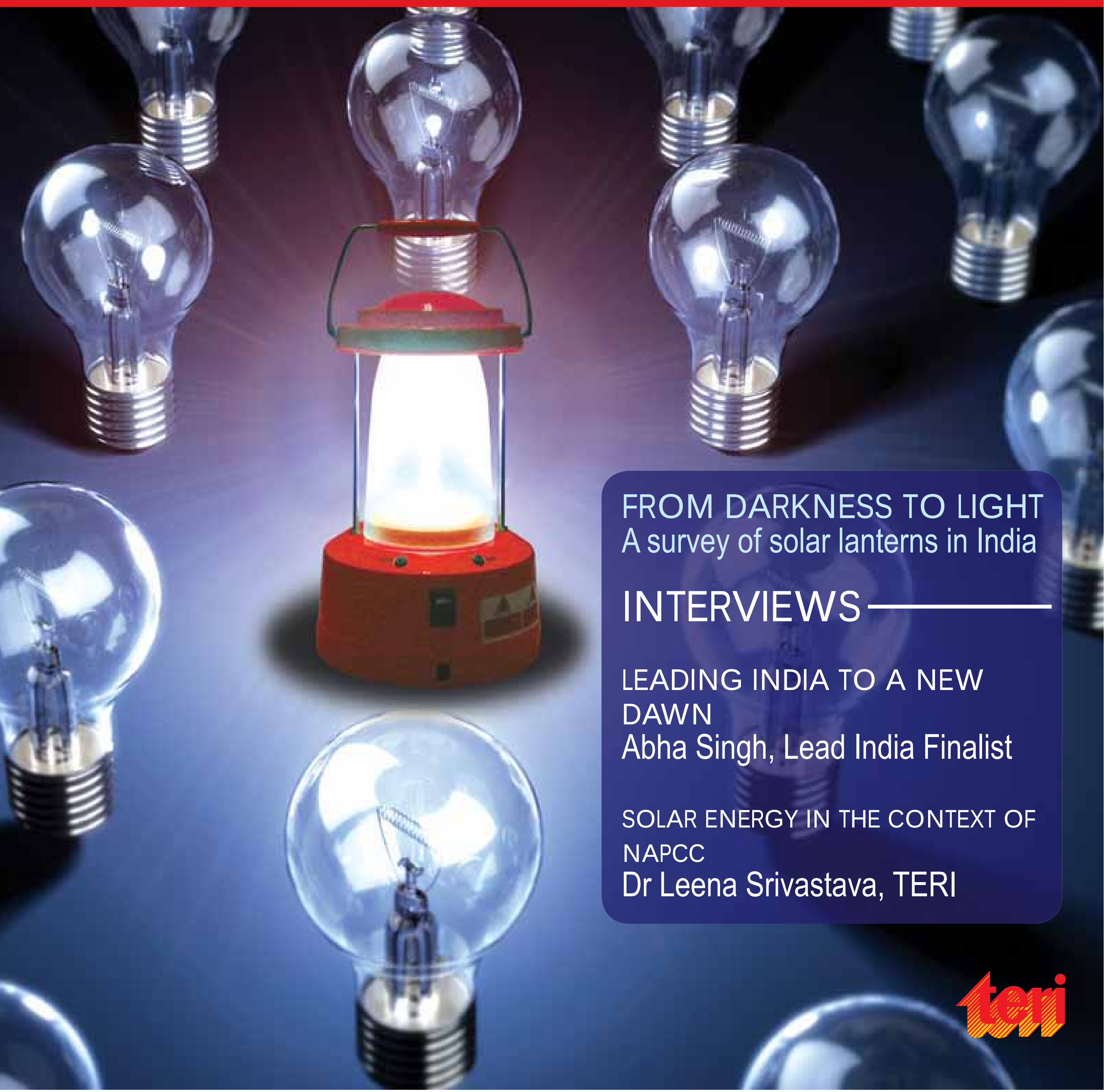
The SOLAR QUARTERLY

The Complete Solar Magazine

Volume 1 • Issue 1 • October 2008

Rs 200



FROM DARKNESS TO LIGHT
A survey of solar lanterns in India

INTERVIEWS

LEADING INDIA TO A NEW DAWN
Abha Singh, Lead India Finalist

SOLAR ENERGY IN THE CONTEXT OF NAPCC
Dr Leena Srivastava, TERI

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What would you like *The Solar Quarterly* to become one year from now—a knowledge disseminator, a platform for sharing your views, a change agent, a reference source, or a leisure read? I would say, a change agent. There has to be a radical shift in our approach to solar. It is no longer a technology earmarked by the planners and funders for the bottom-of-pyramid markets or a technology for the elites in the European markets. It is a technology for you and me who live in residential apartments and depend on battery-inverters for main electricity supply, not back up. It is a technology for commercial and industrial establishments, corporate houses, and owners of institutional buildings who spend a large fraction of their infrastructural expenditure on feeding diesel to their captive power plants; a technology for those who want to go green by using solar garden lights, solar flash lights, and a lot more; and also a technology for setting-up micro-grids, distributed power generation units, water purification plants, emergency power on wheels, and so on.

It is a versatile technology for any application anywhere and in any mode. My next question is why aren't we using it then? Costs apart, where would you get the products and systems as per your choice and needs, where are the outlets, sale and service centres, and where is the market for buyers to buy and sellers to sell? We have to radically shift our perception of solar from being a subsidy-driven market to a ready-to-explode market and work collectively towards bringing about this shift. This is the role that I envisage for this magazine one year down the line. Be our patron and share your vision, views, and contributions. Till then, enjoy reading the second issue of India's first and the only solar magazine.

Akanksha Chaurey
Director, TERI

Owned, printed, and published by Dr R K Pachauri from The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003, Tel. +91 (11) 2468 2100 or 2468 2111, E-mail teripress@teri.res.in, Fax +91 (11) 2468 2144 or 2468 2145, Web www.teriin.org/pub, and printed by him at Batra Art Press, A-41, Naraina Industrial Area, Phase-II, New Delhi-28.

The Solar Quarterly is being brought out at a particularly opportune moment. Oil prices are at an all time high, with prospects of further increases in the coming months. Research and development on renewable sources of energy, particularly those designed to utilize the sun's direct energy have languished and in fact declined since 1985 when oil prices plummeted sharply. The current situation now requires a major step up in research and development on solar energy technologies and applications, which indeed is likely to happen.

Even more important is the prospect of several projects being implemented on the ground for ensuring that current knowledge moves along the path of early commercialization. Indeed, there is now enough experience and substantial interest in implementing solar energy projects employing various approaches and technologies that would help to increase the share of this source of energy across the globe. *The Solar Quarterly* attempts to fill up an extremely relevant gap in published material that would provide current knowledge on this critically important field for the benefit of researchers, academics, business leaders as well as policy-makers. This publication lays appropriate emphasis on applications, deriving knowledge from actual projects implemented and applications, which would provide real world experience and insights.

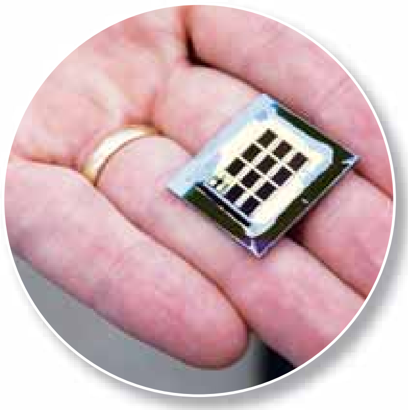
This magazine consists of commentaries on specific subjects of interest related to solar energy, detailed case studies, interviews with distinguished policy-makers and technologists as well as information and analysis on solar energy using equipment. Technology demonstration based efforts to implement large-scale solar projects would also find due place in the magazine. As with any publication, the personality of *The Solar Quarterly* will also undergo changes based on comments and feedback received from those who read this publication. At the end, it is hoped that this magazine would contain enough information and analysis to bring about a significant shift in thinking and action for expanding use of solar energy at least in this part of the world.

I have great pleasure in being part of this major initiative that would undoubtedly be welcomed by those interested in sustainable energy solutions worldwide.

R K Pachauri
Director-General, TERI

Contents

VOLUME 1 • ISSUE 1 • OCTOBER 2008



4 NEWS

- The new milestone in solar electricity production
- The magic figure of $1/$W_p$
- Matching efficiency with cost
- The shooting price line for pure silicon
- DuPont materializing big
- Here comes the big sun power in Nagpur
- Sharing of solar base

8 FEATURE

- Collecting more power from less: solar concentrator technology **8**
- Reaching higher with the sun: grid-connected solar rooftop PV in India **16**

23 COMMENTS

- Understanding the p–n junction: overview of solar cell technologies

30 SPECIAL STORY

- Solar energy on the move: a look at solar charging for e-bikes **30**
- Mission solar: solar energy in the NAPCC **39**
- Lighting up lives... **42**

47 ORGANIZATION FOCUS

- Financing solar home systems: Aryavart Gramin Bank shows the way **47**

49 UNIVERSITY FOCUS

- Taking solar energy research to new heights: Asian Institute of Technology **49**

52 INTERVIEW

- Solar energy in the context of NAPCC **52**
  Dr Leena Srivastava, Executive Director, TERI
- Leading India to a new dawn **54**
  Abha Singh, Lead India finalist

57 PRODUCT UPDATE

- Clean power for cooking and lighting: cookstove controller

59 LEARNING PACKAGES

- Evaluating renewable energy projects: simulation of grid-connected solar PV system using RETScreen

61 EXPERT SPEAK

- Answers to questions on solar energy
  Dr V V N Kishore, Professor, TERI University

63 PRODUCT OVERVIEW

- From darkness to light: a survey of solar lanterns in India

74 BOOK REVIEW

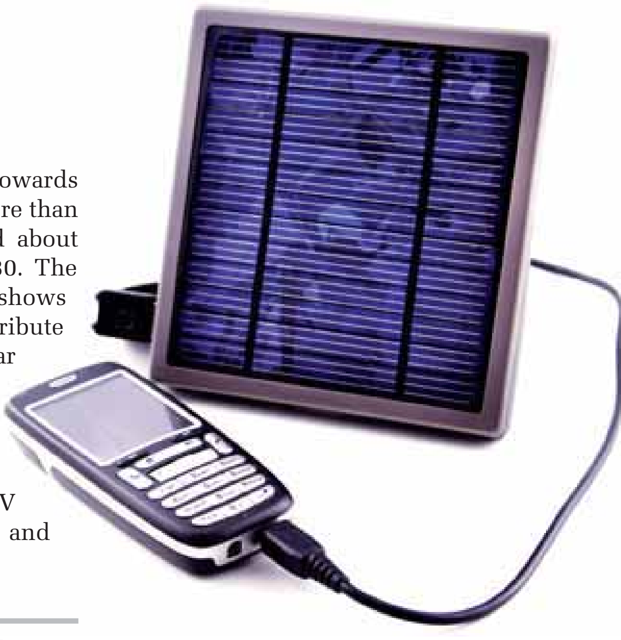
- The Solar Entrepreneur's Handbook

75 BOOK ALERT

76 EVENTS CALENDAR

The new milestone in solar electricity production

Use of solar power is growing by the day. The *Solar Generation Report*, a joint publication of Greenpeace and the EPIA (European Photovoltaic Industry Association) predicts the global PV (photovoltaic) installations to go beyond 1800 GW (gigawatt) mark by 2030. It typically represents more than 2600 TWh (terawatt-hour) of electricity production on an annual basis or equivalent to about 14% of the cumulative electricity demand. This may well fulfill the power needs of more than 1.3 billion people in the developed world and over 3 billion people inhabiting the unelectrified rural areas. One more positive would be large-scale creation of green-collar jobs. Available estimates point towards the possible employment of more than 2 million people by 2020 and about five times that number by 2030. The Solar Generation scenario also shows how solar electricity will contribute towards creating green-collar jobs. Currently, almost 120 000 people are employed in this sector. Most of the jobs – involving the installation, maintenance, and sale of PV systems – are created locally and boost local economies.



The magic figure of $1/$W_p$

Space-application-based solar cells have a much higher price tag than the terrestrial cells for a variety of reasons. However, the same cannot be tolerated for the cells, which are primarily intended for use of rural poor. Intense comparisons are presently being drawn between grid electricity and solar electricity with the latter still proving to be a costly affair. Various economic estimates highlight the fact that solar cells when priced at $1/$W_p$ can ensure parity with the grid. It is a moot question if any of the solar technologies today is closer to that final mark. As per IEEE, First Solar is the lone solar company inching closer to it. It is an Arizona-based startup company whose thin-film solar cells may well compete with coal within the next 2–4 years to attain the much needed grid parity. It is equally true that nearly 80 companies are presently pursuing that much-cherished goal. Technologies like CdTe (cadmium telluride), CIGS (copper indium gallium diselenide), silicon on glass, and the combination of Ge (germanium), GaAs (gallium arsenide), and GaInP (gallium indium phosphide) may be quite interesting to watch through. Crystalline silicon has edged out the rest right through its commercial beginning in the 1950s. Lately, it has been hit hard at times due to the shortages of silicon material, due to which the price has varied between $3/$W_p$ and $4/$W_p$.


Dish concentrator powering a Stirling engine

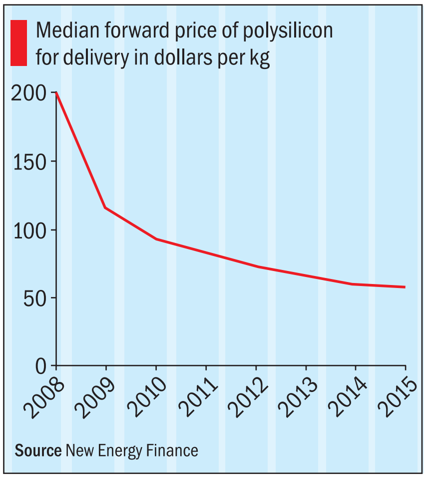
Photo courtesy: DOE/NREL

Matching efficiency with cost

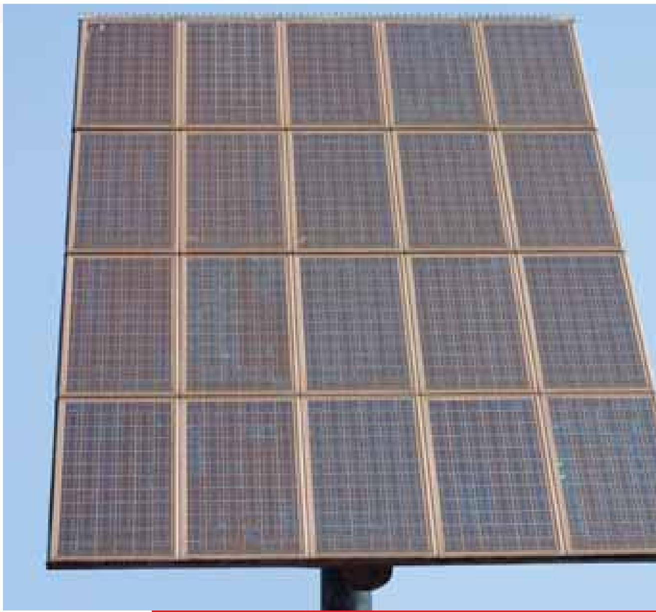
The present-day crystalline silicon modules deliver up to 75 W at a solar-to-electric conversion efficiency of about 13%. As per available market estimates, its manufacturing cost comes to about $1.14/W_p$. This price is well below the selling price of $2.45, which reflects a sound margin of profit. The buck does not stop here though, as the solar industry would have to bring down its manufacturing cost to $0.65/W_p$ and $0.70/W_p$. To realize this stringent objective, the cell efficiency must go up to 12%. Expectedly, new materials like CdTe may well stand up to this great challenge and fill more sunshine within it.

The shooting price line for pure silicon

The logical thinking of price coming down steadily with a corresponding improvement in technology and increasing volumes has come true with solar panels too. This trend has been continuing for the last 40 years or so as per a recent report published in the *Economist*. However, in 2004, Germany witnessed a huge demand for solar power primarily due to increased subsidies. The negative fallout was that the key component of majority of solar cells, that is, pure silicon was vastly outpaced. With the result that its price shot quickly from $25/kg in 2003 to as much as $250/kg in 2008 immensely hitting the prospects of realizing low-cost solar panels across the world.



It is equally true that silicon producers have traditionally been on the side of biggest customers, that is, chipmakers paying little attention to far less voluminous solar industry. There is an established view that it takes about three years for a new silicon generation plant to come up and the fruits of all new capacities established for the exclusive use of solar industry may still be in waiting at least till the early onset of 2010.



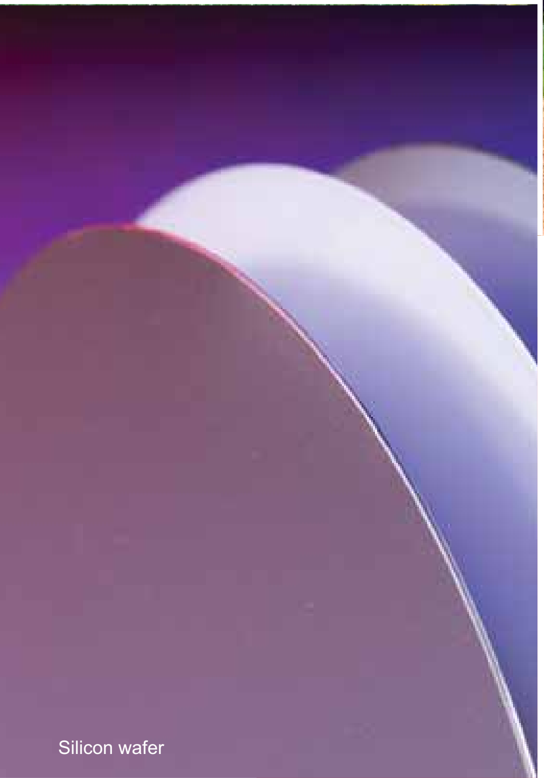
DuPont materializing big

PV material availability is most often talked about in terms of silicon wafers. However, that is not all, as a whole range of products like films, resins, encapsulants sheets, flexible substrates, and conductive pastes for both crystalline silicon and thin-film solar modules are needed. Well, this is what the globally acclaimed DuPont company is contributing to the solar industry worldwide. It has now announced the launch of DVPS (DuPont Photovoltaic Solutions) business in India. DuPont is a science-based products and services company founded in 1802 and with operations in more than 70 countries. The company is investing into materials, technology development, and manufacturing with an ultimate objective of enhancing the lifetime and efficiency of PV cells and modules besides facing up to an ever-increasing demand of above-mentioned materials. It is embarking on a major plan to set up a PV laboratory by 2010 at the DuPont Knowledge Center in Hyderabad. To showcase its increasing commitment to solar power and also meet a part of energy requirements through green power, it will also be putting up a PV array at this centre. DuPont expects that its sales of several product lines into the PV industry could exceed $1 billion within the next five years.

Here comes the big sun power in Nagpur

A grid-interactive solar thermal power plant of 10-MW capacity is set to come up in Nagpur, which gets high solar radiation round the year. The power thus produced is planned to be put on the national grid, a rich blend of traditional and non-conventional energy sources. This plant is expected to have a high demonstration value with definite scope for replication elsewhere in the country. India has got very limited experience with the use of solar power generation so far. The plant at Nagpur may ensure a plant load factor ranging between 80% and 90% of the installed capacity. A unique advantage of this plant will be in the form of zero transmission and distribution losses. The Ministry of New and Renewable Energy has already set the ball rolling by approaching the concerned state government of Maharashtra for land allotment, and so on.

Dish Stirling system



Silicon wafer

Sharing of solar base

BHEL (Bharat Heavy Electricals Ltd) and BEL (Bharat Electronics Ltd) are in the process of setting up a JV (joint venture) in solar power. As per the available reports, an investment exceeding Rs 10 000 million is to be arranged for the purpose. The key objective of this JV is to tap the immense solar energy potential in the country. This JV between these two premier public sector units involves setting up of polysilicon silicon production unit at Bangalore. Once established, it may also help lessen the near total dependence of the Indian SPV industry on the imported wafers from countries like Russia and China. It may still take some time before concrete action is taken with regard to the finalization of the following few issues: nature of collaboration, type of plant, and investment type. Both BHEL and BEL happen to be in the routine production of solar cells and modules. The plant likely to come up now is expected to produce about 2500 tonnes per year of polycrystalline silicon.

Sun to your rescue, anywhere

Recollect the time when you were on the road for long and could not recharge the battery of your laptop or music player. Now forget all about such teething situations as a Freeloader is at your doorstep. It is an easy-to-use, 185-g solar-powered charging station capable of powering most of the hand-held devices. With its twin small and extendable solar panels, this handy impact with good endurance can hold its charge for about three months. Thus, it can lend power to an iPod for 18 hours, a PSP for 2.5 hours, and a mobile for 44 hours as claimed by its manufacturers. In addition to attachments for digital cameras, PDAs, two-way radios, GPS devices, and so on, Freeloader is also equipped with adapters for quite a few popular type phone handsets like Nokia, LG, Motorola, Samsung, and BlackBerry.

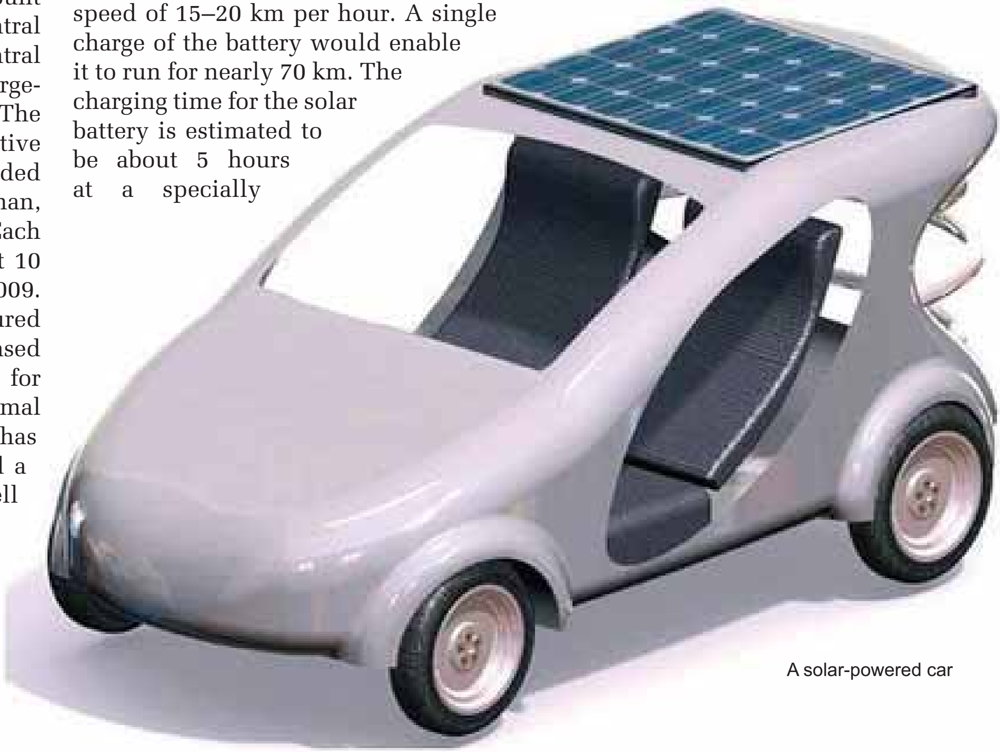
Gujarat showing the solar way

The state of Gujarat has earned the distinction of becoming the first state in the country to sign a PPA (power purchase agreement) with Euro Solar Power Ltd. Under this agreement, Gujarat will purchase about 5 MW of solar power from this company at a fixed tariff of Rs 3.37/kWh for a period of 20 years and beyond. Euro is intending to invest Rs 125 crore for this specific project in Kachchh district of the state. It is pertinent to mention here that per unit cost of grid-interactive SPV-derived electricity is about Rs 15 at present. This being an expensive affair would be made comfortable with the balance amount of Rs 11.63 committed by the central government. It is basically a central incentive in a bid to promote large-scale generation of solar power. The MNRE is to make such an incentive available, which may also be extended to a few more states like Rajasthan, West Bengal, Haryana, and Orissa. Each of these states may generate about 10 MW of solar power capacity by 2009. These initiatives have largely matured as a follow-up of the generation-based incentive announced by MNRE for both the solar PV and solar thermal technology areas. The response has been quite encouraging so far and a total capacity of 50 MW may well come up by 2010.

Louis Palmer with Solar Taxi at Bali

Blending tradition with modernity

Chandni Chowk holds a place of pride for India's capital city of Delhi. It is flanked on either side by historical monuments and heritages, which draw a large number of both Indian and foreign visitors to its fold. It is soon going to add one more feather to its cap, as solar-powered rickshaws are to become roadworthy on Gandhi Jayanti, that is, 2 October 2008. These rickshaws would weigh about 210 kg and may run at a leisurely speed of 15–20 km per hour. A single charge of the battery would enable it to run for nearly 70 km. The charging time for the solar battery is estimated to be about 5 hours at a specially created charging facility planned above the Delhi metro stations. It is being seen as a pilot project, which may well be extended to other areas of Delhi later on. However, this effortless rickshaw is not going to come dirt cheap, but with a price tag of Rs 17 000.


A solar-powered car

Background

SPV (solar photovoltaic) technology is making inroads both across the developing and developed regions of the world. This type of assertion is simply not new excepting the fact that the PV industry could grow even faster. The viewpoint could again be on the expected lines of reducing the capital investment and thereby the cost of the end products and systems. So, the moot question is whether strategies employed so far have lacked the charisma of low-cost product delivery? Well, to put it straight, the cost of silicon material (that is, wafer) generally makes up for more than 50% of the total module cost. So, an obvious trend being watched with an absorbing interest is to use less and less quantity of the expensive silicon material. The other familiar line of thought is to use thin-film coatings on low-cost substrates. These could typically include materials such as amorphous/microcrystalline silicon, cadmium telluride, and copper gallium indium diselenide on glass or other cheap substrates. One more striking option exists in the form of collecting more sunlight in a process known as solar concentrator technology.

Rationale for concentrator technology

The area of a solar cell is a key determinant of the product cost. It simply means gaining some cost advantage by reducing the cell area considerably. Is there a definite possibility to put that into practice? Sure enough, it comes under the ambit of a technology now known as the PV concentrator technology. The trick is to use concentrating optics to focus the available sunlight onto small-area cells. Design choice of the optics rests in accordance with the low or high concentration requirements. In case of low sun concentration, we can make use of low-cost solar cells, whereas the higher concentration would require more expensive high efficiency solar cells. The plain intention is to have a lower cost per watt of the installed solar cell capacity.

Concentrator cell technology: why now?

PV concentrator technology has been around for a long time though it has lagged behind the flat-plate crystalline cell technologies. It has mostly been talked about in terms of academic and research goals, but not much on the commercial front. There are quite a few reasons responsible for the low-lying commercial interest in CPV (concentrator PV) technology, more so during the last decade or so. The reasons mainly include the following.

- PV applications like rooftop systems and BIPV (building-integrated photovoltaics) mainly occupied the centre stage in various countries like Germany, Japan, and US, whereas CPV products are ideally suited to solar farms.
- There was not a mile of efficiency difference between the flat-plate cell and concentrator cell. The latter was about 30% efficient then.
- The PV industry had not grown to this much proportion. Economies of scale could result in lower price with the use of concentrator cells, but for the very small size of the market then.

The global market for SPV as well as the PV industry itself has grown substantially in 2007 and during the early part of 2008. This includes the CPV industry too, which is now poised for a large growth. Market estimates point to an investment of about $1 billion on the CPV front, which is no mean achievement. As stated above, solar farms can best be served through the use of PV concentrator technology. It is expected to turn into a large-scale market opportunity for the concentrator products and systems. We often talk of PV industry not achieving economies of scale to realize lower costs.

Photo courtesy: DOE/NREL

Collecting more power from less

solar concentrator technology

State-of-the-art two-axis tracker for evaluating PV modules

Now with CPV technology in tow, producing cheap PV products may not be a distant reality. Market studies vouch for realizing low costs of PV electricity mainly through recourse to the high-efficiency solar concentrator cells.

SPV concentrator technology versus solar thermal

Both solar thermal and SPV technologies are used for concentrator applications. However, the SPV approach has an edge over its thermal counterpart mainly due to the following few reasons.

- Higher flexibility in size of installation
- Better performance under cloudy conditions
- Relatively more electricity generated per installed kilowatt (in comparison to flat-plate panel) under tracking conditions

Latest developments in concentrator cells

There has been a definite increase in the efficiency of flat-plate solar cells over the years. However, as of now, the highest efficiency solar cells promise just about 22% conversion of incident solar radiation into useful electricity. It is equally true that the upper practical limit to crystalline silicon solar cell efficiency ranges between 26% and 28%. In contrast, the concentrator solar cells have been able to achieve quite high conversion efficiencies thus fuelling a renewed interest and approach in concentrator cell technology. A premier concentrator company, that is Spectrolab, has just attained the highest cell efficiency of about 41% for its triple-junction GaInP/GaInAs/Ge cell. It is to be understood as to why such multi-junction cells offer the highest efficiency standards so far. It is primarily because of the following few technical considerations.

- The spectral distribution of the sun can best be matched by choosing multiple semiconductor materials with different band gaps, thus resulting in highest possible theoretical efficiency.
- The use of direct-gap compound semiconductor materials, which can be grown with near-perfect quality.

There is a wide ranging perception that multi-junction solar cells alone can guarantee still better efficiency cells (~50%) in the time to come. In fact, the highest solar-to-electric conversion efficiencies have been obtained for multi-junction cells. The annual increase is taking place at a rate of nearly a per cent over the last few years.

Key determinants of CPV technology

Feedstock

At a global level, silicon continues to be the workhorse of the still dominant crystalline silicon cell technology. Silicon wafers are the most sought after component by majority of the PV industry today. As against this, the multi-junction cell production for the space applications has relied primarily on germanium wafers. Germanium metal is mainly obtained as a by-product of zinc refining or coal burning (retrieved from fly ash). As per the available estimates, about 100 metric tonnes of Ge was produced by the Ge suppliers in 2007. Bulk portion of it was in terms of GeCl4 (germanium tetrachloride) and GeO2 (germanium dioxide). China and Canada happen to be world's

Solar PV panel

two largest Ge sources, with each contributing to more than 33% of the global Ge production. It is believed that nearly 15% of Ge produced in 2007 was used to meet the electronic and SPV applications. Market estimates point to the large-scale availability of Ge so as to meet a yearly CPV-based installation rate of about 4000 MW (megawatt). Of late, there is a renewed thrust in replacing Ge with lower cost catalysts like titanium-based solution. When that happens in full, the cost of cell production may go down further.

