroots adoption of energy storage and public / private sector collaboration.

Efficiency before new technology

Power Efficiency is no easy task. So far the state of the art reaction is demand response programs, which requires behavioural changes and is not relied upon by the distribution grid operators. The US electric grid is one the greatest engineering feats of the 20th century, but the cost to upgrade and maintain the grid is rising exponentially as it ages.

The software industry has taken on similar efficiency challenges in the past in other domains. It's time we apply ourselves. This new era is about using software to improve efficiency of trillions of dollars of capital equipment already in place, at a fraction of the cost compared to adding more hardware. The grid is incredibly complex, but so is our collective level of software sophistication and intelligence.

A key problem facing solar and PV energy providers in much of the developed world is a decreasing amount of new energy that can be added to the grid without improvements to the infrastructure. As mentioned above this a costly venture that no-one wishes to fund alone and efficient use of power in the system will open up the grid and enable an increase in renewable energies to be added to the mix. It can also act as a stepping stone to plan longer term infrastructure improvements to national grids. This isn't just some pie-in-the-sky idea. All across America businesses and organisations are beginning to implement intelligent energy storage and power efficiency solutions in order to cut costs and relieve strain on the grid. If these technologies were implemented across the entire United States, some estimate that we could save the energy equivalent of 4,000 coal plants per year.[6] Everyone wins in the entire value chain if we can utilise power more efficiently.

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Integrating **variable energy**

A new report from the International Energy Agency highlights that solar and wind energy is now a viable energy source for any country. The transformation of power systems is key for all regions to guarantee flexibility over long term. The key is understanding the different challenges that different markets face.

Solar photovoltaics (PV) and wind power are crucial to meeting future energy needs while decarbonising the power sector. Deployment of both technologies has expanded rapidly in recent years, one of the few bright spots in an otherwise-bleak picture of clean energy progress, and International Energy Agency (IEA) scenarios indicate that this trend will continue for decades. However, the inherent variability of wind power and solar PV is raising concerns: Can power systems remain reliable and cost-effective while supporting high shares of variable renewable energy (VRE)? And if so, how?

A landmark study released by the IEA addresses these concerns and confirms that integrating high shares - i.e., 30 percent of annual electricity production or more - of wind and solar PV in power systems can come at little additional cost in the long term. However, costs depend on how flexible the system currently is and what strategy is adopted to develop system flexibility over the long term. Managing this transition will be more difficult for some countries or power systems than others, the study says.

“Integrating high shares of variable renewables is really about transforming our power systems,” IEA Executive Director Maria van der Hoeven said as she launched The Power of Transformation - Wind, Sun and the Economics of Flexible Power Systems, the latest in a series of IEA reports shedding light on the challenges and opportunities of integrating VRE into power systems globally.

“This new IEA analysis calls for a change of perspective,” she explained. “In the classical approach, variable renewables are added to an existing system without considering all available options for adapting it as a whole. This approach misses the point. Integration is not simply about adding wind and solar on top of ‘business as usual’. We need to transform the system as a whole to do this cost-effectively.”

Transforming fortunes

Currently, wind and solar PV account for just about 3 percent of world electricity generation, but a few countries already feature very high shares: In Italy, Germany, Ireland, Spain, Portugal, and Denmark, wind and solar PV accounted respectively from around 10 to more than 30 percent of electricity generation in 2012 on an annual basis.

The report says that for any country, integrating the first 5-10 percent of VRE generation poses no technical or economic challenges at all, provided that certain conditions are met. Uncontrolled local “hot spots” of VRE deployment must be avoided . VRE must contribute to stabilising the grid when needed, and VRE forecasts must be used effectively. These lower levels of integration are possible within existing systems because the same flexible resources that power systems already use to cope with variability of demand can be put to work to help integrate variability from wind and solar. Such resources can be found in the form of flexible power plants, grid infrastructure, storage and demand-side response. Going beyond the first few percent to reach shares of more than 30 percent will require a transformation of the system, however. This transformation has three main requirements: deploying variable renewables in a system-friendly way using state-of-the art technology, improving the day-to-day operation of power systems and markets and finally investing in additional flexible resources.

The challenges of such transformation depend on whether a power system is “stable,” meaning no significant investments are needed to meet demand in the short term, or “dynamic” which requires significant investments short-term, to meet growing power demand or replace old assets.

Successful perception

The publication helps to clarify the very different perception of wind and solar around the globe. In stable systems, such as those in Europe, the existing asset base will help to provide sufficient flexibility to increase VRE generation further. However, in the absence of demand growth, increasing VRE generation in stable systems inevitably comes at the detriment of incumbent generators and puts the system as a whole under economic stress. This outcome is based on fundamental economics and market effects are thus not only a consequence of variability. The transformation challenge in stable systems is twofold with scaling up the new, flexible system while scaling down the inflexible part of the old.

Governments with stable systems face tough policy decisions about how to handle the distributional effects, in particular if other power plants need to be retired before the end of their lifetimes and, if so, who will pay for stranded assets. Meeting these challenges will only be possible through a collaborative effort by policy makers and the industry.

In any case, “these surmountable challenges should not let us lose sight of the benefits renewables can bring for energy security and fighting dangerous climate change. If OECD countries want to maintain their position as front runners in this industry, they will need to tackle these questions head-on,” Ms. Van der Hoeven said.

By contrast, in “dynamic” power systems such as in India, China, Brazil and other emerging economies, wind power and solar PV can be cost-effective solutions to meet incremental demand. VRE grid integration can - and must - be a priority from the onset. With proper investments, a flexible system can be built from the very start, in parallel with the deployment of variable renewables. “Emerging economies really have an opportunity here.

They can leap-frog to a 21st-century power system - and they should reap the benefits,” the IEA Executive Director concluded.

Inverter **merger**

Danfoss A/S and SMA Solar Technology have announced a tie-up that will see a trade of cash and shares to form a giant inverter company for the industry. Ash Sharma, Senior Director of Solar Research at IHS discusses the merger and looks at the challenges that will face the new venture.

The recent announcement that Danfoss would sell its entire solar inverter business line to SMA and in return acquire a 20% share of SMA for just over €300m highlights the on-going consolidation of the European solar manufacturing business in a declining local market. The tie-up does not come as a huge surprise given the struggles the industry currently faces as it deals with a shrinking European market, rapid price declines but conversely booming overseas demand.

SMA and Danfoss have announced plans to enter into a strategic partnership to beef up competitiveness. The two system technology specialists will take full advantage of economies of scale and joint development initiatives. Danfoss will acquire 20% of SMA's outstanding shares in return for selling its complete solar inverter business to SMA. Combined, SMA and Danfoss held a 25% share of the global solar inverter market in 2013 (down from 35% in 2012) and more than 35% of the European market. This tie-up undoubtedly strengthens their position but also provides SMA with other benefits.

Danfoss will receive 6.94 million of SMA shares at a price of €43.57 per share from the SMA founders, their trusts and families. The cash consideration corresponds to a premium of 50% to the volume-weighted average share price over the last 60 days. The transaction volume amounts to €30,238 million. After completion of the transaction the freely tradable free float of the SMA share will be at 25.05%. The SMA founders, their trusts and families will hold 54.95% of the SMA shares after the transaction is completed. Danfoss will not buy or sell shares for a lock-up period of at least 2 years. The share purchase is subject to regulatory approval. Closing of the acquisition of shares and the cooperation contract is expected within Q3 2014.

Outcomes and expectations

Firstly, the alliance will open up a cheaper supply of components to SMA via Danfoss' much greater purchasing power. This alone will drive down SMA's bill of materials; if in addition SMA has access to Danfoss' manufacturing facilities this will further allow SMA to drive down costs using Danfoss' economies of scale. This will become even more critical to manufacturers as government incentives for solar continue to drop and competition from low-cost Chinese vendors intensifies.

