The Complete Solar Magazine

The SOLAR QUARTERLY

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HARNESSING THE POWER OF THE SUN

The development of megawatt-capacity solar power plants

SERVING FROM THE FRONT

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EVALUATING RENEWABLE ENERGY PROJECTS

A review of RETScreen Software

COLD STORAGE GOES SOLAR

Battery-less solar PV refrigerator

teri

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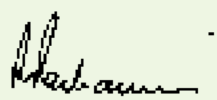
Message from the chief patron

The Solar Quarterly is being launched at a particularly opportune moment. Oil prices are at an all time high, reaching the unprecedented level of $146 per barrel, with prospects of further increases in the coming months. Research and development on renewable sources of energy, have languished and, in fact, declined since 1985 when oil prices plummeted sharply. The current situation now requires a major thrust on 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, which would help to increase the share of this source of energy across the globe. *The Solar Quarterly* being launched by TERI would fill up the gap and provide current knowledge on this critically important field of solar energy for the benefit of researchers, academics, business leaders as well as policy-makers. This publication will not be based on theory. It would lay appropriate emphasis on applications, deriving knowledge from actual projects and applications, which would provide real world experience and insights.

The magazine would consist 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 on equipment using solar energy. Technology demonstration based efforts to implement large-scale solar projects would also find due place in the magazine. As with any new publication, the personality of *The Solar Quarterly* will also undergo change based on the comments and feedback that would be 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 the use of solar energy at least in this part of the world.

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



R K Pachauri
Director-General, TERI

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Time has come to believe in solar. The sun is warming up. The solar market is growing at an annual rate of 254% since 2004, according to a report released recently. The market attracted investments worth $28.6 billion last year. Among various applications of solar, grid-connected solar PV (photovoltaic) has been the fastest growing energy technology in the world, with 50% annual growth in cumulative installed capacity in 2006 and 2007. Majority of this capacity is contributed by about 1.5 million homes across Germany, Japan, Spain, and the US, which have installed small PV systems (few kilowatts to tens of kilowatts) on their rooftops, feeding electricity into the grid through two-way meters and enjoying the benefits of net-metered electricity bills at the end of the month. BIPV (building integrated PV), wherein aesthetically designed PV panels double up as electricity generators as well as building facades, tiles and walls, by replacing the building material, have begun to get noticed by the architects and builders. Similarly, mandates to incorporate solar hot water systems into new construction represent a strong and growing trend at both national and local levels. About 50 million homes worldwide enjoy hot water from their rooftop collectors.

Rooftop solar PV systems (as well as thermal) have a potential to be a viable demand-side-management option for Indian cities. For instance, 1-kWp capacity SPV (solar photovoltaic) installed on 1000 roofs in any city will offer 1 MW market to the industry. This in turn, would help in meeting the green obligations of the utility and incentivize the roof owner to reduce his monthly electricity bill through net metering of electricity. The recently announced generation-incentive-based policy of the MNRE (Ministry of New Renewable Energy) for 1-MW plus capacity grid-connected SPV and solar thermal power plants will encourage private sector investment in this sector. At the same time, SPV will continue to find relevance in decentralized off-grid markets for providing clean and efficient electricity services in domestic, telecommunications, water pumping, and other markets. The National Solar Mission, while setting physical targets for both PV and thermal systems, emphasises on R&D, international collaboration on technology development, strengthening of domestic manufacturing capacity, and increased government funding and international support.

With the sun getting warmer, time has come to dedicate an exclusive magazine to solar. *The Solar Quarterly*, a first-of-its-kind magazine in India, sets for itself a vision that is in sync with the national mission on solar. At the same time, it will keep a tab on what is happening elsewhere. The magazine, in times to come, will be known for its well-researched original articles on industry trends, policy announcements, programme implementation, and R&D status. In addition, it will provide a channel for introducing new products, research updates from universities and academic institutions, book reviews, self-learning corner as well as unspoken and unheard stories from the rich experiences of NGOs, and local- and state-level institutions engaged in disseminating information on solar energy in the country.

The first issue of *The Solar Quarterly* is in your hands. Looking forward to your patronage.