Cell

The efficiency of concentrator cells has been going up at an annual rate of 1% since last few years or so. The efficiency levels of such cells are expected to reach 45%–50% in the time to come. Take for example Spectrolab, which has demonstrated a record cell efficiency of about 40.7% closely followed by Emcore at 39% and NREL (National Renewable Energy Laboratory) cell at 38.9%. Technically speaking, it is possible to achieve a record cell efficiency of 50% or so by adding multiple junctions. However, it may add to the cost and thus not necessarily translate into any impressionable benefit.

Optics

In general, cheap plastic Fresnel lenses perform the simple trick of focusing the desired sun concentration onto small-area solar cells fairly well. However, there have been a few concerns about the yellowing or pitting of plastic lens and even the need for washing. As a remedial measure, few companies are making use of glass lenses mainly to do away with the abrasion problem in case of plastic lenses.

Tracker

Flat-plate systems do not use trackers by and large. They perform well without such paraphernalia. However, trackers are a must under the concentrated light conditions. Microprocessor-based trackers as well as those operated mechanically are available in the marketplace today. The latter type is more prone to field problems. This may also lead to some reduction in performance and at an expense of a higher maintenance cost.

The CPV industry

Concentrator cells

In reality, the CPV industry is a good mixture of some old names like Amonix, Spectrolab, Emcore, and Emtech in association with more than 10 start-up companies. The key strength of the industry is derived from the very high efficiency attainments by the first-category companies. Today, a number of companies, notably Spectrolab and Emcore, have the capability for epitaxial growth of multi-junction cells. Table 1 gives a quick glimpse into such efficiency levels across the spectrum.

Currently, more than a dozen startups are working on techniques to use mirrors and lenses to concentrate sunlight hundreds of times onto tiny, highly efficient solar cells. These systems are intended to reduce the share of expensive silicon material in the power-producing unit, that is, the solar cells.

Industry setup

The renewed interest in CPV technology has catalysed the interest of quite a few companies at various levels, be it cell development, cell assembly, or system integration. Table 2 provides brief details about such companies, now better known as the startup ventures. It would be pretty interesting to watch as to how far such companies could actually take off.

Table 1 Efficiency levels across the CPV industry

Company	Remarks
Spectrolab	Minimum average cell efficiency of 36% and cell assemblies at 50 W/cm^2
Emcore Amonix Emtech	Typical cell efficiency of 36% and receivers at 470 suns
Spire (bandwidth)	Typical cell efficiency of 35% at 500 suns
CESI IQE ARIMA EPISTAR SHARP VPEC	Cell efficiencies between 30% and 35%

Table 2 Details of some start-up ventures

Company	Location (s)	Key details	Remarks
SolFocus	California with presence in Spain	Just completed the first 200-kW installation of a 3-MW concentrating SPV plant at Spain's Institute of Concentration PV Systems	This startup company has already raised $95 million from several enterprises including Moser Baer India
Cyrium Technologies		Produces the multi-junction solar cells for CPV systems	
Solar Systems	Australia	Developed the CS500 dish concentrator PV unit, which stands 14 metres high, has 112 curved mirrors (each 1.2 square metres), and tracks the sun on a mounted steel frame	Claim to produce 30% more electricity per installed watt and is cheaper per installed watt than traditional PV
Green Volts	San Francisco	Developed a sun tracking concentrating system known as the CarouSol which can concentrate sunlight up to 625 times	Claim to produce energy at less than half the cost of traditional PV
Concentrix Solar	Germany	Markets concentrating systems known as Flatcon with plans to start up another 25-MW production line	Claim to produce electricity 10%–20% cheaper than standard PV
Silicon Valley Solar		It produces a flat-plate internal concentrator, which is low cost and delivers two times the concentration and does not rely on tracking system	Claim to reduce the silicon consumption by 50%
Energy Innovations		Developed Sunflower which is known as world's first CPV system for both commercial rooftop and ground mounted applications	
Soliant Energy		Developed a concentrator system, that uses triple-junction cells, which can deliver 40% efficiency and the lenses concentrate sunlight by 500 times	Claim to have rooftop concentrating panels of the same dimension and weight as conventional panels thus making their installation easy
Green and Gold Energy	Australia	Prior commitment to sell 400 MW per year of its Sun Cube CPV systems	Intends to sell about 1-GW of Sun Cube manufacturing facilities across the world including India Claims to have placed the largest CPV industry order to date for 105 MW of Emcore's (world's leading company) 1000 sun concentrator cells
Pyron Solar	California	Developed a functional 6.6-kW prototype of an unusual solar system, which floats in water. This helps to cool the system.	It uses three 15-metre diameter arrays on a two-axis tracker with multi-junction solar cells from Spectrolab
Sol3g	Spain	Currently building a part of the 3-MW solar system for Institute of Concentration PV systems	Claims that the PV surface of its system is about 400 times smaller than that of a conventional PV system
Cool Earth Solar		Develops inflated mirror concentrators, within which half is made of reflective mylar and half clear film. There is a high-efficiency PV receiver inside the bubble.	
Zytech Solar		Involved in production of both high- and low-concentration PV systems	
Arima Eco	Taiwan	It has already placed several pilot installations in Canada and US	Involved in the installation of a 300-kW concentrator system

PV concentrator installations

PV flat-plate installations have grown bigger and bigger in size over the last five years or so. Multi-megawatt grid interactive systems are now being set up on more or less a regular basis. There has been a steady growth in the number of companies pursuing the CPV technology at various levels, more so during the last five years or so. The CPV industry's projection of deploying megawatt-scale system was realized for the first time in 2007. Prior to which just kilowatt systems were the order of day. Table 3 gives a list of a few major CPV installations.

Table 3 Few major CPV installations

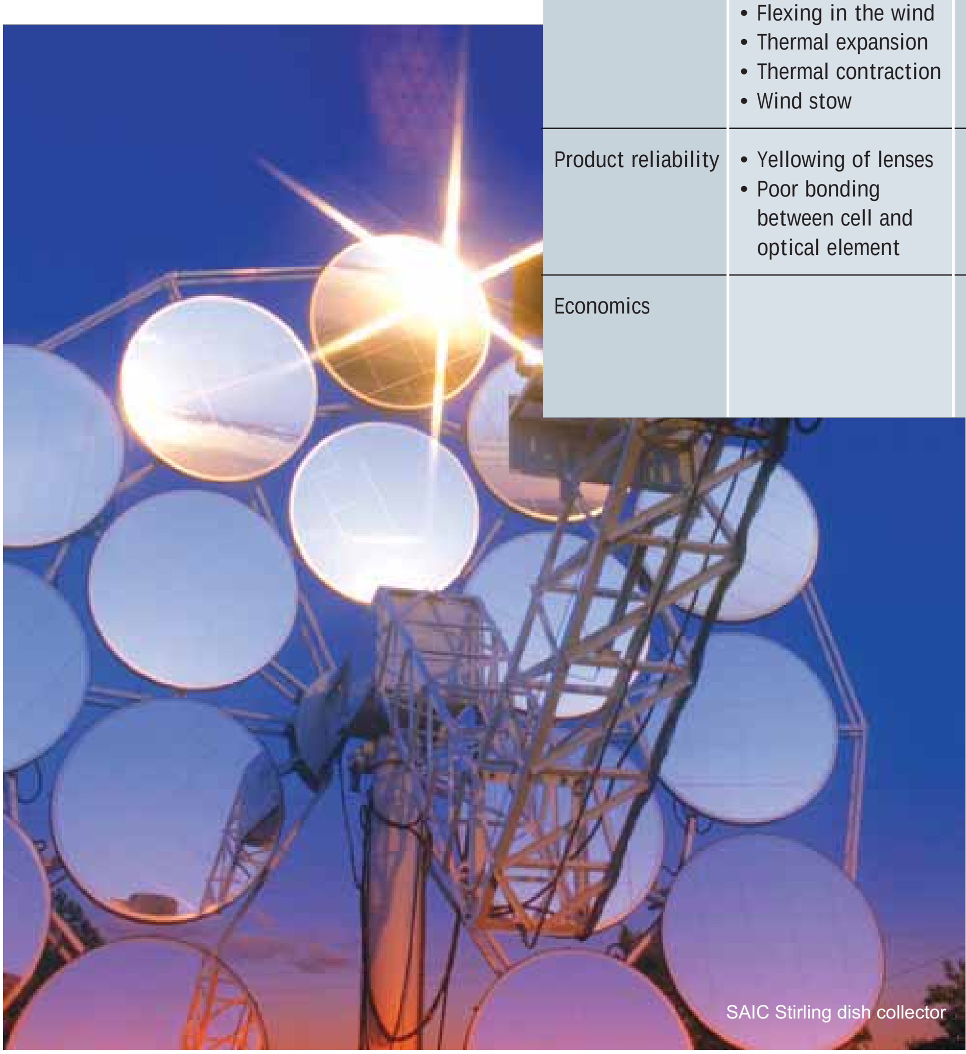
Company	Location	System type	Size of installation
Amonix	USA	Lens, pedestal	> 100 kW (Si-based)
Concentrating Technologies	Alabama	Small mirror, pedestal	>1 kW
Cool Earth Solar	USA	Inflated mirrors	>1 kW
Energy Innovations	USA	Lens, carousel	
Entech	USA	Lens, pedestal	>100 kW
GreenVolts	USA	Small mirrors, carousel	>1 kW
Menova	Canada	Modified trough	
Guascor Foton	Spain	Lens, pedestal	>10 MW (Si-based)

Key problematic issues

Unlike flat-plate technologies, CPV technology is still passing through successive stages of improvement and growth. Various efforts are being made by the CPV companies to offer systems with the best possible performance value. A common perception is that tracking mechanism in a CPV system adds to the complexity of a concentrator system. However, there a few more issues, which are summarized below in Table 4.

Table 4 Issues with CPV technology

Parameter	Physical issue	Technical issue	Broad objective
Field performance	• Soiling • Flexing in the wind • Thermal expansion • Thermal contraction • Wind stow	• Cooling of the cells • Efficiency of the optical setup • Errors in tracking	To enhance the overall reliability of the concentrating system and ensure lower cost of power delivered
Product reliability	• Yellowing of lenses • Poor bonding between cell and optical element	• Unsatisfactory performance of the tracking system	
Economics		Use of cheaper components and automated assembly setup	



SAIC Stirling dish collector

Economic estimates

From a technical viewpoint, higher the concentration of sunlight onto a small cell area, lower is the expected cost. Simply put, the cell cost in \$/W (dollars per watt) has a strong dependence on the level of sunlight concentration. Table 5 shows the cost per watt based on two sales records of Emcore, out of which one was executed in July 2008.

Table 5 Cost per watt of cells based on two sales record of Emcore

Supplied	Supplied to	Concentrator cell volume (multi-junction cells)	Sale value	Cost per watt
Emcore	Green and Gold	105 MW	$24 million	0.23
Emcore	ES Systems (Korea)	70 MW	$28 million	0.41

Emerging trends in CPV technology

Organic dyes have been the subject of quite a few wide-ranging discussions for their likely ability to cut down the cost of PV-derived electricity by at least 50%. This is borne out of the recent research studies carried out by the MIT researcher. They have created sheets of glass coated with advanced organic dyes that concentrate sunlight more efficiently than the conventional concentrating mechanism. These glass sheets are expected to reduce the amount of expensive semiconducting material, that is, silicon and thus provide a cheap way to extract more energy from high-energy photons such as that at the blue end of the spectrum. The amount of light concentration varies in accordance with the size of glass sheet. This way, the traditional optical arrangement is avoided as the glass sheets concentrate light using a combination of organic dyes. It would be of interest to know as to how much effective such dye-based technique of concentrating sunlight turns out to be.

Indian scenario on PV concentrator technology

The early development

The MNRE (Ministry of New and Renewable Energy) has been providing the requisite support to R&D (research and development) activities in SPV technology since 1976. Universities, IITs, research organizations, and industry too have benefited through such support. The obvious priority was to develop flat-plate crystalline silicon cell technologies. However, CEERI (Central Electronics Engineering Research Institute), Pilani, a constituent unit of CSIR (Council of Scientific and Industrial Research) spearheaded the limited efforts in the direction of concentrator module development. It undertook a major initiative to develop solar cells for use under concentrated light during 1979–84. A special pho-


Fresnel lens


Solar cell

tolithographic process was developed in-house for obtaining the fine grid pattern on the cell front surface. This helped in achieving an efficiency of more than 15% on cells of 15-square-centimetre area under one sun operation. The effort progressed to the level of obtaining efficiencies of 12.5% at 9 sun and 10% at 30 sun illumination conditions on single crystal silicon cells (50-mm diameter), respectively.

Indian Institute of Sciences (Bangalore) and CSIO (Central Scientific Instruments Organisation) undertook the development of plastic-base Fresnel lenses for concentrating sunlight onto small-cell areas. Another important component in a PV concentrator system, that is, a system for automatic two-axis tracking of the sun was also designed and developed by CEERI, Pilani. The resultant effect was the fabrication of a 40-watt concentrator panel exposed to actual field conditions for some duration. It used indigenously developed high-efficiency solar cells fabricated at CEERI along with imported-make Fresnel lenses.

Misplaced focus

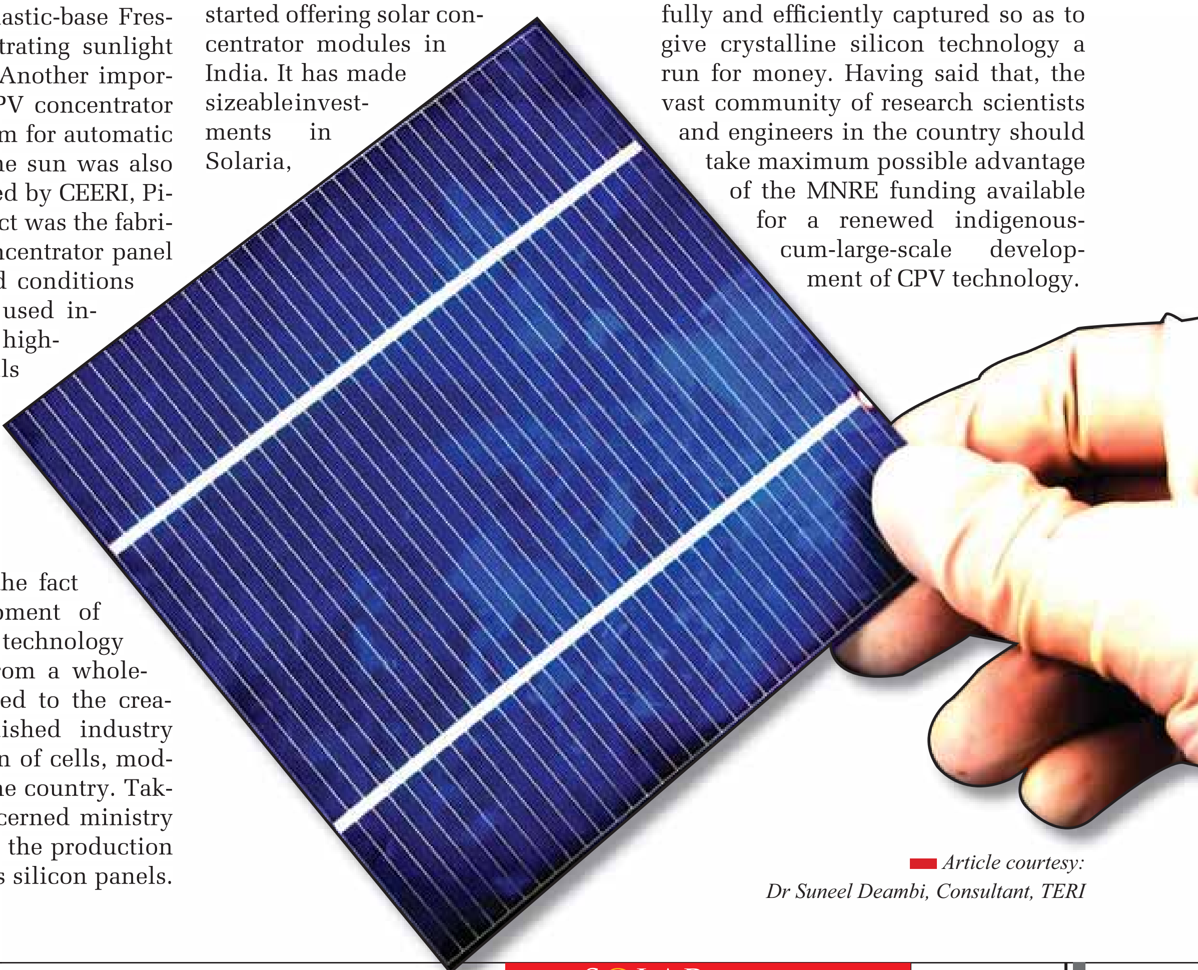
There is no denying the fact that efficient development of crystalline silicon cell technology was quite desirable from a wholesome perspective. It led to the creation of a well-established industry base for the production of cells, modules, and systems in the country. Taking it further, the concerned ministry set up a pilot plant for the production of thin-film amorphous silicon panels.

However, the potential of concentrator-type single crystalline silicon solar cells was not fully explored in the country despite initial success at CEERI. There is still a dire need for launching a major initiative for design, development, and fabrication of high-efficiency concentrator cells in the first place. It gains added significance for the fact that the local PV industry still has a very large reliance on the imported wafers. The concentrator cells if, developed successfully in a commercial production setup can surely partake some of the requirement for imported silicon. It is important to note here that a startup company under the name of Sunsource India Ltd was announced with much fanfare to produce various types of concentrator cells. However, nothing much was heard about such a venture lately.

Most recent initiatives

Moser Baer Photovoltaics, a recent entrant to the Indian PV industry, has started offering solar concentrator modules in India. It has made sizeable investments in Solaria, which is a PV concentrator technology company based in Freemont, USA. Solaria lays claim to the fact that its unique CPV process is capable of producing power twice or thrice the power using the same amount of silicon material. It remains to be seen as to how the Indian market braces up for such a novel technology use.

Market reports suggest a strong inclination of a few more CPV companies like Solar Cube and Prism Solar to make forays into the Indian market. After all, solar farms are being talked about like never before and CPV technology may rule the roost in the time to come.



Conclusion

Solar concentrators use lenses, mirrors, parabolic dishes, or other optics to trap energy from the sun. The booming solar industry is in the midst of an argument as to which material technology/process will steal the march over others. Within that ambit, CPV technology is also being seen as a strong contender. Who knows sunlight may be wonderfully and efficiently captured so as to give crystalline silicon technology a run for money. Having said that, the vast community of research scientists and engineers in the country should take maximum possible advantage of the MNRE funding available for a renewed indigenous-cum-large-scale development of CPV technology.

Article courtesy:
Dr Suneel Deambi, Consultant, TERI

REACHING HIGHER WITH THE SUN

grid-connected solar rooftop PV in India

India needs to harness its vast pool of renewable energy sources like solar energy than never before. The reasons are not hard to find within an existing situation of the ever-increasing gap between demand and supply of conventional power. That is not all. It is now becoming increasingly difficult to achieve high economic growth and attain energy security too. In 2007/08, the electricity demand was estimated at 739 billion units as against the actual supply of 666 billion units. This points to a huge deficit of 73 billion units and represents a national energy shortage of 9.9% and peak shortage of 16.6%.

Figure 1 shows the maximum contribution of coal, oil, and gas to the total installed power capacity in the country. The non-availability of adequate reserves of indigenous coal together with an inherent drawback of high ash content are reasons enough to go all out for renewable sources of energy. Clean coal technologies are also driving the demand for imported coal. All these factors put together go strongly in favour of attaining increased market penetration of various renewable energy technologies, including solar.

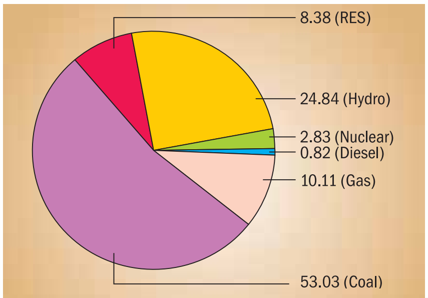


Figure 1 All India installed capacity in % terms by source as on 31 July 2008

There is an additional reason to think about an increased role for renewable energy technologies—growing environmental concerns. In recent years, the atmospheric concentration of carbon dioxide has been rising at a rate of about 0.5% per year.[1] Thus, there is an urgent need to lessen our dependence on carbon-emitting fuels like coal by replacing some of the power generation capacity by renewable energy. The net effect would be visible in terms of a cleaner environment both for the present and future generations.

Amongst the renewable energy technologies, wind and small hydro system installations are usually linked to the availability of site-specific resource. In contrast, solar energy is almost available everywhere

[1] Details available at <http://www.eia.doe.gov/oiaf/ieo/emissions.html

Solar inverter

except the polar regions and within the dense forests. Today, off-grid PV applications are rampant whereas on-grid PV systems are yet to make any noticeable impact. However, the same is not true of countries like Germany, Japan, Spain, and California with reasonably high number of PV-grid installations.

Solar energy as a technical resource

Solar energy is a dilute source of energy as compared to the conventional sources of energy. As such, large stretches of land are needed to collect the incident solar energy. A 1-kWp SPV system (based on crystalline silicon cells) usually needs about 7 square metre of land area for installation purposes. Thus, it tilts the balance in favour of small-capacity SPV systems primarily for peak load shaving in urban areas. Roof space is generally available there within the residential and commercial complexes (like shopping malls and hotels) and can be put to such use. Therefore, rooftop SPV system could be considered as a viable DSM (demand-side management) option for a country like India braving severe energy shortages.

Rooftop SPV system

Grid-interactive rooftop SPV systems are designed to operate in parallel with, and interconnected, with the electric utility grid. Such systems include a solar array, grid-connected inverter, roof mounting assembly, prewired circuit breaker, and distribution board. This system results in more effective utilization of generated power. However, the technology requirement of both, that is, from the utility and PV system side needs to be safeguarded from the risk of interconnection issues. A typical arrangement of grid-interactive SPV power plant is shown in Figure 2.

The modular characteristics of an SPV system provide flexibility to upgrade it to any desired capacity. Such systems are designed by connecting PV modules in large number of series and parallel arrays depending on the actual load requirement.

The output of a solar module is connected to a PCU (power conditioning unit). It converts the DC power into AC power of desired electrical parameters (that is, voltage, current, and frequency) for feeding to the grid. This process is commonly known as grid evacuation.

Metering of power supply

A specially designed two-way meter is installed at the point of power evacuation system to take care of metering and billing issues. Such a protocol is generally known as net metering and basically records the amount of electricity going from a PV system into

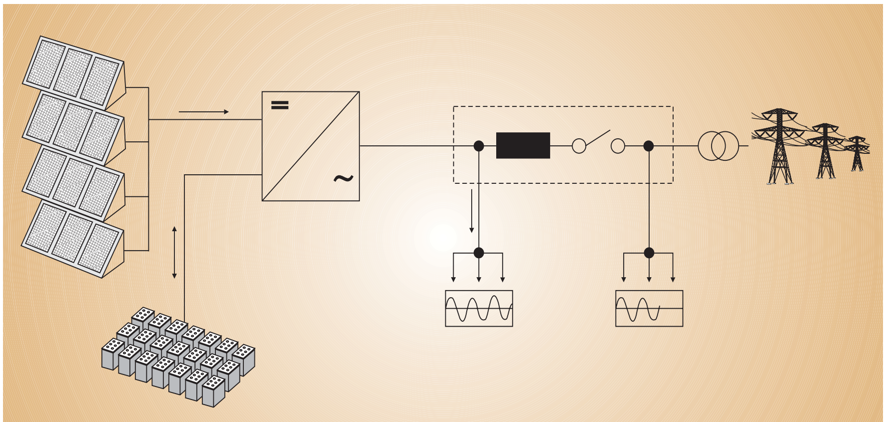


Figure 2 Schematic of grid-connected rooftop SPV system

the grid. Reverse flow of electricity makes the meter spin backwards so as to record the power withdrawn by a consumer from the grid. This provides a customer full retail value for all the electricity produced through SPV system.

Consumer segmentation

There are usually two types of consumers, that is, institutional and residential, who may have a certain liking to put up PV rooftop systems. Power capacities generally involved range from a few kilowatts to a few megawatts. The rooftop systems are connected to 11-kV three-phase supplies at high voltage levels. It is under the premise that the power generated is fed directly into the grid (minus a battery bank) owing to reduced outages at high voltages. The battery bank is not a preferred choice due to high voltage levels involved.

Contrast this with the use of low-capacity systems in the residential sector. These systems are also connected to the grid, but to a single-phase supply of 220 V. The striking disadvantage is that of frequently occurring outages at low voltages thus making the grid less reliable. A battery can be added to the system so as to make it more useful to a consumer. The system normally operates in grid-connected mode, transmitting all the power generated from SPV system into the grid. The following type of situations may result.

- The control circuitry in the inverter delinks the system from the utility network and the solar system meets the priority load demand of the premises. Normal operation resumes upon re-energization of the grid.
- The battery bank takes care of power needs during night time or on cloudy days in the absence of both grid power and solar power.

International practices

California

The PV market in California grew by about 50% in 2007. It has a vast array of programmes and incentives to facilitate use of SPV systems. Its rebate programme began in 1998 and required three major utilities to mobilize about $540 million to develop state-wide renewable energy market. Following few are the key highlights of the Californian solar programme.

- The government approved funds of $54 million for a multi-year rebate programme to offer incentives for installation of SPV system.
- Maximum rebate of $3 per peak watt offered for PV systems during 1998–2000.
- Increase in rebate to $4.50/Wp to a maximum of 50% of total system cost owing to state's energy crisis.
- Accelerated deployment of the PV systems to the tune of 300 systems (on an average) per month in 2001.
- Additional $118 million allocated for rebates under an altered programme, 'Emerging Renewable Program' in February 2003 typically to stimulate the use of small-capacity systems.
- A subsidy of 44 cents per watt with up to half of the total cost covered for systems up to 30 kW with a reduction by 20 cents per watt every six months.
- The total installed cost of solar PV systems declined substantially from more than $12/watt in 1998 to $9/watt in 2004/05 due to an overall shift in the market trend towards lower cost system due to increased market competition and global drop in solar module prices.

Solar rooftop PV installation

Photo courtesy: DOE/NREL

The California Public Utility Commission approved new feed-in-tariff for small renewable energy generators up to 1.5-MW capacity. The tariff rate was fixed between 15 and 31 cents per unit in relation to the states market price for conventional power.

Germany

The German PV market occupied a share of just under 50% in 2007 and still continues to be the largest market for solar panels. It offers the most successful example of a rapid transition towards renewable energy system use mainly due to feed-in-tariffs. It generates about 12.5% of its electricity needs from such sources and involves more than 1500 PV companies giving employment to about 215 000 people too. Key features of the German SPV programme are as under.

- First solar energy promotion initiated by the German government between 1989 and 1994 under a widely known programme called the '1000 Roofs Programme'.
- About 70% of an individual system cost was met by the government.
- Mega programme of 100000 solar roofs launched in 1999 replacing the capital subsidies by low-cost loans at a total outlay of $550 million, thus making it one of the largest single government promotional budgets worldwide.

- Massive shortfall of about 50% in the targeted capacity of 18 MW primarily due to absence of any direct subsidies.
- Replacement of 'RE Sources Act' by 'Feed-in-Law' in 2000 thus enabling the payment of 50 cents/kWh by the utility besides availability of interest free loans from the government.
- Reduction in tariff @ 5% per year for systems installed thereafter.
- The tariff for systems installed after 2004 reduced by 5% each year so as to make PV cost-effective rather than being dependent on government subsidy.

Japan

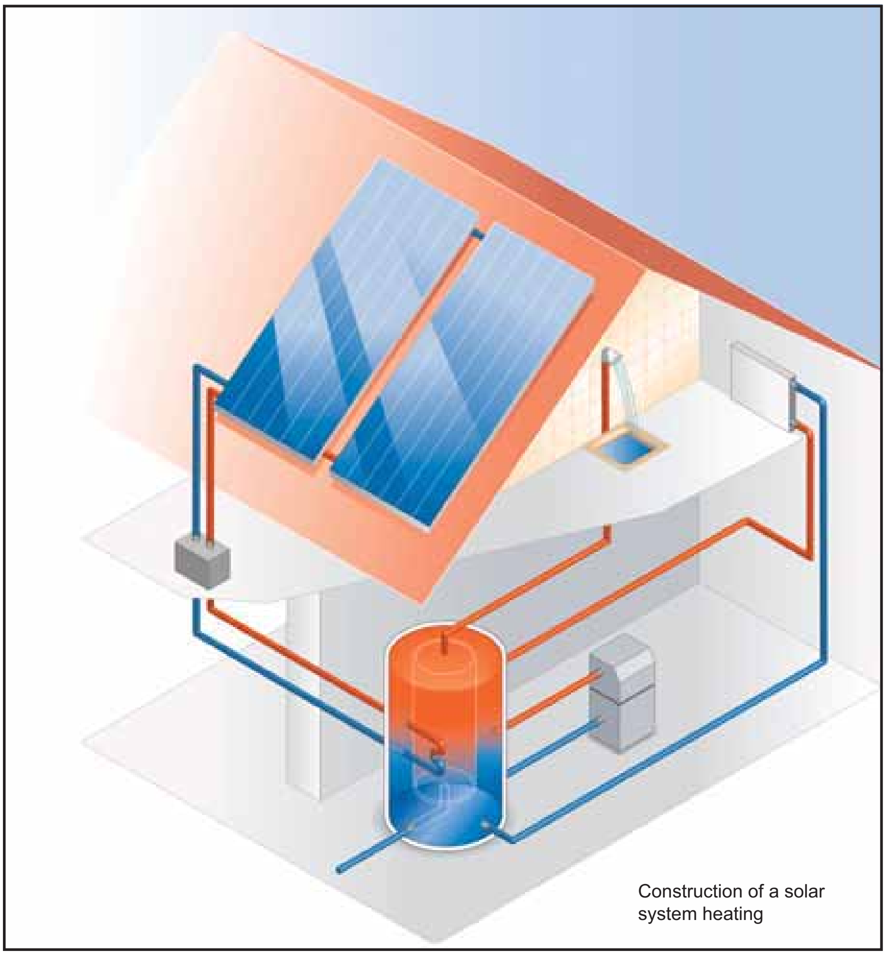
The Japanese PV market occupies a share of nearly 8%. It is not only the land of rising sun but has also come to be known as the land of rising solar energy. Solar energy first made its mark here with the advent of the 'New Sunshine Program' in 1992. The significant objective of this programme was to remove the obstacles in introducing new and renewable energy on a national and local level. The programme participants had to meet certain eligibility criteria. Residential solar had to be grid tied and use net metering. Following few are the key features of the Japanese programme.

