The SOLAR QUARTERLY

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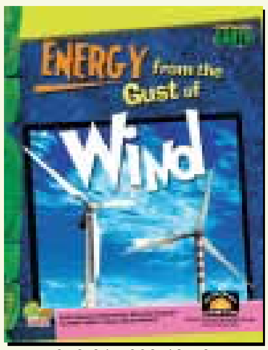

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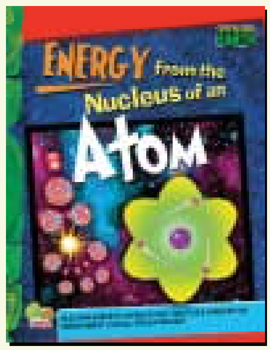

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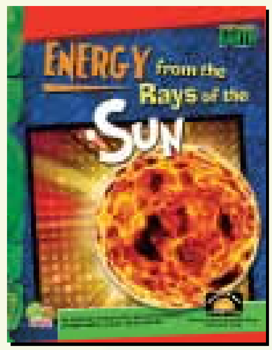

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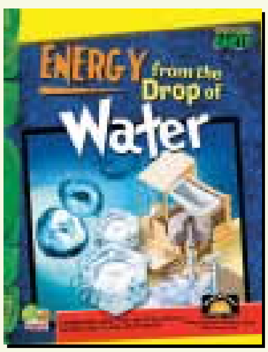

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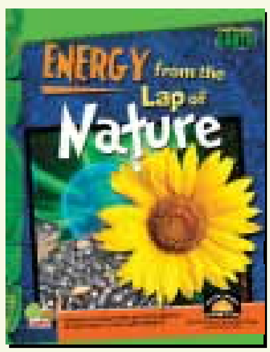

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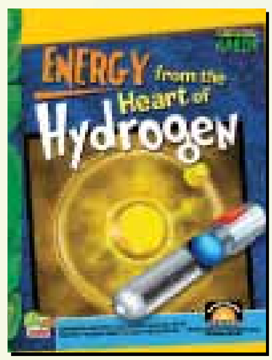

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KNOWLEDGE BOOKS ON ENVIRONMENT, WHICH SUPPLEMENT THE ENVIRONMENT EDUCATION CURRICULUM

Cover picture courtesy: Randy Montoya/Sandia Labs

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From the editor's desk...

This quarter saw the emergence of two important associations. The first one–the South Asia Regional Task Force had its kick-off meeting at Jodhpur, Rajasthan, on the 13th of September. The RTF is designed to be an independent non-profit, non-partisan, non-political, and technology neutral association, slated to be incorporated as a non-profit organization. The other association is that of the Solar PV Manufacturers' Association, which has come up recently as an effort of more than 20 companies from India associated with solar manufacturing. The latter is an industry association formulated to address the challenges faced by the manufacturers and to suggest solutions for the growth of the industry in India. The two associations, in their independent arena, will work towards addressing barriers and accelerating the development of solar energy in the country to ensure that its benefits reach the masses where it is required. However, I do see a missing link that will translate the efforts of the two associations into a sustainable and viable use of solar energy applications by the communities spread across several villages, towns, and cities in India. Let me elaborate . . .

Most of the industry reports say that the production costs of PV have come down due to rapid technological advancements, increasing scales of production, and consistent demand side pull from national programmes. However, the fruits of this cost reduction are yet to reach the off-grid sector where the cost to serve is still high due to several reasons such as lack of volume discounts, high cost of balance-of-system components, high cost of transportation, storage, labour for installation, among many other things. The off-grid market still struggles in areas such as enforcement of standards for product, services and after-sales service, and access to low cost finance among others. The objectives of RTF towards sharing knowledge on technology, standards, incentives, risk mitigations, and that of the Indian Solar PV Manufacturers' Association for the growth of solar industry, will not be taken forward to the demand side effectively unless the communities and the practitioners (programme designers and managers, installers, integrators, and technicians) of solar energy applications come together to demand the quality services at reasonable prices.

Therefore, the above two associations need to be complemented by a third, which represents the communities and the practitioners of solar energy applications who would work towards bridging the gaps of the supply and the demand side particularly in the context of off-grid sector where solar energy can bring about major changes.

With this new thought, I give the first issue of the 4th quarter of TSQ to its patrons and readers.

Akanksha Chaurey
Director, TERI

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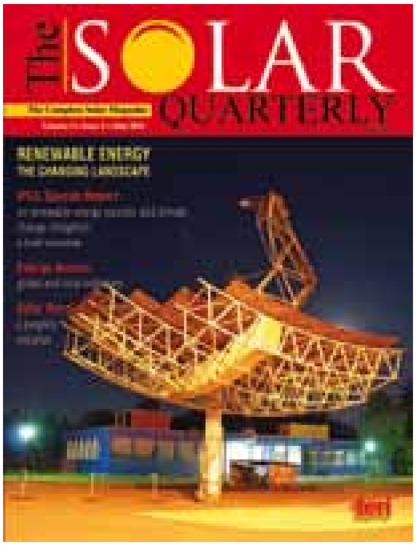

The Solar Quarterly is one of India's leading popular magazines on solar PV and technologies. I am a regular reader of the magazine. I find the magazine very informative and up to date.

The independent research findings on contemporary themes make it a favourite among the researchers new to the field. Kudos to the team of The Solar Quarterly for conceptualizing such a useful magazine!

Aishwarya Mohan
Jharkhand

I am a regular reader of *The Solar Quarterly*. The IPCC report on renewable energy sources and climate change mitigation was alarming. It highlighted the need for immediate action to be taken if people wish to save the planet for our children.

Dr Pachauri's analysis of the same was quite thought provoking.

I hope the editorial team of *The Solar Quarterly* continues to carry articles that are of immediate relevance.

Shiju Joseph
Kerala

I am research associate. I really like the magazine *The Solar Quarterly*. The magazine attempts to fill up an extremely relevant gap in published material by providing current knowledge on this critically important field for the benefit of researchers, academics, and policy-makers.

Hoping the magazine continues to maintain the high standard it has set for itself. All the Best!

Aditya Krishna
Chennai

I am a research scholar and I must say that this magazine has really helped me understand and clarify a lot of concepts and specifications. All the articles are well researched and drafted.

I thank you for sharing with us this relevant piece of information on solar energy.

Pratigya Arun
Bengaluru

I have been reading *The Solar Quarterly* since its inception in 2008. The magazine is very informative and quite well researched. All the same, it would be really nice if you could include some subject specific quiz or puzzles. The magazine tends to be very high and dry at times with a lot of serious stuff. The quiz would be of help to students as well who participate in subject specific quizzes.

A debate section would also prove to be highly beneficial.

Ankura Nair
Delhi

I have been following the magazine since its inception. Though, I love the content of the magazine, I feel that the editorial team should try to change the layout of the same. The magazine has too many pictures and it will be good if the pictures are decreased. Many pictures in the magazine are generic and can be done away with.

At the same time, I would like to write that I am really impressed by the content of the magazine. *The Solar Quarterly* has a good mix of generic and scientific articles.

All the best for the future issues of the magazine.

Rohit
Delhi

Thank you very much for your encouragement. The editorial team of The Solar Quarterly will make every effort to make this magazine highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvement in terms of content and presentation.

Editor
The Solar Quarterly

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First Abengoa and E.ON joint concentrated solar power plant comes online

In southern Spain, the sun shines for over 300 days a year. This solar energy will now be used by a large solar power station near Seville, built and operated jointly by E.ON, one of the world's leading power and gas companies, and Abengoa, a Spanish company which is a world leader in concentrating solar power plants.