Secondly, this deal allows SMA to take advantage of Danfoss' design and manufacturing expertise. Technically, solar inverters are very similar in design to drives which Danfoss has manufactured for more than 40 years and according to IHS was the 5th largest supplier of these products globally in 2012. Danfoss' background in the drives industry allowed it to very quickly make advances in the solar inverter industry and was one of the first suppliers of three-phase string inverters which revolutionised commercial solar projects. This experience and know-how will likely prove incredibly valuable as SMA seeks to advance inverter designs whilst driving down costs.

Thirdly, as the solar industry globalises and new end-markets appear in a vast number of emerging countries, suppliers of solar products will need to have a global footprint, not just for sales but perhaps more importantly for after-sales service. Whilst SMA was already the largest

solar inverter supplier prior to this deal with a presence in most of the key markets, this deal will further strengthen this position. Danfoss has more than 23,000 employees in 51 countries and will allow SMA to effectively serve the emerging markets of Latin America, Middle East and Asia.

Geographical challenges

Having an investor such as Danfoss holding a 20% share, with a no buy/sell lock-up period for two years will also provide SMA with some much needed, albeit short-term stability amid fears of other European suppliers facing bankruptcy and acquisition. Despite all of these advantages that this deal presents to SMA, it will undoubtedly face on-going challenges: There is considerable overlap between SMA's and Danfoss' inverter business. Both were largely focussed on the European market with 55-60% of their 2013 business coming from this region. They also have a very similar product line-up, both with particular strength in three-phase string products for commercial and utility-scale PV installations. Despite access to Danfoss' enhanced procurement, SMA will still face intense challenges from low-cost suppliers from China who benefit from cheaper components sourced locally and also huge economies of scale given the booming domestic market. Furthermore, this tie-up with Danfoss will not improve SMA's position in the China and Japan solar markets which will account for nearly 50% of all PV installations in 2014.

In the past two years this had been one of the biggest weaknesses of SMA as it had little presence in these booming markets. Unfortunately Danfoss has also had limited success in China and Japan and this alliance is unlikely to help them see a significant improvement in addressing these important markets. Danfoss' solar inverter business, that was almost entirely focused on Europe struggled in 2013 as its core markets dwindled. Whilst it was ranked as the 5th largest supplier of solar inverters in 2012, it fell to outside the top 20 in 2013 according to IHS' latest analysis. Similarly, SMA's global share of the inverter market fell from 30% in 2012 to around 23% in 2013. The combined venture aims to strengthen both companies.

60 MW in 60 days

One of the difficult aspects of running a solar installation company is the pressure to finish jobs before policy changes take effect. Array Technologies and SunEnergy1 had just 60 days to erect a 60MW project to make a tax break deadline.

DEADLINES ARE ALWAYS TIGHT, but what if your target was to install more than 56 MWdc of solar technology in just 60 days? Array Technologies, Inc. (ATI) and SunEnergy1 recently faced this reality and working together were able to achieve the deadline.

In the final months of 2013, five solar sites in North Carolina that were being developed by SunEnergy1, a North Carolina solar installer, were reaching a dealine. The end of the year signalled a tax credit deadline that meant the company had to complete all five solar farms in only 60 days.

ATI was already working with SunEnergy1 and the two companies worked togather to develop a plan that would allow them to achieve the construction as required. ATI and SunEnergy1 signed the Supply Agreements a mere three months before the December 31st tax credit deadline.

SunEnergy1 is based in Mooresville, North Carolina and are developers of utility scale ground mount solar. They benefit as a company by being the preferred EPC to Duke Energy Renewables. With well over 100MW provides fully integrated system processes from project conception and design, to post-construction testing, commissioning and maintenance.

ATI was selected as the ground mount solutions provider for these projects due to previous efforts that SunEnergy1 was aware of. ATI's DuraTrack HZ and DuraRack fixed-tilt mounting system was used for the project and its claims to have the fastest on-site install rates in the industry helped secure the deal.

In order to facilitate installation of 56 MW at five sites in less than two months, ATI needed to extend the company capacities to provide engineering services, factory kitted assemblies, on-site project management support and accelerated shipments to ensure SunEnergy1 could meet the imposing deadline.

"I'm really impressed with the way ATI and SunEnergy1 were

able to come together, work side-by-side, and respond quickly to make sure the projects met tight deadlines which were critical to investors," says ATI Founder and CEO, Ron Corio. "The team effort in this case was truly exceptional."

"We at SunEnergy1 are thrilled to now be converted to ATI racking. Truly head and shoulders above the competition, both in tracking and fixed tilt solutions," explains Kenny Habul, CEO of SunEnergy1. "Through design excellence, clever packaging and pre-assembly, ATI's product is one of the reasons we could install 200,000 panels in less than 60 days."

Progress as required

North Carolina's solar industry has experienced positive growth thanks to the state's tax breaks and subsidies. SunEnergy1 has benefited greatly from this to become one of the state's leading solar companies. They have now progressed from building solar farms to owning and running PV power stations. The North Carolina solar power industry has experienced impressive growth with employment jumping 121 percent to about 3,100 workers in 2013 alone moving the state to a top 10 nationwide position. The tax break changes to the state support saw a flurry of activity for the sector at the end of 2013.

Dogwood Solar Power, Windsor Cooper Hill Solar, Bethel Price Solar, Washington Airport Solar and Highway 92 Solar, all located in eastern North Carolina, were the first to receive the new DuraTrack HZ and DuraRack product enhancements. These included such attention to detail as integrated grounding module mounting clamps which optimize materials and install time.

All three DuraTrack HZ projects and both DuraRack projects were designed to withstand more than 100 MPH winds in North Carolina's hurricane prone environment. All five projects were commissioned on-time before the 31st of December 2013.

Slashing costs in thin film manufacturing

Researchers from North Carolina State University have developed a "superabsorbing" design that may significantly improve the light absorption efficiency of thin film solar cells and drive down manufacturing costs.

THE SUPERABSORBING DESIGN could decrease the thickness of the semiconductor materials used in thin film solar cells by more than one order of magnitude without compromising the capability of solar light absorption.

"State-of-the-art thin film solar cells require an amorphous silicon layer that is about 100 nanometers (nm) thick to capture the majority of the available solar energy," says Dr. Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of a paper describing the work. "The structure we're proposing can absorb 90 percent of available solar energy using only a 10 nm thick layer of amorphous silicon. "The same is true for other materials. For example, you need a cadmium telluride layer that is one micrometer thick to absorb solar energy, but our design can achieve the same results with a 50 nm thick layer of cadmium telluride. Our design can also enable a 30 nm thick layer of copper indium gallium selenide to fully absorb solar light. That's a huge advance."

Cao notes that the deposition of semiconductor materials stands as a major bottleneck for improving manufacturing productivity and lowering the cost of thin film solar cells.

"A decrease in the thickness of semiconductor materials by one order of magnitude would mean a substantial improvement in manufacturing productivity and reduction in cost," Cao says, because the cells would use less material and the thin films could be deposited more quickly.