Akanksha Chaurey
Director, TERI

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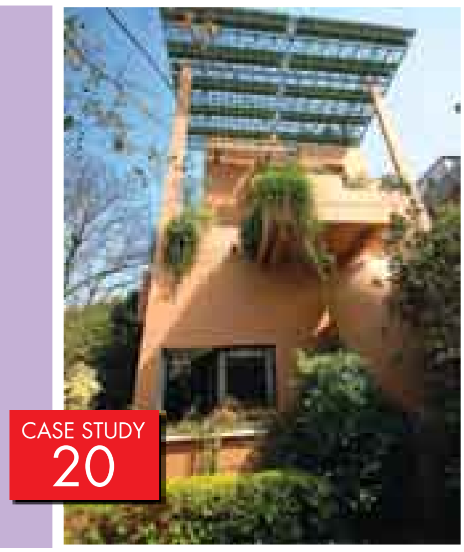


National

Lighting a Billion Lives initiative: TERI leads the way

About 1.6 billion people across the world are still living without electricity. Out of these, about 25% live in India alone. They use kerosene oil lamps, dung cakes, firewood, and crop residues for lighting purpose, which results in health, environment, and safety risks. In this backdrop, TERI (The Energy and Resources Institute) has undertaken an initiative called LaBL (Lighting a Billion Lives), which makes the use of solar lighting devices. The aim is to give a better life to people in Indian villages, both through lighting and lighting-induced entrepreneurship opportunities. Nearly 200 million solar lanterns are required to replace the traditionally used lighting devices. The TERI-run campaign makes use of both CFLs (compact fluorescent lamps) and LEDs (light-emitting diodes) to meet the lighting needs on a day-to-day basis. LaBL is a unique initiative that forges partnership with several agencies such as local government units, NGOs, grass-roots workers, and more importantly, donors comprising corporate entities.

Solar power showing the nerve of steel

Clear Skies has announced a $20-million agreement with Power Cube, a company based in Uttar Pradesh. The objective is to develop and construct the first of several solar energy projects in India through mutual support. The company will design and construct a multi-megawatt PV (photovoltaic) power system to supply power to a steel mill and thus support the local grid system as well.

Indo-China deal: wafer thin

MBPV (Moser Baer Photovoltaics Ltd) has signed an agreement with China-based LDK Solar for the sale and delivery of multi-crystalline silicon wafers over a 10-year period beginning middle of 2008 through to 2017. LDK will deliver these wafers to MBPV for production of solar cells having capacity equivalent to about 640 MW. The 10-year contract is based on a blend of take-or-pay and market-linked pricing mechanisms.

Use of solar water heaters on the rise

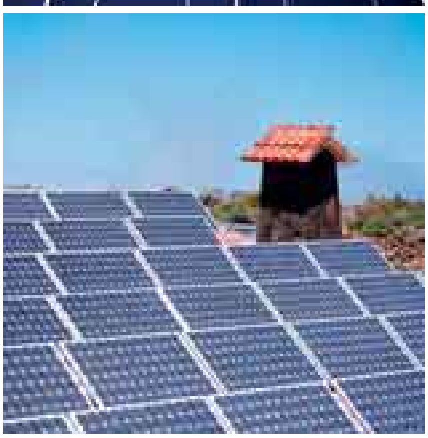
Solar water heating systems still have a very small market share in the country. This is despite the fact that these have a zero running cost and small payback periods. There is a huge requirement of hot water in canteens, for de-greasing in various industries, and so on. The payback period could be as low as three years if the solar heater is used throughout a year. Merolin TermoSanitari is an Italian company, the subsidiary company of which has a share of about 25% in the Indian solar water heater market. It makes electrical, gas-based, and solar-power-based water-heating systems. It is a deviation from the industry scenario in 1990s. That is, when the fly-by night operators set up facilities for the production of solar water heaters and solar cookers—the prime reason being the huge subsidies available from the government. Today, this sector is largely organized, but there is still a long way to go.