Helioenergy 1, the first of two identical plants, started commercial operations on September 1, 2011. Helioenergy 2 is planned to come online later this year. The size of the two solar thermal power stations is impressive, spreading over 220 hectares. The area, corresponding to more than 300 soccer fields, is home for 121,000 installed mirrors which concentrate sunlight and generate steam at a temperature of 400 degrees. The steam then drives two 50MW turbines which generate electricity. The renewable energy generated will cover the average energy needs of 52,000 households and prevents 63,000 tons of CO_2 from being emitted into the atmosphere each year. Abengoa contributes expertise in solar technology and solar plant operations, while E.ON brings conventional power station construction and operation experience.

Source *EQ International*

Record low silicon consumption achieved by Sovello

At only 135μm thickness, Sovello produces world's thinnest crystalline wafers used in a photovoltaic industrial manufacturing process. As an integrated manufacturer Sovello is now in a position to produce wafers and cells far thinner than any other PV manufacturer. The pilot manufacturing of these cells is an ongoing ramp-up. Sovello Chief Technology Officer, Hans-Jörg Axmann explains: "For

Courtesy: SELCO

several years Sovello has been independently developing STRING RIBBON™ products. We are the first company to reach this break-through which has been an objective of the PV Industry for many years. I am excited to have achieved this milestone. This programme demonstrates the specific advantages and potential of our unique innovative technology." The specific advantage of this technology Sovello produces are the wafers with less than half the silicon and energy consumption required by traditional wafer sawing processes. Sovello CEO, Dr Theodor (Ted) Scheidegger adds: "Sovello's thinner wafers and cells now allow an even more intelligent use of resources–this accompanied by continued high efficiency of our solar modules securing outstanding energy yield for our customers. Already now we contribute in a meaningful way to low impact renewable energy generation and reduction of greenhouse gases for the benefit of future generations."

Source *EQ International*

Courtesy: Abengoa

High efficiency rear-passivated screen printed solar cells

Approximately 80% of today's silicon solar cells industrially manufactured worldwide apply screen printing for the metallization of the silver front and aluminium rear contacts. In production, conversion efficiencies of 18%–18.5% are achieved using monocrystalline silicon wafers. A baseline process has been implemented at ISFH that is very similar to the industry-standard process, displaying conversion efficiencies of up to 18.5%. An analysis of the solar cells reveals that the conversion efficiency is limited in particular by the shadowing loss due to the silver front-side metallization, as well as infrared light being absorbed in the aluminium rear-side metallization. Recent developments at ISFH have resulted in a 19.4% efficient large-area screen-printed solar cell, when applying a print-on-print silver front-side metallization and an SiO_2/SiN_x rear-surface passivation.

Source *PV-Tech.org*


Solar-powered processor

Intel showcases computer with solar-powered processor

Showcasing what the future holds in the computing arena, chip-maker Intel unveiled a computer with a processor running on a postage stamp-size cell powered by solar energy. Underlining Intel's efforts to push the boundaries for reduced power consumption in computing activities, its Chief, Mr Paul Otellini, demonstrated such a system on September 14, 2011 during his keynote speech at the Intel Developer Forum (IDF) 2011. Asserting that power innovation would reach unimaginable levels, he said Intel's researchers have created a chip that powers up a computer processor on a solar cell which is almost the size of a postage stamp. The computer had its solar-powered CPU drawing sufficient power to run animation and other Windows-based computing processes from two small overhead reading lamps. However, only the processor was being powered by the lamps and other parts of the computer were powered through a traditional power supply. Mr Otellini, however, clarified that the solar-powered computer was not yet a planned product and he was only demonstrating the company's efforts to cut down power consumption in computing processes. Terming the demonstration a lab experiment, he said much more work would be needed to make an entire computer system work on solar power and it was a challenge for the company to figure out how it could take such a system from the laboratory to production lines.

Source *The Hindu Business Line*

PV grid parity projected to arrive soon in European Markets

According to a recent study by the European Photovoltaic Industry Association (EPIA), solar photovoltaic electricity will reach grid parity in some European markets as early as 2013, and in all market segments across the continent by 2020. PV technology has shown impressive price reductions over the last 20 years, with the price of PV modules decreasing by over 20% each time the cumulative sold volume of PV modules doubles. In addition, there is enormous potential for a further generation cost decline–approximately 50% through 2020. The new EPIA report compares the real cost of PV electricity generation to that of other energy sources over the coming decade and highlights that, under the right conditions, PV can be competitive across Europe by 2020. PV electricity is cheaper than the general perception. In the coming years, it is going to get even cheaper thanks to ever-improving technology and economies of scale. The increasing costs of electricity from conventional generation sources will also help boost the PV's competitiveness. EPIA's analysis of five markets–France, Germany, Italy, Spain and the UK–examined the evolution of Europe's future energy mix and PV's role in it. The research was conducted with the support of strategic consulting firm A.T. Kearney.

Source *Solar Industry*

Gujarat secures US $100 million ADB loan for solar park

The ADB has offered a US $100 million loan to help build the 500MW Gujarat Solar Power Transmission Project. The Asian Development Bank (ADB) has offered a US $100 million loan to Gujarat to help speed up construction of its new large-scale solar power facilities. ADB's 25-year loan will finance the Gujarat Solar Power Transmission Project, funding a substation, transmission lines and other equipment to collect and distribute power generated by systems in the Charanka Solar Park in Gujarat's Patan district. These facilities are a boon to the PV industry in India, and Gujarat in particular, making it far more attractive, from a financial perspective, for private companies wishing to build large-scale PV plants."By putting in reliable power transmission facilities in the solar park, ADB will help draw in private sector developers, while providing a model which can be replicated to scale up solar power in a significant manner in India," said Naoki Sakai, ADB's senior climate change specialist. The Charanka Park, which hopes to eventually ramp up capacity to 500MW, is one of a number of large-scale parks planned in Gujarat to meet the rising energy demands in the state. The parks will provide developers with the necessary permits and services to fast track system installation and also help the Indian government achieve its goal of generating 20 GW through solar by 2022.

Source *PV Tech.org*

Solar heat for oil wells

There is a lot of energy from ancient sunshine stored in the oil that sits below the deserts of Oman. There is also a lot of sunshine hitting those deserts today. A new wrinkle to an established technology should allow some of that current sunshine to be employed to get at more of the ancient stuff. Using heat—in the form of steam—to liberate thick and gunky oil which would otherwise stay in the ground is nothing new. Such enhanced-recovery techniques date back to the 1950s and 40% of California's oil production now depends on steaming subterranean rocks. The steam, however, is made by burning other fossil fuels—normally natural gas—and because heating rock takes a lot of steam, making that steam costs a lot of money. It also adds to the oil's climate footprint. GlassPoint, a small Californian company, is on the process of making steam more cleanly and cheap for oil recovery by using sunshine to do the heating. Solar-thermal power stations, which employ mirrors to concentrate sunlight on boilers and thus raise steam to generate electricity by turning turbines, are far from cheap when compared with gas-fired stations. But solar-thermal electricity faces exacting challenges. A turbine will need particularly pure steam, which may stand to be a problem in a desert.

Source *The Economist*

New Hybrid Solar Collector produced by SolimPeks Corporati

SolimPeks Corp, a solar company based in Karatay, Turkey, has released the Volther Hybrid Solar Collector, which produces electricity and hot water simultaneously. The product hybrid modules produced by this company allows extra module heat to be absorbed to produce hot water, thus optimizing efficiency. Historically, the main drawback of many conventional photovoltaic systems has been the high

Courtesy: NREL/DOE

initial cost as well as the limited amount of electrical output when compared to the solar input. This Volther hybrid solar collector system allows excess heat to be recaptured and boosts the system's return on investment, according to SolimPeks Corp.