- 'Residential PV system, Monitor Programme' took off in 2001 to accelerate renewable energy development at a whopping government spending of $800 million on the solar rooftop programme during 1994–2001.
- Subsidy of 50% provided on total installed cost of solar system (4–5 kWp) during 1994–96 and brought down to 33% between 1997 and 2001.
- Existing subsidy is evened out at 120 000 Yen per kWh with owners of PV systems at liberty to sell back excess electricity to the utility @ 25 yens per kWh.

Spain

The Spanish PV market experienced a spectacular growth of nearly 300% to approximately 426 MW of new installed PV capacity in 2007. It has implemented a very effective 'feed-in-law' on the lines of a German PV programme. It has resulted in many gains apart from emerging as one of the top few global PV manufacturers. Following few are the key highlights of this solar programme.

- Energy Conservation law enacted as early as in 1980 accompanied by the process of introducing and refining the key legal guarantees of a feed-in policy along with guaranteed access, price, and purchase contract with the utilities.
- New electricity law put in place in 1994, under which, a Royal Decree set prices rather than the Ministry of Energy and Industry besides specifying a minimum of five years for purchase contract.
- Better predictability of the electricity prices as prices, premiums, and incentives are determined as a fixed percentage of average electricity tariff announced by the year end and being valid for the following year.
- The regulated tariff for electricity produced in PV plants of less than 100 kW is 575% of average electricity tariff.
- The regulated tariff for electricity from renewable sources generally drops after 5, 15, 20, or 25 years from when the installations were commissioned.
- The premiums and incentives however remain at fixed percentage throughout the useful life of a plant.
- The electrical distributor has an obligation to buy electricity produced under the special system at a price set in Royal Decree and the National Commission of Energy
- Only such distributors are reimbursed for as have paid the price, premiums, and incentives as laid down in Royal Decree
- The existing favourably placed feed-in-tariff mechanism is due to terminate by 28 September



Construction of a solar system heating

2008. Efforts are underway for its extension beyond the stipulated date to spur the growth of PV grid-connected systems further.

Potential of rooftop SPV systems in India

India has a sizeable number of residential and commercial consumers who can benefit through an abundantly available solar energy resource. Residential type of rooftop PV systems offer the best estimated potential of about 500 MW. If realized in practice, it could tide over to some extent the existing energy shortages in a city like Delhi. As per the available estimates from CEA (Central Electricity Authority, 2005), the peak demand is expected to almost double from 4075 MW in 2007/08. Commercial entities can also gain via the use of well-designed PV systems on roof space available with them.

Origin of Indian rooftop SPV programme

The MNRE (Ministry of New and Renewable Energy) launched the grid-connected PV rooftop programme in 2000 mainly as an effective DSM tool in urban areas. The state nodal agencies for renewable energy were involved in this programme so as to establish the necessary field experiences. Nearly 25 rooftop systems (25–100 kWp) were put up on various government-owned buildings. However, the outcome was not encouraging mainly due to poor reliability-cum-availability of grid. It often resulted in frequent system failures. That is not the case anymore as grid quality has vastly improved and so has the inverter technology. The confidence on the technology development front is now discernible from the most recent initiative of WBREDA (West Bengal Renewable Energy Development Agency). It has just opened up India's first solar complex namely Rabi Rashmi Abasan in Kolkata. Here, each house produces its own power for domestic use and feeds any surplus power into the local grid. Power can also be drawn from the grid on a need basis. The state utility has fixed a rate of Rs 12 per unit to be paid for the grid-inputted solar power on a monthly basis. Expectedly, this rate may drop down to Rs 6 per unit as the solar market evolves further. It is certainly a welcome development, which can be replicated on a large scale. However, one should not lose sight of finding satisfactory solutions to the existing technical and non-technical barriers vis-à-vis rooftop PV systems.

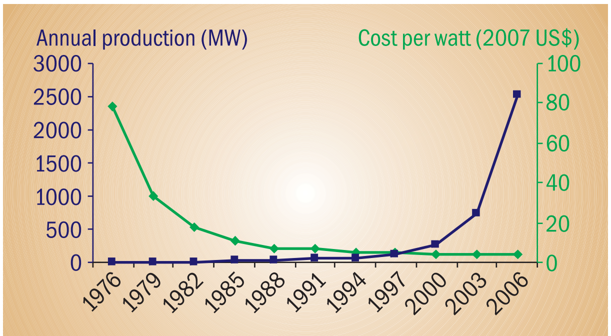


Figure 3 Annual production and cost per watt of SPV systems

Existing barriers to rooftop SPV

High cost of solar power

SPV systems for sure have a high initial capital cost, when compared to conventional power and even a few renewable energy technologies like wind and small hydro. The good part is that the cost of PV has reduced to one-tenth of its price in early 1980s during the last 15 years or so. The breakthroughs in technology and corresponding increase in annual production has caused the cost per peak watt to reduce to Rs 200–250 in 2008 from Rs 3500–4000 in early 1980s (Figure 3).

Connectivity standards and safety issues

All power-generation systems require evacuation facilities for transmitting generated power from the system. Most of the renewable energy systems require interconnection with the medium or HT network. However, rooftop PV systems are small-sized systems connected to LT or distribution-level network. Therefore, this could cause a serious security hazard to the system operator if the same is not able to isolate itself at the occurrence of fault. In developed countries, standards exist for interconnection of SPV systems to the grid but in India, no such standards exist to connect small systems to the distribution network.

Regulatory issues

Section 61 of the Electricity Act 2003 prescribed the philosophy to be followed by SERCs (state electricity regulatory commissions) for determining tariff. Accordingly, many SERCs have issued tariff orders for various renewable energy technologies such as biomass, wind, small hydro, and municipal solid waste. However, till now, just three SERCs namely those of Punjab, Rajasthan, and West Bengal have announced preferential tariff to procure power from solar. Further, MNRE has recently announced generation-based incentive for PV grid systems of 1-MW capacity or more but not in case of seemingly large potential ridden small-capacity rooftop segment.

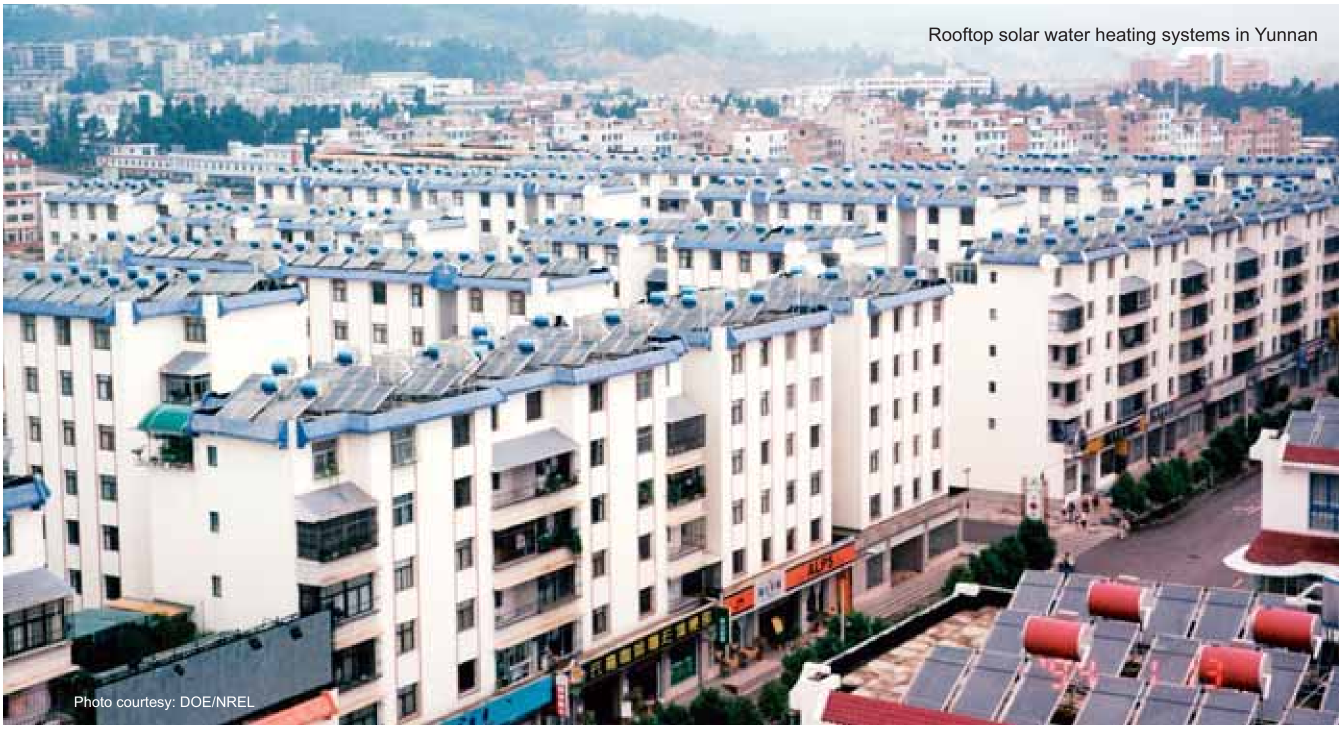
Lack of awareness

There is an undeniable need to propagate key advantages and limitations of SPV systems amongst the potential customer segments. One of the approaches can be to dissuade urban users from using diesel gensets. Economic estimates point towards an equivalence of per unit cost of electricity from such gensets and the SPV system for daily outages of about 3 hours. Ironically, majority of the PV manufacturers themselves hardly mention such benchmark comparisons in the material intended for public dissemination. With barriers having been brought to the fore, it is now proper to chalk out a roadmap for a smooth PV programme implementation as under.

Roadmap for implementation

Finance

The key barrier for a subdued market penetration of PV systems continues to be its high initial capital cost. As per TERI estimates, the existing per unit cost of generation ranges between Rs 16 and Rs 20 in accordance with the size and site specifics. Obviously, it is almost 3–4 times the cost of



Rooftop solar water heating systems in Yunnan

conventional power. So, attaining grid parity is not simply a far cry but a real need indeed to make solar more acceptable. Ready-to-use economic estimates need to be prepared in respect of each key solar application after factoring in the available financial and fiscal incentives. This may suffice to lure the residential and importantly, the industrial customers towards SPV use.

Technology

There is a dire need to develop standardized plug-and-play rooftop SPV systems comprising essentially of solar modules, inverter, and balance of system. The resultant gain could be in the form of ease of system designing and their fast field implementation. A rooftop installation should adhere to the existing IEEE interconnecting standard so as to enhance the plant operator safety in case of fault occurrence. The plug-and-play system following IEEE standards has already been designed and implemented in various American and European states. However, indigenous SPV industry manufacturers have not been forthcoming in investing on R&D of SPV system. Perhaps, MNRE and Ministry of Power should take the first-hand initiative of framing guidelines related to sizing and interconnection of rooftop solar system to the distribution network.

Regulatory intervention of policy

All the SERCs should announce preferential tariffs or feed-in-tariff for grid-connected rooftop SPV systems. This may stimulate an increasing participation from the private sector. Feed-in-tariff is simply a guaranteed price set by the government for anyone who wants to sell renewable electricity to the grid. It is also a guarantee that PV power supplier will have a ready access to the grid. This policy scheme of feed-in-tariff has been successfully implemented in more than 20 countries so far, with Germany being the most successful example. Furthermore, all SERCs should mandate distribution utilities to procure minimum percentage of power from renewable sources and particularly from rooftop SPV systems, under the RPO (Renewable Purchase Obligation).

Implementation

It is becoming increasingly necessary to design various PV system market-delivery models like an ownership or leasing model. The former model envisages receipt of a pre-agreed incentive for sale of power to a utility, whereas in the latter, model ownership of the system rests with an ESCO (Energy Service Company). SPV (special purpose vehicle) could also be formed amongst MNRE, IREDA (Indian Renewable Energy Development Agency), and SPV manufacturers. These may then invest in a rooftop system on a long-term lease basis akin to the BTS (Base Receiver Station) concept in the telecom sector. The accompanying modalities must be worked out to involve consumers with varying paying capacities.

Way forward

It being an era of participatory management, all the stakeholders must pitch in to evolve ways and means to implement the rooftop programme. The key objective should be to set up some pilot-scale projects with a wide geographical outreach. That alone will accord the much-needed impetus to such a novel technology use.

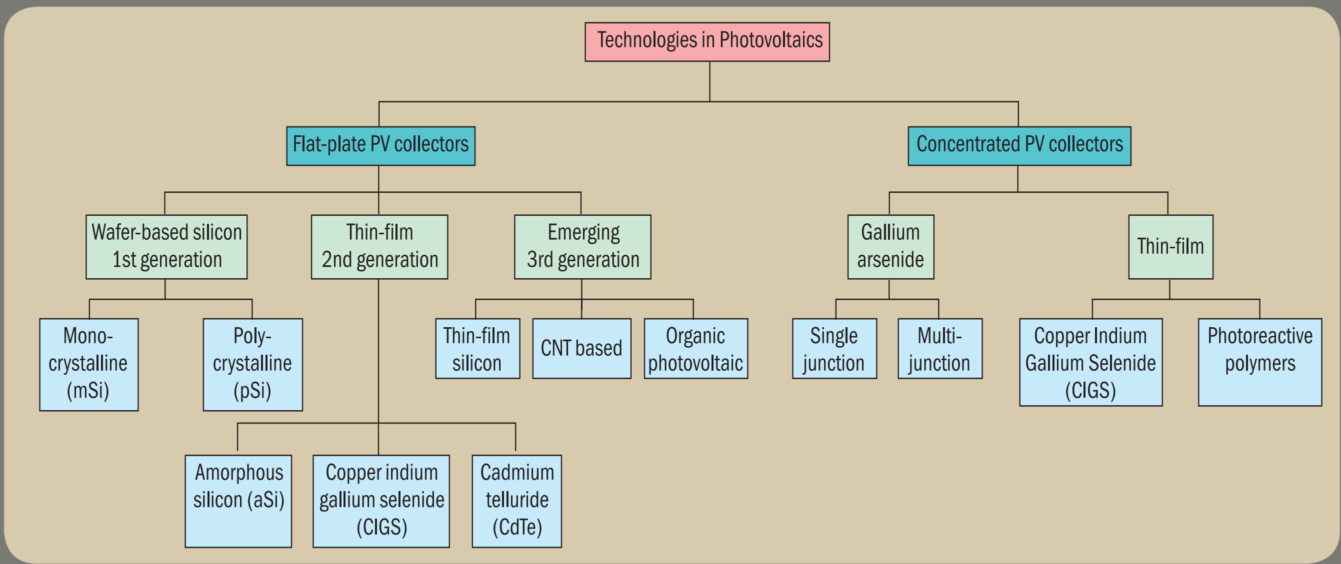
Article courtesy:
Himanshu Agarwal, Nidhi Maurya, Anjali Garg
TERI

Photo courtesy: DOE/NREL

UNDERSTANDING THE p-n JUNCTION

overview of solar cell technologies

The development of first p–n junction Si PV (silicon photovoltaic) device (solar cell) was reported in 1954. Since then, the science and technology of solar cell and its systems has undergone revolutionary developments. At present, the best single-crystal Si solar cells have reached a laboratory efficiency of 24.7% compared with the theoretical maximum efficiency of 31%. Besides crystalline Si solar cells, research in other solar cells (of different materials) is underway in order to improve the efficiency and reduce the cost of the solar cells.



There are several ways of classifying the solar cell technologies depending upon the method of collecting the solar radiation (flat-plate type or concentrator), type of absorbing material used (silicon based or compound semiconductor based), manufacturing technique/process adopted (wafer based or thin film), type of junction formed (single junction or multi junction), and so on.

If we categorize the solar cell based on the method of collecting solar radiation, there are two approaches: (i) collecting/absorbing sunshine at its natural flux intensity (as it 'falls'), that is, flat-plate type or (ii) concentrating sunlight to intensify the collection area, that is, solar concentrator type. Flat-plate collectors work with global average solar energy density (of 1.36 kW/m^2) and convert this flux to as much electricity as possible, while concentrators first focus the light up to 1000 times this intensity. For solar concentrators, there have been several different methods to concentrate sunlight—from lenses (for example, a magnifying glass) to parabolic mirrors to complicated waveguides. The advantage in a solar concentrator is in reducing the requirement of expensive SPV cells/modules per watt of incident energy. So far, with 41.7%, GaAs (gallium arsenide)-based solar concentrator cells have yielded the highest conversion efficiency. However, given the significant infrastructure required the solar concentrator is so far only useful for large-scale (MW-scale) power generation. For small-scale power generation, flat-plate type is widely used.

Photo courtesy: DOE/NREL

In general, solar cell technologies may be broadly classified into three categories.

- Wafer-based crystalline silicon solar cell technology (first-generation solar cells).
- Thin-film solar cell technology which includes thin-film silicon, CIGS (copper indium gallium diselenide), cadmium telluride, a-Si (amorphous silicon), and so on (second-generation solar cells).
- Emerging technologies such as dye-sensitized solar cells, polymer organic solar cells, nano-structured cells employing fullerenes, or quantum dot cells, and so on (third-generation solar cells).

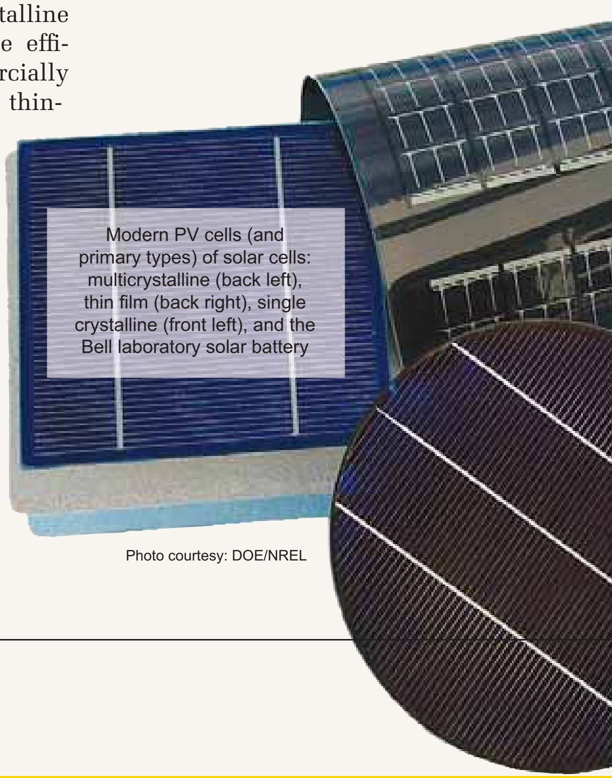
Out of all solar cell technologies, wafer-based crystalline silicon is one of the most reliable and most developed solar cell technologies and shares more that 90% of the total market worldwide. The wafer-based crystalline silicon cell is broadly categorized as single (mono) crystal silicon solar cells and poly-crystalline/multi-crystalline silicon solar cells. Crystalline silicon solar cells with module efficiency of 15%–16% are commercially available worldwide. As far as thin-film solar cell technologies are concerned, they are potentially cheaper to manufacture as compared to crystalline silicon solar cells. However, the module efficiency is less (in the range of 8%–10% at the commercial level) as compared to that of the crystalline silicon solar cells.

Besides crystalline and thin-film modules, DSSC (dye-sensitized solar cell), organic polymer cells, and so on are the emerging new solar cell technologies. Although DSSC is still at the pilot production stage, it is becoming popular because of its potential for high-energy conversion efficiencies at reduced cost. Besides DSSC solar cells, other organic solar cells such as polymer organic solar cells have shown the promise of easy manufacturing at low temperature and at low cost. However, the efficiency as well as the long-term stability has to be improved further for it to compete with conventional solar cells. OPVs (organic photovoltaics) using carbon nanotubes are an attractive alternative to traditional silicon-based solar cells because of their unique electrical properties and abundance of bulk material (carbon). Much work is being done to reduce the cost of manufacturing carbon nanostructures. Once this challenge is overcome there are very many interesting possibilities for nano-structured PV.

Comparative assessment of different technologies

Highest achieved lab efficiencies of different technologies

Table 1 shows the trend of highest achieved lab efficiencies of different technologies for last 14 years.



Modern PV cells (and primary types) of solar cells: multicrystalline (back left), thin film (back right), single crystalline (front left), and the Bell laboratory solar battery

Photo courtesy: DOE/NREL

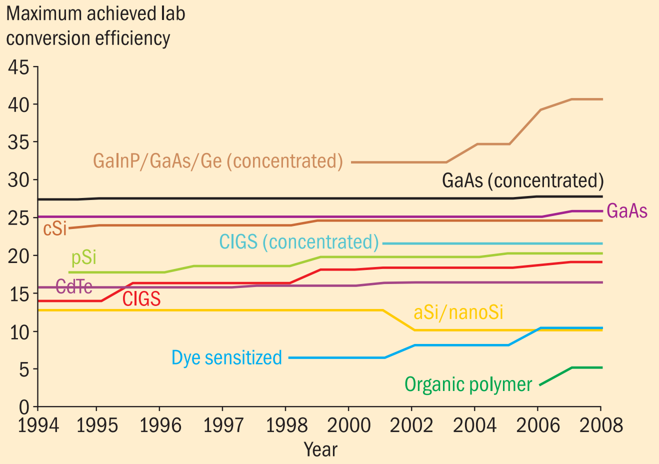


Figure 1 Progress of solar technology
Source Author's compilation from *Progress is Photovoltaics*

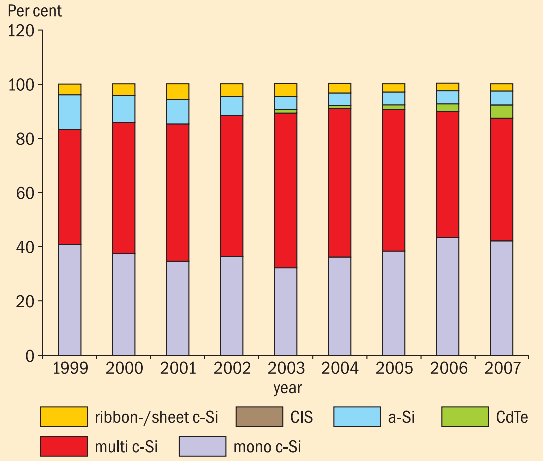


Figure 2 Cell technology shares in last 9 years (1999–2007)

From the graph, it can be seen that the highest achieved lab efficiency of the crystalline silicon solar cell has been constant for last 10 years. Therefore, there might be a little scope to increase the lab efficiency further. However, different studies suggest that the production techniques of such solar cells are becoming more reliable and efficient and commercial efficiency of such solar cells have been increasing while reducing cost.

From the graph, it can be seen that the highest lab efficiency so far is achieved by GaInP/GaAs/Ge concentrated solar cell. So far, these solar cells are being used mainly for space applications due to their significant cost.

The table above shows that more than 50% of the total PV cell production is by world's 10 leading manufacturers and most of them manufacture crystalline silicon-based solar cells.

Technology share (by year)

The graph in Figure 2 shows that crystalline silicon technology (mono crystalline and multi crystalline) has been dominating the market. After losing market share since 1999 (12.3%) a-Si technology has now started to climb, from a 4.7% share in 2005 to 5.2% share in 2007. Although the contribution of thin-film technology to the total market share has started increasing, it is too early to say that it will dominate the market in the next 2–3 years.

Similarly, the crystalline silicon technology dominates the Indian market and currently more than 98% of the market share is of crystalline silicon solar cell in India.

Table 1 Technology share of world's 10 leading manufacturers

World ranking	Company	Production share (%)	Technology
1	Q-Cells	9.1	Crystalline silicon, a-Si, CIGS, CdTe
2	Sharp	8.5	Crystalline silicon
3	Suntech	7.9	Crystalline silicon
4	Kyocera	4.8	Crystalline silicon
5	First Solar	4.7	CdTe
6	Motech	4.1	Crystalline silicon
7	SolarWorld	4.0	Crystalline silicon
8	Sanyo	3.9	Crystalline silicon, a-Si
9	Yingli	3.4	Crystalline silicon
10	JA Solar	3.1	Crystalline silicon
11	Rest of World	46.6	Crystalline silicon, a-Si, CIGS, CdTe, and so on

Source Photon international

BENCHMARKING OF SOLAR CELL TECHNOLOGIES

Technologies	Research institutions: national/ international	Maximum achieved efficiency lab/industry (%)	Cost/watt (USD)
Wafer based: mono/poly crystalline Silicon	Various institutes involved worldwide. The main research now is on process technique and cost reduction	Lab: 20.3%/24.7% industry: 15%/20%	6.1(mono) 4.6(multi)"
Thin-film solar cell technologies			
Amorphous Silicon (a-Si)	National:Indian Association for the Cultivation of Science (IACS), Jadavpur University International: National Renewable Energy Laboratory (NREL), Fraunhofer Institute for Solar Energy Systems, Sandia Lab, University of New South Wales (UNSW), Signet Solar, Uni-Solar, Applied Materials etc"	Lab:10.1% Industry:6% (Signet Solar)	3.2
Copper Indium Gallium Diselenide (CIGS)	National:IIT Delhi, IISc Bangalore International: NREL, Nanosolar, Globe Solar, Ascent Solar	Lab:19.2% Industry:13% (Globe Solar)	1 (claimed by Nanosolar)
Cadmium Telluride (CdTe)	National:Jadavpur University,IACS, Inernational: NREL, Beijing National Laboratory for Molecular Sciences, Konarka Tech, First solar"	16.5% 9% (First Solar)"	1.17 (claimed by First Solar)
Emerging technologies			
Thin-film Crystalline silicon solar cell	National: Jadavpur University, IIT Bombay, International : Fraunhofer Institute for Solar Energy Systems, UNSW		
Dye Sensitized Solar Cells (DSSCs)	National: Alagappa University, National Physics Laboratory, International: NREL, Fraunhofer Institute for Solar Energy Systems, Plextronix	10.4% N/A	N/A
Organic photovoltaic Polymers	National: IACS, Beijing National Laboratory for Molecular Sciences, International: Konarka Tech., Beijing National Laboratory for Molecular Sciences,	5.15% N/A	N/A
Nano-structured cells: Quantum dots, Fullerenes and other nano-particles	International: NREL, Sandia lab, UNSW, Cambridge	N/A	N/A

Advantage	Concerns	Global Market Share
• Most matured and commercially established • It is well understood as the technology was originally developed for the microelectronics/semiconductor industries.	• High material costs (~40% of production cost) • Energy intensive production process • Established technology, little room for further optimization"	93%
• First thin film technology to be commercialized • Simpler/faster fabrication technique than wafer based technology • thin film manufacture easily scalable for large scale production • novel deposition substrates allow for flexible/light-weight cells - possibilities for building integrated and even space applications • multi-junction cells show promise of improving efficiency and reducing degradation	• One of the biggest concerns of a-Si cells is its low stabilized efficiency • Upon initial exposure cells degrade 10–20% in efficiency before they stabilize	3%
• High lab efficiency combined with a relatively low cost production method have made CIGS a promising prospect • Basic system is stable and does not degrade significantly with time • Several construction/optimization methods have been developed by industry and production is ramping quickly • Can be deposited on a variety of flexible and rigid substrates • Potential for many building integrated and other novel applications	• Based on trace metals, supply issues may arise with large scale production (Indium is of particular concern) • Much work is still needed to refine and reduce the cost of production, large scale industrial processes have yet to be proven"	0.60%
• CdTe technology is one of the oldest thin film technologies, under development for over 20 years • Fairly high laboratory efficiency • Relatively straightforward production process works well in mass production • Has recently become the largest market-share thin film technology largely thanks to Industry leader First Solar"	• Also based on trace metals, Cadmium supply may become an issue with widespread production • The high toxicity of CdTe has necessitated a full solar cell recycling program to be developed in conjunction with industrialization. • Some countries have banned CdTe cells based on concerns of toxic seepage"	3.30%
• Several solar cells can be made from the same material which has been used for making a single wafer based silicon solar cell, thus reducing the overall cost	• Yet to be fully commercialized. But the process of commercialization is progressing fast	N/A
• DSSCs have long intrigued researchers as photoreactive systems based on cheap, stable, widely available materials • Have been researched for almost 20 years • recently 'quasi-semiconductor' systems have overcome many of the durability issues • new multi-junction dyes show promise for higher efficiencies	• Complex charge collection, 'bound excitons' rather than electrons difficult to gather/harvest energy • multi-phase system (solid/liquid) improved carrier mobility and efficiency but introduced significant stability/durability issues	N/A
• Simple production methods (no vacuum required) and cheap constituents promise cheap solar if commercialized • Recent efficiency improvements (5.15% from <1%) mean the technology may soon be marketable • photovoltaic plastic could be incorporated into other devices, even clothing	• Significant stability issues remain • Bound excitons short lived and resistive • Currently polymers must be maintained < minus 50 degrees C to remain stable • Dopants and additives (e.g. Fullerenes) still costly as development is largely at the laboratory scale	N/A
• Nano-particles such as quantum dots and fullerene molecules have unique and useful optical properties • Due to their size (on the order of wavelengths within the visible spectrum) they react very differently to light than bulk of the same material - These properties (in relation to absorption, charge separation and conduction) could circumvent many of the challenges/limits in traditional solar	• Not yet well understood, research is still at an academic level • High purity nano-particles are still very difficult and costly to produce/sort • Much more research is needed to understand/ predict behaviour then reduce the cost of production	N/A

Global PV cell manufacturing share (by region)

The graph shows the share of PV cell manufacturing by region in the year 2007. It can be seen that China has become the world's biggest PV cell manufacturing country in the world surpassing Japan and Germany standing at second and third position respectively. If the trend of growth of PV manufacturing for last two years is observed then it is found that China and Taiwan are the fastest moving countries in the area of PV cell manufacturing.

As far as the PV manufacturing in India is concerned, it contributes very little (about 1% of the total PV manufacturing in the world) to the total PV manufacturing in the world. However, the PV manufacturing capacity of India has increased from 35.1 MW in 2006 to 80 MW in 2007.