Sun in the air: a cool feeling

Aquacell Technologies, believed to be the lone holder of a patent for the production of solar PV-based air conditioners, has recently installed an air conditioning unit at the Mumbai facility of Reliance Industries Ltd. The company has already begun the process of business discussions with some of the major PV companies in India for market delivery of its PV air conditioners. The air conditioner provides grid-free climate control, making use of just two panels. It combines the most efficient PV technology with DC air conditioning engineering capabilities so as to provide reliable systems. Aquacell AC can cool an area of about 600 square feet.

Solar cells gaining popularity

The production of PV cells in the country is expected to boom with the MNRE (Ministry of New and Renewable Energy) declaring a preferential tariff for grid-interactive solar power projects. Currently, there is a growing interest from the IT (information technology) companies to set up PV cell manufacturing facilities. For example, Jupiter Technologies, a maker of Frontech brand of PC monitors, has tied up with Centrotherm of GmbH (Germany) to produce PV cells with a capacity of about 300 MW.



Utilizing the power of the sun

MBPV has showcased a 1.2-kWp (kilowatt-peak) capacity PV array at the SEC (Solar Energy Centre) in Gual Pahari, Haryana. This array uses high-concentration solar panels, which concentrate solar radiation equivalent to about 500 suns on the cell surface. A direct gain is the use of very small cell areas, thus leading to vast savings of an otherwise expensive PV silicon material. The SEC is expected to test such an array in terms of several important parameters including power being produced under actual field operating conditions.

International

3000-MW solar power by 2017 in California

California has set up a very ambitious goal of producing 3000 MW of solar power by 2017 and has earmarked a whopping sum of $3.3 billion for the purpose. Those interested in taking advantage of these incentives can simply approach a company known as SUNGEVITY. It has set up an interesting online option for the existing home owners by streamlining the site analysis process. Once a potential customer logs in simple details like street number and mail-ID, the company generates a quote for installing a solar PV system. This takes into account the complete perspective of the incentive-based scheme.

Crystalline silicon market grows

The crystalline silicon market grew at a rate of about 39%, according to the latest available figures from Gartner Inc. The demand for solar silicon consumption is expected to exceed the electronic-grade silicon demand for the first time during this year. Q-Cells occupied the first place for the first time, pushing back the established Japanese manufacturers, who struggled to secure the polysilicon supplies. Q-Cells grabbed the market share of 17.2% of the total market, with 70% more revenue collection in comparison to the figure in 2006. However, the fastest growing company was Suntech Power. Its revenue increased by about 98.3% in 2007. At present, five major producers of crystalline silicon cells are Q-Cells, Sharp (with a market share of 15.3%), Suntech Power (14.1%), Kyocera (7.3%), and Deutsche cells (6.0%) apart from others (40.1%). In 2007, the total revenue from the shipment of crystalline silicon solar cells was $6652 million as compared to $4796 million in 2006, thus, registering a net increase of about 38.7%.

NREL: thinning out the efficiency difference

The US NREL (National Renewable Energy Laboratory) has created thin-film solar panels, which are very close to the more traditional crystalline silicon-based panels in terms of efficiency. The CIGS (copper indium gallium di-selenide) thin-film solar cells reached an efficiency of about 19.9% under laboratory conditions—a new record of sorts. This value is quite close to the recorded efficiency of 20.3% for a multi-crystalline silicon panel.

Markets for concentrated solar power to increase

Greentech Media and Prometheus Institute believe that CST (concentrated solar thermal) and CPV (concentrated photovoltaic) could become a $200-billion market within the

The PV array at the SEC uses high-concentration solar panels next 10–12 years, that is, by 2020. During the last six months, various plans have been announced for concentrator solar power, which is in excess of about $30 billion.

Going the solar way

Shortage of polysilicon is not only limiting the potential growth of the PV industry but also impacting the manufacturing costs. Companies have to pay 10%–20% of the total contract cost upfront to the polysilicon suppliers—all this to secure supplies of polysilicon for various programmes. A possible way is to use thin-film modules in greater numbers. Thin-film modules are expected to occupy about 20% of the total market share by 2010. The global revenue of PV cells is expected to increase by as much as $22.1 billion in 2012, up from $9.6 billion in 2007. As per available estimates, by 2020, about 50 000 MW worth of PV systems (MWp) will be installed annually.