There are two systems very common to use the energy generated from the sun. First, we have the solar collector that makes hot water out of the energy from the sun. Second, there are PV (Photovoltaic) modules, which convert sunlight into electricity. Both systems have a black or dark surface that faces the sun. However, when a PV module gets heated it also loses some capability to make electricity. The power output lost is about 0.5% for every degree, so every 10 degree rise in the temperature from a PV module would mean a loss of about 5% of electricity output. Experiments are on to find a solution to this problem.

Source *www.solimpeks.com*

Solar power plant on Narmada branch canal near Sanand

The erstwhile sleepy town of Sanand in Gujarat is gearing up to house yet another first-of-its-kind project–a solar power plant to be built on the Narmada branch canal passing through Sanand. As part of a novel concept, the Gujarat government has decided to install solar power panels on one km stretch of Narmada branch canal near Sanand. To be developed on public private partnership (PPP) model, the solar plant on Narmada branch canal would generate one MW of power, once fully operational. Interestingly, the solar project is expected to save 100,000 litres of water a year by reducing evaporation of the canal water in that particular stretch of one km. The entire stretch would be covered by solar panels, thereby reducing evaporation of water. As per the industry estimates, a one MW solar power project roughly requires five acres of land. Installation of solar panels on river canals would also take care of land issue for solar power project.

SunEdison, a subsidiary of US-based global solar energy player MEMC, will execute the project near Sanand. This is for the first time such a project is being developed in India. The state government has already cleared the project and a new company is being floated to develop the project. There are different concepts being developed for solar power generation. Developing a solar power generation facility on the water canals is one of such concepts. But for any such effort, first of all a feasibility study needs to be carried out as it is entirely different from the existing projects being developed in India.

Source *Business Standard*

Empa produces flexible CIGS solar cells

Scientists at Empa, the Swiss Federal Laboratories for Materials Science and Technology have successfully produced flexible solar cells with an 18.7% record efficiency. Key to the breakthrough is the control of the energy band gap grading in the copper indium gallium (di) selenide semiconductor, also known as CIGS, the layer that absorbs light and converts it into electricity. The Empa team achieved this by controlling the vapour flux of elements during different stages of the evaporation process for growing the CIGS layer.

High-performance flexible and lightweight solar cells, say, on plastic foils, have excellent potential to lower the manufacturing costs through roll-to-roll processing and the so called "balance-of-system" cost, thus enabling affordable solar electricity in the near future. Thus far, however, flexible solar cells on polymer films have been lacking behind in performance compared to rigid cells, primarily because polymer films require much lower temperatures during deposition of the absorber layer, generally resulting in much lower efficiencies.

The research team at Empa's Laboratory for Thin Film and Photovoltaics, led by Ayodhya N Tiwari, has been involved in the development of high-efficiency CIGS solar cells on both glass and flexible substrates with a special focus on reducing the deposition temperature of the CIGS layer. The group has repeatedly increased efficiency of flexible CIGS solar cells over the past years–first at ETH Zurich and now since three years at Empa. With their current record value of 18.7%, Ayodhya N Tiwari and his team nearly closed the efficiency gap to cells based on multi-crystalline silicon (Si) wafers or CIGS cells on glass. To achieve


Courtesy: Randy Montoya

such high efficiency values, the recombination losses of photo-generated charge carriers had to be reduced. CIGS layers grown by co-evaporation at temperature of around 450 °C have a strong composition grading because of inadequate inter-diffusion of intermediate phases and preferential diffusion of gallium (Ga) towards the electrical back contact.

Source *Science Daily*

Optofluidics may help solve the problem of energy challenge

Optofluidics, the study of microfluidics, is the microscopic delivery of fluids through extremely small channels or tubes combined with optics. Demetri Psaltis, Dean of EPFL's School of Engineering, and his co-authors argue that optofluidics is poised to take on one of this century's most important challenges: energy. EPFL is the world leader in optofluidics.

By directing the light and concentrating where it can be most efficiently used, researchers could greatly increase the efficiency of already existing energy producing systems, such as biofuel reactors and solar cells, as well as innovate entirely new forms of energy production. Sunlight is already used for energy production besides conventional solar panels. For example, it is used to convert water and carbon dioxide into methane in large industrial biofuel plants. Prisms and mirrors are commonly employed to direct and concentrate sunlight to heat water on the roofs of homes and apartment buildings. These techniques already employ the same principles found in optofluidics, i.e., control and manipulation of light and liquid transfer– but often without the precision offered by nano and micro technology.

Source *Science Daily*

Harvesting solar power through nature

Clean solutions to human energy demands are essential to our future. Sunlight is the most abundant source of energy at our disposal. According to Prof Greg Scholes, University of Toronto, the answers to developing clean solutions can be found in the complex systems at work in nature.

Solar fuel production often starts with the energy from light being absorbed by an assembly of molecules. The energy is stored fleetingly as vibrating electrons and then transferred to a suitable reactor. It is the same in biological systems. In photosynthesis, for example, antenna complexes composed of chlorophyll capture sunlight and direct the energy to special proteins called reaction centres that help make oxygen and sugars. It is almost like plugging those proteins into a solar power socket.

Scholes and colleagues from several other universities examined the latest research in various natural antenna complexes. Using lessons learned from these natural phenomena, they have provided a framework for how to design light harvesting systems that will route the flow of energy in sophisticated ways and over long distances, providing a microscopic "energy grid" to regulate solar energy conversion.

A key challenge is that the energy from sunlight is captured by coloured molecules called dyes or pigments, but is stored for only a billionth of a second. This leaves little time to route the energy from pigments


Courtesy: Peter Zoon

to molecular machinery that produces fuel or electricity.

The natural photosynthesis becomes important herein. More than 10 billion photons of light strike a leaf each second. Of these, almost every red-coloured photon is captured by chlorophyll pigments which feed plant growth. Learning the workings of these natural light-harvesting systems fostered a vision, proposed by Scholes and his co-authors, to design and demonstrate molecular "circuitry" that is 10 times smaller than the thinnest electrical wire in computer processors. These energy circuits could control, regulate, direct and amplify raw solar energy which has been captured by human-made pigments, thus preventing the loss of precious energy before it is utilized.

Following is the brief summary of lessons from nature about concentrating and distributing solar power with nano-scopic antennae.

The basic components of the antenna are efficient light absorbing molecules. These photo-energy absorbers should be appropriately distributed to guarantee that there is an even probability of converting sun energy into vibrating electrons across the whole antennae.

Take advantage of the collective properties of light-absorbing molecules by grouping them close together. This will make them exploit quantum mechanical principles so that the antenna can: i) absorb different colours, ii) create energy gradients to favour unidirectional transfer, and iii) possibly exploit quantum coherence for energy distribution—several energy transfer pathways can be exploited at once. Make sure that the relevant energy scales involved in the energy transfer process are more or less resonant. This will guarantee that both classical and quantum transfer mechanisms are combined to create regulated and efficient distribution of energy across short and long-range distances when many antennae are connected.

An antenna should transfer energy not as fast as possible but as fast as necessary. This means that regulatory mechanisms need to be integrated in the antenna. For instance, if necessary, combine light-absorbing molecules with a few local "sinks" that dissipate excess of damaging energy.