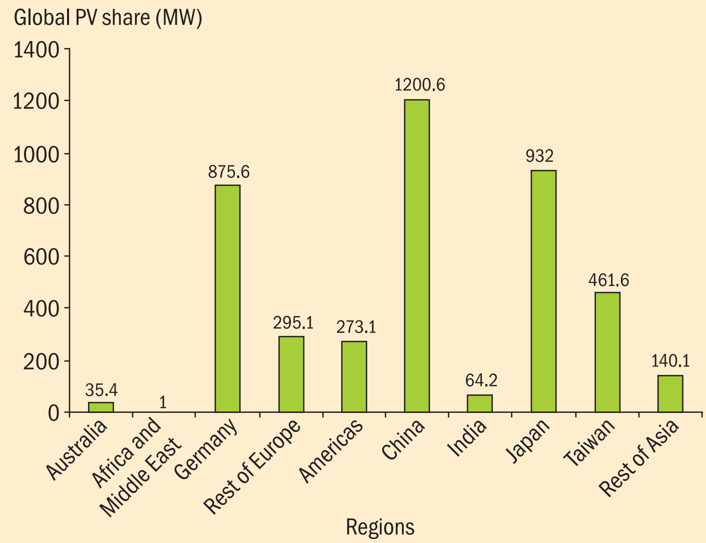


Figure 3 Global PV cell manufacturing share (by region)
Source Photon International

R&D thrust area

At present the main barrier to SPV around the world is the high cost of electricity produced. The electricity produced by SPV technology is in the range of Rs 12–25/kWh. This high price range makes it almost impossible to compete with conventional fossil fuels unless subsidies are in place or the transportation costs of the fossil fuel is high. It is also well understood that almost half of the cost of the entire PV system is for the solar cells/modules alone. Therefore, despite 30% of the SPV market growth the world over, it is now well understood that unless and until the cost of the solar cell is reduced further, the large-scale application would not be commercially viable. Hence, the worldwide thrust on research on SPV is to produce low-cost solar cells with moderately high efficiency and stability at field condition.

At present, the thrust areas of research on solar cell are, broadly, on material (thin-film development) and large-scale manufacturing (processes involved).

For large-scale manufacturing to be successful, large-scale processing and fabrication techniques for PV cells and modules should be studied. Similarly, development of new thin films involves looking at new materials and fabrication techniques. Besides R&D on solar cells, thrust is also on producing efficient, reliable, and compact PV products. To summarize, thrust areas of research are on (i) material (ii) large-scale manufacturing processes, and (iii) PV products.

Current R&D status of crystalline silicon solar cell technology

The efficiency of crystalline silicon solar cells has been increasing considerably in last few decades (from 7% in 1976 to 24.7% in 2007). However, higher cost is still the limiting factor for PV market penetration. Therefore, the main objective of the R&D on crystalline silicon solar cell technology is reduction of cost by the following ways.

- Use of thinner wafers
- Development of low-cost processes (production technique)
- Use of advanced processes to improve cell efficiency
- Improved production efficiency and yields for cells/modules
- Improvements in module life to over 25 years

To summarize, the recent technological development on crystalline silicon solar cells is capable of reducing the cost by producing thinner wafer and by adopting newer and more efficient processing and fabrication technique. However, the recent development has to be translated into larger scale of production. The concept of Indian R&D is almost in line with the international R&D though some variation exists at the commercialization stage of solar cells.

Current R& D status of thin film solar cell technology

The emerging thin-film technologies are yet to make significant impact as compared to matured c-Si technology. However, they do hold niche position in low power (<50 W) and consumer electronic applications and may offer particular design options for building integrated application. Although thin films are potentially cheaper than c-Si solar cells because of their lower materials costs and larger substrate size, they are less efficient (production module range from 6% to 10%). Even some thin-film materials have shown degradation of performance over time and stabilized efficiency can be 20%–30% lower than the initial value.

Therefore, the main approach of the R&D on thin-film technology is to improve the performance of the thin-film solar cells by different measures such as the following.

- Selection of suitable substrate, absorber, and TCO (transparent conducting oxide)
- Development of improved window/ hetero-junction layer
- Reducing the optical and contact losses of multi-junction devices.

As far as research in thin-film solar cells is concerned, India has a strong presence in the world scenario of thin-film solar cells research and has made some tremendous progress in some of the thin-film technologies such as a-Si/micro-crystalline Si technologies. Some of the indigenously developed technology and manufacturing processes in India is on the verge of commercialization.

Current R&D status of new emerging material

Besides semi-conductor thin-film modules, other photo-reactive systems are under investigation for their potential to convert sunlight to electricity. DSSC (dye-sensitized solar cells), organic polymer cells, and nano-particle-based systems (for example, quantum dots, fullerenes, and CNT [carbon nanotubes]) are showing promise as new solar cell technologies.

DSSCs have been under investigation for over a decade, and can now be found in a few niche applications. Until recently, DSSCs have been hampered by complications arising from a two-phase (liquid dye–solid electrolyte) but new 'quasi-solid state' system designs show promise. In spite of limitations, DSSCs are the most developed 'organic' technology with a few projects at the pilot production stage. The lure of DSSCs is the potential to produce an effective solar cell with far cheaper materials and simpler processes than required for semiconductors (thin film or silicon wafers). Special plastics, properly layered and doped, are also showing promise and generating industry interest. However, lifetime and stability issues are yet to be resolved.

Nanoparticles have recently offered new possibilities in absorbing/ interacting with light. Given their size (on the order of wavelengths for visible light), the physical constraints of the system have significant effects on the electrical behaviour.

These systems are being tested and tailored in order to produce efficient solar absorbers, an approach that potentially avoids many of the limitations and pitfalls of traditional solar cells. Employing fullerenes or CNTs as charge acceptors in macroscopic systems is another approach, attempting to harness some of these benefits in a bulk system. As these technologies mature, the prospects are exciting but it remains to be seen if they can compete with mainstream solar technologies.

Quantum dots of the same material of different sizes emit different characteristic wavelengths

MNRE's R&D thrust

Currently the MNRE (Ministry of New and Renewable Energy), which is the nodal ministry for promoting different renewable energy technologies in India, has identified 8 major thrust areas for solar PV R&D.

- Development of crystalline silicon thin-film layers and low-cost substrates for deposition of films
- Development of large-size solar cells/ modules based on crystalline silicon thin films.
- Development of multi-junction amorphous silicon solar cells/ modules—pilot plant demonstration
- Development of process technology for polycrystalline thin-film solar cells/modules—pilot plant demonstration
- Development of devices based on new materials/concepts
- Improvement in solar cell efficiency to 15% at the commercial level and >20 % at research level
- Improvements in PV module technology, higher packing density, suitability for solar roofs, and so on.
- Development of lightweight modules for use in solar lanterns and similar applications

If the R&D conducted in India is seen, most of the research going on in India is on thin-film-based cells, and deals with pure fundamental research. Little research is going on in innovative ways of fabrication of silicon solar cells, or other ways to reduce the cost of these existing solar cells.

Solar cell technologies in India: a glance

- Crystalline silicon cells in commercial production by about 20 companies—megawatt annual production capacity.
- Single crystal silicon cells: conversion efficiency 13%–15%; wafer size 4–6 inches.
- Multicrystalline silicon cells: conversion efficiency 13%–14.5%; wafer size 5–6 inches.
- Pilot plant for high-efficiency laser grooved cells set up by CEL; 16%–18% efficiency cells made; capacity 500 kW per year.
- Amorphous silicon thin-film solar cells at pilot stage.
- Single junction: 11% initial efficiency; degradation about 20%–25%. Amorphous silicon modules degrade in the first few months after exposure to sunlight.
- Double junction: 10%–11% initial efficiency; degradation about 18%–20%; sub modules 6%–8%.
- Pilot plant for making 1 feet x 1 feet single-junction amorphous silicon cell modules. Initial efficiency about 6%. Degradation about 20%–25%.
- New process equipment designed by IACS (Indian Association for Science Calcutta) for making 1 feet x 1 feet size double-junction amorphous silicon solar cell modules. 7% efficiency module fabrication demonstrated.
- Cadmium telluride: At research level 10% efficiency solar cells made by National Physical Laboratory, New Delhi.
- Copper indium diselenide: 16% efficiency solar cells made by Indian Institute of Science, Bangalore.

Article courtesy: Parimita Mohanty and Joel Slonetsky, TERI

Solar energy on the move

a look at solar charging for e-bikes

Background

Time seems ripe for accelerating the deployment of solar power by exploring some new frontiers of use. One such potential area could be using solar power for limited commuting needs both in the urban and rural locations. Lending further credence to it is the stark fact that a candidate contested a state assembly election from South India (Bangalore) by choosing solar car as his election symbol. He lost the political race though, but certainly not the solar race, which he is still treading on with a lot of enthusiasm. That is not all. He won the admiration of a few prestigious eco-conscious groups in the process. Well, it is his desi version of 400 kg, which he aptly calls as a solar car or a cart. The motivation for doing this has been entirely not his own, but triggered off by the exemplary zeal of a Swiss schoolteacher namely Maverick. Maverick has so far traversed a distance of about 38 000 km (kilometre) in his two-seater solar-powered vehicle spreading the message of solar energy far and wide.

The solar car designed by the Bangalorean Sajad Ahmed can take four people on board and can move calmly at 40 km per hour. It has three solar panels on the roof besides one on the bonnet. This prototype has not cost a fortune for him, but just a lakh of rupees, which he expects would come down further with an increasing demand. After all, the running cost is just Rs 0.30 per km, which seems dirt cheap in this era of escalating petroleum prices.

Photo courtesy: DOE/NREL

Drawing support

The Ahmedabad-based CEE (Centre for Environment Education) was among the first to announce its support for Ahmed's solar vehicle. No less than UNDP (United Nations Development Programme) came forward to fund this initiative under its small grants programme. Soon, some more organizations like the prestigious Raman Research Institute at Bangalore, chipped in alongwith KREDL (Karnataka Renewable Energy Development Ltd). This support came despite the fact that solar cars still continue to be demonstration pieces and their commercial promise is still on a dividing line.

Are we ready for this great solar initiative?

The answer is not so easy to come by considering the fact that about a lakh of villages are still reeling under darkness through all these years since our independence. However, lately, initiatives like the LaBL (Lighting a Billion Lives) are moving in the direction of providing bare minimum lighting to such villages. The moot question is whether villagers would also continue to face difficulties in commuting to the neighbouring towns, and so on. After all, they cannot bear the huge burden of transportation in this age of rising prices of oil. Can solar-powered vehicles make forays into such territories is a question worth answering in this article. As for the urban areas, solar power can certainly add pleasure to office goers or factory workers, and so on, within a limited contour though.

Defining a solar vehicle

Simply put, a solar vehicle is an electric vehicle driven by solar energy obtained from the surface mounted SPV (solar photovoltaic) panels. As of now, solar vehicles do not fall into the commonly accepted categories of transportation modes. Instead, these are primarily demonstration vehicles and engineering exercises often promoted for raising public awareness. These often combine technology typically used in aerospace, bicycle, alternative energy, and automotive industries. However, the design of a solar vehicle is generally limited by the energy input into the car (batteries and power from the sun). Nearly all solar vehicles designed and developed till now have found use in the solar car races with few notable exceptions indeed.

System engineering

The electrical system is the most vital part of the car's systems because of its ability to control all the power that gets in and out of the system. The battery pack in a solar car plays a role very similar to a fuel tank in a normal car. A few solar cars have complex data acquisition system to monitor the entire electrical system. In contrast, the mechanical system of a solar car is designed to keep friction and weight to a bare minimum, though not at the risk of overall endurance. A general practice is to use titanium and composites to maintain a good strength-to-weight ratio.

PV panel on a boat

Photo courtesy: DOE/NREL

Cal Sol's solar car from the University of California, Berkely

Photo courtesy: DOE/NREL

Zebra battery

Global scenario on solar vehicles

The first practical solar boat was designed around 1975 in England. These passenger boats began to appear with a routine continuity from 1995 and are now in widespread use. It was in 1996 that Kenichi Horie made the first solar-powered crossing of the majestic Pacific Ocean and thereafter the inaugural solar-powered crossing of the Atlantic Ocean occurred in the winter of 2006/07. Plans are now afoot to circumnavigate the globe in 2010, which may well mean a landmark in the history of solar-powered vehicles.

The first solar 'cars' were actually tricycles or quadricycles built with bicycle technology. These were called solar mobiles at the first solar race, the Tour de Sol in Switzerland in 1985, with 72 participants. The solar cars have been in development right from 1980 with such modern day cars having reached an average speed of about 91 km/hour in 2007. The World Solar Challenge organized by Australia involves a run of about 3021 km, which is also supplemented further by North American Solar Challenge under an almost similar objective of promoting solar energy use for mobility.

The HAA (high-altitude airship) is an unmanned, long-duration, lighter-than-air vehicle using helium gas for lift, and thin-film solar cells for power. Japan's biggest shipping line Nippon Yusen KK and Nippon Oil Corporation is visualizing a scenario of using solar panels capable of generating 40 kW of electricity atop a 60 000-tonne car carrier ship to be used by Toyota Motor Corporation. These case-specific examples clearly highlight the development of solar-powered vehicles for use on land, in air, and on water.

The Swiss Initiative

The Swiss Initiative is a fascinating case of solar power use at a long stretch. This Swiss project, Solar taxi, seeks to build a road-worthy solar car with a trailer, carrying a 6-m²-sized solar array. It makes use of Zebra batteries, which enable a range of 400 km without recharging. The car can also run for 200 km without the trailer with its maximum speed being 90 km/h. The weight of car and trailer is about 500 kg and 200 kg, respectively. As per the available projections, it is amenable to mass production. The Solar taxi has already toured the world in December 2007 to put across the message of using solar power as an eco-friendly alternative to the polluting fossil fuels.

The Indian experience so far

Seemingly, solar boats are the most perfect examples of sustainable transport. Solar panels sit pretty on the canopy of the boat and generate some useful electricity. It is then stored in batteries to power an electric motor. In fact, electric boats are not new and these remain the preferred means of transport on inland waterways. The solar Pichola happens to be the world's first commercial solar boat built in UK at the sole inspiration of Shriji Arvind Singh Mewar. He, as the managing trustee of the MMCF (Maharana Mewar Charitable Foundation), Jaipur (India), felt quite concerned at the pollution levels in Pichola lake in Udaipur. The boat acted as a taxi service operating in silence with no pollution, noise,

Overland coach electric shuttle bus

Photo courtesy: DOE/NREL

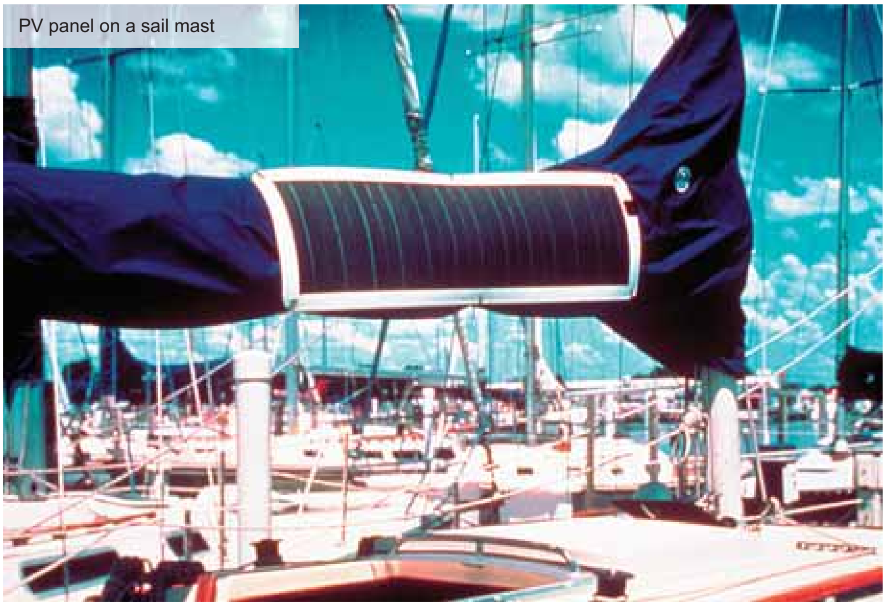


Photo courtesy: DOE/NREL

or emissions. The boat has now been transferred to Gajner, Rajasthan where it takes tourists, scientists, and government officials on bird watching in perfect peace and solace on the beautiful lake. Following the success of the Solar Pichola, Shriji Arvind Singh Mewar approved the conversion of one of his tourist boats into a solar-powered boat capable of carrying 12 passengers.

Design feature

It uses a quite simple design as per which a canopy of 8 x 50 Wp solar panels produce electricity. This is used to charge a 12-V, 60-Ah battery that in turn propels a small trolling motor. A solar controller monitors the current to and from the battery for maintaining it in a proper form.

Other small initiative

SPV-assisted and electricity-powered, India's first Quadricycle was developed in 1996, in the Surat city of Gujarat. Recently, the Delhi College of Engineering has designed and developed a prototype model of an FRP-material-based solar car under its in-house project 'Solaris'. It is planning to display this 350-kg solar car at the forthcoming Solar World Challenge.

The big possibility

Battery electric vehicles fitted with solar cells can very well extend their range and allow recharging while parked anywhere in the sun. However, with present and near-term engineering considerations, it seems that the more likely place for solar cells will generally be on the roofs of buildings, where they are always exposed to the sky. Moreover, the weight is largely irrelevant, rather than on vehicle roofs, where size is limited. Energy from rooftop panels can then be stored in the batteries.

Perhaps solar-powered boats can be a significant source of support while tackling the disaster-management measures like those recently witnessed due to the fury of Kosi river in Bihar.

The emergence of e-bikes

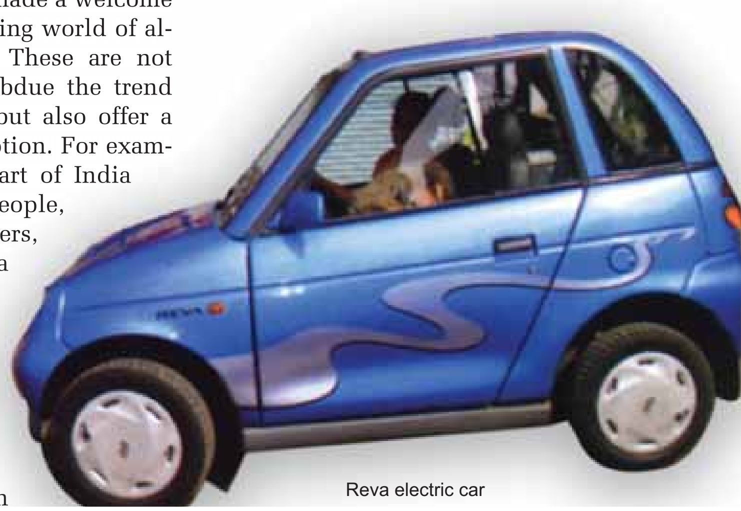
Perhaps we have just made a welcome entry into the burgeoning world of alternate fuel vehicles. These are not only attempting to subdue the trend of rising fuel prices, but also offer a greener and cleaner option. For example, in the western part of India (that is, in Gujarat) people, especially the youngsters, have started taking a liking to a new breed of bikes. These are commonly known as the Yo Bykes and need no petrol but get charged akin to your mobile phone. Yo Bykes have been launched by an Ahmedabad-based company Electro-Therm India and require every day charging.

India has been a late starter for this product, whereas China went into mass production of these vehicles, mainly two-wheelers, a decade ago. Today 90% of the powered two wheelers in China are run on battery power. Indian two-wheeler market psyche is controlled by big players like Hero-Honda, Bajaj, TVS, Yamaha, and recently Honda and Suzuki. Riders are quite attracted to the power, range, and macho looks. With this influence, the consumer expects the e-bikes also to match the claims of gas bikes. Well, e-bikes are a class apart from these. However, the key problems with an electric vehicle mainly include the following.

- Drop of range per charge over its life
- Increasing cost of battery replacement

Key constituents of an electric vehicle

The heart of an electric vehicle is a motor, which moves the vehicle. The power for the motor comes from a bank of batteries, which are the lungs of the vehicle. Higher the storage capacity of the batteries, longer the distance the vehicle will run. The power to the motor from the batteries is rationed through an electronic controller, which is the brain of the vehicle. The controller senses the position of the charge being taken in and out of a battery.



Reva electric car

Table 1 Comparison between a petrol-driven and battery vehicle

Characteristics	Petrol bike	E-bike (500 W)	Remarks	Key areas of use
Approximate initial cost	40 000	22 000 (minus batteries)	Cost of an e-bike is lower	
Cost on petrol (assuming a run of 12 000 km and mileage of 50 km per litre	13 000	1200 (@ Rs 4 per unit and a total of 300 units)	Sharp rise in the price of petroleum products at times, when compared to electricity prices	
Nominal maintenance cost	3000			
Running cost per km	1.33	0.77	Net saving of Rs 6720 indicating a payback time of about 4 years for an e-bike	Well suited for office goers, working women, housewives, and senior citizens too

Indicative economic analysis

It makes a definite sense to draw some economic comparison between a conventional petrol-driven vehicle and a battery vehicle as given in Table 1.

Market projections for e-bikes in India

Electric two-wheelers, a totally new category in India, are beginning to witness a good growth. As per AC Nielsen survey conducted in 2006, the electric vehicles category is estimated to grow by more than 150% in 2009. The target profile of electric two-wheelers includes 14–18 year olds, primarily lifestyle bicycle riders, who have an aspiration to ride bikes. The other segment is the 25+ group that would convert from the internal combustion engine scooter segment. The universal appeal of the product makes it ideal for both men and women. They could be riding a petrol scooter and are looking at economy and utility. From a market conversion perspective in 2009, there will be an opportunity to convert at least 15% of the scooter and moped segment (which would stand at 1.5 million units by end of 2008). Hence, the electric two-wheeler market would grow from the current 100 000 units to over 225 000 units. Following few are some of the major reasons driving the renewed growth of scooters.

- The booming economy has set new trends in place
- Urbanization has been on a fast increase
- There are an increasing number of nuclear families around
- The gender balance has changed with more and more women now going out for work
- A large majority of senior citizens and college-going females now prefer easy-to-use products like automatic or ungeared scooters
- Cities where distances are not huge, where public transport is not so well developed, and where people seek value for money, scooters are doing great business.

Urban outlook

Table 2 presents two basic scenarios vis-à-vis an urban transport setting. There seems to be a clear preference at least for moving within the short distance limits.

Case for solar hybrid charging stations

The e-bikes, if provided with a hybrid charging option, can certainly go places in a smooth and effective manner. The key advantages of mixing solar with the conventional grid power may well offer the following few advantages.

- Act as fast charging stations in vantage points in our cities
- Can charge your e-bike while you go out for work

ABN Amro showing the way

The Indian corporate world is agog over first-time publishing of sustainability report by the ABN Amro bank. It essentially mentions the steps taken in

Table 2 Two scenarios in an urban transport setting

Traffic Situation-I	Traffic Situation-II	Remarks
Majority of vehicles operate on hydrocarbon fuels	Average distance traveled by a person is about 30 km.	Electric scooters can meet the desired scenario-II quite convincingly and thus turn out to be the best option for urban mobility
The number of such vehicles is moving up and up	Average speed of a city vehicle is around 40 km	Such scooters can also draw power from solar-powered charging stations put up at well thought out locations
Increasing traffic congestion is affecting the air quality besides increasing noise levels	There is a distinct preference for using small-size vehicles Vehicles owners are desperately aspiring for low running and maintenance costs	Cost of these scooters will come down further as volume sales take place

A solar car at the 2005 American Solar Challenge

Photo courtesy: DOE/NREL

the area of poverty alleviation and promoting green energy practices. These are much in sync with an international process of developing and disseminating globally applicable sustainability reporting guidelines. The ABN Amro NV's Indian unit opened a green bank in Ahmedabad, which makes use of solar power besides conserving water. So far so good, but is it the lone exception? Yes, it is so, in terms of asking its employees to use electric scooters, when delivering banking services to customer's offices and homes. The next logical step is to advise them to use solar mode of charging for their e-scooters. Expectedly, more and more such entities will follow the suit of incorporating solar alongside their traditional energy use.

The rural scenario

Rural surroundings are by and large devoid of any sustainable mode of transport. People often have little choice but to cover long distances on foot or use a bullock cart. However, a noteworthy thing is that a good number of rural people now have some basic familiarity with the use of solar power, be it for lighting, drawing water, or viewing of a community television or running of a fan. The micro-credit facilities are also making gradual inroads into such hinterlands where the e-bikes can also be pushed in for commuting within short distances. Here, one would like to refer to the solar charging stations for the solar lanterns, where the ownership of the solar part does not rest with an end user. In some cases, a solar lantern is just made available on a rental basis. The user pays primarily for the services in the form of a few hours of lighting every day. The same concept can well be practised in case of a solar-operated charging station for e-bikes.

The big question

It is anybody's guess if solar-powered scooters can find any takers in rural environs. After all, why should anyone invest in such an option despite the known absence of any modes of safe transport? Well, it would not be wrong to say that a possibility or two exists for sure as can be made out from Table 3.

Possible means of supporting the rural initiative

- Corporate entities (under their corporate social responsibility mandate)
- Manufacturers of e-bikes to popularize the use of e-bikes amongst the potential customer segments
- Ministries of New and Renewable Energy, Rural Development, Health, and so on
- Multilateral funding agencies for concept demonstration and possible replication in other developing regions of the world

TERI's initiative: solarizing the electric scooter

The Indian automotive industry is the second-largest two-wheeler manufacturer in the world, and the fourth-

Table 3 Possibilities for e-bike use in rural areas

Indicative of user	Purpose of use	Possible type frequency of use	Remarks
Shopkeeper	Purchase of essential commodities from a town-based shopkeeper (for use within the village)	Weekly	**a.** SPV-based charging station can be set up at some convenient place, perhaps at the town post office. In lieu of the services provided, the post office or any designated body may be authorized to collect a nominal charge. Students may be permitted to use this facility free of charges
Health workers	For providing the health care facilities including immunization	Fortnightly or even weekly	
Postman	For delivery of all postal material, including the money order	Daily or on alternate days	**b.** A successful business model may well involve a dedicated PV equipment producing and servicing company, a micro-finance company in coordination and support of a local NGO and possibly a charitable organization
Technicians	Responsible for the upkeep of solar appliances, and so on	As the need may be	**c.** Perhaps, corporate bodies adopting villages nowadays under the CSR mandate may chip in with requisite support to finance such an initiative
Students	For attending the schools/colleges in neighbouring towns	Almost daily	
Employees	Includes those who are posted at distances of about 25 km from their homes	Daily/weekly	
Patients (needing emergent medical care)	Includes those who need immediate medical support at a neighbouring town clinic	On a case-to-case basis	

largest car market in Asia. Electric vehicles have been available for many years, but these are yet to make any widespread impact. Lately, several companies have started producing various models of electric bikes or simply e-bikes. These e-bikes can either be charged through diesel gensets or via conventional power system. However, the big issue is the lack of availability of quality power for the entire duration of the charging process. The resultant effect is visible in the form of improper charging of the e-bike battery. A way out may be to use SPV in conjunction with the available grid power mainly on account of the following few reasons.

- It enhances the overall reliability and flexibility of the charging process
- Solar-based charging of the battery is quite an efficient process being an eco-friendly process too.

As a step forward, TERI has undertaken an initiative to showcase the feasibility of SPV-based hybrid-charging station for e-bikes. The hybrid charging station will have the provision of charging the e-bike from conventional grid and PV system. Any excess power thus generated can be readily transferred to the grid or made use of for multi-purpose battery charging.

TERI has so far developed a small prototype unit of an e-bike, which is currently undergoing extensive field-

An e-BIKE

testing-cum-evaluation. Preceding this, it gained some useful insight into the following few issues of significance.

TERI began by assessing the full market potential of various e-bike models in the country. Nearly 1.7 lakh e-bikes were actually sold during 2007/08 with projected sales slated to touch 2.40 lakh in the current year as per NDTV profit. Expectedly, successful demonstration of hybrid charging mode by TERI could fuel a huge demand for e-bikes for a variety of end-use considerations. Following few innovative steps have been undertaken so far in the direction of charging an e-bike via SPV.

System design

The TERI team customized the design of SPV charging station for e-bikes following an in-depth analysis of the technical specifications and accompanying charging mechanism of the batteries used in the commercially available models like Yo Bykes, and so on.

Design and development of SPV-based charging station for e-bikes

In order to showcase the concept, TERI has made a beginning by designing and developing a micro-controller-operated SPV-based charging station for a small e-bike. The use of micro controller in the charging station makes it a highly flexible and efficient system. An important feature of the system is the PWM-based charging of the batteries of e-bike, wherein charging takes place as per the battery conditions thereby improving the life and productivity of batteries.

Field demonstration

The prototype model has so far yielded good results under the actual field operating conditions at TERI's field station in Gwal Pahari (Gurgaon, Haryana). Such a testing is still underway to effect any further modifications in the system under consideration.

National-level initiative

The MNRE (Ministry of New and Renewable Energy) has been actively promoting the development and production of BOVs (battery-operated vehicles) during the last two decades. It has catalysed the commercial production of various BOV models by different industries. So far so good, but the downside is the abysmally low sales volumes of such BOV's for a variety of reasons. With a view to evolve favourable policy initiatives, MNRE organized a special meet of all the major BOV manufacturers (Mahindra and Mahindra, Bajaj Auto Ltd, Honda Motors, Reva Electrics, Electrothurps, Eco Vehicles, Yo Bykes, and E-bikes) along with representatives of ARAI (Automotive Research Association of India) and Tata Motors on 17 June 2008. Following few points of significance emerged out of such wide-ranging deliberations.

Issues and prospects

- Running cost of the BOVs is definitely lower than the conventional vehicles, that is, petrol/diesel based, but the cost of replacement of the batteries is very much.
- Centralized charging facility of batteries may help in league with leasing of batteries
- Setting up of extensive dealer networks together with spares availability is going to accelerate the growth of BOVs in tandem with awareness generation measures

The concerned ministry has put in place a subsidy structure (Table 4) to give a fillip to the rather subdued fascination for use of BOVs across all potential customer segments.

Table 4 Subsidy structure for battery operated vehicles

Vehicle type	Operational requirements	Quantum of central (MNRE) subsidy payable	Beneficiary contribution	Eligible beneficiaries
New, locally manufactured battery-operated buses/mini-buses (with a seating capacity of 10 or more persons)	A minimum of 70 km range in a single charge of batteries; maximum speed of 40 km/hour	@ 33% of the cost of vehicle (exclusive of excise duty, sales tax and all other levies), or Rs 3.50 lakh per vehicle, whichever is less.	Balance cost of BOV	Government organizations, Government undertakings and autonomous institutions, public/private limited companies, registered voluntary institutions under the Societies Registration Act, Registered
New, locally manufactured battery operated three-wheelers (with a seating capacity of 8 or more persons)	A minimum range of at least 90 km prior to recharge of traction batteries; maximum speed of 45 km/hour	@ 33% of the cost of vehicle (exclusive of excise duty, sales tax and all other levies), or Rs 80 000 per vehicle, whichever is less.	Same as above	
New, locally manufactured battery-operated passenger cars (with a seating capacity of 4 persons) (each four seater)	A minimum range of at least 90 km in a single charge of batteries; maximum speed of 50 km/hour	@ 33% of the cost of vehicle (exclusive of excise duty, sales tax and all other levies), or Rs 75 000 per vehicle, whichever is less.	Same as above	Only for public institutions (that is, government organizations, public sector organizations, educational institutions, hospitals and tourism, and archaeological sites among others.