Dye-sensitized cells show improved efficiency

According to the University of Washington, there has been a significant improvement in the efficiency rates of dye-sensitized cells. These have an ability to manipulate light and more than double the efficiency of cells. The dye-sensitized cells were invented by Michael Gratzel and Brian way back in 1991. However, they are still half as efficient as the crystalline silicon-based cells, which makes them less attractive for a large number of market applications.

EPA releases survey report

The Solar EPA (Electric Power Association) has just released a new report based on a national survey of the electric utility and current problems related to grid-connected PV installation. The survey was conceived and carried out by the EPA in association with the Inter State Renewable Energy Council. In all, 63 US utilities representing a cross-section of the utilities participated in the survey.

A novel way of storing solar thermal energy

Questions have always been raised on storing solar power for use at night. Batteries are not well equipped to store energy on a large scale for a variety of reasons. A new technique of storing solar thermal energy is doing the rounds in Spain. It is a power tower, similar to a water tank on stilts, surrounded by hundreds of mirrors, which tilt on two axes. One is to follow the sun across the sky in the course of day, while the other in the course of a year. There are tens of thousands of gallons of molten salt in the tower and in a tank below. These can be heated to very high temperatures and still not reach high pressures. This type of tower design seems to be suitable for high latitudes or places that receive less solar energy. Presently, a power house based on this design is taking shape at Seville, Spain, which can light up to 6000 homes.

IBM introduces giant PV magnifying glass

IBM has found a way of increasing the amount of thermal energy that can be concentrated onto PV cells during the CPV process. Using a large lens to concentrate the sun's power onto a 1-cm^2 cell, IBM reports that it is able to capture a record 230 W (watts) of energy. The energy is converted into 70 W of electrical power—five times

IBM has come up with a way of increasing the amount of thermal energy that can be concentrated onto photovoltaic cells the electrical power density generated by typical cells that use CPV technology in solar farms. If successfully transferred from the lab to real life, this magnifying glass, IBM believes, can significantly reduce the cost of a typical CPV-based system, as fewer components would be needed. The company says it can cut the number of PV cells and other components by a factor of 10.

Solar-powered football team

PV modules manufacturer Trina Solar has entered into a sponsorship agreement with the Spanish Premier League football team Real Club Deportivo Espanyol de Barcelona. Under the agreement, Trina Solar will supply Espanyol with 500 kW of PV modules for the rooftop PV installation in the club's new stadium. Trina Solar will also feature as the official sponsor on the back of the team's shirts for the next three seasons.

New Mexico utilities cooperate on CSP

Four major utility companies in New Mexico have issued a joint request for proposals from solar developers for the construction of a solar parabolic trough generation facility to provide solar electricity to each utility by 2012. El Paso Electric, Xcel Energy, PNM, and Tri-State Generation and Transmission Association have outlined several requirements that need to be met. These include that the location must be in New Mexico, parabolic trough technology must be used, and the utilization of thermal energy storage should be encouraged. Finally, the facility must be able to deliver between 211 000 MWh and 375 000 MWh of power per year.

Fraunhofer wins award for silicon cells

Researchers at Fraunhofer ISE have won the Eni Award 2008 for their research into new cell structures and metallization concepts for thin silicon wafers. A research team headed by Dr Stefan Glunz received the award for having produced what is said to be a world record efficiency of 20.3% for multicrystalline silicon solar cells, a thin-film monocrystalline silicon solar cell with a thickness of 40 micrometre and an efficiency of over 20%, as well as a non-contact metallization process using aerosol printing. Another contributing factor that helped Fraunhofer clinch the award is its close cooperation with the PV industry. The innovations are currently being transferred to industries for mass production.

Toronto installs solar-powered swimming pools

The largest city in Canada will heat seven of its swimming pools with the largest municipally owned solar thermal installations in the country. Toronto will install 312 m^2 of collectors on the Jimmie Simpson recreation centre, which will be the largest solar pool heating system in Canada. There are two pools at this location, each serviced by its own system, and the smaller solar system covers an area of 94 m^2. Scarborough Centennial recreation centre will install 250 m^2 and the Agincourt recreation centre will install 241 m^2. The costs of the solar heating systems were covered by the city's Energy Retrofit Program, with the Toronto Atmospheric Fund contributing $52 786 and the federal government providing $26 031.