Source *Science Daily*

Research improves performance of next-generation solar cell technology

Researchers from the University of Toronto (U of T), King Abdullah University of Science and Technology (KAUST) and Pennsylvania State University (Penn State) have created the most efficient colloidal quantum dot (CQD) solar cell ever.

Quantum dots are nano-scale semiconductors that capture light and convert it into electrical energy. Because of their small scale, the dots can be sprayed onto flexible surfaces, including plastics. This enables the production of solar photovoltaic (PV) cells that are less expensive than the existing silicon-based version.

The process of how to shrink the wrappers that encapsulate quantum dots down to the smallest imaginable size – a mere layer of atoms was studied initially. A crucial challenge for the field had been to strike a balance between convenience and performance. The ideal design had to be one that tightly packs the quantum dots together. The greater the distance between the quantum dots, the lower was the efficiency.

Until now, quantum dots have been capped with organic molecules that separate the nano-particles by a nanometer. On the nano-scale, that is a long distance for electrons to travel. To solve this problem, the researchers utilized inorganic ligands, sub-nanometer-sized atoms that bind to the surfaces of the quantum dots and take up less space. The combination of close packing and charge trap elimination enabled electrons to move rapidly and smoothly through the solar cells, thus providing record efficiency.

Source *SolarServer*

First International Conference on Solar Heating and Cooling for Buildings and Industry

San Francisco will host the first International Conference on Solar Heating and Cooling for Buildings and Industry – SHC 2012 from July 9–11, 2012. The scientific conference is organized by the International Energy Agency's Solar Heating and Cooling Programme (IEA SHC), which coordinates research on solar thermal technologies.

SHC 2012 is the first of this new series of annual scientific conferences on solar thermal.

Around 53% of all energy is used for heating and cooling. While only 19% of the world's energy usage is electricity, the sector usually draws all the public attention, IEA SHC accentuates. But 53% of all energy is used for heating and cooling purposes. The SHC 2012 conference puts the spotlight on the fastest growing technology in this sector: solar thermal energy.

The worldwide capacity of solar collectors already stands at 200 GW_{th} and installation numbers are growing in countries around the world. Solar heat is used to prepare domestic hot water, to heat buildings, and in industrial processes. It is also fed into district heating networks and used for air conditioning and other cooling applications. SHC 2012 offers a platform to discuss the latest advancements in solar heating and cooling technologies. IEA SHC has teamed up with great partners to make SHC 2012 happen. The conference is supported by the International Solar Energy Society, ISES, and the European Solar Thermal Industry Federation, ESTIF.

Source *Solar Server*

Major Asian PV markets to reach 3.3 GW total in 2011: Solarbuzz

On July 27, 2011, Solarbuzz Inc. (San Francisco, California, US) announced a new report which predicts that Asia Pacific solar photovoltaic (PV) markets will grow to 25% of global demand by 2015, up from 11% in 2010.

"Asia Pacific Major PV markets" further predicts that China, Japan, India, Australia and South Korea will install an aggregate of 3.3 GW of PV in 2011.

"Market growth expectations are high for the region, China and India in particular, as they each have multi-gigawatt project pipelines," states Solarbuzz President Craig Stevens.

However, the largest challenge facing many of these projects is the need to secure financing amidst a still evolving policy and regulatory environment.

The report also notes that Japan and China both doubled their market size in 2010, and that Australia experienced near quadruple growth.

Solarbuzz also notes that each national market is currently undergoing significant alterations to its policy structure, with Japan and South Korea facing policy transitions that are re-stimulating their domestic demand over the next two years.

Solarbuzz also predicts that the Chinese market will grow 174% in 2011 due to national and provincial programmes to stimulate domestic demand.

In terms of market segments, the company states that growth will be led by utilities, which it expects to displace the residential segment to become the largest segment by 2015.

www.solarserver.com

Indianapolis Airport

Indianapolis Airport to develop 10MW-AC PV plant through ET Energy Solutions

On September 20, 2011, the Indianapolis Airport Authority (IAA, Indianapolis) announced that it has selected joint venture ET Energy Solutions LLC (Indianapolis, Indiana, US) to develop a 10MW-AC solar photovoltaic (PV) plant on Indianapolis International Airport property. ET Energy will finance, design, construct and operate the plant, which will be eligible to participate in a pilot feed-in tariff program through utility Indianapolis Power and Light Company (IPL, Indianapolis, Indiana, US).

The plant will occupy 24 hectares and utilize 41,000 280-watt polycrystalline silicon PV modules. At this scale it will be much larger than any PV plant currently in operation in Indiana. The plant is also the largest size that can participate in IPL's pilot feed-in tariff (FIT), which is limited to 10 MW-AC. Through the programme, IPL will purchase electricity from the plant at a rate of USD 0.20/kWh for a term of 10 years.

ET Energy Solutions is a joint venture (JV) between Johnson-Melloh Solutions Inc. (Indianapolis, Indiana, US), Schmidt Associates Inc. (Indianapolis, Indiana, US) and Telamon Corporation (Indianapolis, Indiana, US), with Telamon owning 50% of the JV.

The project is a great example of the public sector utilizing private sector investment to generate revenue. The sustainability initiative is gaining momentum and positive local impact from the IAA's decision to work with local companies is expected—including a substantial economic impact that will create much needed construction jobs.

www.solarserver.com

Baja Sun Energy to build 100 MW factory in Mexicali

In September 2011, Baja Sun Energy SRL (Mexicali, Mexico) announced that it will build a manufacturing facility to produce concentrating solar photovoltaic (CPV) modules in Mexicali, Mexico, and use these modules to construct a 10 MW CPV plant.

Arima EcoEnergy Technologies Corporation, Taipei, Taiwan, will outfit the factory with an equipment line to produce cells, modules and dual-axis tracking systems.

The manufacturing facility will represent an estimated investment of USD 500 million over the next four years, and will be built out to a capacity of over 100 MW annually. Baja Sun estimates that it will break ground on the new factory later in 2011.

Both the CPV module factory and CPV plant will be located in the Silicon Border CleanTECH Park in Mexicali.

Officials with the Silicon Border CleanTECH Park note that due to the North American Free Trade Agreement, they will be able to produce CPV modules compliant with the "Buy American" provision in the American Recovery and Reinvestment Act of 2009 ("stimulus package"). These officials also claim that from this location, it is possible to reach most locations in the Western United States by truck in less than one day.

Baja Sun states that it has secured a "top-tier" customer for the 10 MW CPV plant. The company also plans to establish sales and marketing operations in San Diego, California, United States.

Mexico has more sunshine per capita than most countries in the world, and it is only fitting that a Mexican company begins the process to capture the sun for our own use in the state of Baja California. The solar market is expected to grow from the currently installed 2.1 GW at the end of 2009 (according to the Solar Energy Industries Association) to 44 GW by 2020 in North America over the next 10 years. Mexico can be one of the world's largest players in this process given our cost and location advantages."

www.solarserver.com

ASSESSMENT OF INDIGENOUS INITIATIVES IN THE SOLAR PV SUPPLY CHAIN

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The Indian solar PV programme is marching from strength to strength. However, there are still a few issues that concern full scale indigenization of the valuable supply chain. Once realized in practice, it would also be possible to achieve the much needed economies of scale.