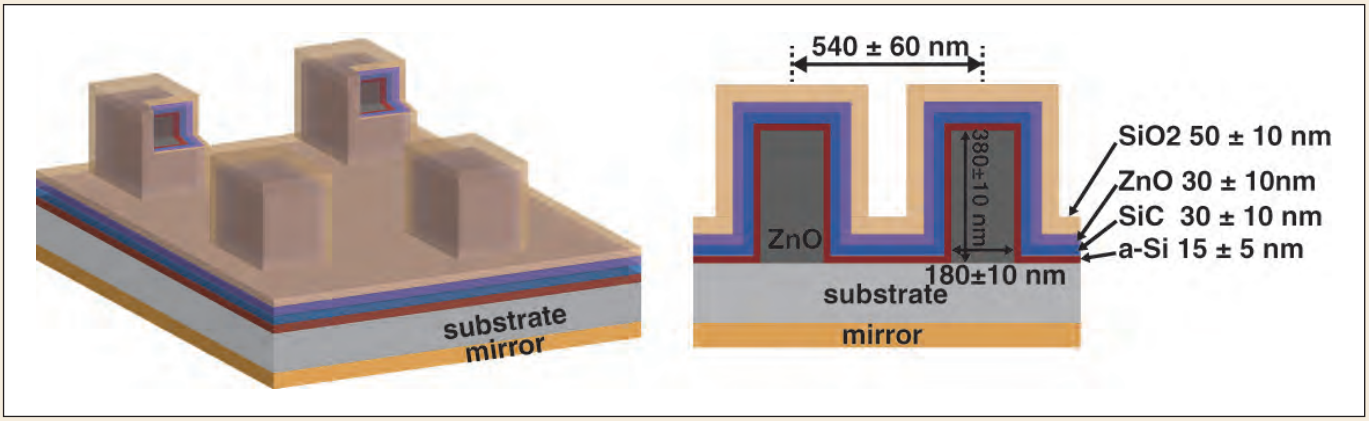
In cross-section, the new design looks like a rectangular onion. The light-absorbing semiconductor material coats a rectangular core. The semiconductor, in turn, is coated by three layers of anti-reflective coating that do not absorb light.
To develop the design, the researchers began by examining the maximum light absorption efficiency of semiconductor materials using light-trapping techniques. They found that maximizing solar absorption requires a design in which the light-trapping efficiency for solar light is equal to the intrinsic absorption efficiency of the semiconductor materials. In other words, in order to maximize solar absorption, you need to match the amount of solar light trapped inside the structure and the amount of solar light that could be absorbed.

The researchers then designed the onion-like structures to match their light-trapping efficiency with the absorption efficiency of the semiconductor materials in thin film solar cells.

"We first theoretically predicted the maximum solar light absorption efficiency in given semiconductor materials, and then proposed a design that could be readily fabricated to achieve the predicted maximum. We developed a new model to do this work, because we felt that existing models were not able to find the upper limit for the solar absorption of real semiconductor materials," Cao says "And if this works the way we think it will, it would fundamentally solve light-absorption efficiency problems for thin film solar cells.

"The superabsorbing structure is designed for the convenience of fabrication, and we are looking for partners to produce and test this design," Cao adds. "The structure should be very easy to produce with standard thin film deposition and nanolithography techniques. We are happy to work with industry partners to implement this design in the production of next-generation solar cells."

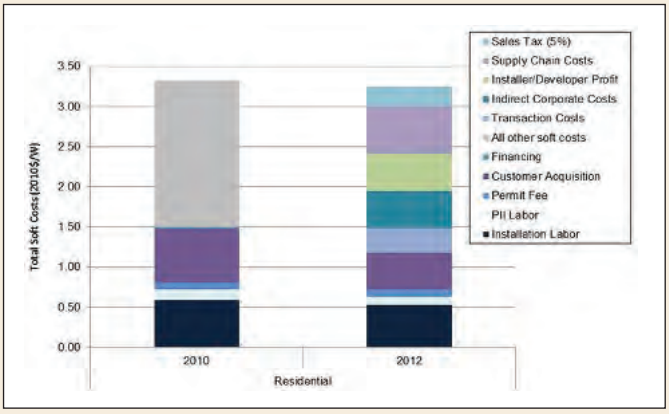
The paper, "Semiconductor Solar Superabsorbers," was published Feb. 17 in the journal Scientific Reports. Lead author of the paper is Yiling Yu, a Ph.D. student at NC State. The paper was co-authored by NC State Ph.D. student Lujun Huang.



Largest cost is soft element of installation

Two reports from the Energy Department's National Renewable Energy Laboratory (NREL) find that solar financing and other non-hardware costs, often referred to as "soft costs", now comprise up to 64% of the total price of residential solar energy systems, reflecting how soft costs are becoming a larger fraction of the cost of installing solar.

The first report, "Benchmarking Non-Hardware Balance-of-System (Soft) Costs for U.S. Photovoltaic Systems, Using a Bottom-up Approach and Installer Survey " is a follow-up to the first edition published in 2012, but offers a more in-depth look at non-hardware business process and installation costs associated with photovoltaic (PV) solar energy systems. Research interviews included 55 residential PV installers representing about 27 megawatts of capacity installed during the first half of 2012. Researchers also gathered data from 22 commercial PV installers representing 269 commercial PV installations for the same time period, for a total of 66 megawatts of capacity.



The authors found that in the first half of 2012, soft costs represented the majority of all costs, 64% of the total price for residential systems, up from 50% of the total price in the first edition. Similar results were found for small and large commercial installations, 57% of the total cost for small (less than 250 kilowatts) commercial systems (up from 44%); and 52% of the total costs for large (250 kilowatts or larger) commercial systems (up from 41%).

For residential systems, the greatest soft costs were supply chain costs ($0.61/watt), installation labour ($0.55/W), customer acquisition ($0.48/W), and indirect corporate costs ($0.47/W), such as maintaining office management and accounting functions. Other soft costs examined for the report included costs for permitting, inspection, interconnection, subsidy applications and system design.

Soft costs for small commercial (<250kW) and large commercial (>250kW) systems were also collected and analysed. In contrast to the first edition of the report, the new report unpacked the "other" soft costs category, using a detailed "bottom-up" cost-accounting framework to quantify five sub-categories: transaction costs, indirect corporate costs, installer/developer profit, supply chain costs, and sales tax.

By modeling a third-party ownership structure — solar energy systems leased to homeowners, for example — the new approach captured costs of doing business that had not been previously quantified. Those costs include engineering, procurement, and construction; developer and finance department staff and overhead; professional and legal services; capital costs during construction; and other costs.

The second report "Financing, Overhead, and Profit: An In-depth Discussion of Costs Associated with Third-party Financing of Residential and Commercial Photovoltaic Systems" takes a deeper look at the five sub-categories identified in the benchmarking study that had been lumped together in the first edition of the benchmarking study.

Researchers and industry developed and vetted a bottom-up analysis of costs associated with developing, financing, constructing and arranging the financing for third-party owned systems. The model quantifies the indirect corporate costs required to install distributed PV systems as well as the transactional costs associated with arranging third-party financing.

The authors conducted in-depth interviews with members of finance departments at large PV installation companies and collected data from corporate public filings.

They found that third-party ownership added $0.78 per watt for residential systems and $0.67 per watt for commercial projects. They also noted three of the main benefits of third-party financing arrangements:

Third-party financiers offer additional services, such as shopping for systems, maintaining systems, and applying for incentives.
Third-party financing may effectively lower the levelized cost of energy over time through economics of scale.
Businesses offering third-party ownership of installations have gained approximately 70% of residential market share in the United States, driving much of the PV demand.

The findings in these reports provide benchmarks and help track progress of the SunShot Initiative, a national effort to make solar energy fully cost-competitive with traditional energy sources by the end of the decade.

Boost to light absorption

Engineers are developing an optical nanocavity to boost light absorption in semiconductors; it could improve solar cells, cameras and more.

AN OPTICAL CAVITY is an arrangement of mirrors that allows beams of light to circulate in closed paths. These cavities help us build things like lasers and optical fibers used for communications. Now, an international research team pushed the concept further by developing an optical "nanocavity" that boosts the amount of light that ultrathin semiconductors absorb. The advancement could lead to, among other things, more powerful photovoltaic cells and faster video cameras; it also could be useful for splitting water using energy from light, which could aid in the development of hydrogen fuel.

The team, comprised of faculty and students from the University at Buffalo and two Chinese universities, presented its findings Feb. 24 in the journal Advanced Materials. The paper, called "Nanocavity enhancement for ultra-thin film optical absorber,"

"We're just scratching the surface, but the preliminary work that we've done is very promising," said Qiaoqiang Gan, PhD, lead author and UB assistant professor of electrical engineering. "This advancement could lead to major breakthroughs in energy-harvesting and conversion, security and other areas that will benefit humankind."