The big state-government initiative

REVA occupies a place of pride, being India's first battery operated car. It has finally caught the fancy of Delhi government by offering 15% subsidy on the base price of the vehicle together with a 12.5% exemption of VAT and refund of road tax and registration charges. These measures are expected to bring down the cost of REVA to nearly Rs 2 90 000. Important to note here that such exemptions are going to be in place for all battery operated two-, three-, and four-wheelers. It is expected that other state governments will follow suit so as to promote these eco-friendly vehicles wherever possible. E-bikes very well fit into this category and solar-power-based charging can garner an extra advantage.

Rallying for public awareness of BOVs

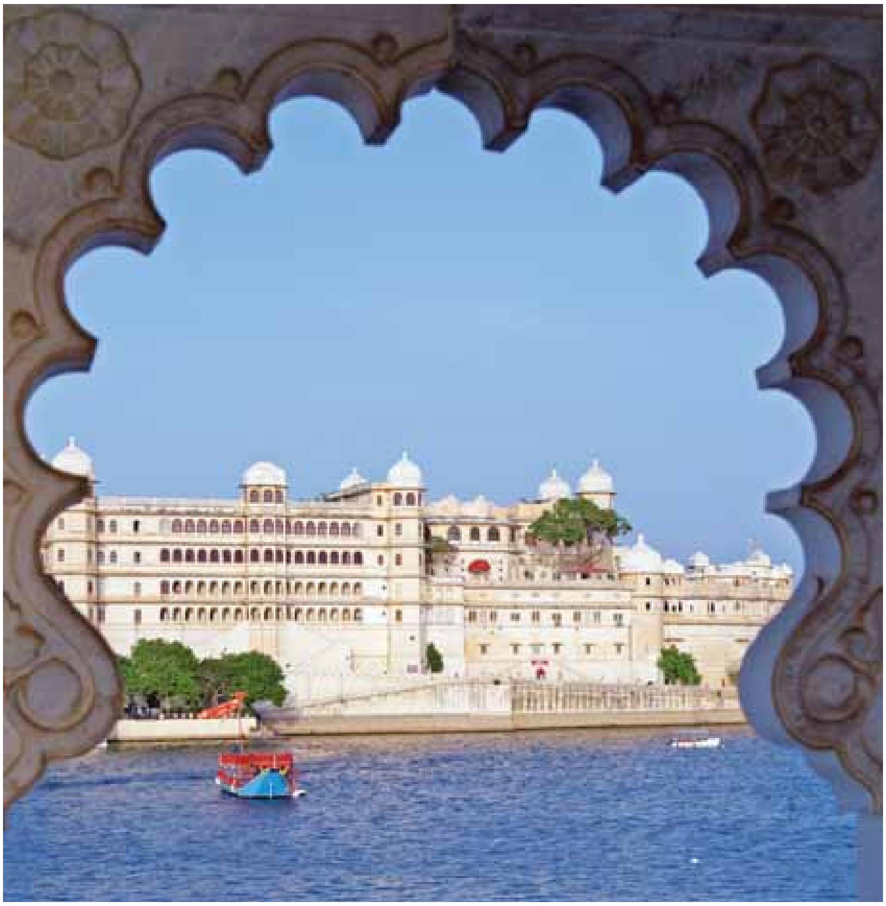
The MNRE (Ministry of New and Renewable Energy) organizes Akshay Urja Diwas across the country annually. This year, a few BOVs were also displayed in full public view by a few state governments. Prior to this, the famous station of Auroville held a parade of about 30 vehicles on 26 July 2008. Such entourages are quite desirable to propagate the taste for such green vehicles in common minds keeping in view their utility in the following few situations.

- Historical monuments and heritage sites
- Ecologically sensitive areas like bird sanctuaries, zoological parks, and water bodies
- Airport shuttle services
- Premises of academic, research, and professional organizations
- Manufacturing premises of industrial establishments
- Golf clubs
- Commuting within city limits
- Upcoming residential colonies

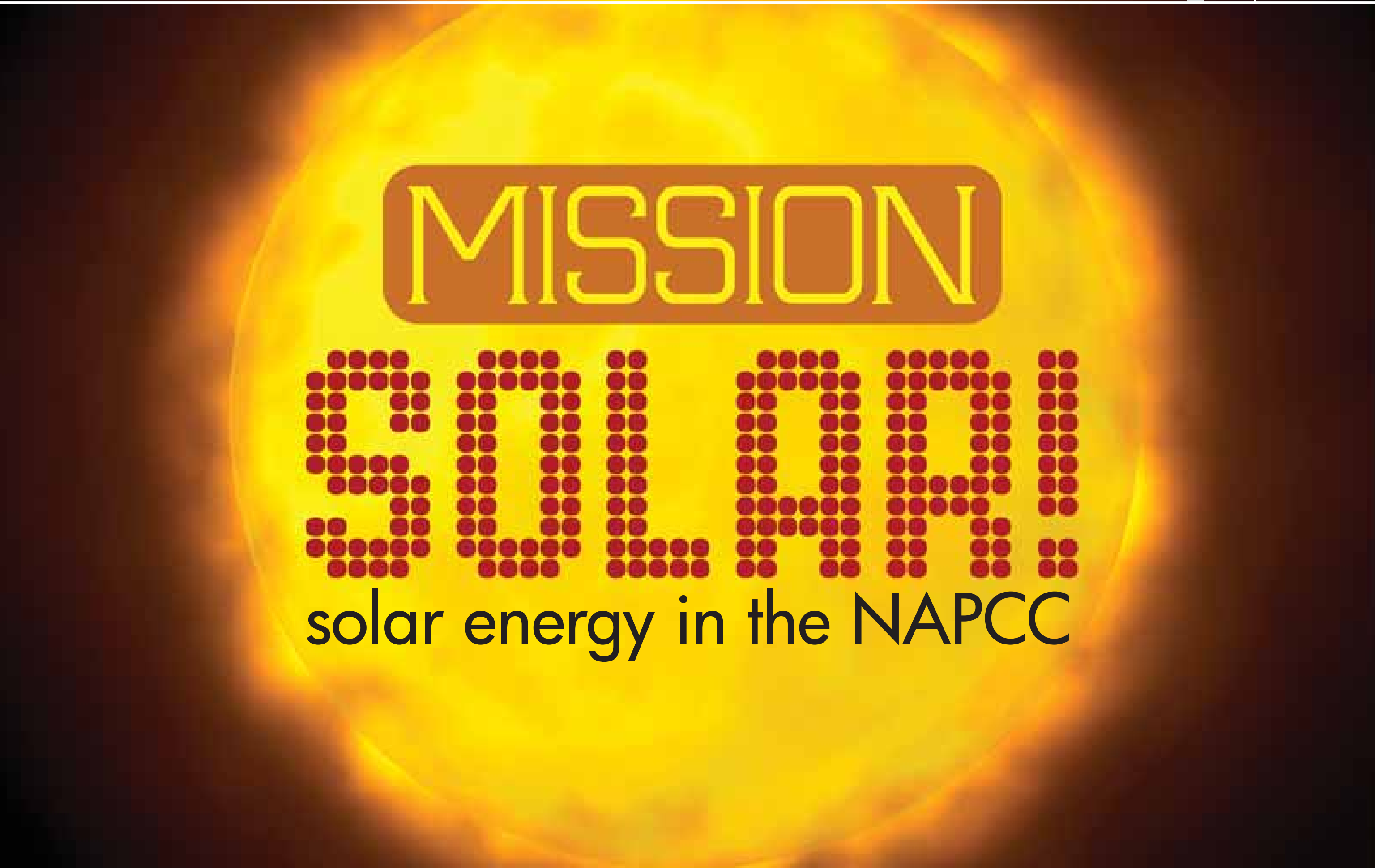
Conclusions

The sun is shining fairly bright on the Indian horizon now. Solar products and systems are now finding an increasing acceptance for a variety of end-use considerations. Solar-powered transportation modes like the e-bikes may well mean an additional but an effective medium to multiply the overall gains further, not to talk of easing the movement of people further. So, all possible support channels must be pursued to open up new vistas.

Article courtesy:
Dr Suneel Deambi, Consultant, TERI
Varun Gaur, TERI



Pichola lake, Udaipur



MISSION SOLAR!

solar energy in the NAPCC

The story so far

India has a civilizational legacy that treats nature as a source of nurture and not as a dark force to be conquered and harnessed to human endeavour. There is a high value placed in our culture to the concept of living in harmony with nature, recognizing the delicate threads of common destiny that hold our universe together. With development, however, many things are increasingly changing. People now not only want higher standards of living, but also clean water to drink, fresh air to breathe, and a green earth to walk on. The recently announced NAPCC (National Action Plan on Climate Change) incorporates India's vision of sustainable development and the steps to be taken to implement it. NAPCC's Solar Mission promises to promote use of solar energy in homes, commercial establishments, and for power generation through photovoltaics, solar thermal, and concentrating solar power. The mission does set a target of 80% coverage for all low-temperature and 60% coverage for medium-temperature solar energy applications in urban areas, industries, and commercial establishments.

The average intensity of solar radiation received on India is 200 MW/km^2. With a geographical area of 3.287 million km2, this amounts to 657.4 million MW. However, 87.5% of the land is used for agriculture, forests, fallow lands, and so on; 6.7% for housing, industry, and so on; and 5.8% is either barren, snow bound, or generally inhabitable. Thus, only 12.5% of the land area amounting to 0.413 million km^2 can, in theory, be used for solar energy installations. Even if 10% of this area can be used, the available solar energy would be 8 million MW, which is equivalent to 5909 MTOE (million tonnes of oil equivalent) per year. In comparison, the total commercial energy consumption in India was 216 MTOE in 2005/06. Thus, the available solar energy is nearly 26.5 times the commercial energy consumption. However, since solar energy is a dilute source, large areas are needed for collection.

As per TERI's estimates, total commercial energy consumption increases from 284 MTOE in 2001 to 1727 MTOE in 2031 (CAGR: 6.2%) in a BAU (business-as-usual) scenario. Coal remains the dominant fuel in the commercial energy mix and it increases by 6.4 times from 148 MTOE to 940 MTOE during 2001–2031. Petroleum consumption also increases rapidly, mainly on account of the transport sector, and increases by over six times over the period 2001–31. This exercise further indicates that the maximum allowable indigenous production levels for all fuels are achieved by the year 2016. Therefore, the dependency on imports for coal, oil, and gas would increase significantly in the future—even with scenarios that reflect higher efficiencies and large reductions in CO_2 emissions. In a BAU scenario, the total installed power generation capacity (centralized and decentralized) is expected to be around 744 GW as compared to the present installed capacity of 145 GW. Moreover, CO_2 emissions from the energy sector are estimated to increase from 0.9 billion tonnes in 2001 to 5.8 billion tonnes in 2031.

In view of the energy security and climate change concerns, the country should prepare to aggressively pursue solar energy applications especially in the power sector. Accordingly, if the country were to embark along this path, it should undertake to demonstrate 4 GW by 2011 as planned such that the learning could bring about cost reduction in the technology and lead to rapid increase in installed capacities (a possibility of solar thermal capacity doubling every 5 years and reaching a level of about 70 GW by 2031). This level of solar capacity addition would displace more than 300 MT of coal and over 440 MT of CO_2 in 2031.

Against this backdrop, the indigenously available solar energy resource can be used gainfully for meeting the country's energy requirements – thermal as well as electricity – of domestic, industrial, and commercial sectors. On the applications side, the range of solar thermal energy is very large. At the high end, there are megawatt-level solar thermal power plants whereas at the lower end there are domestic appliances such as solar cooker, solar water heater, and PV lanterns. In between, one can have applications such as industrial process heat, desalination, refrigeration and air-conditioning, drying, large-scale cooking, water pumping, domestic power systems, and passive solar architecture.

In India, as a result of efforts made during the past two decades, a significant infrastructure has emerged for the manufacture of different solar energy systems/components including solar PV cells and modules; solar collectors; solar water heating systems; and solar parabolic dish. Some of these have also been exported to the US, Asian countries, Europe, and Latin America albeit sporadically. On the other hand, about 30-odd energy centres in various academic institutions have been contributing by way of developing the specialized human resources. The PV manufacturing capacity in the country is expected to reach 1000 MW by 2009. The Clinton Foundation Initiative has identified 3 states for implementing a total of 5-GW capacity based on various solar thermal power generation technologies.

Strategies of the mission

In order to increase the share of solar energy in the national energy pie by an order of magnitude, it would be essential to involve all the major stakeholders in this exercise, especially the industry and R&D institutions, right from the beginning.

To start with, the mission would focus on the following key markets.

- Power generation (distributed generation as well as grid connected)
- Industrial process heating and cooling
- Residential/commercial thermal applications (including water heating as DSM option)
- Rural energy services

Coverage of these markets would entail a whole spectrum of solar technologies for instance the following.

- Low-, medium-, and high-temperature technologies in case of solar thermal energy
- Different SPV technologies including concentrating PV

In order to meet the minimum rural energy needs, particularly for cooking and lighting, a public-investment-driven approach to enhance energy equity and the quality of life will be pursued. All the households still using kerosene for lighting will be provided with solar lanterns. However, suitable delivery models would be designed which ensure that a nominal service charge is paid by the households in lieu of getting improved lighting services.

Decentralized energy supply for the industrial, commercial, and household sectors in urban as well as rural areas would be promoted through private sector participation, NGOs, and cooperatives. This would include development of a range of delivery mechanisms for installation and maintenance of solar systems against remuneration for the electricity or

In India, as a result of efforts made during the past two decades, a significant infrastructure has emerged for the manufacture of different solar energy systems heating services provided. The broad approach for enhancing the supply of grid-connected electricity from solar energy would be to encourage increasing cost-competitiveness with conventional as well as commercialized renewable energy resources based power-generating technologies.

The strategy is to stimulate markets and private capital mobilization through an enabling policy environment; selective and targeted investments for provision of minimum energy needs and in the development of human resources, technologies and indigenous production capacity; and provision of direct and indirect incentives to promote commercialisation and market development.

To leverage the expertise that India has developed in the field over the years, the mission would design suitable measures to expand the indigenous manufacturing base of solar energy systems and components. This would not only help in servicing the domestic markets with standard equipment and devices but also in positioning India as a 'Solar Hub' for catering to the growing export markets. The advantage of such an approach would be in terms of bringing down the costs of solar energy systems through economies of scale (and therefore ease of introduction of the latest technologies/processes).

Plan of action

This exercise of developing a PoA (plan of action) is conceptualized as multi-faceted, multi-disciplinary set of activities, which includes the following.

- Detailed analysis of the Indian energy landscape (including renewable energy sub-sectors)
- Identification of the key barriers to the up-scaling of this sector
- Analysis of the industrial, infrastructure, and fiscal policies
- Analysis of regulatory practices having a bearing on mainstreaming solar energy
- Identification of gaps in the present policy/regulatory regime
- Identification of ways to attract investments
- Develop long term data base of solar resource availability across the country

PV panels on a residential complex

- Identification of major research areas, including those requiring international collaboration
- Develop long-term R&D Plan for technology development and adaptation—including promotional schemes for private sector R&D
- Develop application-specific roadmaps with clear goals, timelines, roles, and responsibilities
- Develop a nationwide outreach and awareness generation programme targeting all stakeholders of solar energy in the country.

Institutional arrangements

A secretariat for the mission is proposed to be set up in a reputed institution, which can be decided in initial brainstorming sessions with the relevant stakeholders.

The mission would also have an R&D Vision and Technology Development Task Force.

Collaborating agencies

Since the solar energy application in many of the sectors may be benefited by the ongoing/planned government programmes and schemes, the mission would coordinate with the respective ministries and departments, for example, Ministry of Urban Development; Ministry of Rural Development; Ministry of Power; Ministry of Micro, Small, and Medium Enterprises; Bureau of Energy Efficiency; and Petroleum Conservation Research Agency.

For R&D, collaborative agencies would comprise major national research organizations, academic institutions, and the leading industrial houses. Besides, there could be collaboration with international institutions, which have developed a strong research base on critical aspects of solar energy, such as

- National Renewable Energy Laboratory, USA
- Risø National Laboratory (Denmark), Denmark
- Fraunhofer Institute, Germany
- German Aerospace Centre (DLR), Germany
- NEDO, Japan
- Solar Platform, Almeria, Spain
- International Energy Agency, Paris

It is proposed to assign monitoring and evaluation of different programmes to an independent group, not involved in activities of the mission being monitored or evaluated.

The way forward

Climate Change is a global challenge. It can only be successfully overcome through a global, collaborative, and cooperative effort. India is prepared to play its role as a responsible member of the international community and make its own contribution. Solar energy is the key to a sustainable future for India.

Article courtesy:
Amit Kumar, TERI

Solar energy shows the way

The recently released Global Status Report on Renewables 2007 says that grid-connected SPV (solar photovoltaics) has been the fastest growing energy technology in the world with 50% annual growth in the cumulative installed capacity in 2006 as well as in 2007. The majority of the above capacity comes from about 1.5 million homes across Germany, Japan, Spain, and the US, which have installed small PV systems (a few kilowatts to tens of kilowatts) on their rooftops, feeding the electricity into the grid through two-way meters and enjoying the benefits of net-metered electricity bills at the end of the month. Technologies such as BIPV (building integrated PV), where PV panels double up as electricity generators as well building facades, tiles, and walls by replacing the building material with aesthetically designed PV panels, have begun to get noticed by the architects and builders. This market is virtually non-existent in India which otherwise has a good track record of utilizing solar PV technology for off-grid applications ranging from power for off-shore oil and gas platforms to lighting up remote rural homes with solar home systems.

Of the total reported 25 lakh homes worldwide that use solar home systems today about 3.6 lakh are in India, second only to China which has 4 lakh solar home system users. In fact, India's early commitment to promote solar PV arose from its concerns about energy access and energy security for all. The market for solar PV continues to be relevant in such decentralized off-grid applications even after huge resources were made available under the rural electrification schemes of the Ministry of Power and the Ministry of New and Renewable Energy. About 7.6 crore homes still use kerosene for lighting. Though lighting is not synonymous with electrification, and which by no means can be equated with energization (that includes energy for cooking, among others), it still is one of the primary amenities required by a household to step on to the socio-economic-cultural developmental ladder. This basic amenity is not provided to 56.5% of the 13.8-crore rural homes and 12.4% of roughly 5.37 crore urban homes in India, which continue to burn biomass, wax candles, and kerosene lamps, spending Rs 2 to 5 per day.

The solar lantern, a portable lighting device that uses CFL, has its own rechargeable battery inside that can be charged everyday using an 8- to 10-watt solar panel. This is an ideal device to light up homes that currently use biomass or kerosene for lighting. About 5.8 lakh solar lanterns have been distributed in India in the past 7 to 8 years under the programme of MNRE. The solar lantern with its solar panel currently costs about Rs 3200–3600 of which the user generally pays only 50%, as the remaining amount is supported through a central subsidy. It is also given free to some user categories. However, an upfront payment of Rs 1800 often becomes a deterrant for the prospective user who can afford and probably is willing to pay smaller amounts on a daily or weekly basis. Such a scenario points to a potential microfinance market, provided the prospective user can be convinced about paying an instalment for a device that does not fetch him/her any direct income.

Bangladesh's success of micro financing users of solar home systems rests on this approach of linking enterprises and livelihoods; it involves selling and using solar home systems. A solar lantern, though much cheaper compared to a solar home system, has not found much favour either with the lender or with the borrower except in a few pilots where the less expensive versions of white LED based solar lanterns are being sold to rural communities. While white LEDs and other advanced lighting technologies are going to revolutionize the lighting market, one should not forget that these technologies have to penetrate the urban market first, before they can be accepted by the rural masses.

The urban home has just recently shifted to CFL from its incandescent bulbs and white LED-based lighting devices (torches, night lamps) are still novelties. Till such time the white LED replaces the CFL completely, the CFL solar lantern will probably continue to find favour in rural homes as their first modern lighting device. This, despite the fact that it is costlier compared to its LED counterpart, because the former requires more wattage and hence a larger solar panel.

When we shift the focus to the benefits rather than costs of switching to solar lanterns from the current options of kerosene lamp and candles (or nothing), the results are interesting. As per the National Sample Survey Organization's survey on energy consumption patterns in 2005, and TERI's rural energy projects data, a rural household consumes an average of 4 litres of kerosene per month for lighting. A total of 7.6 crore rural households would thus be consuming an average 3.6 billion litres of kerosene annually. At carbon emission intensity, or a release rate, of 2.4 kg CO_2 per litre of burnt kerosene, the atmosphere gets polluted by 9 million tonnes of CO_2 annually. This may well translate into a $90 million carbon market annually at a modest rate of $10 per tonne of CO_2. Quite apart from direct carbon revenue benefits, each solar lantern offers a net annual saving of Rs 1200 by way of avoided kerosene subsidies estimated at approximately Rs 25 per litre. If the cumulative subsidy amount is instead targeted at solar lanterns, it would lessen the burden on a rural household to switch to a solar lantern.

The Kasturba Gandhi Balika Vidyalaya is a flagship scheme of the government that provides hostel facilities for schools for girl children of SC/ST and OBC categories. In the absence of reliable grid supply in most of these hostels, either the school authority, district administration, or in some cases, families of the hostel residents spend money on kerosene and candles for their wards. Provision of solar lanterns will strengthen the objectives for which these hostels have been set up, and be a good example of public–private partnership if the corporate sector came forward to equip the hostels with solar lanterns. There could be many such examples of such interventions improving health, welfare, and livelihood opportunities.

Let us now once again shift the focus, this time to the delivery and after sales service of solar systems. Who, where, how, and at what cost


Charging station for solar lanterns

Solar lanterns provided through the LaBL campaign are being used for a variety of purposes

Solar lantern being used in a rural school

can deliver these services in remotest corners? Apart from the resources available through avoided kerosene subsidies, how will an initiative of lighting millions of homes using solar lanterns be financed and sustained? Let us first think from the user's perspective. A household or a rural enterprise (shop, kiosk) would probably not have a constraint in spending Rs 2 to 5 per night for the use of solar lantern, even without actually owning the device. Some may even want to rent additional lanterns if charged lanterns are available on rent within a village. Also, it cannot be assumed that a village resident can easily purchase an item worth Rs 3200. Alternately, he/she may want to spend about half that amount (Rs 1600–1800) to purchase a lantern without the solar panel and pay a daily fee for charging, if such a facility is locally available.

We are talking about a delivery and service model familiar to most rural and per-urban communities where households purchase new or recycled car batteries and charge them from the nearest battery-charging shop running either on diesel-generating set or grid electricity. This fee-for-service model is well established and thriving in most power-deficit areas. These one-stop entrepreneurial outlets offer repair, maintenance, and all other related services. If this model were to be adopted for solar lanterns, then we are talking about setting up solar-charging stations at village level, with not just solar-charging services for lanterns but also for mobile telephones, and other battery-operated devices.

Other locally available renewable resources such as wind and biomass can be harnessed to augment the capacity of charging stations. These solar charging stations would be operated and maintained by local youth, NGOs and local enterprises that can be selected through a process offering maximum equity (or any other criteria) and can be trained and incubated for a pre-specified time. These charging stations can be set up using resources from the government (they can be treated as basic infrastructure) or from corporations setting up rural outlets for their own products and services; solar charging stations would be an added value to their services.

All of the above is not wishful thinking, it is already happening in parts of West Bengal, Rajasthan, Haryana, Assam and is likely to extend soon to Bihar, Orissa, and Madhya Pradesh under the 'Lighting a Billion Lives' Campaign, an initiative of TERI that was formally launched by the Prime Minister on 7 February 2008 at Delhi's Vigyan Bhavan. As Dr R K Pachauri, Director General of TERI and chairperson of IPCC, this year's joint winner of the Nobel Peace Prize, says, 'Millions and millions of

The LaBL is an attempt at brightening the lives of one billion people

people do not see light after the sun goes down. Some 1.6 billion people worldwide do not have access to electricity. LaBL will be a vehicle to deliver a package of technology-based solutions to meet the various needs of a community through schemes like "Adopt a Village". The institute has developed several products like solar torches, solar fans, solar milk churner, and biogas plants, which are being used widely in rural areas. Our aim is to enable all rural communities to be self-reliant and develop capabilities for removal of poverty.'

TERI has embarked upon this campaign wherein it commits to brighten the lives of one billion people by displacing kerosene and paraffin lanterns with solar lighting devices; providing better illumination and kerosene-smoke-free indoor environment; and providing opportunities for livelihoods both at the individual and village level.

The Implementation Model

The campaign is based on an entrepreneurial model of energy service delivery, developed, and successfully implemented by TERI. This will involve provision of solar lanterns to rural communities across the world by setting up solar lantern charging stations in villages and distributing charged lanterns to households on nominal fees; providing lanterns to facilitate and advance ongoing programs on education, health, and livelihoods; and identifying and training rural entrepreneurs to operate the charging stations

Environmental benefits

A vital aspect of the campaign is the positive impact on the environment in the form of carbon benefits. Each solar lantern from the campaign will save 40–60 litres of kerosene each year, thereby mitigating 319 lbs (145 kg) of CO_2 (carbon dioxide) emissions per year.

The Lighting a Billion Lives campaign allows individuals, as well as organizations, to join hands in bringing light to the lives of billions and contributing towards sustainable development through various sponsorship opportunities. These include individual sponsors and organizational sponsors.

Individual sponsors

Each package consists of a solar lantern, which will be an individual's contribution towards lighting a life, and a solar torch, which will be TERI's gift to the individual for his/her valued support in building a brighter world!

Organizational sponsors

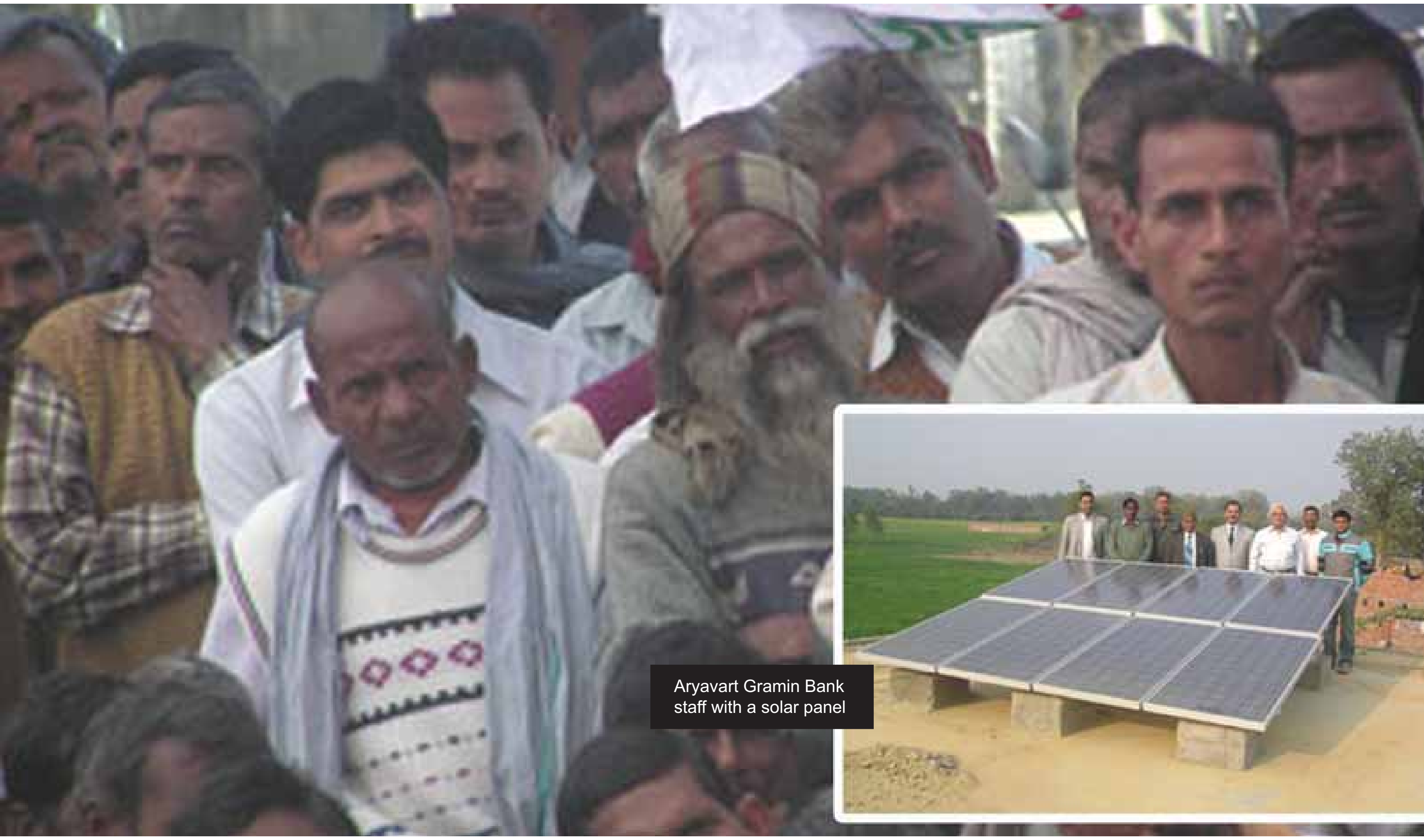
As an organizational sponsor, one can contribute through various sponsorship packages, which will help in meeting the capital cost of equipment as well as part of implementation and outreach costs for Lighting a Billion Lives. For this contribution, TERI provides the organization solar torches that it can use as corporate gifts to its associates and employees!

A solar lantern is a powerful tool to take rural communities from darkness to light. It is also a commitment that would bind governments, corporations, the non-governmental sector, civil society, and individuals to light up a billion lives not only in India but across the globe as well.

Article courtesy:
Akanksha Chaurey, TERI

Financing solar home systems

Aryavart Gramin Bank shows the way



Aryavart Gramin Bank staff with a solar panel

Uttar Pradesh is one of the poorer states in India. For centuries, people have been subsistence farmers, growing rice, wheat, lentils, and mustard seeds. Some cash crops like sugar cane, potato, and mentha are now also cultivated on a large scale. Buffalos are reared for milk and meat. Over the years, the farms have become smaller as the land is divided between children. Many rural areas of the state have no grid electricity and even where the grid is available there are frequent power cuts. Some shops provide a battery-charging service so that people can run DC lights and small appliances from car batteries.