Background

The sun seems to shine even brighter now on the Indian horizon. Gone are the days when solar products used to be branded simply as liability items both for the government and individuals alike. Solar technology is now becoming cheaper as we bid adieu to the past perceptions, trends and practices. It is now quite heartening to witness this sunshine sector in an unprecedented activity mode. This has largely become possible because of the Jawaharlal Nehru National Solar Mission (JNNSM) which was launched a year or so back. The supply chain is gearing up to the change with avid enthusiasm. One such noticeable opportunity is the solar module manufacturing within India. The mission driven guidelines clearly support the use of indigenously developed solar modules for the grid connected solar power plants thus indicating a sizable demand for solar modules in a phased manner. A significant objective of the mission is to encourage domestic manufacturing. It has been made mandatory for all the projects to use cells and modules manufactured only in India for solar PV projects selected in the second batch during the financial year 2011–2012. However, the solar modules made from thin film technologies or concentrator cells may be procured from any country much in accordance with the meeting of qualification criteria. Thus the message sent across is loud and clear–to promote/strengthen the local manufacturing base for solar modules in more ways than one.

Against such a backdrop, this article takes a close look at the component level perspective of solar module in terms of its primary need, existing availability (local), percentage dependence on imports and importantly, the cost considerations among many other aspects.

Why solar modules

A solar module happens to be the power producing part of any solar system. It comes across from a minuscule unit of just a few watts to around 300 Wp capacity now. However, irrespective of its size, it makes use of a silicon wafer developed into an efficient cell structure and then as an environment protected assembly. Several types of materials and processes unify together to produce a long-life endurance module unit.

But what is the real issue at hand? The problem at hand is that module manufacturing has by and large been dependent on the use of import dependent items like the following few:

- Silicon wafers
- Low iron content glass
- Ethylene Vinyl Acetate
- Tedlar

The balance of system components like for example battery, power conditioning unit, wiring and cabling together with sensing and safety devices are available within the country. Thus the wholesome issue is of tracing the impact of module manufacturing vis-à-vis the availability of processing materials like those mentioned above. Incidentally, the efforts to produce these items indigenously have met with only partial success that too only in the case of silicon wafers. The Indian PV industry is still heavily dependent on the use of EVA and Tedlar in a full measure. It is interesting to probe if the low volume demand for these specific items was reason enough for the dwindled interest of any manufacturer to set up the shop locally. The following section analyses the current and future demand for solar modules in the Indian market.

The escalating demand

Before we delve deep into these component formations, let us first quantify the module demand at this point of time. The larger the canvass for the module the greater is the demand expected to be realized under the ambit of JNNSM as per the following breakup:

- Phase 1 (2010–2013): 500 MW
- Phase 2 (2014–2017): 2000 MW
- Phase 3 (2018–2022): 7500 MW

Some of the state governments have framed their own policies. As per the available estimates, aggregated module demand of around 1400 MW is expected within the next two years alone (2011–2012). Added to it is a surging demand for off-grid end-use applications like potable lighting, indoor lighting, outdoor lighting, etc. Market experts peg the existing supply of modules in the Indian market anywhere between 700–1000 MW. The already established market players are also firming up business proposals to scale up their module production further. The increasing demand for solar modules across the globe is also becoming a growing concern. Like for example there was an increase of around 55% in the annual solar PV capacity worldwide in 2009. In MW terms, it went up from 14 GW by the end of 2008 to more than 21 GW in 2011. Table 1 sums up the projected growth of solar modules for the decade ahead.

Table 1 Estimated demand for solar modules by year (GWp)

Year	Capacity Demand (GWp)
2010	13.6
2011	20.2
2012	23.8
2013	33.0
2014	45.3
2017	85.0
2020	200.0

The given table clearly, points out the appreciable market potential for the solar module industry.

The business opportunity in monetary terms

In the PV supply chain, module manufacturing happens to entail lower investment in comparison to that for wafers and solar cells. Thus an entrepreneur may not find the same very taxing while planning a module production facility. Table 2 shows cost comparative levels of this nature.

Table 2 Key component production plant cost(s) per MW capacity

Component	Investment cost (per MW)
Silicon Wafers	$0.6 million
Solar Cells	$1.25 million
Solar Module	$150,000

The question still remains herein if there is a space for the new players to take a plunge into this market. The answer is a clear yes as there is only limited number of big players in the field.

Module material availability concerns

The solar PV industry is expected to soon chart the course of the Indian mobile telephony sector. The route related to the process of technology adaptation is followed up by a thorough encouragement for establishing the manufacturing facilities at the local level. This way the module fits into the visionary outlook of the JNNSM as it will ultimately help in either fully eliminating or getting rid to a large extent the dependence on imported items like EVA and Tedlar in particular. A sound beginning has already been made in this regard as far as the indigenous manufacturing of low iron content glass is concerned. Several Indian industries seem to have welcomed the move of the Indian government along these considerations. This also removes an apprehension about the dumping of components in India by the overseas companies. However, a downside to it is also the fact that the project developers may not have fully realized their envisaged interests.

It is a known fact that cells are largely imported even though there are around 40 module manufacturers in the country today. There is a school of thought which says that 100% local content restriction may slow down the deployment of new and innovative solar technologies. A free run has been given both to the thin film and concentrator technologies for the simple reason of their near total non-indigenous availability in the country. The crux of the matter is that all solar power developers will have to build base for local suppliers. Yet another offshoot of the demand for using the indigenous content is that it will be difficult to indigenize the new technologies very quickly.

Solar modules form around 70% cost of the power plant project. Majority of India's solar PV industry is dependent on imports of critical raw materials and components including silicon wafers. Thus it will be interesting to watch as to how material inventories take shape. The solar mission targets a cumulative generation of 20000 MW of power by 2022. It aims to attract investment into the capital-intensive sector which can pave way for setting up of manufacturing capacities of poly silicon material for example. The government in its budget for 2010-2011 had announced a concessional customs duty of five per cent on machinery, instruments, equipment and appliances required for setting up solar power units. The projects are also exempt from central excise duty.

The following section traces the importance, requirement and the efforts undertaken at the indigenous development of the material components—silicon wafers, glass, EVA, and Tedlar–required for solar module fabrication.

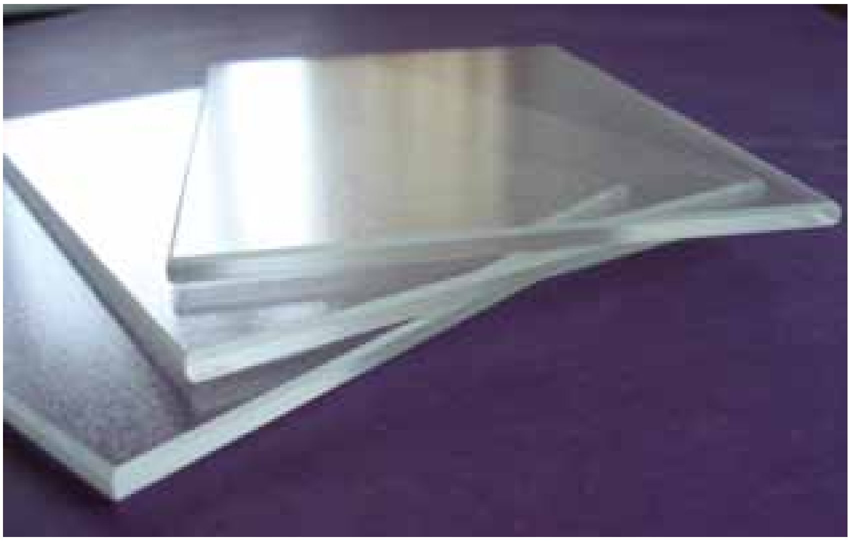
Wafers

The earliest efforts at silicon wafer development in India began with Metkem Silicon—a subsidiary unit of Chemplastics. It developed process know-how for fabrication of silicon ingots/wafers in a participatory mode of research and development with the Indian Institute of Science (IISC), Bangalore. Pilot scale manufacturing facilities were set up at Mettur in TamilNadu and it started meeting just the partial needs of the

local PV industry. Around 80% of the silicon wafers continued to be imported from diverse sources abroad. Selective few efforts came up for an intended trial but met with little success till Maharishi Solar Technology Limited set up the facilities for producing solar grade polysilicon and therefrom ingots and wafers. Lately, Lanco Solar is setting up a 1250 MT poly silicon plant and 80 MWp wafering facility in Chattisgarh. Located in a sprawling space of 250 acres at Rajnandgaon, Raipur in Chattisgarh, it is likely to commence production by early 2012. The company aims to meet around 15% of the projected demand of 7500 MT domestic demand for solar energy sector from this facility. It equates to meeting a capacity requirement of 250 MW of the indigenous industry per annum. This facility is coming up within the purview of a special incentive package of the Ministry of Communications and Information Technology (MICT). A few more silicon material development ventures are expected to shape up in the time ahead.