Australian state funds cheaper solar cells

Four research projects in Victoria will receive Aus $8 million, with one project designed to develop new solar cells. Funding worth $6 million will go to the Organic Solar Consortium to research the next generation of large, non-silicon, flexible, and cheap organic solar cells. That is half of the cost for a project headed by the University of Melbourne to develop and increase the efficiency of organic solar cells as an alternative to silicon-based cells in the generation of solar power. The project could lead to the establishment of a centre of excellence in research in Victoria. Partners in the research include Monash University, CSIRO, Securency (including Innovia Films), BP Solar, Merck, Bluescope Steel, and NonoVic. The research on organic solar cells is above other investments in solar energy such as the $420 million Solar System's 154-MW photovoltaic power station in Northern Victoria. ■

Special incentive package

a boost for semiconductor industry

Background

The semiconductor industry in India has just received a shot in the arm with the announcement of a policy called 'special incentive package for semiconductors'. India is emerging as one of the largest electronics markets in the world, with an estimated global market share of 11% by 2015. Few key elements of this policy have an impact on the solar PV (photovoltaic) industry as well. These elements are as follows.

- The threshold NPV investment shall be taken as NPV investment made during the first 10 years of project life, and discount rate would be at 9%.
- The state government incentive can be over and above the above-mentioned incentive.
- The period of 10 years shall imply the first 10 years of the project life from the start of the project and not with regard to the start of any subsequent phase.
- The incentive will be available for manufacturing all types of semiconductor devices, including those based on solar PV.
- A key benefit is the grant of SEZ status for such a type of manufacturing unit.

India is emerging as one of the largest electronics markets in the world

Table 1

Benefits of the special incentive package

Unit type	Threshold NPV of investment (in million rupees)	Incentive in SEZ category	Incentive in non-SEZ category
Fab unit	25 000	25%	25% (plus exemption from CVD)
Ecosystem (PV and so on)	10 000	20%	25% (plus exemption from CVD)

Silicon cells

- Any unit is free to choose either an SEZ or non-SEZ status.

Table 1 gives the benefits of the special incentive package in per cent of the capital expenditure.

Catalysing the growth

TF Solar Power is the most recent entrant in the group of solar PV companies in the country and is planning to establish a cell-manufacturing unit in the country. As per the available reports, this company has put forth its EoI (expression of interest) to the Government of India to make use of incentives available under the policy on semiconductor fabs, and so on. The number of proposals received under the SIPS (special incentive package scheme) is 11. It is important to note here that the norms for such a scheme were announced in the last quarter of 2007. Thus, the cumulative proposed investments have gone up to nearly Rs 800 billion.

As per the reliable estimates, the cumulative investment proposed by TF Solar Power, with respect to thin-film PV module technology, is a whopping Rs 23.50 billion. Some of the most prominent SIPS-specific applications received by the concerned ministry so far are from Moser Baer PV technologies and Videocon Industries (total capacity 1.3 GW), Titan Energy System

(500 MW capacity of cell, modules and wafers, and 250 MW for polysilicon), KSK Energy Ventures Pvt. Ltd (50 MW proposed to be raised to 700 MW within the next 10 years).

Signet Solar Inc. also intends to put up a manufacturing capacity of 1000 MW per annual output. So far, the largest investment plan under this specific fab scheme has evolved from Mukesh Ambani promoted Reliance Industries Ltd. In fact, it has just submitted two proposals in excess of Rs 300 billion for setting up a semiconductor fab along with a solar PV module entity (capacity of 1000 MW) in India.

Phoenix Solar India is also awaiting clearance for setting up a solar PV cell and module project worth about Rs 12 billion. Another PV major Tata BP Solar – a joint venture project between the Tata Group of companies and BP Solar – is embarking on a massive investment close to Rs 17 billion.