Semiconductors form the basis of modern electronics. They work by manipulating the flow of energy in electronic devices. The most common semiconductor material, silicon, is used to make microchips for cellular phones, computers and other electronic devices.

Industry has kept pace with the demand for smaller, thinner and more powerful optoelectronic devices, in part, by shrinking the size of the semiconductors used in these devices. The problem, however, is that these ultrathin semiconductors do not absorb light as well as conventional bulk semiconductors. Therefore, there is an intrinsic tradeoff between the ultrathin semiconductors' optical absorption capacity and their ability to generate electricity.

As a result, researchers worldwide are trying to find ways to boost the amount of light that ultrathin semiconductors can absorb. Harvard University researchers recently had varying degrees of success by combining thin films of germanium, another common semiconductor, on a gold surface.

"While the results are impressive, gold is among the most expensive metals," said Suhua Jiang, associate professor of materials science at Fudan University in China. "We illustrated a nanocavity, made with aluminum or other whitish metals and alloys that are far less expensive, can be used to increase the amount of light that semiconducting materials absorb."

The nanocavity consists of, from bottom to top: aluminum, aluminum oxide and germanium. In the experiment, light passed through the germanium, which is 1.5 to 3 nanometers thick, and circulated in a closed path through the aluminum oxide and aluminum.

The absorption rate peaked at 90 percent, with germanium absorbing roughly 80 percent of the blue-green light and aluminum absorbing the rest. This is ideal, said Haomin Song, PhD candidate in electrical engineering at UB and the paper's first author, because the bulk of the light stays within the semiconducting material.

"The nanocavity has many potential applications. For example, it could help boost the amount of light that solar cells are able to harvest; it could be implanted on camera sensors, such as those used for security purposes that require a high-speed response. It also has properties that could be useful for photocatalytic water splitting, which could help make hydrogen fuel a reality," Song said.

Before any of that happens, however, more research must be done, especially as it relates to how the semiconductor would turn the light into power as opposed to heat.

Gan's research group is collaborating with Alexander Cartwright, PhD, UB professor of electrical engineering and vice president for research and economic development, and Mark Swihart, PhD, UB professor of chemical and biological engineering, to develop ultrathin energy-harvesting devices. Gan is also working with Hao Zeng, PhD, UB associate professor of physics, to study its effect on photocatalysis.

Light-induced degradation in amorphous silicon thin film solar cells

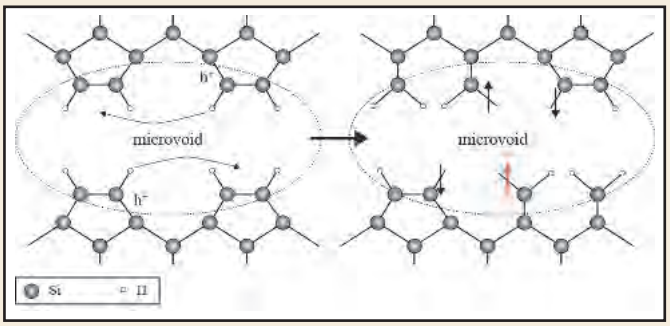
Researchers at the Helmholtz Center Berlin (HZB) have taken a leap forward towards a deeper understanding of an undesired effect in thin film solar cells based on amorphous silicon – one that has puzzled the scientific community for the last 40 years.

The researchers were able to demonstrate that tiny voids within the silicon network are partly responsible for reducing solar cell efficiency by some 10 to 15 percent as soon as you start using them. Their work has now been published in Physical Review Letters (DOI: 10.1103/PhysRevLett.112.066403).

Amorphous silicon thin film solar cells are considered a promising alternative to solar cells based on highly purified silicon wafers, which have been dominating photovoltaic power generation. A major advantage of amorphous silicon thin film photovoltaics, where a glass substrate is coated with a light active material less than a thousandth of a millimeter thick, is that the cell fabrication is considerably simpler and much less costly than in the case of conventional crystalline silicon solar cells. On the other hand, a potential disadvantage is the low conversion efficiency from solar energy to electricity. Because of the disordered nature of amorphous silicon, solar cells are subject to the Staebler-Wronski effect, which reduces the solar cell efficiency by up to 15 percent within the first 1000 hours.

This undesired effect is triggered by internal annihilation of charge that has not been extracted from the solar cell. The released recombination energy induces defects in the amorphous network - which is why this effect is not observed in crystalline wafer solar cells. “However, where defects are produced in the material and whether voids of nanoscale size play a role in all this has not been understood – until now, that is,” says HZB’s own Matthias Fehr of the Institute for Silicon Photovoltaics. Fehr together with his HZB colleagues, scientists from Jülich Research Center and the Free University of Berlin have now made major strides towards unraveling this mystery.

Since the defects that form exhibit paramagnetic properties, they have a characteristic magnetic fingerprint, which depends on their microscopic environment. The Berlin researchers were able to identify this fingerprint using electron-paramagnetic resonance (EPR) spectroscopy and electron-spin echo (ESE) experiments. With the help of these sensitive techniques, they determined that defects in amorphous silicon actually come in two types: those that are uniformly distributed and those that are concentrated in clusters on internal surfaces of small voids, known in scientific



In the initial state (left), the voids’ internal surfaces are saturated with hydrogen atoms so that no defects are observed. Light-induced charge carriers (h+) destabilize atomic bonds. The breaking of atomic bonds causes defects (indicated by the vertical arrows on the right hand side), which translates to reduced solar cell efficiency

circles as microvoids, which form within the material during the solar cell manufacturing process.

“Our findings seem to suggest that microvoids most likely contribute to light-induced degradation of amorphous silicon thin film solar cells. For us, it’s been a leap forward towards a better understanding of the microscopic mechanism of light-induced degradation,” says Fehr who, in 2013, spent a year conducting research in the US as a Feodor Lynen Scholar of the Alexander Humboldt Foundation. A new series of experiments has been designed to allow the Berlin researchers to glean further insights into the atomic and electronic processes of the Staebler-Wronski effect, named for the two scientists who first discovered it.

The work is part of the EPR-Solar network funded by the German Federal Ministry for Education and Research and the HZB’s and FUB’s Berlin Joint EPR Lab. According to the head of the project, Prof. Dr. Klaus Lips, “this is one of the major projects of one of the HZB’s newest research departments, which is currently in the founding stage and whose mission is the fundamental physical characterization of energy materials with the goal of making an important contribution to the energy transition.”

References:
[1] Fehr, M., Schnegg, A., Rech, B., Astakhov, O., Finger, F., Bittl, R., Teutloff, C., Lips, K. (2014) Metastable defect formation at microvoids identified as a source of light-induced degradation in a-Si:H. Phys. Rev. Lett. (accepted)