Glass

The first glass plant in India was set up in 1908 at Talegaon in Maharashtra. So, the glass industry in the country is more than hundred years old. Today the glass industry is estimated to be worth more than $ 2.5 billion as per the National Glass Manufacturers Association. The growth of Indian economy has given a fillip to the growth of glass industry in India. Glass being chemically inert and pure and thus safer to be used has resulted in its increased popularity and demand among the consumers. Majority of the raw materials needed by the glass industry are available indigenously thus providing excellent scope for growth and development. In a country like India where the temperatures vary from 0–45 °C in many cities, usage of laminated and glazed glass play an important role in energy conservation. The float glass segment of Indian glass industry is still at the nascent stage with just around eight lines as compared to 196 in China. India's total capacity for float glass is around 4700 tons per day which is worth $0.57 billion. Several innovative changes have

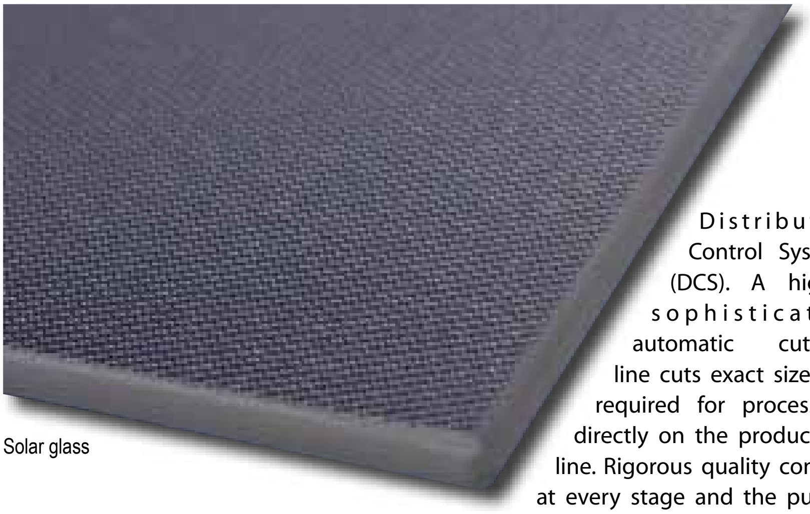


taken place in the production of glass with new properties like the low iron tempered glass.

Knowing glass back and front Glass is silica with a bunch of elements, including iron. Removing iron from glass takes out the green tint in glass, often seen on table tops or glass windows. But the green tint is not good for solar modules. Solar panels respond to the red part of the sun's energy and iron-free glass aids in that process. But till now there has been only limited demand for iron-free glass (used only in specialized applications like microwave ovens) which indicates that solar grade, iron free, or 'white glass' as the industry dubs it, is imported from China and Taiwan. Several solar companies have been in talks with glass makers like Saint Gobain, etc., to make low-iron glass. The industry wants at least a gigawatt (or 1000 MW) of solar deployments per year to justify such investment. So far, in India, it has been an average of several hundred megawatts or so. Lately, the module production capacity is moving up inches closer to 1 GW mark. The glass manufacturers have instead chosen to focus on glass for cars, for buildings and few other categories, where the demand has surged in the recent years. Market experts believe that indigenous availability of glass has the potential to lower the cost of solar PV power by 15–20%. This also indicates a reduced per unit cost of manufacturing too. The resultant effect is expected to be still more in the case of solar thermal technology as glass comprises around 33% of the total cost.

Solo solar glass manufacturing initiative in India

Low iron content glass is used for multi and mono crystalline solar photovoltaic modules. The content of iron oxide is significantly lower than in normal flat glass. This gives it a distinctive, nearly colourless appearance particularly when seen from the edge, and makes it a high solar energy transmitting glass. The textured surface helps to diffuse the light and inhibits the reflection of a part of the solar energy back into the atmosphere as compared to a polished surface, thus enhancing solar energy transmission. Gujarat Borosil Limited has been engaged in the production of high quality sheet glass from its Bharuch plant in Gujarat. In a first solar initiative of sorts, the company has now started the production of low iron glass to meet the fast emerging PV applications worldwide. High quality low iron solar glass is now being produced in various sizes with thickness values of 3.2, 4 and 5 mm. This will meet the needs of solar modules, solar thermal collectors, and greenhouses as well. Gujarat Borosil has also established a tempering facility for the glass and it has enabled local supply of both the tempered and annealed glass. The solar glass produced at the


Solar glass

state-of-the-art plant in Gujarat offers the highest light transmission exceeding 91.5%. It thus meets the international standards including EN 12150 for the solar applications. As per the available company information, it has already crossed sales of ₹590 million from its solar glass operations; a major portion of it being export market driven.

Technical attributes of solar glass

Borosil's Low Iron Glass is produced in an ultra modern rolled glass manufacturing facility. The entire equipment for glass batching, melting, forming, and cutting has been sourced from West European companies. This facility is dedicated exclusively to the year-round production of extra clear low iron glass. No other glass is melted here, so as to ensure the highest quality. The entire manufacturing process is run by a state-of-the-art Distributed Control System (DCS). A highly sophisticated automatic cutting line cuts exact sizes as required for processing directly on the production line. Rigorous quality control at every stage and the purest raw materials guarantee the finest quality. Glass sheets, cut exactly to size are fed into fully automatic computerized edging machines, which impart a high quality pencil edge. The corners are dubbed for safety in handling. After washing, sheets with finished edges are processed by a high quality tempering line that tempers the glass as per internationally prevailing norms, example EN12150.

Manufacturing capacity

Gujarat Borosil has the capacity of producing 13,000 square meters of glass, in terms of 3.2 mm thickness per day. It equates to capability of producing more than 4.2 million m^2/year. This is enough to help generate nearly 600 MW of solar power. Customer specific requirements can also be met. Table 3 indicates the key technical specifications of this range of solar glass.