PV (photovoltaic) SHS (solar-home-systems) can be very effective in providing power for lighting and small appliances. However, in many parts of India, and other developing countries, the main obstacle for rural families who want to have an SHS is finance. Throughout India, there is a well-established network of Regional Rural (Gramin) Banks, which were set up from October 1975, to make banking facilities available in remote rural areas, and to make small loans easily accessible to farmers and other rural people.

The Aryavart Gramin Bank, Lucknow (after amalgamation of three Regional Ruaral Banks namely Avadh, Barabanki, and Farrukhabad sponsored by Bank of India w.e.f. 3 October 2006) caters to six districts of Uttar Pradesh, namely, Lucknow, Barabanki, Farrukhabad, Hardoi, Kannauj, and Unnao covering about 8500 villages. Of these, more than 2500 villages do not have grid power.

Aryavart Gramin Bank has set an example that could be followed by the other banking/finance institutions and they can play a vital role in removing the darkness in the lives of Indian villagers. With this objective of discharging corporate social responsibility, the bank came up with an innovative idea of financing SHLS (solar home-lighting systems) to its proven customers and devised a scheme.

SHLS were chosen because they carry underlying social, economic, and environmental benefits.

- The system is very simple with low operating and maintenance cost.


Solar light


Aryavart Gramin Bank solar-powered medical shop

- The power generated can be utilized for domestic as well as commercial purposes.
- Method of installation is simple and the unit is easily transportable.
- Cost of installation is a one-time affair and constant supervision is not required. The maintenance charge is also negligible.
- The system is free from noise and air pollution, and other health hazards.
- There is an improvement in the living environment with uninterrupted and sufficient light.
- There is also an increase in income due to availability of light for longer period resulting in extended working hours.

The scheme

To make the scheme acceptable to, and for the benefit of the common man, the bank thought it prudent to look into the following factors before launching the project.

- The cost of the SHLS should be such that a common borrower is able to afford it because subsidy was not available in the scheme.
- SHLS should be of a reputed company.
- Quality of the SHLS should be indisputable.
- Business facilitators should be engaged to maintain the SHLS.

Economics of the solar home lighting systems

The economics of the SHLS was as follows.

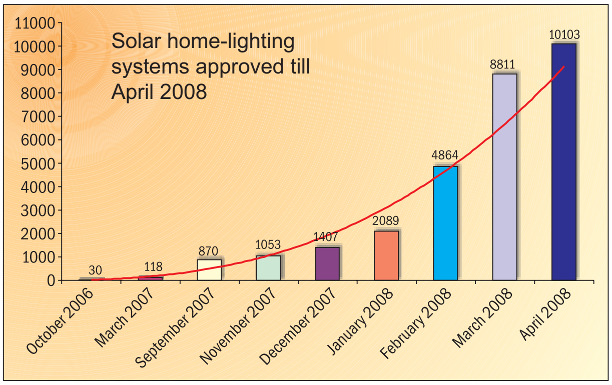
Project cost: Rs 13 520
Amount of finance: Rs 11 000
Down payment: Rs 2520
Equated monthly instalment: Rs 245*
(*with interest @ 12% per annum on reducing monthly balance)

A villager presently uses minimum lighting of 2 hours for cooking and up to dinnertime, which requires a minimum of 8 litres of kerosene per month, costing Rs 280 approx. at street price of Rs 35 per litre. Thus, the borrower does not have to bear any extra cost/burden.

For maintaining 100 such systems, the branch managers identify a local youth who is trained by the company/dealer. He is provided with a kit by the company to maintain the system. The bank pays him Rs 10 000 per annum (Rs 500 per month and Rs 4000 in lumpsum if he maintains 100 systems all throughout the year [as reflected by 100% recovery of monthly installments]).

The bank foresaw immense potential to make the project successful in a big way, through the network of its 287 branches (now 290) spread in 6 districts of Uttar Pradesh with a growing customer base. Majority of staff being local, they have excellent rapport with the clientele and can spread the message of social, economic, and environmental benefits of the scheme amongst them. The bank communicated the benefits of the scheme by initiating steps to bring about awareness, organizing camps, and lecture demonstration on the working of the system, and so on.

For its efforts, the bank was awarded the prestigious International Global Green Energy award by Ashden Trust for the year 2008 for pioneering work done by it in financing SHLS and solar power packs. The award was received by the founder Chairman, Aryavart Gramin Bank, from Dr Wangari Maathai, the 2004 Nobel Peace Laureate at a ceremony held in London on 19 June 2008.



Article courtesy: N C Khulbe, CMD, AGB

Taking solar energy research to new heights

Asian Institute of Technology

Introduction

The AIT (Asian Institute of Technology), located 42 km north of Bangkok, Thailand, was established in 1959. Its mission is to develop highly qualified and committed professionals who play leading roles in the region's sustainable development and its integration into the global economy. AIT promotes technological change and sustainable development in the Asia–Pacific region through higher education, research, and outreach. Since its establishment, AIT has become a leading regional postgraduate institution and is actively working with public and private sector partners throughout the region and with some of the top universities in the world. Recognized for its multinational, multi-cultural ethos, the institute operates as a self-contained international community. Besides the usual labs and academic buildings, the main campus includes housing, sports, and medical facilities, a conference centre, and a library with over 230 000 volumes, and 830 print and online periodicals.

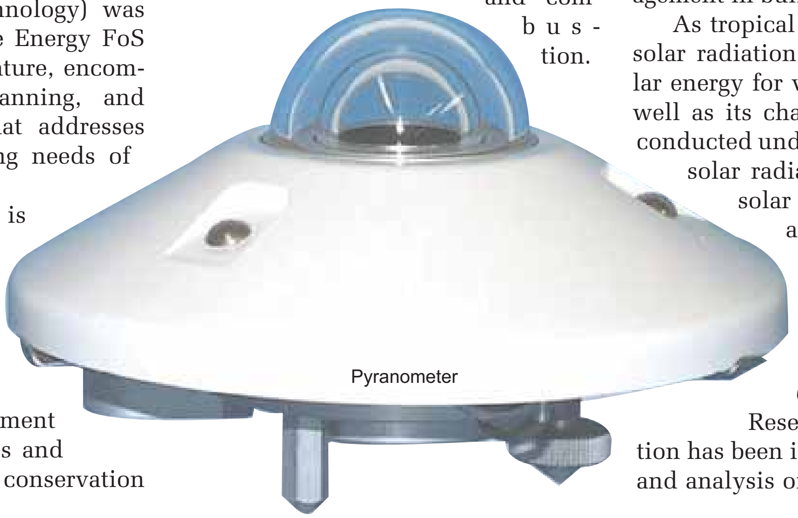
Energy studies at AIT

The Energy FoS (Field of Study) of the SERD (School of Environment, Resources, and Development) at the AIT (Asian Institute of Technology) was established in 1979. The Energy FoS is interdisciplinary in nature, encompassing technology, planning, and management aspects, that addresses the current and emerging needs of the energy sector.

Energy technology is an area of specialization under the Energy FoS, which aims to train graduates for positions in national and international institutions, research and development departments of industries and energy utilities, energy conservation agencies, and consulting firms. The other areas of specialization include EEP (Energy Economics and Planning), and EPSM (Electric Power Systems Management). Energy technology focuses on RSE (Renewable Sources of Energy) and RUE (Rational Use of Energy). The RSE encompasses the fundamentals and practical aspects of solar thermal and PV (photovoltaic) conversion, thermo-chemical conversion of biomass, other renewable energy sources, and the environment. The topics covered in RUE are in the area of energy analysis and system optimization, energy conservation, energy management in industries and buildings, and clean energy technologies.

Solar research and training facilities

A well-equipped solar thermal and PV laboratory having a large outdoor testing area known as the energy park is used for teaching, research, and the testing of commercial products. The park with an area of nearly 4000 m2 contains solar and bio-energy devices, experimental set ups for day lighting and building energy studies, and a meteorological station. Other facilities available at the energy field of study include standard laboratory apparatus for the study of heat transfer, refrigeration, fluid mechanics, and combustion.



Pyranometer

The meteorological station at the energy park has a pyrheliometer to measure direct radiation and pyranometers to measure global horizontal radiation, diffuse radiation, global radiation at 15-degree inclined surface, temperature probe to measure ambient temperature, and wind speed sensor. This collected data is used for students and researchers to carry out studies related to solar radiation and day lighting, as well as performance testing of different solar devices. This has led to many manufacturers of solar products to use the facility to test their product performance, especially in a tropical setting. The testing services provided are for solar thermal collector performance test, solar water heater system performance test, and PV systems.

Solar energy research

In the area of energy technology, research in renewable sources of energy includes renewable energy and environment, solar thermal and PV processes, day lighting, renewable energy hybrid system, integrated renewable energy resources, and biomass conversion. Research area in RUE includes assessment of co-generation in different types of industries, rational use of energy in industry, and energy management in buildings.

As tropical regions have abundant solar radiation, several studies of solar energy for various applications (as well as its characteristics) have been conducted under four main categories: solar radiation and day lighting, solar drying, solar thermal applications for heating/cooling, and PV applications.

Solar radiation and day lighting

Research on solar radiation has been in the area of estimation and analysis of solar radiation and its various components since the early 1980s, as well as its application to day lighting. These studies include analysis of radiation, development of models, and measurement and its analysis. The meteorological station at AIT with its array of pyranometers, pyrheliometers, and so on is used in this context. Some of the studies carried out under this topic in recent years include the following.

- Study of tropical daylight and its illuminance through window have been investigated considering indoor daylight quality.
- Day lighting through light pipes for deep interior illumination considering heat gain was studied by using an adjustable reflector for reflecting sunlight through light pipe. This can illuminate the deep interior space of a building.
- Studies on turbidity of the atmosphere indicate that it varies with seasons. Atmospheric turbidity is relatively low and quite stable during dryer months and increasing in wet season.
- Day lighting through unshaded and shaded windows is another topic being studied.


Pyrheliometer

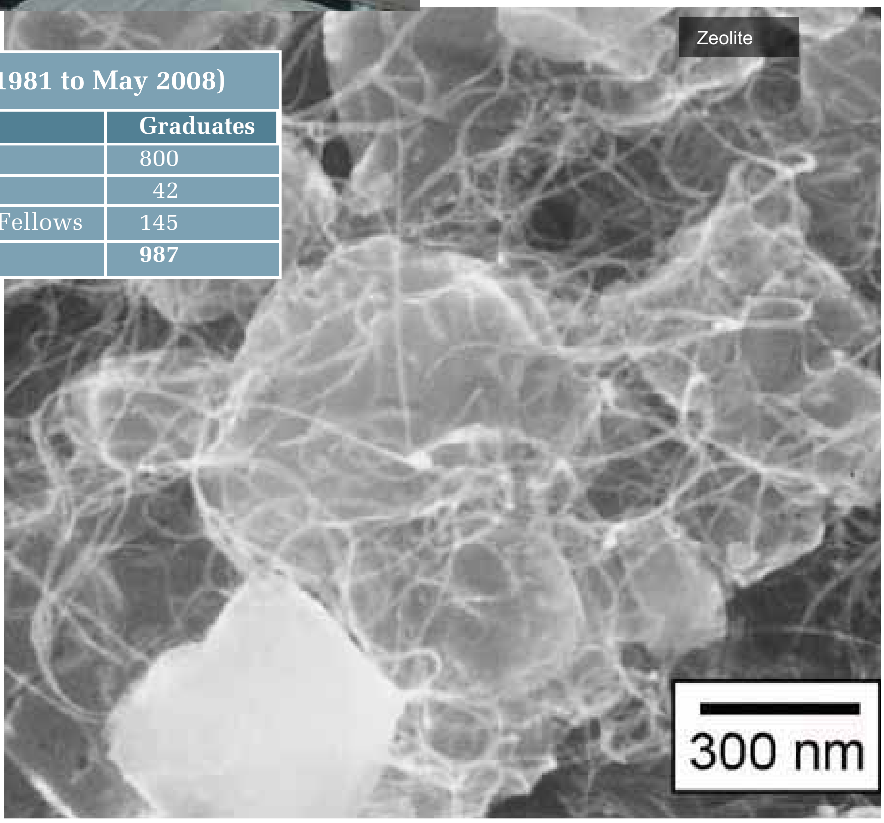
Solar drying

Studies on solar drying were initiated in the 1980s primarily for grain drying. Currently, research is concentrated on the application of solar energy for drying vegetables, fruits, and fish. Many dryers have been developed at AIT.

Theoretical and experimental investigation of a solar–biomass hybrid air heating system for drying applications was carried out by designing and investigating the performance of a renewable-energy-based (solar–biomass) hybrid air heating system with thermal storage. The air heating system using only renewable solar and biomass energy for its operation presents itself as a reliable alternative to other renewable-energy-based dryers with conventional backup heaters for medium-scale drying of food products.

ENERGY GRADUATES OF AIT (1981 to May 2008)

Type	Graduates
Masters	800
Doctoral	42
Diploma, Special, Certificate, Research Fellows	145
Total	**987**



Zeolite

ENERGY GRADUATES SORTED BY COUNTRIES (TOP 15)	
Countries	*Graduates*
Thailand	204
Vietnam	163
China	57
Philippines	55
India	53
Sri Lanka	53
Pakistan	43
Nepal	42
Bangladesh	30
Myanmar	28
Laos PDR	26
Indonesia	20
Cambodia	18
Bhutan	12
Malaysia	11

Solar thermal energy for heating/cooling/heat pump system

Research on the use of solar energy for heating (in solar water heaters) and cooling is in progress with studies looking at various possible configurations. A solar–biomass hybrid air conditioning system for residential application plans to investigate a small-scale hybrid renewable energy air conditioning system for residential applications using solar–biomass hybrid absorption chiller by developing a mathematical model of a hybrid solar–biomass absorption chiller. The research will also study the performance of the system, analyse the influence of various parameters, and experimentally investigate the absorption air conditioning system using heat from solar (from solar collector) and/or heat from biomass to heat the generator.

A study on upgradation/storage of solar thermal energy by solid absorption chemical heat pumps used a zeolite–water solid adsorption chemical heat pump coupled to a solar water heater for energy storage and upgrading purpose. This was done by estimating the useful energy delivered and temperature of hot water produced by using the Transient System Simulation program and the Artificial Neural Network, by developing mathematical models for solid adsorption heat pump system (NaX zeolite–water), solid–gas (ammonia) system, coupled solar–solid gas system, and the coupled solar–solid adsorption (zeolite–water) heat pump system. Once this was done, the theoretical predictions were compared by conducting experimental studies on a coupled solar–solid adsorption system. The study illustrated the feasibility of coupling renewable energy source to a chemical heat pump, and thus upgrading heat and store energy for useful purposes. Such systems will be useful for many applications in tropical locations where solar energy is available throughout the year.

Solar photovoltaic studies

Many studies have been carried out on the application of PV systems for electrification and income generation in the region. A study on renewable-energy-based hybrid system for rural electrification addressed the issues related to the use of PV hybrid system for rural electrification including the performance of the PV hybrid system, that is, PV, diesel generator, inverter, and battery for storing energy. This was done by developing a PV hybrid system model that incorporates technical, financial, and social aspects. Experimental studies and survey on a PV hybrid system installed in an island community and in laboratory showed the potential to use the PV hybrid system to supply basic energy services that is desired in rural settings

Research on solar energy has been carried out through sponsored projects at AIT as well as in the region, in the areas of solar drying and PV (www.retsasia.ait.ac.th) with partner institutions (government, academic institutions, private sector, and non-governmental organizations) in Nepal, Bangladesh, Laos PDR, Cambodia, Vietnam, and the Philippines. These were aimed at promoting mature and nearly mature technologies.

Conclusion

In line with AIT's research focus in the future – climate change and sustainable development – research and training on solar energy (fundamental and applications) is expected to grow, and studies will be linked to policy analysis for the promotion of solar energy technologies. Specifically, studies will focus on introducing solar energy for reducing the energy bill in buildings (cooling, thermal comfort and electricity), development and application of high-temperature solar collectors (concentrating), adaptation of solar technologies for applications in the food and manufacturing industry, and the role and potential of solar energy in the urban energy mix.

Article courtesy:
Prof. Sivanappan Kumar, Energy Field of Study, School of Environment, Resources and Development, Asian Institute of Technology

Solar energy in the context of NAPCC

India's NAPCC (National Action Plan on Climate Change) sets out eight focal points for the government's sustainable development strategy through 2017. The NAPCC is likely to become a significant driver of new investment opportunities in the country's renewable energy portfolio, and in solar generation in particular. The solar mission, one of the focal points, will aim to develop a solar industry capable of delivering solar energy competitively against fossil options over the next 20–25 years. *Dr Leena Srivastava, Executive Director, TERI* talks about the solar mission, in an interview with *Ambika Shankar*.

Q. The fact that the NAPCC has placed solar energy on top of the agenda is encouraging. What are your thoughts?

A. Solar energy is going to be an extremely important energy resource both in the medium and long term. India's energy choices are limited both in terms of overall energy security and climate change point of view. We will necessarily have to reduce our coal consumption and cannot take the position that India is a coal-rich country forever. I think the sooner we look at solar energy as a clearly defined agenda on the energy front, I think the better we will do.

Q. The mission states that technology transfer of solar thermal and PV systems is required for the development of cost-effective and suitable costs for India. How important, do you think, technology transfer really is keeping in mind the current scenario?

A. I think before technology transfer, we still have to see certain degree of maturity in the technology itself. By maturity, I mean increasing the efficiency as well as bringing down the cost because affordability of solar energy is going to be a very critical factor in its dissemination in the country. India you know is struggling to provide electricity excess to almost 400 million people and if they start moving to very expensive options it would place tremendous, possibly unbearable, burden on the government. So refinement of technology making it affordable comes first and then technology transfer is extremely important. It should be ensured that we do not have to pay a very high price for this technology again from the affordability argument. There is lot of research and development going on in several western countries. And I think the onus lies on them to ensure that affordable technology is available to India.

Q. Do you think that the use of solar technologies for lighting up rural homes has been addressed adequately?

A. The issue has come back to us and the cost of providing solar solutions to rural areas is still little high. I think we have not been able to ensure a good delivery mechanism. The lighting of billion lives programme that TERI has started is addressing both of these issues. By making it part of larger local good agenda we are trying to ensure that we bring down the cost, especially the first cost, of solar technology as well as design. Hopefully that should set a good example for others to follow.

Q. In this context, can the LaBL programme be a part of this larger agenda? What implications will it have?

A. It will have an implication for the climate agenda but it is not linked at all. What we have is hope and what it is beginning to do is showing the way for many more entities to get involved and adopt similar kinds of initiatives. MNRE has found this concept attractive and it is part of their initiative. We hope that many more people would partner in this whole initiative.

Q. The mission talks in terms of indigenous PV production. Given the current scenario, by when do you think self-sufficiency would be reached?

A. Yes, we do have indigenous PV production capacity and it is being enhanced as well but to some extent it is still a chicken and egg situation. We need to see how market would grow and what impact is provided to this market by policy and regulations. Manufacturing would follow the expectation of demand growth. We have the capability to meet the demand and all that is being produced today is imported. But that is a fairly small amount. I think India needs to revamp production to a fairly large scale that should go to gigawatt or maybe at least megawatt.

"All the objectives set in the solar mission are achievable... but if anything, we need to be much more ambitious especially on at the rate solar energy is introduced and manufacturing facilities we need to put in place... initially by focusing on the urban and industrial market, we could definitely bring economies on scale into place and bring down cost..."

Q. How does the mission aim to network Indian research efforts in solar technology with global initiatives, as stated in the mission?

A. There is, as I mentioned, lot of research going on to bring down the cost per unit of solar energy production. And it is a combination of efficiency, improvement, and cost reduction. India has the capability, India can provide lower cost option for manufacturers, and through both these areas of corporation we can definitely help bring this technology in a much larger way into the Indian market. Indian research on the technological side is a little weak but we can contribute to the international effort.

Q. The mission sets out several objectives for the future. In your opinion, would it be possible to achieve whatever has been stated?

A. I think all the objectives set in the solar mission are achievable. But if anything, we need to be much more ambitious especially on at the rate solar energy is introduced and manufacturing facilities we need to put in place. Second, initially by focusing on the urban and industrial market, we could definitely bring economies on scale into place and bring down cost. For results, I think that is the starting point.

Q. Compared to other missions that the NAPCC enumerates, how does the solar mission hold its own? Considering the fact that solar energy is the energy of the future, do you think it requires a larger mission plan?

A. The mission per se is yet to evolve and would come in place by December 2008. So, this question should be answered at that time. From all signals we are getting from the concerned ministry, this is going to be a major programme. I think this is something we could go forward with.

Q. Keeping in mind the current scenario, what direction do you see the Indian solar industry taking?

A. Both the solar photovoltaic and solar thermal technology options are equally important for India and I hope the industry would respond appropriately in both these ways. Apart from this, I believe that the solar rooftop programme and therefore, the scale in intervention they are talking about in this programme, would be extremely important. So, the industry has itself to get up both for small-scale industrial applications as well as the large-scale market.

Leading India to a new dawn

She is a heady mix of beauty and power. Inspiring at work, caring at home, and tough when it comes to delivering result. Abha Singh strongly believes that the concept of ideal India is one that is free of corruption and injustice. And a leader, she feels, should give a clear vision, which can be translated into results and take masses along with it. An officer of the Indian Postal Services and presently the Director, Postal Services, Lucknow headquarters, Abha Singh is responsible for planning and management of postal operations in one of the largest circles in the country. It was her initiative that saw large number of post offices in the rural areas of the state of Uttar Pradesh being electrified with solar power, which could also be an answer to the India's energy crisis. *Abha Singh* answers questions on this and more in this interview with *Roshni Sengupta*.

Q. What are your thoughts on solar energy having found a prominent place in the NAPCC (National Action Plan on Climate Change)?

A. I think the NAPCC has done a good job by placing solar energy on top of the agenda. Solar energy is the best alternative to traditional power sources and among the alternative sources, solar power is the 'cheap and best' deal. The other available power sources like diesel, petrol, and petroleum gases are limited and costly. Chances are that they may finish in the near future. But solar energy is unlimited and is available without any cost. The additional advantage of solar energy is that it is eco-friendly while the other sources lead to pollution. I feel it is the best option to use solar energy for generation of electricity.

Q. The international money transfer service with solar panel back up has been installed in various districts in Uttar Pradesh under your tenure. How successful has this intervention been?

Does it showcase renewable forms of energy as a viable form of alternative fuel?

A. Electric supply was unavailable in some rural areas to run international money transfer service in some important post offices where it was required. But now we have introduced a solar panel back up system in six post offices in the Lucknow region and are able to run important services like savings bank, instant money orders, and speed post booking in these post offices. It was difficult to run computer-based services.

Q. You have also undertaken a scheme to run a computer centre by solar energy. Do you feel that the IT sector can be benefited by the introduction of solar energy?

A. Yes, we have undertaken a scheme to run the computers in the post office with solar energy. We have designed the system to suit the needs of a post office. It can bear the load of three computers, two dot matrix printers, one server, and two 11-W (watt) CFL bulbs for five hours. In all, the total electricity load on a single unit of solar hybrid system is 612 W. This has brought generator expenses down by 85%. This has also assisted us in reducing the dependency on conventional fuel like diesel. This is also eco-friendly to the environment and has produced a good working atmosphere. I would also like to share a small incidence with you. We have a post office in Lucknow High Court premises. Due to frequent electricity failure, a generator was required but the judicial authorities did not permit installation of a generator due to 'noise and air pollution'. To overcome these crises, we installed a solar unit in that post office. By this, we not only overcame the problem of energy crisis but also gave the message of using environment-friendly technology.

Q. Is our energy situation, in your opinion, precarious? How can we improve it?

A. Yes, I agree the energy situation in our country is certainly not in a good shape. We have limited conventional energy and the only option is to use other sources of available energy like solar, tidal, and wind. But since solar energy is available everywhere and is unlimited, it is the best possible option. The speedy expansion of technology in the whole world has also increased the demand for power. Thus, to meet the requirement it is required to generate more electric energy and the best way to combat this situation is adoption of solar energy in a big way.

"Due to frequent electricity failure, a generator was required but the judicial authorities did not permit installation of a generator due to 'noise and air pollution'. To overcome these crises, we installed a solar unit in that post office... By this, we not only overcame the problem of energy crisis but also gave the message of using environment-friendly technology."

Q. Has India been using and promoting solar energy as best as it can?

A. No, the amount of solar energy produced in India is merely 0.5% compared to other energy sources. Till date I don't think India is using and promoting solar energy as best as it can. The main cause of this is less awareness on solar energy among the masses. Of course, the Government has initiated many programmes to popularize the use of solar energy but we still have miles to go in this regard. There is need to carry out more research in this area which can help solar panels to become more cheaper. Print and electronic media can play a vital role in this arena by popularizing the power of solar energy. Government can give tax rebate to manufacturing units/house holds using solar energy. More funds/solar loans should be made available through banks to enable people to set up /install solar units in their houses.

Q. What, in your opinion, are the specific areas within the broad focus on solar energy that we in India can emphasize on?

A. India has an agricultural economy. There is vast scope to use solar energy in agriculture especially in operation of agricultural equipments tools and plants. We may also use solar energy for water pumps and lighting, operation of signals, computers, and many other electrical equipment. Using solar power in security applications is also another alternative where a remarkable job can be done after some research work. Apart from this, premises can be illuminated by solar light. We have installed solar compound light with the provision of 2x6 watt LED on four poles which is 100% depended on solar system and dusk to dawn operation at Akbarpur Post Office situated in Kanpur (Dehat).

Q. When do you think India can reach self-sufficiency as far as photovoltaic technology is concerned?

A. At the moment it is a bit difficult to predict the actual time when India can reach self-sufficiency as far as PV technology is concerned but there is no doubt that the pace is slow and we have to make a lot of efforts in this area. Similarly, I agree to this point of view that we have good technocrats and also have good resources. What is required is encouragement in the right direction. India is facing acute shortage of energy. This can be bridged by this technology. Our step forwards nuclear energy is in the right direction.

Q. Do you think India can reach the levels of development delineated in the NAPCC?

A. Yes I think India can reach the levels of development delineated in the NAPCC.

Q. You have travelled widely and have had a chance to take a look at the global solar industry? In comparison, what direction do you see the Indian solar industry taking?

A. In comparison to other developing countries India is in a good position and certainly we are marching positively. However, if we look at developed countries I think we have to do more. I am told that 90% of solar panels made in India are being exported to Germany. The cost of these panels is very high. Hence, it becomes difficult for the common man in India to use solar panels in his house. Its high time that subsidy is given to solar units in a big way.

"In comparison to other developing countries India is in a good position and certainly we are marching positively. However, if we look at developed countries I think we have to do more..."

Q. In your opinion, is research & development in the field of solar thermal and PV comparable to international standards? How far is India from the rest of the world?

A. Research and development in the field of solar thermal and PV compared with international standards is yet to reach a large scale. However, with constant research and motivation by the government, we can come up in this area. If in Germany every household can install solar units, why cannot it be done in India where at least 8 months in a year have ample solar energy.

CLEAN POWER FOR COOKING AND LIGHTING

cookstove controller

Most households and industries in Asia, particularly in rural areas, use wood energy for various purposes. The equipment that they use, like ovens and kilns is generally simple, made from locally available materials, and of poor quality (smoky and inconvenient). Efficiencies are low, because a lot of the heat is lost to the surroundings. This means there is a large scope for improvement of technologies and fuel conservation.

In the early seventies, as a reaction to the oil crisis and concern for forest resources, improved cookstove programmes were seen as a possible solution to the fuelwood crisis and a means to reduce fuelwood demand. Several programmes have been implemented since then, with varying success. The early programmes focused strongly on stove efficiency and fuelwood saving, and many programmes failed because they ignored the requirements of the users.

Subsequently, interest in energy issues diminished because of decreasing oil prices, and funding of improved cookstoves programmes reduced, so many came to an end. There is no evidence that improved cookstoves have led to reduced wood energy demand, let alone reduced deforestation, but improved cookstoves can bring several social benefits. So, current programmes pay more attention to user needs, which, besides fuel saving include cooking comfort, smoke-free kitchens, convenience, health and safety.

The main use of wood energy by households is for cooking, for which several types of stoves are used. The simplest and oldest one is the three-stone fire, built by arranging three stones in a triangle around a fire, so the cooking pot can be put on the stones. A variation is the tripod, a metal ring with three legs, which is widely used

Components of a cookstove controller

in Asia. Major drawbacks are dispersion of flames and heat because of the wind, poor control over the fire, exposure to heat and smoke, and fire hazard.

Inefficient use of biomass in traditional cooking stove leads to wastage biomass, indoor air pollution, and health-related problems. It is found that people, especially women, in remote and far-flung regions spend more than half of their day for collecting fuelwood. These activities are not only cumbersome but also prevent the rural masses from engaging in other productive and income- generating activities. Introduction of high-performance biomass-based cookstove characterized by higher efficiency (30%–40%) as compared to traditional cookstoves of efficiency 10%, smokefree clean combustion, uniform and steady flame would serve two objectives: (i) the time in collecting fuelwood can be utilized for other productive and income-generating activities (ii) better indoor air quality can be ensured thus reducing the related health problem.

Various studies have also shown that rural population actually spends considerable amount on very inefficient lighting energy supplies, which do not produce good quality of light. In this context, for rural remote locations, SPV-based lighting system is one of the viable options for lighting. However, one technology that shows promise is SPV-integrated LED-based lighting system (by changing the source of illumination from CFLs to LEDs). As the energy requirement in LED-based lighting system is less (as compared to CFLs, generally used in SPV systems), small PV panels and batteries can be used for lighting applications. Therefore, it is expected that LED-based lighting systems powered through SPV would have relevance in the rural areas and have potential to replace small existing PV-based lightings systems such as solar lanterns.

Improved cookstove programmes can fail or succeed depending on several factors. They have a higher chance of success in areas where people already buy both the stove and the fuel, so they have an incentive to save on fuel use and they are willing to pay for a better stove. Also, when timesaving is considered valuable or smoke is a problem for users, they tend to adopt an improved stove easier.

In stove design and production, several factors play a role. Preferably, surveys should be undertaken to find out if there is an interest and market for improved stoves. Stoves should be designed according to user preferences, they should be designed with assistance from local artisans, and the stoves should perform the same functions as the ones used traditionally. User preferences may be different from area to area, so within a country different stove designs may exist. Gender aspects are important here, because users are generally women.