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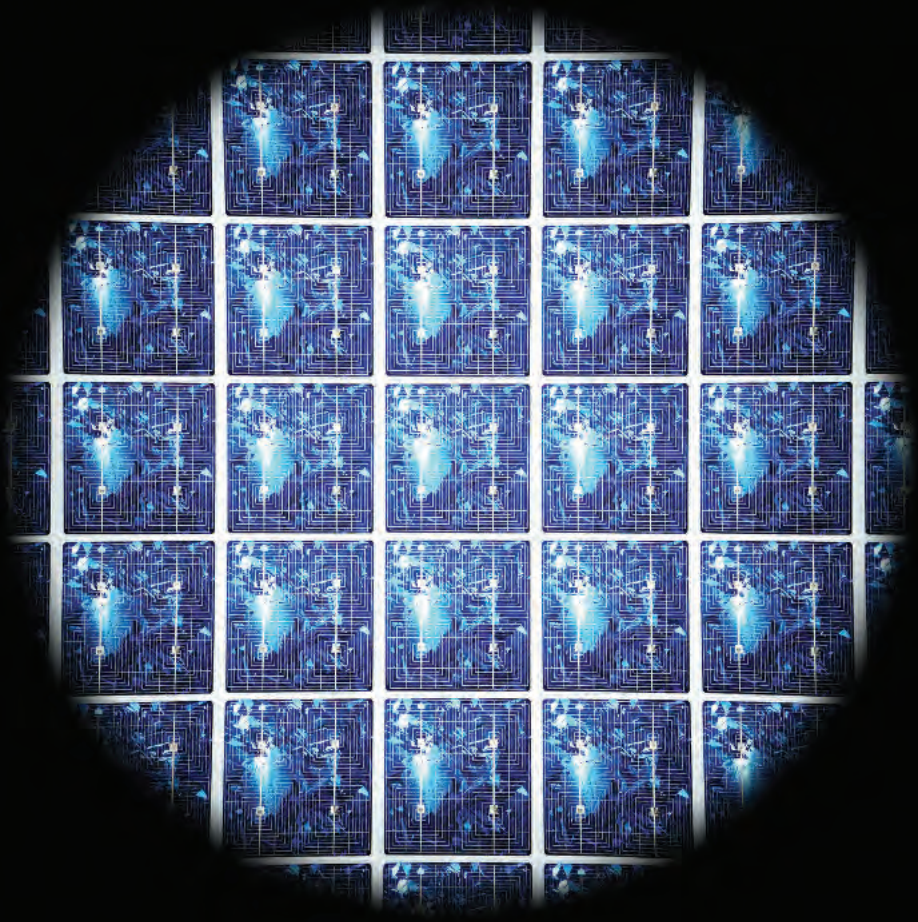

Enhancing coating uniformity for electron beam lift-off

Solar and PV technologies are becoming a key differentiator for companies, especially where microelectronics are a key component. Compound semiconductors form the basis of concentrated PV technology and Philip Greene from Ferrotec, Temescal Division discusses how electron beam evaporators must understand that achieving uniformity in high end devices requires high end technical knowledge.

Solar cells made from compound semiconductor devices, like all such devices, are all fabricated in a similar way. Whether it is solar cells, LEDs, lasers or electronics, production begins with deposition of epitaxial layers onto a substrate, followed by processes that add metal films and contact wires to construct a device housed in a suitable package.

A standard technique for depositing a metal on a compound semiconductor is electron beam evaporation. It may be performed as part of a lift-off process, which involves deposition on a patterned sacrificial layer that is then removed to leave a metallic film on part of the surface. Strengths of electron-beam evaporation include a high effective deposition rate, which enables acceptable deposition times, and a highly directional source that limits detrimental sidewall coverage. Very high-quality films are possible by carrying out electron beam evaporation under a high vacuum: This leads to very low levels of incorporation of background gas contaminants, while scattering of the evaporated materials

is minimised, thereby maintaining the highly directional nature of the evaporated species.

The directional nature limits photoresist via sidewall coverage when the substrate is oriented perpedicularly to the evaporant flux. However, a substrate oriented perpendicularly to the evaporant flux only receives truly normal incident flux at its centre, with some angular variation of the incident flux across the width of the substrate. This can be kept within a desired range by placing it at an appropriate distance from the source. The greater the distance, the smaller the deviation from normal incidence, with a lower deposition rate as one price to pay. Although the rate can be cranked up by increasing the source power density, there are material-based limits to what is practical. Unfortunately, the nature of the process is such that when an array of perpendicularly oriented substrates are placed at a fixed distance from the source, the deposition thickness will not be inherently uniform, but have some variation in thickness across and between substrates at different locations.

At Temescal, a division of Ferrotec based in Livermore, California, we have devoted much effort to exploring the critical interrelationships between electron beam system architecture, material behaviour and process methodology in order to devise approaches that lead to higher uniformities for electron beam evaporation. Our success includes the development of a process methodology that could reduce losses from uniformity masks and offer significant improvements

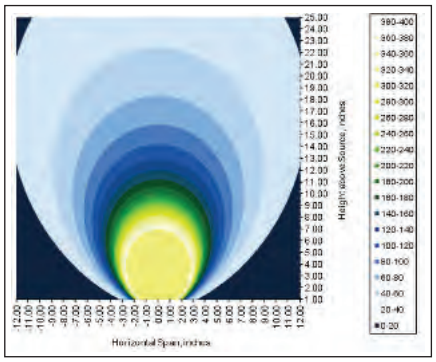

Figure 1. Growth rates of metals in an electron-beam evaporator decrease with distance from the source to the substrate, and vary with angle

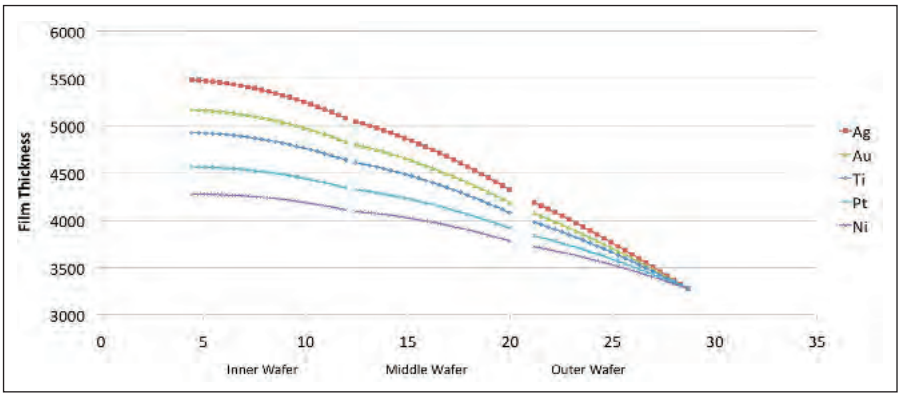

Figure 2. In a single-axis rotating dome, deposition without a mask produces variations in metal film thickness of +/-12.8 percent to +/-24 percent, depending on material

to collection efficiency (see Compound Semiconductor March 2013, p. 29). We have also explored the more general issue of attainable film uniformity, and here we consider what can be achieved with the historical techniques and the newest methodologies available.

Realising a highly uniform film is not just an end in itself – it is critical to several processes, including the formation of eutectic films used for bonding. In these films, small variations in the ratio of materials can lead to a rise in melting temperature, and ultimately be the source of bonding issues across the substrate. That's because composition variations have to be addressed by turning to a higher temperature to ensure melting across the entire film. The composition variation also has the unwanted side effect of possible changes in film morphology upon cooling.

Users of electron-beam evaporators face many potential sources of non-uniformity, and it is not possible to cover all of them here. So we will focus on the main factors influencing uniformity, and assume that film deposition is carried out using a well-controlled evaporation source, housed in a tool with tight mechanical tolerances relating to its geometry.

One factor having a big influence on film uniformity is the shape of the vapour cloud. Its impact on the uniformity of films deposited on 150 mm wafers is quite different in two of our tools designed for high-volume production: the Temescal FC-4400, which features a wafer carrier with a single axis of rotation that holds up to 30 wafers in three radial tiers; and the Temescal UEFC-5700, a tool with dual axes of rotation that either accommodates: 36 wafers in six domes, each holding six wafers; or 42 wafers in three domes, each holding 14 wafers. Both tools have similar distances between the electron-beam source and the substrates of about 42 inches.

Vapour clouds

Many factors influence the distribution of the evaporant flux, including the inclination angle and azimuthal angle, the power provided to the source material and its evaporation rate, beam cross section and density (size) and the height and shape of the source.