Table 3 Technical specifications of solar glass

Property/specification	**Specification**
Dimensions (LxBxH) mm	As per specified dimensions
Dimensional tolerance (mm)	±1.0 mm
Nominal thickness (mm)	3.2/4.0 ± 0.2
Weight per mm glass thickness (mm)	2.5 kg/m2
Angularity (maximum difference in diagonal lengths)	Maximum 3 mm
Cut Corners	Maximum 3 mm
Edge processing	At least seamed
Energy transmittance	91.1%
Cleanliness	Irremovable dirt is not permitted

Source Gujarat Borosil

Global market perspective on solar glass

There is a sort of unanimity in the solar community that the primary glass manufacturers have been slow in response to solar industry glass demand across the globe. However, it is an undeniable reality that the total solar market has been a very small percentage of the installed float and pattern glass capacity. In 2004, the total solar glass consumption globally accounted for less than 0.1% of the total glass produced globally. Industry experts point to 30–40% CAGR as the primary indicator of market. However, glass manufacturers commonly focus on tonnage and square metres to drive investments. The largest growth area has been low iron pattern glass in the past five years for crystalline silicon technology. The government incentives are driving growth with several countries like India due to the increasing demand for solar glass in near future. The global energy glass consumption is expected to be around 1.1 % of the total market in 2012. It is interesting to take a close look at Table no. 4 below. The available global market annual growth is being projected for the energy segment at 25%, which incidentally is the highest amongst all the key sectors of glass use.

There is no doubt that solar market growth will be high, but several key factors are driving the demand like the government incentives and green building trends. Expectedly, economics will drive solar glass production output and not the hype. The industry needs to drive down the cost to grid parity in order for solar to become a long-term viable business. The production cost per watt of solar glass can simply be calculated as: $ Production/Watt=Cost/m^2 divided by/Watt/m^2.

The module pricing is expected to continue to drop as volumes increase. The price reduction may come through vast improvements in technology and attaining the economies of scale thereof.

Efficiency—a big driver of low iron content glass

It is a common perception that economics ($/Wp) will drive the solar industry at

Table 4 Global Available Market Annual Growth - 2012

Segment	% annual growth	Global annual market ($ million)
Automotive	3.3	23600
Commercial	6.0	15400
Electronics	7.0	200
Energy	25.0	800
Interiors	4.9	400
Interiors (non-mirror)	4.9	600
Residential	4.9	8700
Flat panels	6.9	—
Others	5.5	23700

Source Fredonia 2008

large. The more the solar efficiency the more will be the revenue generation for all the members of supply chain (including for the glass). The level of iron content in the glass varies depending on the efficiency and the total cost of solar application. A general rule of thumb is higher the solar efficiency, a higher transmission glass can be used based on the available economic considerations.

Solar transmission requirement

There are several solar PV technologies currently available in the market. Each of these has its relative merits and demerits with crystalline silicon still emerging as a clear winner. Table 5 gives a quick insight into transmission properties, etc., in respect of available cell technologies. The solar transmission requirements vary based on the following application shown in the table.

Table 5 Relating cell technologies with glass features

Cell/Module technology	Glass thickness (mm)	Transmissivity (%)	Wavelength range (nm)	Module efficiencies (%)
Crystalline silicon	3.0 pattern	>91.0	400–1150	13–19
Amorphous silicon	3.0 pattern	>89.0	400–750 400-1000 (tandem)	6–7% (single junction) 8–10% (tandem)
Cadmium telluride	3.0 float	>90.0	400–900	9–11
Copper-indium-diselenide	3.0 float	>90.0	400–1150	10–12
Concentrated solar power	4.0 float	> 90.7	—	—

Scope for low cost realization of solar glass

As mentioned, low iron containing materials are pivotal for solar glass production. Perhaps the major challenge for low iron glass pattern mainly rests heavily on sourcing of the raw materials which include low iron sand, low iron

dolomite, low iron limestone, and low iron glass cullet

As per market analysts, the low iron containing materials push up the cost of manufacturing both on account of purchase price and associated cost of transportation from the mining sites. Thus economics of scale is still being perceived as an effective measure to realize low cost of solar glass.

The solar glass market: few observations

- Beyond doubt, the solar market is now growing at a fast pace. However, it may still take another 6–7 years for solar glass to emerge as a major glass segment.
- Crystalline silicon technology has so far dominated the glass market and may continue doing so.
- Solar technology is expected to shape up as an economically viable sector drawing closer to the market demand for key sectors of energy economy like residential and commercial, etc.
- Use of float glass in the thin film technology segment along with CSP is expected to increase manifold in the coming years.

Ethylene Vinyl Acetate (EVA)

EVA is a co-polymer of ethylene and vinyl acetate. It is an extremely elastic material yet tough that can be sintered to develop a porous material much like rubber. EVA is three times as flexible as commonly used low-density polyethylene (LDPE). It has a peak melting temperature of around 96 °C. It is believed to be competitive with rubber and vinyl in several electrical applications. This material possesses a good clarity and gloss with almost zero odour. EVA has been in use for solar applications since many years now. It is thus interesting to take a close look at how it finds use in solar modules as a case specific example.

EVA: the solar way

A solar module is an inter-connected combination of several solar cells. In a commercial module design, these solar cells are normally packaged between a back sheet on the bottom and a tempered glass window on the top. The cells are then encapsulated by a polymer encapsulant so as to mainly serve the following few purposes:

- mechanical support
- electrical isolation
- resilience to module laminate to avoid cracks in glass and cells
- protection against outdoor environmental elements like
- moisture
- UV radiation
- temperature stress

There are several choices available for this purpose. However, EVA has emerged as a clear winner for solar applications. It is generally supplied in the form of a sheet with the following few desirable properties:

- it is not an adhesive at room temperature for easy handling
- it makes a permanent and adhesive tight seal in the solar cell system
- it attains high optical transmittance properties thus enabling it to provide good adhesion to various module materials

The EVA sheet is placed between the solar cells and the back sheet/glass. It is heated, pressed into place followed up by its curing at a particular high temperature for some duration.

Knowing EVA further

Based on the crystalline solar cell, the sheet, one of the constituents of the solar cell, can be divided into two layers; back sheet layer located at the lowest, protecting the solar cell from external environment and an encapsulate layer located at top and bottom of the solar cell, performing adhesion and cushioning functions. This sheet layer is closely related to the effectiveness of solar cells and recognized as a key factor

to the life span of solar cells. The sheet is in spotlight with its rapid growth of the solar cell market. It is proved that the cross-linkable EVA sheet (XL EVA Sheet; Cross-linkable Ethylene Vinyl Acetate Sheet) type among encapsulates is excellent in economics and performance compared to other materials and as a result its use has been spread to the thin-film.

The properties of EVA sheet are influenced by resin, which can be varied with VA content and molecular weight. One with 7~60% VA contents is called EVA resin, another with less than 7% VA contents is PE and other with over 60% VA contents does not show properties of plastic. EVA sheet should have high penetration ratio and adhesion and it should be well cross-linked to expand the life span of the PV module to the maximum in the external environment. Ethylene Vinyl Acetate (EVA) has been the most versatile and trusted encapsulant material used in the manufacture of mono crystalline, poly crystalline and thin film photovoltaic modules since ages. In addition to the above important material properties, the type of manufacturing technology, processing conditions and formulation are critical factors in producing a high-performance encapsulant material.

Indian solo EVA manufacturing initiative for solar use

EVA has been an import dependent commodity for the solar applications. It still continues to be so for the simple reason that no manufacturing initiative has been realized in actual practice. No entrepreneurship activity has also been thought about till date in India. It is equally true that lack of technology availability has also proved to be a deterrent apart from limited size of the PV market till very recently. All that may change for the better now as an Indian company by the name of Renewsys has firmed up its plans to produce EVA. Renewsys is the photovoltaic division of its flagship group company, "Positive Packaging Industries". This company will be catering to the needs of solar energy sector by setting up India's first EVA encapsulant sheet line at Bengaluru. Plans are also underway to evaluate the possibility of an exclusive line for production of backsheets in the near future. The technology provider for the EVA encapsulant sheet line is a well-known German company having proven experience in this field. Commercial production of TUV certified EVA SHEETS is expected to start from the first quarter of 2012. The underlying reasons for Renewsys to take a plunge in this hitherto subdued area of investment are the mainly due to:

- decades of Polymer processing experience
- state-of-the-art German manufacturing technology
- GMP/clean room facilities
- supply partners – world leaders
- low shrinkage film – leading to higher productivity with low module rejects

The underlying philosophy of the company is that the future of world is the responsibility of each and every individual. So, any effort towards environmental sustainability must start with a serious commitment to conserve, preserve and reserve energy by using it effectively and efficiently.