Against this backdrop, TERI introduces a rural energy package for cooking as well as lighting based on a small SPV system. The stove is designed for the power output ranging from 2 kW and 5 kW to 10 kW. A typical 1-kW cookstove is designed to operate through a 2-W DC fan, which can be supplied through a small PV system consisting of a solar panel, battery, and controller. As it is expected that the cooking would be for 3 hours in a day and power requirement for such option would be very less, the same solar panel can be used for lighting purposes. The system can supply power to two small LED-based lighting systems for 3 hours. TERI proposes to undertake demonstration project in Karauli district of Rajasthan for sustainable market development of such rural energy package through the involvement of grass-roots-level institutions.

The concept is being developed with two-fold objectives.

- Introducing the cooking and lighting packages in remote villages as an alternative to only PV-based smaller lighting system
- Developing a women-centric model for trials and dissemination

The scope of work includes

- Selection of region and 2–3 active SHGs/NGOs in each state
- Demonstration of the PV-integrated high-performance cookstove in the selected region.
- Integrating the livelihood activities
- Facilitating and creating the market linkages for the NGO/SHGs

Article courtesy:
Parimita Mohanty, TERI

Evaluating renewable energy projects

simulation of grid-connected solar PV system using RETScreen

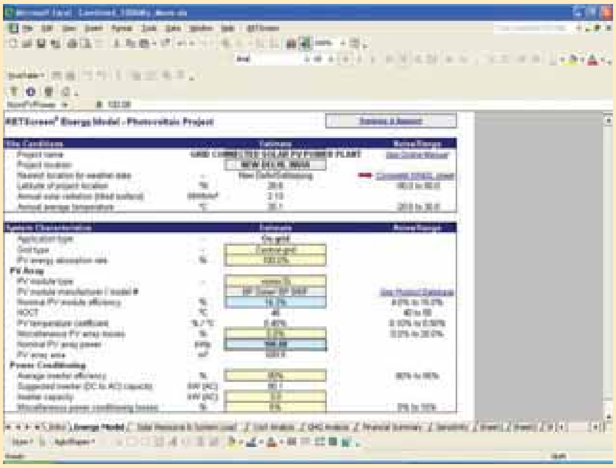
The RETScreen Clean Energy Project Analysis Software is a unique decision-support tool to evaluate the energy production and savings, costs, emission reductions, financial viability, and risk for various types of renewable energy and energy-efficient technologies. A grid-connected SPV (solar photovoltaic) system is a two-way grid interconnection technology that generates more solar power than what users need and exports the excess back to the main grid. These systems use sophisticated control equipment so that when the system produces more power than needed, the excess power is fed back into the grid. When the system doesn't produce enough power, then one can get power from the grid. The following steps are involved in the simulation of grid-connected SPV systems.

Step 1 Development of energy model

In energy models, the specifications and technical parameters associated with various components of grid-connected SPV are defined. The characteristics of solar PV module (namely efficiency, model, and so on) and PCU (power conditioning units) are given as input. In order to get standard inputs, the software links the user to product gallery in which all specifications of the modules manufacturing various national and international companies are available. One can select any model or add any new module in the product gallery. Results are calculated in common MWh (megawatt-hour) units for easy comparison of different technologies.

The site conditions associated with estimating the annual energy production of an SPV project requires details as project name and location; nearest location for weather data, annual solar radiation, and average ambient temperature; DC energy demand for months analysed; AC energy demand for months analysed; water demand for months analysed, and so on.

The system characteristics associated with estimating the seasonal energy production of a PV system have to be defined as application type, grid type, PV energy absorption rate, PV system configuration, base case power system, PV water pump, power conditioning, battery, PV array, and so on. Some other system characteristics can be found in the load characteristics section of the SR&SL (solar resource & system load) worksheet.



Step 2 Solar Resource and System Load

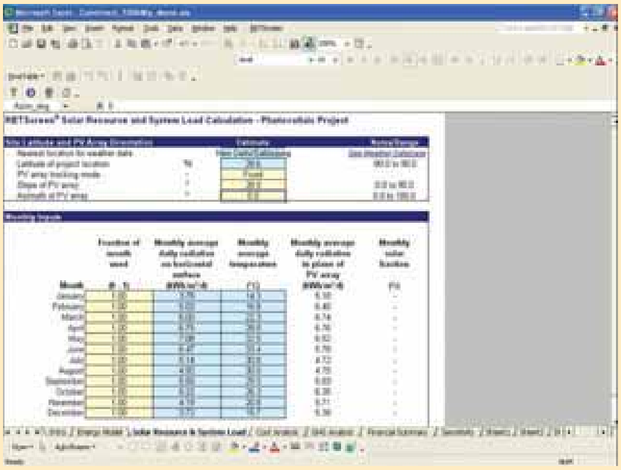
As part of the RETScreen, the SR&SL calculation worksheet is used in conjunction with the Energy Model worksheet to calculate the energy load and energy savings of a PV system. The performance of the SPV system varies with the solar radiation and ambient temperature. Since the solar radiation is site specific, in this worksheet the location parameter (latitude, longitude, and so on) has to be filled. This sheet gives the monthly average daily values of global solar radiation and ambient air temperature on horizontal surface of the respective location. The worksheet gives the facility to estimate solar radiation over inclined and tracking surfaces also. The annual global radiation input obtained from this worksheet is linked with the energy model.

The RETScreen has solar radiation database for various locations around the world. In case if any location is not in the online database, the site provides the link to NASA satellite weather database, in which only the solar radiation and ambient temperature data may be generated providing the latitude and longitude. This is the outstanding feature of this software. The important inputs to be defined in this section are site latitude and PV array orientation, monthly inputs (monthly fraction, and so on), and choice of specific system type under consideration (on-grid or off-grid).

After the completion of Step 2, the annual energy production section of Step 1 gives the renewable energy collected and delivered throughout the selected period at the respective location along with specific yield and overall SPV system efficiency. The technical model comprises only the above two steps. The effect of climatic conditions, operating conditions, efficiency of solar cell used, and other technological parameters on required area of installation of a power plant of specific capacity and renewable energy delivered over the selected period of the year can be evaluated.

Step 3 Cost analysis

The cost analysis worksheet is used to help the user estimate costs associated with an SPV project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The data to be provided in the various sections of the worksheet are mainly type of analysis, currency, cost references, second currency, rate, 1st currency, 2nd currency, % foreign, foreign amount, initial costs, annual costs and periodic costs, and so on.



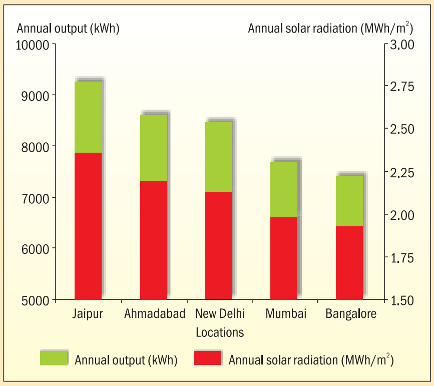
Step 4 GHG analysis

This step provides GHG (greenhouse gas) analysis worksheet to help the user estimate the GHG emission reduction (mitigation) potential of the proposed project. The exercise of emission reduction analysis worksheet contains four main sections: Background Information, Base Case System (Baseline), Proposed Case System (Project), and GHG Emission Reduction Summary. The Background Information section provides project reference information as well as GHG global warming potential factors. The proposed case section provides a description of the emission profile of the proposed project, that is, the SPV project. The GHG Emission Reduction Summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections and from values entered or calculated in the other RETScreen worksheets. The results are calculated as equivalent tonnes of CO_2 avoided annually. The GHG Analysis worksheet of each workbook file has been developed with a common framework so as to simplify the task of the user in analysing the viability of different projects. Hence, the description of each parameter is common for most of the items appearing in the worksheet. One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers.

Step 5 Financial summary

As part of the RETscreen software, a financial summary worksheet is provided for each project evaluated. This common financial analysis worksheet contains six sections: annual energy balance, financial parameters, project costs and savings, financial feasibility, yearly cash flows and cumulative cash flows graph. The annual energy balance and the project costs and savings sections provide a summary of the energy model, cost analysis and GHG analysis worksheets associated with each project studied. In addition to this summary information, the financial feasibility section provides financial indicators of the project analysed, based on the data entered by the user in the financial parameters section. The annual cash flows section allows the user to visualize the stream of pre-tax, after-tax, and the cumulative cash that flows over the project life. The financial summary worksheet of each workbook file has been developed with a common framework so the task of the user in analysing the viability of different project types is made simpler. This also means the description of each parameter is common for most of the items appearing in the worksheet.

Estimating annual electricity generated through a grid-connected SPV of 5-kW capacity using the software



The primary benefit of using the RETscreen software is that it facilitates the project evaluation process for decision-makers. The financial summary worksheet, with its financial parameters input items (for example, avoided cost of energy, discount rate, debt ratio, and so on), and its calculated financial feasibility output items (for example, IRR, simple payback, NPV, and so on), allows the project decision-maker to consider various financial parameters with relative ease. A description of these items, including comments regarding their relevance to the preliminary feasibility analysis, is included below.

Step 6 Sensitivity

As part of the RETScreen software, a sensitivity and risk analysis worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. This standard sensitivity and risk analysis worksheet contains two main sections: sensitivity analysis and risk analysis.

The sensitivity analysis section is intended for general use, while the risk analysis section, intended for users with knowledge of statistics. Both types of analysis are optional and the inputs entered in this worksheet will not affect results in other worksheets.

Article courtesy: Ishan Purohit, TERI

ANSWERS TO QUESTIONS ON SOLAR ENERGY

Solar energy is a promising source of future energy supplies because not only is it clean, but also remarkably abundant. Not only is the potential of solar power enormous, we also already have the technologies to take advantage of it. We can design our homes to take the maximum benefit of solar energy. Solar water heaters can reduce our electricity bills and solar electricity can power our homes, and even our cars. All we have to do is start using it on a wider scale. However, there are many questions in the minds of a consumer who wants to use solar energy in his day-to-day life. This section attempts to answer some such questions, however basic they may be. Dr V V N Kishore, Professor, TERI University fields questions on solar thermal and PV (photovoltaics).

Q1. How do PV systems work?
Akshay Sinha, Ranchi

A1. PV panels operate on the principle of the photoelectric effect. Electromagnetic radiation (solar radiation is part of the electromagnetic spectrum) can be thought of as a bunch of particles called photons, with different energy levels. Semiconductors have a characteristic energy band gap, measured in eV (electron-volts). When the photons have energy levels higher than the band gap, free electrons are released, which then contribute to the electric current. The more the intensity of radiation, the more the number of photons, and hence more the photoelectric current. Concentration of radiation by focusing increases the intensity; hence, more current can be generated by the same panel.

Q2. How can we estimate the potential for solar thermal power? What is the realistic potential of solar power?
Mahendra Sharma, Bhopal

A2. To estimate the potential of solar power generation systems, one should clearly understand the following.

- The nature of the resource, that is, the solar radiation; and
- The mechanisms of converting solar radiation into electricity

Solar radiation has a spectral distribution ranging from about 0.15 μm (micrometre) (ultraviolet) to about 4 μm (near infrared). While solar thermal systems use the entire spectral range, solar PV systems use a narrower range. For example, the spectral sensitivity of amorphous silicon is between 0.4 μm and 0.8 μm. Solar radiation can also be classified as direct and diffuse. The direct component (also called beam radiation) is the one that can be focused by a lens or reflected by a mirror. While a flat-plate collector, which is the main component of a solar water heating system, uses both direct and diffuse components, a concentrating collector can use only the beam radiation. Depending on cloud cover, dust, water vapour, and so on, the hourly diffuse component can vary from about 16.5% to 98% of the total radiation falling on a surface. Hence, solar thermal power plants should be installed in relatively clear-sky locations, typically obtained in desert climates.

The entire Kachchh region and huge tracts of desert land in Rajasthan are ideally suited for solar thermal power in India. Mapping of DNI (direct normal incident) radiation for such regions is a pre-requisite for estimation of potential. The solar radiation, expressed in the units of W/m^2 (watts per square metre) or kWh/m^2 (kilowatt-hour per square metre), is an area-dependant resource. That is, the potential is directly proportional to the area available for installation of solar collectors. The potential for solar power in India is really huge. India has a geographical area of 3.287 million km^2 (square kilometre), out of which 87.5% is used for agriculture, forests, fallow lands, and so on; 6.7% for housing, industry, and so on; and 5.8% is barren, snow-bound, or inaccessible. Thus, only 12.5% land area, amounting to 0.413 million km^2 can, in theory, be used for solar power production.

With an available average solar radiation intensity of 200 MW/km^2, this area corresponds to 82.6 million MW (megawatt) of solar radiation and if one assumes a conversion efficiency of 10%, the installed power would be about 8 million MW. In comparison, the total installed capacity of power plants in India is about 145 000 MW at present.

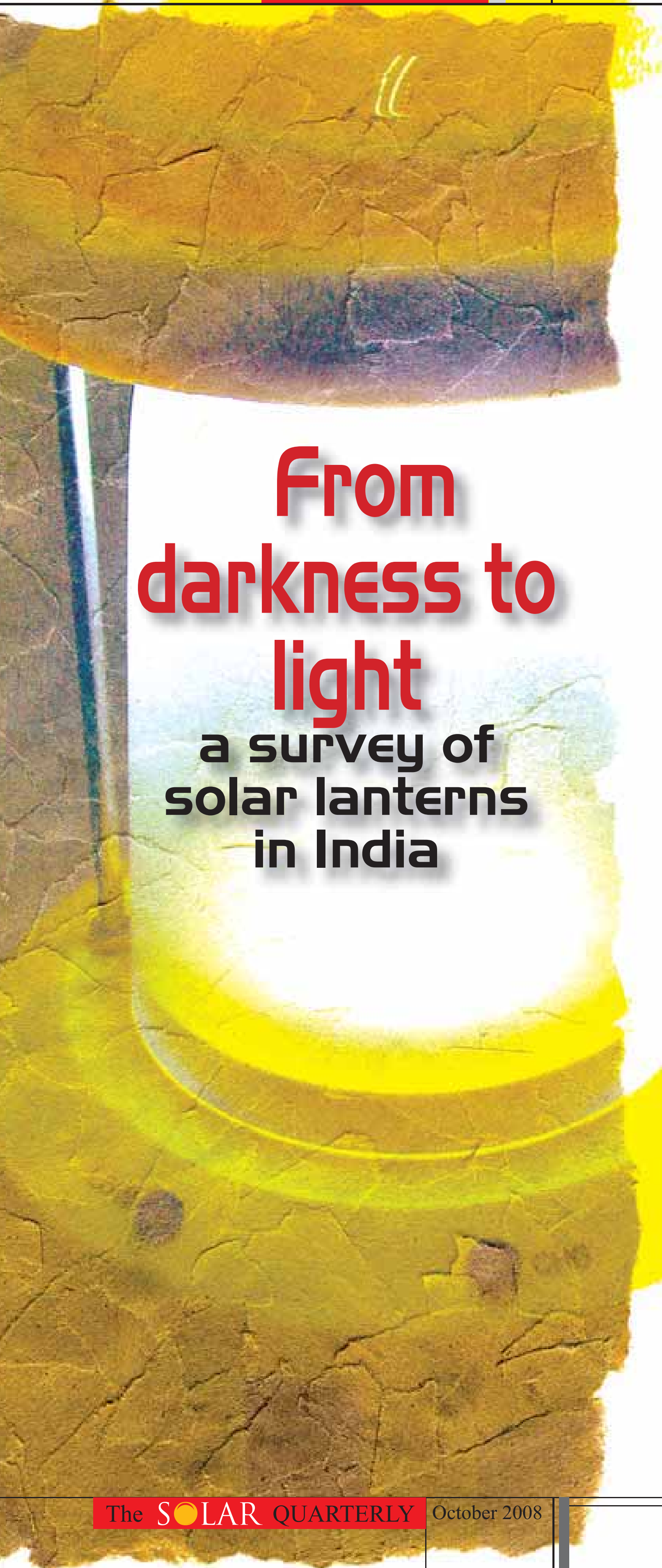
Q3. What is the methodology used to assess solar PV potential in India?
Sahana Vaidyalingam, Chennai

A3. The amount of power produced by a solar PV panel is normally rated as Wp (watt peak), meaning that so many watts are produced under a specified set of conditions such as radiation intensity of 1000 W/m^2 at a cell temperature of 25 °C, and so on. The actual power produced will vary depending on the time and location. An important parameter for potential estimate is the annual energy generated, expressed in the units of kWh/(year) (kWp). The average value for Indian conditions is about 1360, but the exact value has to be obtained for a given location either by field experiments or by simulation methods. Once this number is known, the annual generation can be obtained by the kWp rating of the PV panels installed or proposed to be installed. The area required per kWp depends on the manufacturer, and is generally provided in the panel specifications.

Giving a figure for installed capacity is, however, not straight forward. Coal thermal power plants have a set of parameters such as installed capacity, plant availability, and PLF (plant load factor). The latter two numbers are close to 100% for many modern conventional power plants. The plant availability for a grid-connected PV power plant would be about 30%, and the PLF, defined as 100 × kWh (generated)/(8760 × kWp) would be even lower as the peak power is obtained only for about 2 hours in a day and that too if clear sky conditions exist. The PLF for PV power plants would be about 16%–18%. Thus, one has to specify both kWp and PLF for PV power plants to estimate the potential.

The Solar Quarterly invites readers to send their questions on solar thermal and PV. You may send your queries to:

Ambika Shankar/Smita John Marcus
The Solar Quarterly
E-mail ambika@teri.res.in/smarcus@teri.res.in



From darkness to light

a survey of solar lanterns in India

When in 1847, Thomas Alva Edison discovered the electric light bulb, it would have never occurred to him, that even after 160 years, billions of people across the world would be awaiting access to electricity to switch on the first electric bulb in their lives. Over 1.6 billion people in the world lack access to electricity and about 25% of them are in India alone. Life comes to a complete standstill for these people after dusk. Inadequate lighting is not only a bane to progress and development opportunities, but also has a direct negative impact on the health, environment, and safety of these people who are forced to light their homes with kerosene lamps, dung cakes, firewood, and crop residue after sunset.

In India, about 76 million rural households have no access to electricity. Of this, an estimated 65 million households depend on kerosene for domestic lighting. In essence, each household consumes about 3 litres of kerosene for lighting, bringing the annual consumption of kerosene to 2.4 billion litres. About 100 billion rupees would go up in smoke each year, if one takes the current retail price of kerosene at Rs 46 per litre into account. Adding more to the miseries comes the environmental hazards caused by the emission of 5.9 million tonnes carbon dioxide in the atmosphere per year.

Taking a cue from the grim situation, of late, efforts are on to displace the kerosene and paraffin lanterns with solar lighting devices to provide affordable, reliable, and improved lighting to rural and suburban households. Out of the many solar lighting devices available at one's disposal, solar lanterns have in particular gained more popularity on account of their several benefits. A solar lantern is a portable CFL or LED-based lighting device, which has its own rechargeable battery that can be charged through an SPV system. Due to its simple, reliable, and safe operation, the rural population has easily adapted it, where power supply is quite erratic and scarce. Further, the lanterns can be maintained at minimal cost with its battery replaceable once in every 2–3 years.

Be it a hamlet or a suburb, today, solar lanterns are widely in use for all kind of purposes ranging from household chores to children education to camping and patrolling (streets and farms) to local business activities to a range of other social initiatives like adult education and mass communication, which becomes a challenge after dusk. On the environment front, it has proved to be yet another boon for the society. The fuel used for solar lanterns is solar energy, which is available abundantly in nature and generates no indoor air pollution unlike kerosene lanterns.

In line with the socio-economic and environmental benefits resulting from the use of solar lanterns, the MNRE of the Government of India has implemented many programmes in the past to disseminate SPV systems. Solar lanterns are one of the widely demonstrated SPV systems under the government programme. The ministry started distributing solar lanterns in the early 1990s and even now, it continues to support providing solar lanterns in the unelectrified villages and hamlets of special category states by providing subsidy (central financial assistance) on solar lanterns. As per MNRE, about 70 059 solar lanterns have been distributed in India (as on 31 March 2008).

Despite commendable efforts put in by the MNRE, dissemination of the lanterns under its various programmes is still miniscule when weighed against the potential target of 76 million rural households. Several independent studies also have revealed that there has been limited dissemination of solar lanterns in India under the MNRE programme.

One possible reason could be the fact that other than subsidy support, what is needed is awareness among the general masses about the potential availability as well as the benefits accruing from the lanterns. Lack of public understanding has often been seen to be the key impediment to any social change. This holds true even for the success of solar lantern dissemination in India especially when the market has seen a rise in the number of solar lantern manufacturers in the past few years. *The Solar Quarterly* magazine understands this missing link and has attempted to fill the gap.

The survey

This article collates information on all solar lantern manufacturers in India and put them forward on a common platform to the common people, thus illuminating not only their homes but also their minds.

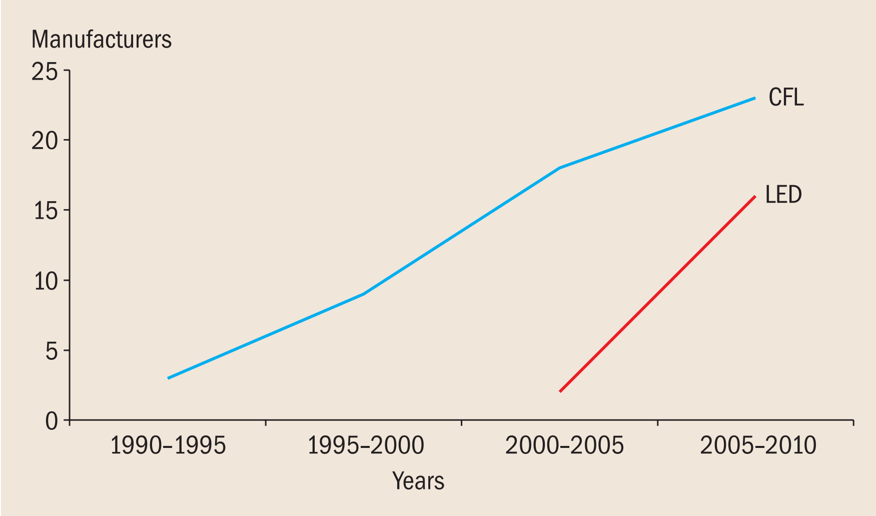
The article provides its readers with a bird's eye view of different models of solar lanterns manufactured in India. For this purpose, a survey was undertaken by TERI, involving 120 solar lantern manufacturers in India, eliciting specific information from them about their lanterns, covering all important and critical aspects of a solar lantern. Survey questionnaires were accordingly prepared and sent out to a list of qualified solar lantern manufacturers by test centres. The list was received from the Solar Energy Centre, a unit of the MNRE for development and promotion of solar energy technologies. TERI's own internal resources were also utilized along with the medium of Internet for identifying the solar lantern manufacturers in India. While doing so, some suppliers might have been missed out inadvertently. In response to the survey conducted, about 20 odd responses were received on 39 solar lantern models. Based on these 20 responses for the time period of 1990–2008, a comprehensive information chart has been prepared on different solar lantern models available in the market. Some preliminary observations have also been made for the benefit of our readers.

To begin with, the survey traces back the steps in history and finds that the solar lanterns have been in the market for the last 18 years with vendors like Geetanjali Solar Enterprises and CEL being among the oldest players. Based on the responses received, the first solar lantern came into the market in the year 1990. And ever since then, the market has continued to show an upward trend. The phase from the 1990s to the 2000s mainly saw the CFL-based lanterns in the market. Subsequently, lightweight LED-based lanterns giving more backups than CFL lanterns but with low illumination output as compared to CFL came into being. Further, it was observed that the market of LED lanterns saw a much steeper rise as compared to the CFL lanterns, which has grown at a rather slow and steady pace over the time span of 18 years.

As regards the type of solar lanterns more popular in the market, it was found that about 58% of the 3.21 lakh (based on average sales per year as reported by the survey) solar lantern models sold in the market were CFL while the remaining 42% LED based lanterns. Here, it is interesting to note that LED based lanterns were introduced in the market in the year 2004. Within a span of 4 years, about 42% of the total lanterns sold was LED based, thus suggesting the market's receptiveness to the LED lanterns.

The 20 odd responses received suggested that the most common type of CFL lanterns available in the market are 7W, 5W and 3W lanterns, of which 73 percent of the 1.85 lakh CFL lanterns sold were 7W CFL lantern; 14% were 3W CFL lantern and the remaining 13% were the 5W CFL lantern model sold in the market so far (Figure 2).

CFL AND LED LANTERN SUPPLIERS BETWEEN 1990 AND 2008



Moreover, 7 W CFL with 12V 7 AH battery was the oldest model in market and also the most successful. These lanterns gave the brightest illumination and runs for around 4 hours but one had to compromise with its heavy weight due to the 12V 7 Ah battery required to run 7W CFLs for 4 hours: As an alternative to the heavy weight lanterns, the year 2000 saw the emergence of low watt CFL based lanterns which were light in weight since they used batteries of less capacity, however due to low watt CFL, the illumination was lesser.

Further, within the 7-W CFL lanterns, there was a range of models available like lanterns with 12-V 10-Wp solar module and 12-V 7-Ah/ 12-V 7.2-Ah/12-V 7.6-Ah batteries. There were also models with 12-V 12-Wp solar module with 12-V 7-Ah/12-V 7.5-Ah batteries and models with solar/ AC mains optional charging. There was also one special model available with dual lighting option (both CFL and LED in the same lantern). The cost of these 7-W CFL lanterns with solar module varied from Rs 2500 to Rs 4350.

The 5-W CFL lanterns also had a variety of models available like lanterns with 6-V 4-Ah battery with 6-V 3-Wp/5-Wp solar module, 12-V 10-Wp solar module with 12-V 7-Ah/12-V 7.6-Ah battery and also models with solar/AC mains optional charging. There was also one special model available with both CFL and LED in the same lantern. The cost of these 5-W CFL lanterns varied from Rs 2000 to Rs 3990.

The survey showed two models with 3-W CFL lanterns having configuration of 6-V 3-Wp solar module and 6-V 4.5-Ah battery, but one was with radio and other without it, from the same vendor. However, the price of these models ranged from Rs 1350 to Rs 1585 depending upon the value-added services available.

In the category of LED lanterns, most of the models were seen with 6-V 4.5-Ah battery with 6-V 5-Wp/ 3-Wp solar module. There were some models with 6-V 4-Ah battery and 6-V 3-Wp/2-Wp solar module and also a few models with 12-V 5-Wp solar module and 12-V 7-Ah/12-V 4.5-Ah batteries. The cost of these LED lanterns ranged from Rs 1340 to Rs 3450 depending on the value-added services available in the lantern. The wattage of LED lanterns was found to vary between 1 W and 3.6 W.

The survey noted that the price of different solar lanterns varied with variation in the battery and capacity of the solar panel used as well as any other value-added services such as mobile charging, dual lighting, and FM radio services.

The illumination of the various solar lanterns addressed in the survey finds that the lumen output of a 7-W CFL lantern varied from 350 to 390 lumens as reported by suppliers. However, it was found to be between 220 and 250 lumens for a 5-W CFL lantern. The lumen output for a 3-W CFL lantern was about 100 lumens. For LED-based lanterns, the lumen output ranged from 80 to 240 lumens depending on the wattage and type of LED used.

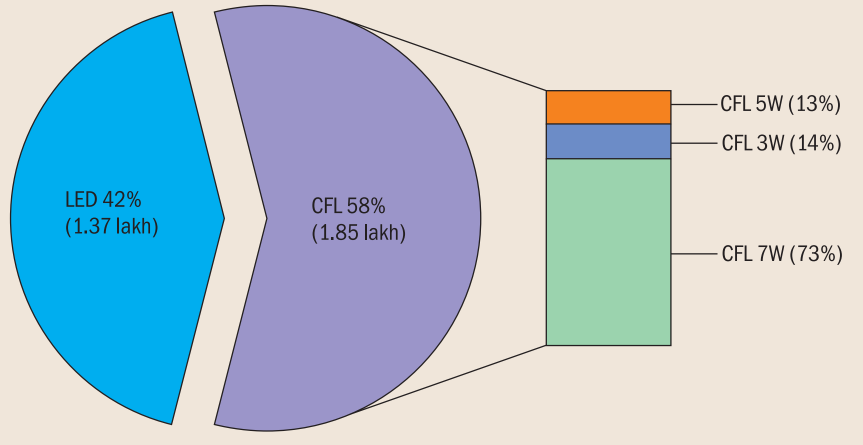
Based on the responses received, it was further observed that the CFL lanterns with 3–4 hours of lighting were the most sold. LED lanterns generally had a capacity of lighting up to 7 hours and it was probably due to this feature that there was a steep rise in the average units sold for the LED lanterns within a span of 4 years.

The survey found an interesting value-added service that got attached to these lanterns recently. It included facilities like mobile charging, dual lighting, and FM radio services. However, the survey results reflected that the lanterns with these value-added services were less sold as compared to simple lanterns presumably because of their high costs.

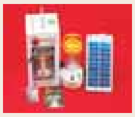
Talking about certification of the lantern models, the survey reflected that out of the 24 CFL lanterns, 18 were certified. While out of the 13 LED lanterns only 1 was found to be certified apparently because MNRE has no specifications for the certification of LED lanterns.

It is worth noting that despite being in the market for the past 18 years and witnessing a steady growth, many manufacturers did not find the product successful enough to take forward. 'We have burnt our fingers over the years. The product is not reliable', said a manufacturer, no longer in business, after incurring losses. No doubt, MNRE has done a remarkable job. But the potential of the market is much greater and still remains largely untapped with 76 million rural households still awaiting access to electricity. The need of the hour is for some concerted efforts both on the part of the government and market players to not only disseminate solar lanterns but also spread awareness among the masses about the benefits. The focus needs to be shifted from mere subsidy support to proper information dissemination support.