We have worked hard to minimise the influence of all these parameters by designing the hardware and refining the process so that it provides the most stable, consistent conditions. One of

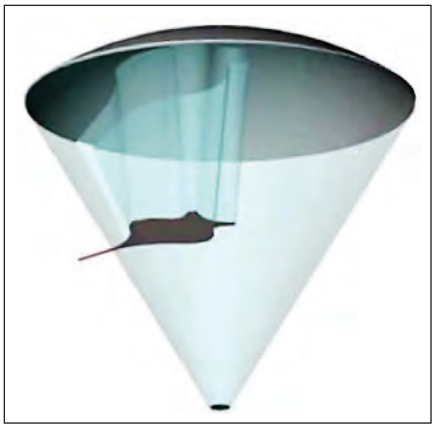

Figure 3. Inserting a shadow mask can improve thickness uniformity in an electron-beam evaporator

our insights is that it is critical to get high levels of uniformity at the source, because any variation here can carry over into non-uniformities for the vapour cloud. Manufacturers of electron-beam deposition tools often mount the substrates on a rotating dome-shaped carrier to minimize the influence of asymmetries in the azimuthal angle. By taking this approach, substrates experience an average of the deposition rate across all azimuthal angles, and thus have a smooth film thickness profile, with high values in the centre and lower ones towards the outer edges of the dome.

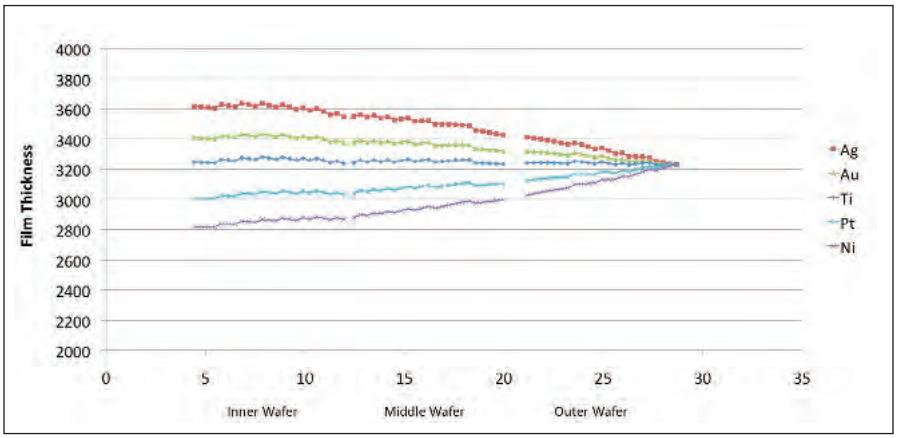

Figure 4. In a single-axis rotating dome, adding a shadow mask improves thickness uniformity. Note that the deposition conditions used to generate the plot shown in figure 2 are repeated, but with the addition of an optimised shadow mask. The vertical axis has been changed in order to better display the data

Engineers will often curve-fit the shape of the thickness profile observed across the wafers and carrier to better predict and understand the influence of measurement errors and small random fluctuations in conditions. One curve function offering a close fit to the observed thickness variation is the cosine power law – using this, one can predict thickness resulting from changes to the hardware, not including measurement error. Here we report the results of the application of that methodology to predict the best uniformity that can be achieved under realistic conditions.

The shape of an azimuthally symmetric cloud of gold vapour emanating from a 6 kW source is shown in Figure 1. This plot reveals the effective deposition rate across a substrate carrier placed normal to the flux. Regardless of source-substrate distance, the deposition rate varies with angle and is highest directly above the source. Given this, one could say that evaporation from the source is 'directed upwards', with a degree that changes significantly with different evaporants – and may even change significantly via modifications to the evaporation rate of a material.

Rotation about one axis…

Over the years, we have expended considerable effort in documenting vapour cloud profiles for numerous materials over a range of process conditions. In this article, we draw on a small fraction of this database to highlight the sensitivity of the system. For example, the choice of material has a big impact on film thickness variation across all substrates: it can range from +/-12.8 percent to +/-24.0 percent in a tool employing a standard single rotation axis, and featuring a lift-off dome configuration (see Figure 2).

Adding one or more 'shadow masks' to block some of the evaporant flux is a conventional approach for increasing the uniformity along the radius of the dome (see Figure 3 for an illustration of this approach). The evaporant flux is greatest towards the centre of the rotating dome, so shadow masks are carefully shaped to block more of the flux heading towards the inner portion of the dome, compared to that travelling to the outer regions.

With a fixed-position shadow mask, each and every material, regardless of deposition conditions, gets the same correction for relative thickness. The improvement can be far from modest – see Figure 4 to gauge the benefit wrought by the addition of a shadow mask designed for the average thickness profiles from the data in Figure 2.

The improved thickness uniformity with the addition of one shadow mask varies from material to material, from a low of +/-0.9 percent to a high of +/-6.9 percent. These results highlight that a well designed mask can tune the uniformity for

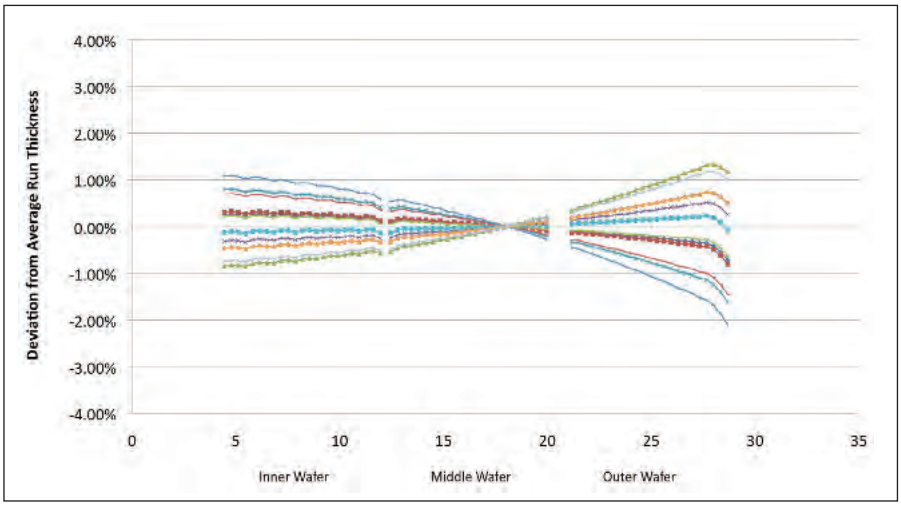

Figure 5. Deposition conditions vary from run to run and evaporator to evaporator. These variations, which impact the thickness profile, are considered in this plot that shows deviations in thickness profiles over multiple runs from six evaporators. Note that to remove the slope across the dome – an inherent feature from a mask that was designed to balance the results from two materials – data were normalized to remove that slope from the average profile

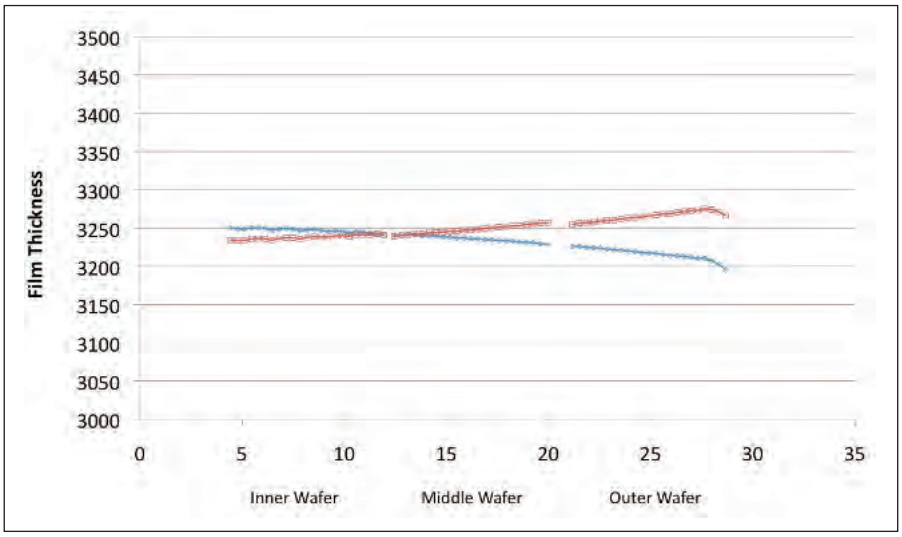

Figure 6. Even variations in the height of the source produce differences in film thickness. This plot show the variations in a single axis rotating dome with a mask, with source heights of + 0.5 inch (blue line) and -0.5 inch (red line)

a given process condition to exceedingly tight standards. However, although these gains are significant, there is a limit to what a single mask can produce, in terms of tuning the uniformity for multiple processes. The obvious solution – and one that has been applied when there is a select set of processes with critical uniformity tolerances – is to work with multiple shadow masks, which are moved into and out of the evaporant cloud at appropriate times. However, it is often impractical to do this for every material, so process engineers only select mask designs for the most critical materials.