Tedlar

Expected market potential for EVA

The Indian solar industry, which is still evolving, holds huge potential for growth. As per the available estimates, the Indian PV module market caters 70% to export markets and 30% to domestic requirements. Even though these market proportions keep on varying owing to a variety of considerations. The National Solar Mission is a key initiative undertaken by the Government of India and state governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of global warming. Mission target for capacity installation is 10 Gwatts in 2022 which is 20 times the present installation of 0.5G watts or slightly more. Such a strong growth would result in demand for EVA film and back sheet, requirements of the encapsulating solar cell. Presently both the materials are imported.

The larger gain in sight

It is a logical consideration for a 'sun soaked nation' like India to have a full range of indigenously available manufacturing capabilities. The PV demand is now picking up and new frontiers of use are being explored everyday. It is quite a welcome change to usher in a new era in solar module manufacturing when initiatives like those based on EVA come on stream. A sound beginning has already been made as far as the indigenous production of low iron content glass is concerned. The purpose at large is not just to make a beginning but to romp home with at least a few more production initiatives of this nature. After all, it should not be a case of just a reduced dependence on imported items like glass, EVA and Tedlar. India is expected to serve as the hub of PV manufacturing in the time to come. So, a mix of both financial and fiscal incentives perhaps in a still greater measure may well be needed. Take for example EVA, which is used for a very large number of applications apart from solar. However, if, incentives are built on the lines of SIP package for an exclusive use within the solar sector, capacities may come up faster than anticipated. In totality, we can realize a larger gain if, it becomes possible to drive home the distinct advantage of setting up manufacturing facilities at a local level. This may ultimately lead to lower costs and enable in achieving the much needed economies of scale too. Simultaneously though, we have to keep the awareness generation measures at each and every level of PV deployment alive. Who knows once PV technology gets fully indigenized; it may very well replicate the mobile telephony magic of a mass market? ■

EDUCATION PARK

A ZERO ENERGY CAMPUS

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The primary block of the Education Park with solar PV modules fitted on the roof

Background

A knowledge-based economy is fast gaining ground throughout the world. Lately, transfer of knowledge via all possible medium has become much easier and faster. The world economies are now becoming increasingly knowledge-based, wherein education is playing a pivotal role towards the furtherance of socio-economic development of a country. It goes without saying that a comprehensive social growth does not merely include education, but also other issues such as healthcare, energy, technology, and a sound economy. It is in this context that the concept of an Education Park took shape. This article focuses mainly on the energy aspect of an Education Park, particularly the way in which it can actually become a zero energy campus.

The Education Park

The Education Park is a non-governmental and non-profit organization located in Bhikangaon, Khargone district of Madhya Pradesh. This park is expected to serve the educational needs of about 60–70 villages located within a radius of 15–20 km.

Therefore, the objective of this Education Park is to *"provide high quality and affordable education and training in rural India"* by focusing on 'Education', 'Economy', and 'Energy' (the 3Es).

The development index

India, in general, and Madhya Pradesh, in particular, lack in all these three aspects of growth index. In Table 1 the status of MP and India is compared with the developed countries of the world. This gives a better picture of where the state and the nation stand. Figure 1 gives a sectional view of the 3Es vital for the realization of a holistic growth of rural India.

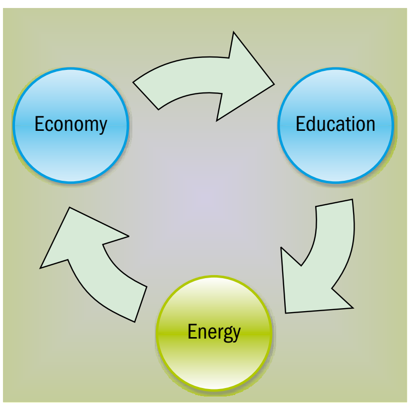

Figure 1 Interplay of 3Es for comprehensive growth of rural India

Table 1 Comparison of 3Es: Madhya Pradesh, India, and developed countries

	Madhya Pradesh	India	Developed countries
Education (literacy %)	50	65	85
Economy (income (₹)/capita/year)	18,000	32,000	1,000,000
Energy (unit (kWh)/capita/year)	350	670	10,000

Approach to zero energy

Access to energy has become essential for day-to-day living and development. We require energy for lighting, running appliances, transportation, and so on. It is nearly impossible to live even for a day without access to energy. However, our country does not have large reserves of fossil fuels. Electricity transmission and distribution network has still not reached every corner of India. According to the Ministry of Power, still about 60,000 villages do not have access to electricity. Some rural areas, which have access to electricity, suffer from frequent power cuts, ranging from 10–22 hours per day. In the region where the Education Park is located, the power cuts vary between 10–20 hours. In this scenario, ensuring continuous power supply to Education Park is not possible until an alternative arrangement like diesel generator and/or inverter is made. These solutions are expensive considering their running cost. Taking all these aspects into consideration, it was decided to use solar power for the daily operation of Education Park. However, with solar power still being expensive, the first step taken was to keep the daily energy usage at a bare minimum.

Incorporating the concepts of solar passive architecture

The energy requirement of a building can be reduced significantly, if the concept of 'solar passive architecture' is taken into account at the designing stage of the building itself. Up to 80% of energy requirements can be reduced, particularly for buildings which are used only during the daytime such as school buildings.

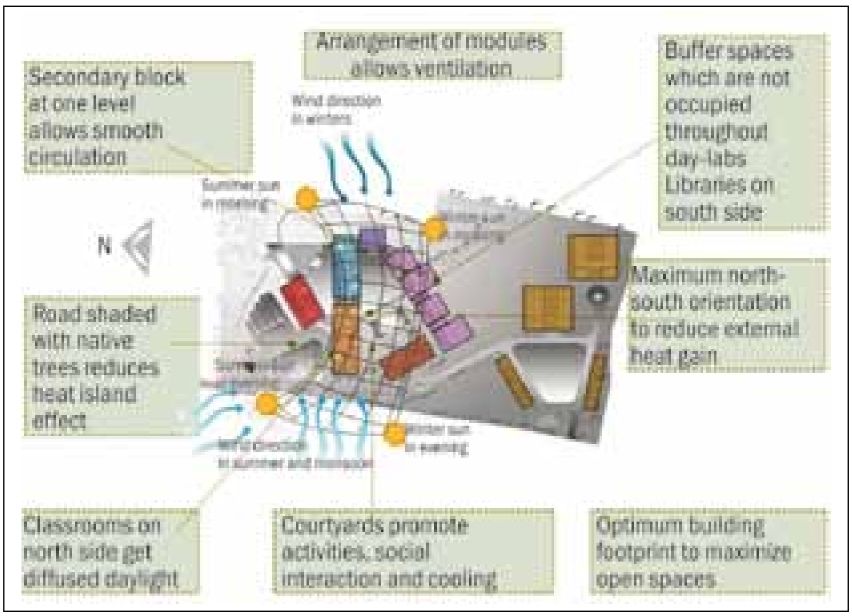

Figure 2 Various aspects that are considered in the design of Education Park campus