ANNUAL DISSEMINATION OF CFL AND LED LANTERNS



CFL LANTERNS (in descending order of CFL wattage)

Lantern Manufacturer	Lantern Model	Photograph	Lantern Housing material	Height of the lantern	Weight of the lantern	Lantern type (CFL/LED)	Wattage of CFL	Lumen output (lumens)	Battery capacity	Duration/hours of lighting
Ritika Systems Pvt. Ltd	IIA		ABS Plastic			CFL	9/7/5 watt	600 to 250	12V, 7Ah	3 to 5 hours
Agni Power & Electronics Pvt Ltd	SLA-7		Plastic Resin (ABS) type	35.56 cm	3.5 kg	CFL	7 watt	357	12V, 7Ah	4 to 5 hours
Arsh Electronics Pvt. Ltd	IIA		ABS and Poly Carbonate	37 cm	3.5 kg	CFL	7 watt	370	12V, 7Ah	4 to 5 hours
Central Electronics Limited	II-A (Base–up)		P.P/ M.S	29 cm	3 kg	CFL	7 watt	370 + 5%	12V, 7Ah	3 to 4 hours
Geetanjali Solar Enterprises	IIA		Plastic	35.56 cm	3.25 kg	CFL	7 watt	370 ± 5%	12V, 7Ah	4 to 5 hours
Info Power Technolgoies Ltd.	SURYADEEP		PVC	35 cm	3.5 kg	CFL	7 watt	370 ± 5%	12V, 7 Ah	4 to 6 hours
Jain irrigation Systems Ltd.	JJL -2		ABS Plastic	33 cm	3.5 kg	CFL	7 watt	360	12V, 7.6 Ah	4 to 6 hours
Maharishi Solar Technology (P) Ltd.	Model 1		ABS Plastic	35.56 cm	3.5 kg	CFL	7 watt	370	12 V, 7.2Ah	6 hours
Noble Energy Solar Technologies Ltd.	127710RM		ABS Plastic	37 cm	3.6 kg	CFL	7 watt	350	12V, 7Ah	3 hours Light & 2 hours Mobile Charging
Noble Energy Solar Technologies Ltd.	122710		ABS Plastic	37 cm	3.6 kg	CFL	7 watt	350	12V, 7Ah	4 hours
Rajasthan Electronics & Instrumentation Limited (REIL)	Model- II A		ABS with Poly carbonate		4.5 kg	CFL	7 watt	370 ± 5%	12 V , 7 Ah	4 hours
M/s. Rashmi Industries	II A		Plastic	33 cm	3.3 kg	CFL	7 watt	370 + 5	12 V, 7 Ah	3 to 4 hours
Sun Energy Systems	2A		ABS Plastic	34 cm	8 kg	CFL	7 watt	352 12Wp, AC: 1 Amp charger	12V, 7.5Ah	5 hours x 2 days

* ex-factory price

Input charging option(sloar, AC, non rechargeable batteries, manual operated	Size of Solar PV panel	Wave shape and frequency of inverter output	Is Lantern certified (yes/no)	Certifying organisation	Market introduction of the model (year)	Price for the Lantern without solar module* (in INR)	Price of the lantern with solar module* (in INR)	Average number of systems sold in a year (Nos)	Additional remarks/other provisions in the lantern
Solar , AC	12V, 10Wp	Near Sine wave	yes	SEC	1995	1,300	3,600.00	15,000	no remarks
Solar	12V, 10Wp	Quasi Sine Wave and frequency as per MNRE spec.	yes	ERTL (East), Kolkatta, W.B	1995	NA	NA		Safety Protection: a) Battery Over charge b) Battery Deep Discharge c) Fuse (output side) d) Reverse current flow blocking (During Charging) 2 Type of Ckts. available (Op-Amp Base or Micro C Controller Base)
Solar , AC	12V, 10Wp	Quasi sine wave and 20–35Khz frequency	yes	MNRE/SEC	1994	1,300	3,300	2,000	Night lamp, mobile charging on optional basis
Solar	16.4 V, 10Wp	Quasi sine wave	yes	CPRI / SEC	1990	1,300	3,900	>50,000	NA
Solar	12V, 10Wp	Quasi sine wave and 33.75 Khz frequency	yes	ERTL	1990	1,600	2,500	4,000	
Solar , AC External Adapter	12 V, 10 Wp	Quasi sine wave and 27 Khz frequency	Yes	ERTL, Kolkata	2005	1,350 (approx.)	3,350 (approx.)	12,000 – 20,000 nos.	Can also be supplied with an in-built Radio & Alarm clock
Solar	12V, 10Wp	Quasi sine wave and 25 Khz frequency	yes	SEC	2004	2,325	4,150	1,000	no remarks
Solar, AC	12 V, 10 Wp		Yes	MNES	2000	1,500	3,600		
Solar	12V, 10Wp	Quasi sine wave and 20–35 Khz frequency	No	NA	2008	2,200	3,700	100	"Radio & Mobile Charging Option"
Solar	12V, 10Wp	Quasi sine wave and 20–35 Khz frequency	yes	MNRE	2000	1,800	3,300	5,000	Extra Duration
Solar	12V,12Wp	Quasi sine wave Inverter	yes	MNRE	1997	1,800	4,300	2,000	no remarks
Solar	12V, 10Wp	Quasi sine wave and 25.31 Khz frequency	yes	C P R I	2004-2005	1,437	3,532	4,733	Nil
Solar, AC	Solar: 12V,	Quasi sine wave	No	NA	2008	1,450	4,200	10,000	

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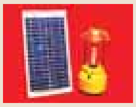
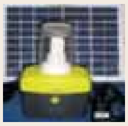
Lantern Manufacturer	Lantern Model	Photograph	Lantern Housing material	Height of the lantern	Weight of the lantern	Lantern type (CFL/LED)	Wattage of CFL	Lumen output (lumens)	Battery capacity	Duration/hours of lighting
TATA BP Solar India Ltd	TATADEEP–MK3		ABS Plastic	34 cm	3.2 kg	CFL	7/5 watt	390 /250	12V, 7Ah	3 to 4 hours/5 hours
Vimal Electronics, Gandhi Nagar	VSL 7710 S		ABS Plastic	35 cm	3.6 kg	CFL	7/5 watt	370/ 230	12V, 7 Ah	3 to 4 hours under SDC
Philips Electronics India Limited	Solar Uday		ABS Plastic	29.5 cm	2.5 kg	CFL	6 watt	250	12V, 5.5Ah	5 hours
Philips Electronics India Limited	Normal		ABS Plastic	29.5 cm	2.5 kg	CFL	6 watt	250	12V, 5.5 Ah	5 hours
Agni Power & Electronics Pvt Ltd	SLA-5		Plastic Resin (ABS) type	35.56 cm	3.5 kg	CFL	5 watt	237	12V, 7Ah	6 to 7 hours (approx.)
Hilite Enterprises	Model 1		Plastic	37 cm	2.9 kg	CFL	5 watt	230 ± 5	12V, 7.6Ah	4 hours
Rajasthan Electronics & Instrumentations Limited(REIL)	II B		ABS with Poly carbonate		4.5 kg	CFL	5 watt	230 ± 5%	12V, 7Ah	4 hours
Solkar Solar Industry Limited	SG-SOL- 010		FRP Plastic	22.6 cm	2.15 kg	CFL	5 watt	220	6V , 4 Ah	3 hours
TATA BP Solar India Ltd	TATADEEP–MK4		ABS Plastic	34 cm	2.5 kg	CFL	5 watt	250	6V, 4Ah	2 hours
Noble Energy Solar Technologies Ltd	6343 JR		ABS Plastic	37 cm	2.6 kg	CFL	3 watt	100	6V, 4.5Ah	4 hours
Noble Energy Solar Technologies Ltd	6343		ABS Plastic	27 cm	2.1 kg	CFL	3 watt	100	6V, 4.5Ah	4 hours

* ex-factory price

Input charging option(sloar, AC, non rechargeable batteries, manual operated	Size of Solar PV panel	Wave shape and frequency of inverter output	Is Lantern certified (yes/no)	Certifying organisation	Market introduction of the model (year)	Price for the Lantern without solar module* (in INR)	Price of the lantern with solar module* (in INR)	Average number of systems sold in a year (Nos)	Additional remarks/other provisions in the lantern
Solar, Mains charging Option	12V, 12Wp/ 12V, 10Wp	Quasi sine wave and 20–35 Khz frequency	yes	CPRI	1998	NA	NA	20,000	no remarks
Solar, AC, Solar+AC combine	12 V, 10 Wp	Quasi sine wave	yes	ERTL / SEC	1998	1,200	3,600	1,000	Optional Mobile Charging & LED night Lamp.
Solar, AC	17.5V, 10Wp/7Wp	Not applicable as the output is for DC lamp	No	NA	2007- Sub Saharan Africa	NA	NA	NA	1) Multiple lantern charging with a bigger panel. 2) 6W DC lamp
AC only	160-270V, 50Hz AC	Not applicable as the output is for DC lamp	No	NA	2007 India	1,499	NA	NA	1) Protection against : overcharge, Auto changeover in power off. 2) Fast Charging circuit. 3) 6W DC lamp
Solar	12V, 10Wp	Quasi sine wave and frequency as per MNRE spec.	Till under certification	ERTL(East), Kolkatta, W.B	2006	NA	NA		Safety Protection : a) Battery Over charge b) Battery Deep Discharge c) Fuse (output side) d) Reverse current flow blocking (During Charging) 2 Type of Ckts available (Op-Amp Base or Micro Controller Base)
Solar, AC	12V, 10Wp	Quasi sine wave	yes	ERTL	2002	1,290	3,990	400-500	FM Radio optional AC model available
Solar	12V, 10Wp	Quasi sine wave	yes	MNRE	1997	1,800	3,800	2,000	no remarks
Solar, AC	6V, 3 Wp	Quasi sine wave and 22Khz frequency	no	NA	2005	1,300	2,000	15,000	a) 3 indications in the light - Low/ Charge/High with beeper when the light is fuly charged b)The product works for 6 hrs from full charge to low charge condition
Solar, Mains charging	6V, 5Wp	Quasi sine wave and 20–35 Hz frequency	yes	ETDC	2003	NA	NA	1,000	no remarks
Solar	6V, 3Wp	Quasi sine wave and 20–35 Khz frequency	no	NA	2004	1,085	1,585	>500	Radio
Solar	6V , 3Wp	Quasi sine wave and 20–35 Khz frequency	yes	ETDC,Fraunhofer ISE tested and PV GAP certification in	2000	900	1,350	25,000	The prices indicated are for certain minimum quantity.

LED LANTERNS (In descending order of LED wattage)

Lantern Manufacturer	Lantern Model	Photograph	Lantern Housing material	Height of the lantern	Weight of the lantern	Lantern type (CFL/LED/ both)	Wattage of LED	Lumen output (lumens)	Battery capacity	Duration/hours of lighting
Arsh Electronics Pvt. Ltd	LED		ABS & Poly Carbonate	24cm	1.2 kg	LED	2.4 watt	230	6V, 4.5Ah	7 to 8 hours
Central Electronics Limited			P.P.	23 cm	1.13 kg	LED	2.7 watt	225	6V, 4.5 Ah	3 to 4 hours
Geetanjali Solar Enterprises			Plastic body	22.86 cm	1.25kg	LED	1 watt		6V, 4 Ah	4 to 5 hours
Hilite Enterprises	Model 2		Plastic	37cm	2 kg	LED	3.5 watt	180	12V-4.5Ah	4 hours
Kwality Photonics Private Limited, Hyderabad	Gramajoti LED Lantern		Plastic body	20 cm	0.4kg	LED	1.2 watt	80~100	3.7V, 2.2Ah Li ion	8 hours
Kwality Photonics Private Limited, Hyderabad	Junior LED lantern kwality		Plastic body	23 cm	1.2 kg	LED	1.2 watt (option 2.4 2.4 watt)	80~100	6V 4Ah~4.5Ah	6 to 8 hours
Kwality Photonics Private Limited, Hyderabad	Jumbo LED lantern kwality		Plastic body	30 cm	3.0 kg	LED	3.6 watt	180~200	12V, 7Ah	8 to 10 hours
Maharishi solar	Model 2		ABS Plastic	22.86 cm	1.2 kg	LED	1.5 watt	120	6V, 4.5 Ah	8 hours
Solkar Solar Industry Limited	SG-SOL-020		FRP Plastic	12.7 cm	1.05 kg	LED	1.5 watt	110	6V, 4 Ah	6 hours
SUN Seven Marketeers Pvt Ltd	ELSPC-01		Polycarbonate and MS body electrostatic painted	27 cm	2.41 kg	LED	1.5 to 2.5 watt	240	6V, 4.5 Ah SMF (VRLA)	8 to 10 hours
SUN Seven Marketeers Pvt Ltd	ELSAC-01		Polycarbonate and MS body electrostatic painted	27 cm	2.41 kg	LED	1.5 to 2.5 watt	240	6V, 4.5 Ah SMF (VRLA)	8 to 10 hours
Suraj Solar System	SL01N		ABS plastic with central MS pipe.	30.5 cm	1.15 kg	LED	1.2 watt	125	6V, 4.5Ah	8 hours daily/ autonomy 24 hours
Vimal Electronics, Gandhi Nagar	VSL 9L		ABS Plastic	23 cm	1.2 kg	LED	2 / 3 watt	100 / 150	6V, 4 Ah	3 to 4 hours

* ex-factory price

Input charging option(sloar, AC, non rechargeable batteries, manual operated	Size of Solar PV panel	Wave shape and frequency of inverter output	Is Lantern certified (yes/no)	Certifying organisation	Market introduction of the model (year)	Price for the Lantern without solar module* (in INR)	Price of the lantern with solar module* (in INR)	Average number of systems sold in a year (Nos)	Additional remarks/other provisions in the lantern
Solar, AC	6V, 5Wp	DC Operated	Under progress	MNRE/SEC	2007	950	2,000	1,000	no remarks
Solar	6V, 3 Wp	NA	No	NA	2007	1,200	2,200	>1,000	NA
Solar	6V, 2Wp	NA	No	NA	2004	600	1,200	250	
Solar	12V, 5Wp	NA	No	NA	2006	1,800	2,800	100	FM Radio provided at extra cost
Solar, AC	6V, 3Wp	NA	There is no MNRE spec. for LED lanterns	NA	2008	800	1,340	50,000 (estimated)	a) Aesthetic b) Highly Portable c) Rugged d) Battery withstands overdischarge
Solar, AC	6V, 3Wp	NA	There is no MNRE spec. for LED lanterns	NA	2006	950	1,490	40,000	a) Very Portable b) Shockproof c) Non-failing light source
Solar, AC	12V, 5Wp	NA	There is no MNRE spec. for LED lanterns	NA	2006	1,500	2,400	20,000	a) Longlife b) Very bright unbreakable Lightsource.
Solar, AC	6V, 3 Wp	NA	No	NA	2005	1,100	1,800		
Solar, AC	6V, 3 Wp	NA	No	NA	2007	1,200	1,900	5,000	a) 3 indications in the light - Low Charge/High with beeper when the light is fully charged b) The product works for 12 hrs from full charge to low charge condition
Solar, A C	9V, 3Wp	NA	In the process of certifications	ETDC, Hyderabad	2008	1,800	2,350	5,000	a) FM radio stereo b) mobile cell phone charger.
Solar, A C	9V, 3Wp	NA	In the process of certifications	ETDC, Hyderabad	2008	2,900	3,450	15,000	a) FM radio stereo output b) Mobile cell phone charger and 1 GB audio flash memory chip with preloaded music and message, which can be retrieved and played back through built in amplifier 3 watts output.
Solar with optional AC	6V, 2 Wp	NA	Yes(by the name of OEM)	ERTL, East	2005	1,250	1,650	8,000	a) Light intensity control. b) Electronic feather touch switch. c) In built mobile charger. d) Low voltage warning and cutoff
Solar, AC, Solar + AC combine	6V, 3 Wp	NA	No	NA	2008	900	2,400	Recently started	No remarks

CFL/LED LANTERNS

Lantern Manufacturer	Lantern Model	Photograph	Lantern Housing material	Height of the lantern	Weight of the lantern	Lantern type (CFL/LED)	Wattage of CFL/LED	Lumen output (lumens)	Battery capacity	Duration/hours of lighting
Jain irrigation Systems Ltd	JJL -2 with LEDs		ABS Plastic	33 cm	3.5 kg	CFL/LED	CFL-7 watt, LED-1.5watt	360	12V,7.6Ah	4 to 5 hours for CFL & 6 to 6 hours for LED
Ritika Systems Pvt. Ltd			ABS			CFL/LED	CFL- 3/5 watt, LED- 0.75 to 3 watt	CFL- 150 to 250 Lumens, LED- 40 to 160Lumens	6V, 4.5 Ah	1 to 8 hours

* ex-factory price

INDUSTRY REGISTRY

MODULES

Sunflower (Sunowe) PV
Contact
San Jiang Road 321071
Shaoxing , China
Tel. +43/150/54850, *Fax* 54860
E-mail sunowe@aon.at
Web www.sunowe.com

Suntech Power Holdings Co., Ltd.
Suntech (NYSE: STP) is a world-leading solar energy company measured by both production output and capacity of high-quality solar cells and modules. Suntech's majority-owned subsidiary, MSK Corp., is one of the top-ranked companies in BIPV in Japan. Suntech's customers are located in various markets worldwide.
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New District Wuxi Jiangsu Province
China – 214 028
Tel. +86/510/8531 8000, *Fax* 8534 3321
E-mail sales@suntech-power.com
Web www.suntech-power.com

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Winfat Global Crossing Ltd
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E-mail marketing@wgc.com.hk
Web www.wgc.com.hk

Yocasol Inc.
Japanese manufacturer of PV modules with excellent quality, certified with IEC61215 and safety class II.
Contact
1-5 Shikashinmachi Omuta City, Fukuoka
837-0907, Japan
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E-mail info@yocasol.com
Web www.yocasol.com

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High quality and performance PV modules from 5W to 220W
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Web www.alex-solar.com

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E-mail solar@era.com.cn, eddie@era.com.cn
Web www.erasolartech.com.cn

Universal Energy
European manufacturer of high-performance PV modules; all products IEC 61215 ed. 2 and IEC 61730 certified, CE mark
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Jiangsu Province – China
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Input charging option(sloar, AC, non rechargeable batteries, manual operated	Size of Solar PV panel	Wave shape and frequency of inverter output	Is Lantern certified (yes/no)	Certifying organisation	Market introduction of the model (year)	Price for the Lantern without solar module* (in INR)	Price of the lantern with solar module* (in INR)	Average number of systems sold in a year (Nos)	Additional remarks/other provisions in the lantern
Solar	12V, 10Wp	Quasi sine wave and 25Khz frequency	no	NA	2004	2,525	4,350	425	
Solar/AC	6V, 3Wp to 5Wp	Near Sine Wave	yes	SEC	2005	1,000	2,400	5,000 approx.	no remarks

Article courtesy: Varun Gaur and Smita John Marcus, TERI

Contact
Via Milano, 7 CH-6830 Chiasso, Switzerland
Tel. +41/91/695 4060, *Fax* 695 4070
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E-mail solartec@solartec.cz
Web www.solartec.cz

Polar Photovoltaics Co., Ltd
The company manufactures large area thin-film solar modules (a-Si solar modules, single junction, tandem junction and semi-transparent).
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Web www.eging.cn

Q-Cells AG
The core business of Q-Cells AG is the development, production and sale of high-performance solar cells made of mono- and multicrystalline silicon.
Contact
Guardianstr. 16, OT Thalheim 06766 Bitterfeld-Wolfen, Germany
Tel. +49/3494/6699-0, *Fax* 199
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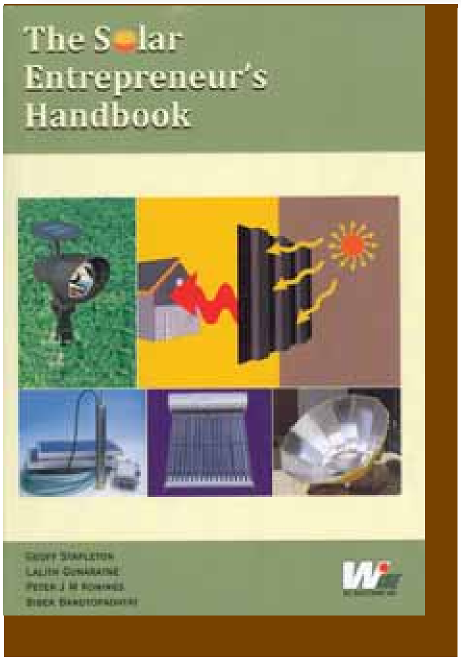
E-mail bernhard.koll@kuraray.eu

The Solar Entrepreneur's Handbook

Stapleton G, Gunaratne L, Konings P J M, Bandyopadhyay B. 2007
World Institute of Sustainable Energy, India and Global Sustainable Energy Solutions, Australia. 259 pp.
ISBN: 81-902925-1-X
Price: Rs 675



The Solar Entrepreneur's Handbook lives up to its title—it is indeed a handbook and it is for the entrepreneur. At a time when news books about renewable energy deal not so much with the nuts and bolts of the technology as with what renewable energy can do to mitigate climate change and how it can contribute to a country's energy security, here is a book that says 'At 10 p.m., it is not important how many solar modules you have on your roof; if the battery is not sized to meet your requirements, you could have a flat battery and therefore no power for your lights and TV.' The book then goes on to explain that although the battery that lies at the heart of the solar system looks like an ordinary car battery, it is different on the inside: 'the battery plates are generally thicker that those of a car battery and the concentration or density of acid is different'.

The handbook is written by practitioners for practitioners: 16 of the 17 chapters are written by those who at one time or the other earned their living either from selling, installing, and maintaining small-scale solar energy systems or training others to do the same. And this field experience – hard-earned not only in Europe and Australia but in Asia and Africa – shines through all their writing. In recommending that customers clean the face of the solar module with a damp cloth every six months (more frequently if very dusty), the authors add that the task is best done early in the morning before the module, the frame, the roof (if metal) become too hot. In the section on tools and equipment, the authors list not only such obvious items as screwdrivers and spanners but also the less obvious: 'A ladder could also be a necessary item. This is required when mounting modules on roofs where there is no easy way to gain access to the roof without a ladder.'

However, technical competence alone does not guarantee success in a business. Indeed, entrepreneurs can buy such competence in the marketplace: to succeed in business, they need a business plan, capital, people-skills or soft skills, and the drive to expand the business. The Solar Entrepreneur's Handbook takes its readers through all the steps between establishing a solar home systems business to after-sale service and growing the business (see the titles of chapters 6 to 16). As Prof. Chaman Lal Gupta puts it in his Foreword, the book, 'written by seasoned entrepreneurs . . . contains not only a straightforward, hands-on sizing and equipment selection procedure but also valuable tips for social marketing.'

Throughout the book are provided helpful checklists, sample pages from logbooks, a detailed troubleshooting flow chart, worked-out examples, case studies, tables, and figures. The last chapter, titled 'Further learning', includes a short bibliography, websites, training programmes, and relevant industry associations.

The dozens of minutiae that are part of any technical trade are offset by the first chapter, which offers a concise overview of developments in solar energy technology in India, up to date enough to mention LED-based solar photovoltaic lighting systems and the forthcoming revised edition of the Handbook of Solar Radiation that takes into account the data collected between 1986 and 2000.

The preface claims that the book 'brings together all the skills required to run a successful solar business in either a rural area or in a city'—a claim that will be hard to contest.

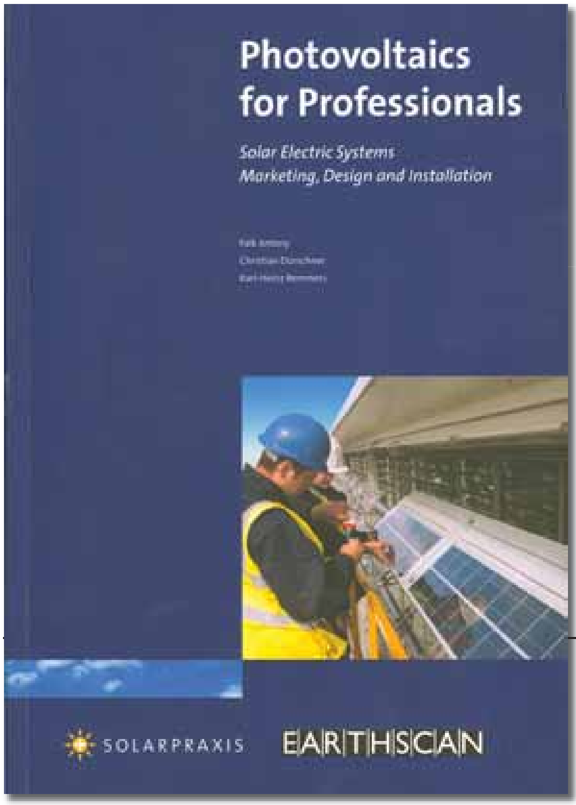
Reviewed by
Yateendra Joshi, WISE

CONTENTS

About the contributors
Foreword by Chaman Lal Gupta
Preface
Acknowledgements
1 Solar energy technology development in India
2 How solar energy can provide service in rural areas
3 Basic design principles for solar home systems and the relationship with the customer
4 System wiring, planning an installation and installation of the system
5 System maintenance, fault-finding, and troubleshooting guide
6 Providing small solar home systems: start of a business
7 What do I need to establish a business?
8 Developing a business plan
9 Building relationships with suppliers
10 Where and how do I raise finance?
11 Day-to-day operations of a business
12 Marketing of solar home systems
13 Sales skills and selling solar home systems
14 Simple negotiating skills
15 After-the-sale customer service: keeping the customer happy
16 Growing your business
17 Further learning

New Book Information

Photovoltaics for Professionals: solar electric systems marketing, design, and installation



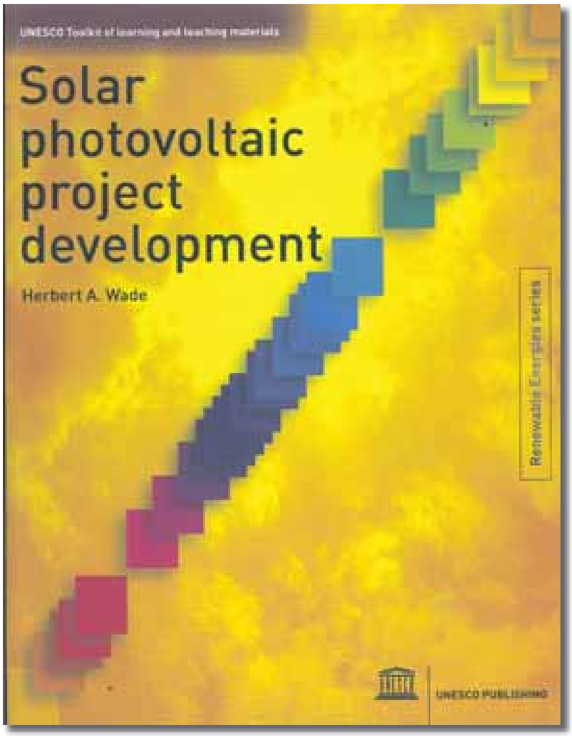
This book describes the practicalities of marketing, design, and installing photovoltaic systems, both grid-tied and standalone. It has been written for electricians, technicians, builders, architects, and building engineers who want to get involved in this expanding industry. It answers all the beginner's questions and serves as a textbook and work of reference, provides designers and installers with the practical specialist knowledge needed to design and install high-quality solar electric systems, and gives a comprehensive overview of major photovoltaic market sectors.

Antony F, Dürshchner C, and Remmers K H. 2007
London: Earthscan. 215 pp.
ISBN: 978-1-84407-461-7
Price: £49.49

Solar photovoltaic project development

This book is primarily intended as a teaching aid to support its companion volume, the Technical Training Manual, which contains detailed text and graphics, as well as discussion of wider issues relating to project development for solar photovoltaic systems. The overall goal is to provide comprehensive training material on installation, operation, monitoring and evaluation, management, maintenance, and rehabilitation of PV systems, as well as information on awareness raising, advocacy, innovation, policy and planning.

Wade H A. 2003
France: UNESCO Publishing
Website www.unesco.org/publishing
ISBN 92-3-103903-2



Events calendar

National events

India Energy Conference 2008
Oil, Gas, and Alternatives: building competitive markets
3–4 October 2008, New Delhi, India

Garima Jain
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110003 / India
Tel. + 91 11 4150 4900
Fax +91 11 2468 2144
E-mail garimaj@teri.res.in
Web www.teriin.org

Green Energy Summit 2008
16–19 October 2008, Bangalore, India

Saltmarch Media
Tel. +91 99015 08099
E-mail info@greenenergysummit.com
Web www.greenenergysummit.com

ICORE 2008
16–17 October 2008, Chennai, India

SESI (Solar Energy Society of India), A-14, Mohan Cooperative Industrial, Estate, Mathura Road
New Delhi – 110 044
Tel. +91 11 6564 9864, 2695 9759
Fax +91 11 2695 9759
E-mail info@sesi.in
Web www.sesi.in

Solar Industry Conference 2008
23–24 October 2008, Madrid, Spain

Tel. 49 30 7262 9630–2
Fax 49 30 7262 9630–9
E-mail julia.krohn@solarpraxis.de
Web www.solarpraxis.de

Third Renewable Energy Finance Forum
20–21 November 2008, Mumbai, India

E-mail webmaster@euromoneyenergy.com
sponsorship@euromoneyenergy.com

Renewable Energy Asia 2008
11–13 December 2008, New Delhi, India

Tel. 91 11 2659 6351
Fax 91 11 2659 1121
E-mail rea2008@gmail.com
Web web.iitd.ac.in/~rea2008

18th International Photovoltaic Science & Engineering Conference & Exhibition
19–23 January 2009, Kolkata, India

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Fax 91 33 2473 2805
E-mail info_pvsec18@iacs.res.in
Web www.pvsec18.in

Biofuels in India: setting new paradigms
4–5 March 2009, New Delhi

Arvind Reddy
Winrock International India
788, Udyog Vihar, Phase V
Gurgaon, Haryana – 122 001
Tel. +91 124 430 3868/66
Fax +91 124 430 3862
E-mail arvind@winrockindia.org
Web www.winrockindia.org

Third Renewable Energy India 2009 Expo
12–19 August 2009, New Delhi

New Delhi (Head Office)
Exhibitions India Pvt. Ltd
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Okhla Industrial Estate, Phase III
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Fax +91 11 4279 5098/99
Rajneesh Khattar, General Manager
Mob +91 98717 26762
E-mail rajneeshk@eigroup.in

International events

10th Renewable Energy Finance Forum
15–16 September 2008, London

E-mail www.euromoneyenergy.com

Bioenergy 2008
23–24 September 2008, Oxford, UK

E-mail www.r-p-a.org.uk

BiomassWorld 2008
23–24 September 2008, Beijing, China

E-mail www.cmtevents.com/eventschedule.aspx?id=499&ev=080950&

Photovoltaic 2008
20–23 November 2008, Athens, Greece

Tel. 30 210 6141164
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PHOTON's 7th Solar Silicon Conference
3 March 2009, Munich, Germany

Tel. 49 241 4003 102
Fax 49 241 4003 302
E-mail petra.boehne@photon.de
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Solar 2009
8–14 May 2009, Buffalo, New York, USA

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ISSN 0974 – 5696