Future product line

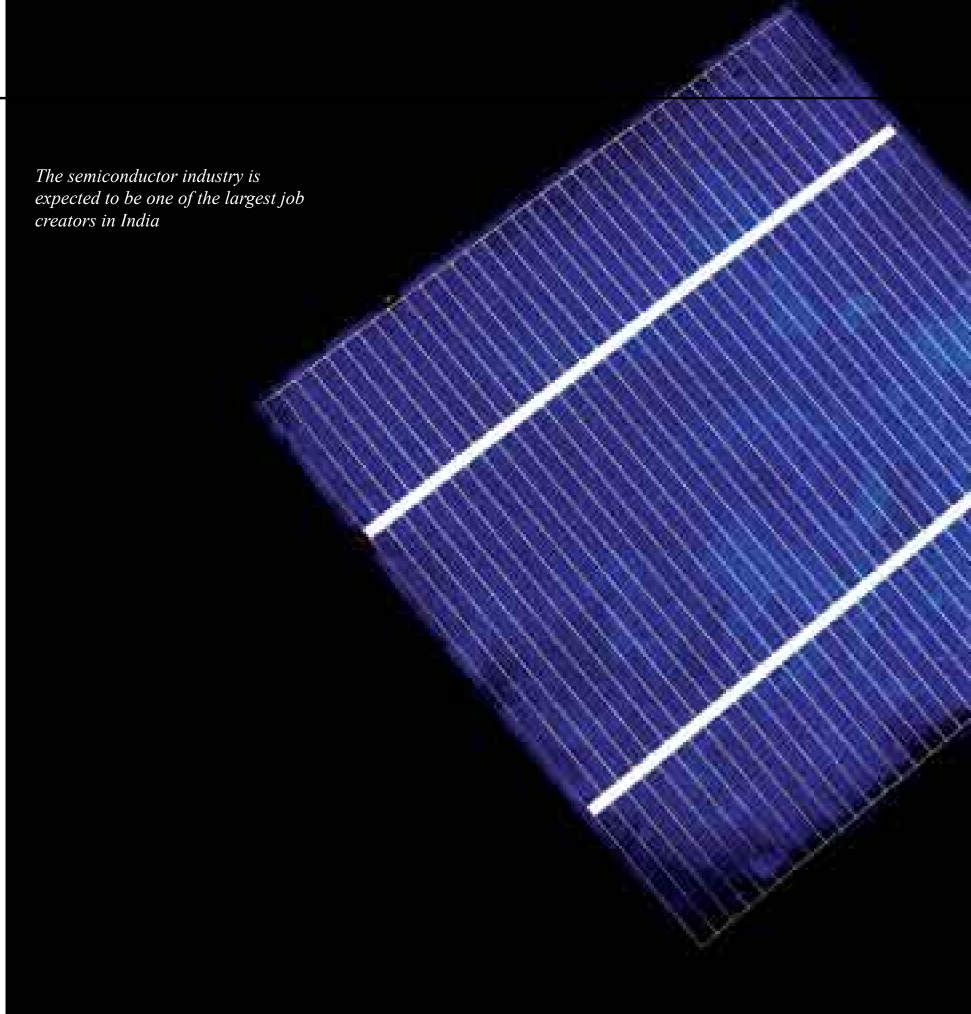
The Semicon policy is projected to give a good boost to the national semiconductor manufacturing service industries in the country. It may lead to a likely contribution of over $202.57 billion to the GDP (gross domestic product) by 2015. The semiconductor industry is anticipated to be one of the largest job creators in India, providing employment to more than 9.35 million people, both in a direct and indirect capacity, as per a recent study by the Indian Semiconductor Association headquartered in Bangalore. Manpower requirement in the solar PV industry is also witnessing an upward trend at all levels.

The solar-PV-specific proposals under SIPS cover manufacturing of the following few major items.

- Polysilicon
- Single crystalline ingots
- Multi-crystalline ingots
- Wafers
- Solar cells
- Solar modules

Project status

As per the latest information available, all the proposals received from the prospective project developers are presently being assessed in terms of a variety of considerations by the concerned ministry. If these solar PV proposals materialize, they could result in a significant push for the



The semiconductor industry is expected to be one of the largest job creators in India

PV sector as a whole and pave the way for reduced cost of PV power generation in an ultimate analysis. It remains to be seen as to how many solar-grade silicon-manufacturing plants finally come up under this scheme.