Complicating matters, associated with every process is a normal variation in the shape of the evaporant cloud. The shadow mask is a fixed component in the system, designed for a particular process (material and rate), and so its correction cannot always match actively changing conditions. The degree of variation strongly depends on the material, although it can be restrained by employing identical source conditions.

So far, we have only presented plots of film uniformity based on representative deposition conditions for each material. When these deposition conditions vary, thickness profiles change. An example of the extent of this change is illustrated in the variations in growth of titanium films deposited in six identically configured evaporation systems (see Figure 5 for changes in radial thickness profile.) By repeating the same deposition process across six tools we explore the influence that variations in deposition conditions have on the uniformity. These results demonstrate that repeatability of the deposition profile can be kept in the +/-1.5 percent range for this practical range of deposition conditions.

The range includes some variation caused by source depletion from within the crucible over the course of multiple runs, as well as other small, unintended differences.

Changes to the height of the evaporant surface also produce variations in the system, but in this case they are independent of material type. To some extent these changes are unavoidable, because as material evaporates from a source, the height of the evaporant will fall. The impact on uniformity can be significant when uniformity tolerances are tight. For example, changes in uniformity of +/-1 percent and a change in the outer position thickness of nearly 2 percent can occur when the source height shifts from 0.5-inch above to 0.5 inch below the nominal evaporant surface (see Figure 6). This is a realistic scenario for several common sources. Processes that require a tighter range on uniformity cannot allow that large a change in source height, so must break more frequently for source replenishment to maintain an even height.

While repeatability in the +/-1.5 percent range is representative of the exceptional performance capabilities of a well-tuned precision system like the FC-4400, it serves as a noteworthy benchmark for conventional methodologies when compared to the levels of uniformity achievable in the UEFC-5700.

Figure 7. Higher levels of film thickness uniformity are possible by switching from a single-axis tool to one that provides dual axes of rotation. An example of the latter is the Temescal UEFC-5700, which accommodates 36 wafers in six domes, each holding six wafers

The tremendous reduction in overall range for each material and the differences in ranges between material types go hand-in-hand with similar reductions in sensitivity of the uniformity profile to run-to-run variation and source height variation. Those variations that caused shifts in uniformity in a single-axis tool of +/-1.5 percent are reduced in their influence to under 0.2 percent

... and two axes

To minimize the inclination angle non-uniformity, we have developed the high uniformity lift-off apparatus (HULA). These patent-pending tools feature a second axis of rotation, which greatly reduces the range in non-uniformity prior to the addition of a shadow mask.

A tool that we have already mentioned in this article, the UEFC-5700, has a HULA configuration (see Figure 7). This tool features six small domes, which each spin about their own axes while rotating about the tool's central axis. Rotating the substrates in this manner has several major benefits: it increases collection efficiency by reducing the need to turn to a shadow mask to increase uniformity; and it greatly reduces sensitivity to material type and process conditions, thereby enhancing uniformity.

With the addition of the HULA motion, calculations indicate that the ranges for unmasked thickness profiles of different metals plummet to just +/-1.74 percent to +/-2.36 percent (see Figure 8). The tremendous reduction in overall range for each material and the differences in ranges between material types go hand-in-hand with similar reductions in sensitivity of the uniformity profile to run-to-run variation and source height variation. Those variations that caused shifts in uniformity in a single-axis tool of +/-1.5 percent are reduced in their influence to under 0.2 percent. The upshot of all of this is a system that delivers very robust uniformity characteristics across a wide range of materials.

Further improvements to thickness variation are possible with the addition of a very small shadow mask (see Figure 9). Using one designed for platinum film deposition, thickness variations are of the order of +/-0.5 percent – values so small that the metrology used to measure film thickness becomes very challenging, and the variations in film thickness may exceed the practical measurement accuracy commonly available.

We have also compared the calculated results for titanium (shown in Figure 8) with measurements on 20 nm-thick titanium films. Comparisons were made by plotting deviations from the average thickness for each substrate, and measuring the titanium film thickness with an optical technique that is sensitive to tiny variations in average thickness over the measurement area. There is good agreement between calculated and measured values, but some discrepancy at levels near +/-0.2 percent (see Figure 10). In this thickness range a 1 percent variation in thickness is comparable to

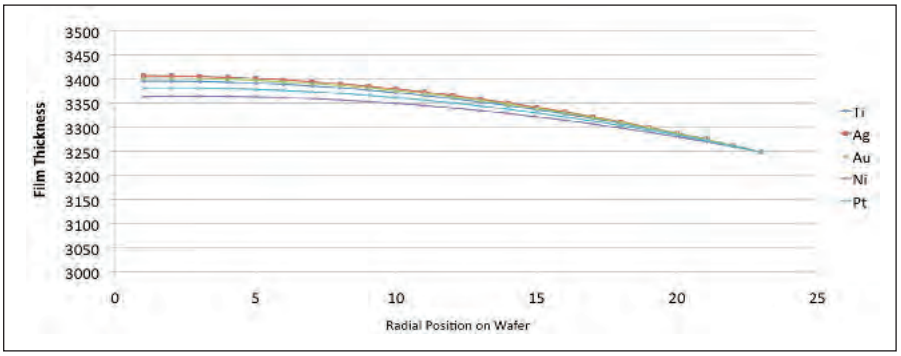

Figure 8. With the high uniformity lift-off apparatus (HULA), which incorporates a second axis of rotation, unmasked thickness profiles are just +/-1.74 percent to +/-2.36 percent. Note that this plot displays the uniformity across the wafers in the radial direction for the same set of material conditions as shown in Figure 2. The scale of the vertical axis has been reduced to better display the range in thickness. Since the wafers in this design are held in a single tier, the uniformity is representative of the shape for all of the wafers

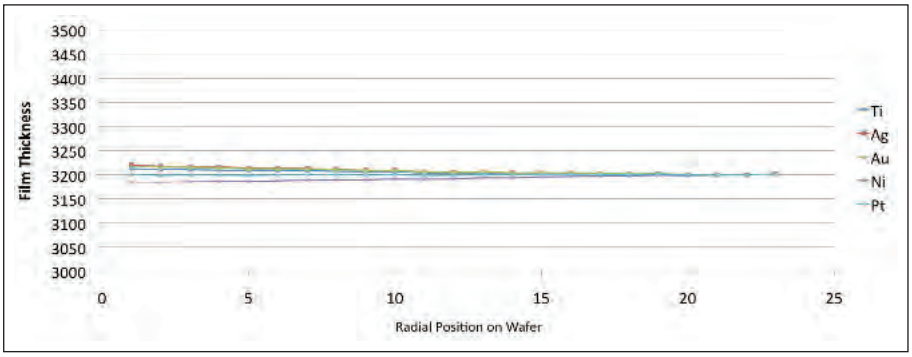

Figure 9. Adding a mask for platinum deposition to a HULA apparatus trims the thickness variations to around +/-0.5 percent

the diameter of an atom, and this level of uniformity indicates a remarkably uniform distribution of atoms across the substrate. Some of these measurements reveal a small decline in thickness between the inner and outer portions of the wafer. However, there is also other structure apparent, which varies from substrate to substrate. Although these features will partly be caused by measurement uncertainty, it is not possible to rule out substrate mechanical positioning as a contributing factor behind the thickness variation. When films are this uniform, variations in thickness that result from an angular tilt to the substrate or a radial displacement of just 0.04" become apparent.

Wafer-related limitations

Another impediment to realising a perfectly uniform film is the flatness of the substrate. For lift-off, the substrate is oriented in such a manner that at its centre, the direction of the impinging incidence flux is normal. Consequently, deposition at the edges of the substrate occurs at a small angle from normal.

Making matters worse, the distance to the source is larger at the edges of the substrate than its centre. This difference is magnified as wafer diameter increases, but can be reduced by increasing the distance between the electron-beam source and the substrate – although this action has downsides, such as reduced deposition rates.

Inserting a shadow mask into the electron-beam evaporator can address variations in film thickness in the radial direction. However, in the direction perpendicular to this – the cross-wafer direction – the mask has a limited influence on reductions in film thickness.

Variation in film thickness due to flat wafers is also influenced by the number of axes of rotation in the system: the HULA motion without a shadow mask gives some slight improvement over the single axis motion without a mask, but the single axis and HULA results are effectively identical after the addition of a shadow mask (see Figure 11).

These uniformities, and those revealed in other plots presented in this feature, indicate that users of electron-beam evaporators have entered a new era for process tolerances and expectations in a production tool. When a single-axis tool is built to tight mechanical tolerances and runs a well-controlled and stable process, select processes can produce a thickness uniformity within a range of +/-1.5 percent on 150 mm wafers.

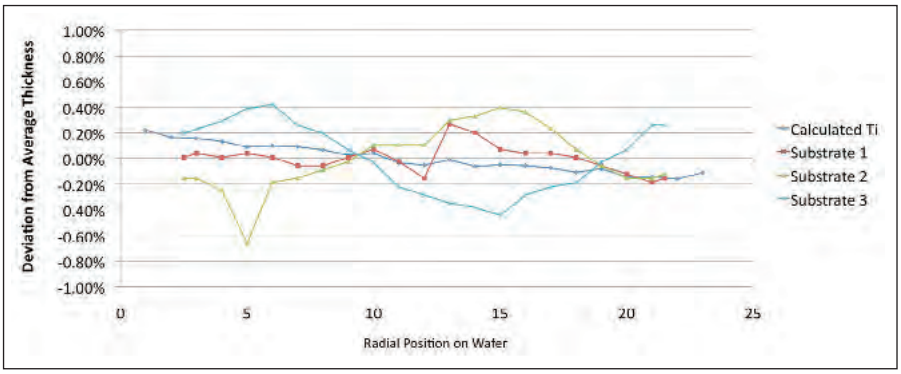

Figure 10. The calculated values can be compared to experimental values

The range of processes capable of delivering this level of uniformity expands with the addition of a second axis of rotation, which is found in the HULA tools.

For the deposition of eutectic films, this level of uniformity can mean the difference between an experimental process and a production wafer. But that's not all, as this level of uniformity can also drive further manufacturing efficiencies, thanks to reduced product binning – the sorting of finished devices based on variations in performance characteristics, such as voltage output, operational frequency and thermal tolerance. Such variations result from process variables and the inherent limits of each process, with a wider spectrum of product binning increasing parametric yield loss, which is the cost-per-wafer after sorting.

To increase uniformity to inside the +/-1 percent range requires the addressing of additional impairments to perfect film growth. This is hampered by wafer flatness, with success demanding even tighter tolerances on the mechanical systems that support and move the substrates. Programmes directed at uniformities of better than +/-1 percent must also consider whether the metrology is capable of accurately and consistently reporting the correct thickness.

This is particularly challenging when the goal is to achieve differences in thickness that are smaller than that of the typical substrate surface roughness, or in the case of thin films, where the difference can be less than the width of an atom.

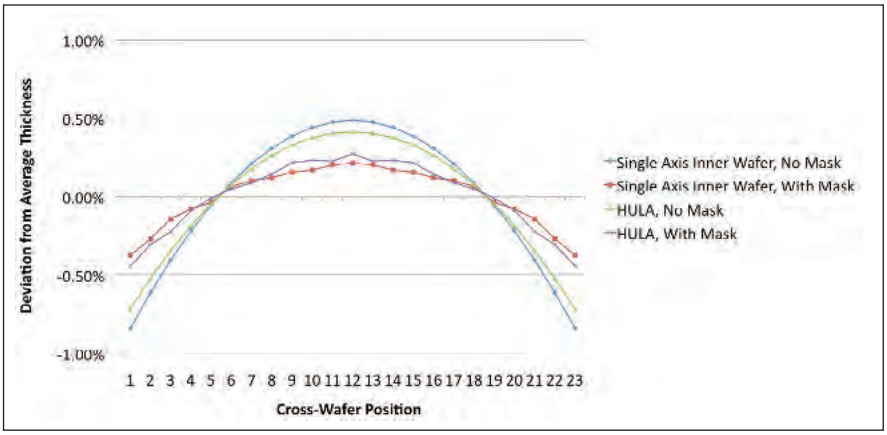

Figure 11. Without a mask, the addition of a second axes of rotation leads to a significant improvement in cross-wafer uniformity. But when the mask is added, this difference is minimal

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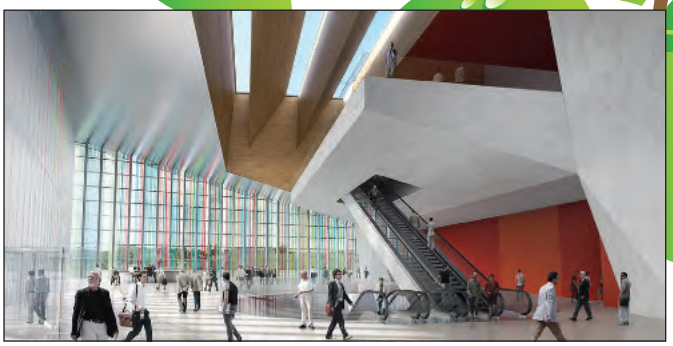

IN A WORLD FIRST, no less than 300m² of dye-sensitized solar cells will be integrated to the facade of Switzerland's new EPFL's Convention Centre. This prototype will constitute the first application of such technology to a public building. The translucent panels are constructed and assembled by local SMEs and make use of an invention conceived by EPFL researcher Michael Graetzel. This project is embedded within the framework of the partnership established in 2009 between EPFL and Romande Energie - whose aim is to create one of the largest solar energy parks in Switzerland.

The west facade of EPFL's future Convention Centre, currently under construction, will be an eye-catcher. The silk-screened glass blinds that had been initially planned for the building will be replaced with translucent and coloured photovoltaic panels, also known as "Graetzel cells" after their inventor.

"I am very pleased to see this technology used in a major architectural project," said Michael Graetzel. This is an important step towards a large scale distribution of dye sensitized solar cells, whose principle is based on plant photosynthesis, explained the researcher.

Unlike opaque solar cells made of silicon, Graetzel units are transparent. The cells at the Convention Centre will exhibit shades of red and orange, as designed by the artist Catherine Bolle from Lausanne.

The production of electricity, estimated at 8,000 kilowatt hours (kWh) per year, only represents a minor part of the overall building consumption. In fact, these types of sensors are less efficient than silicon cells. They perform well with diffuse light.

"What we are doing with this Convention Centre is a display of technology, a platform intended to draw attention to a remarkable device invented at our labs, to full-scale test this technology and to demonstrate its significant architectural potential," said Francis-Luc Perret, VP for Planning and Logistics at EPFL.

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Our Research and Development team is constantly thinking about paste. We are committed to developing leading-edge solutions, which improve the power output and performance of solar cells at a lower cost per watt. We are always mindful of the current and future technology needs of our customers, and are driven to deliver results. So when you think of paste...think of Heraeus.

Leadership through R&D. Breakthroughs via innovation. Achievement by tradition.

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