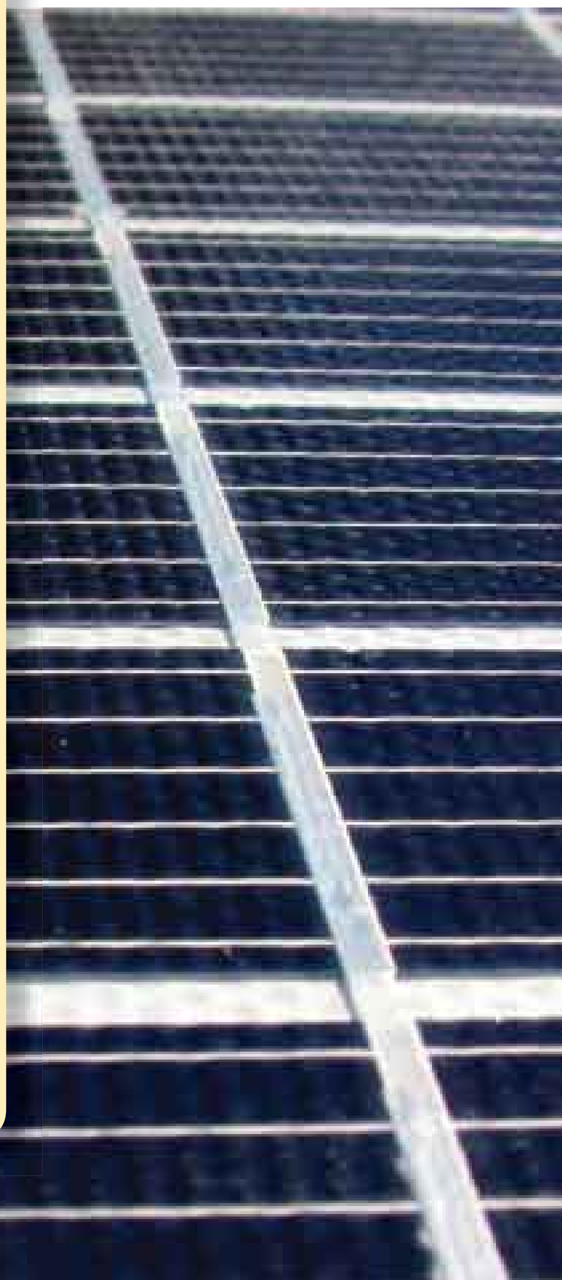
Expected gains

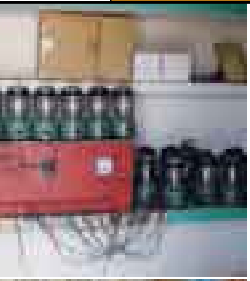
Presently, the unit cost of power generation from a PV system ranges between Rs 12 and Rs 14. The moot question is, whether fresh capacities being planned under the SIP scheme could bring down the cost to anywhere between Rs 4 and Rs 7 per unit within the next few years or so? One can assume as much on account of the expected easing of the international demand–supply unevenness of silicon together with the reduced intake of silicon material, rapid advances in thin-film PV technology, and higher solar to electric conversion efficiencies for crystalline silicon. Reliable estimates point to the fact that the price of 1 MW of solar power may come down to as low as $2.5 million over the next decade or so. After all, economies of scale, if achieved, can surely translate into favourable economics of solar power. ■

With inputs from the research team

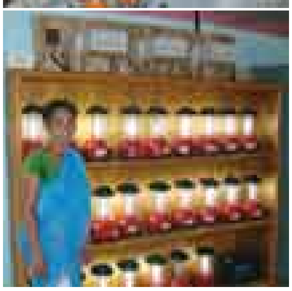
PV proposals received under the special incentive package

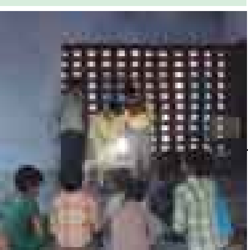
Company	Investment level (in million rupees)	Product line	Specific remarks
Neotech solutions Photon Energy Systems Chandradeep Solar Ram Terra Solar Surana Ventures	(Combined investment of 32 000	Solar cells/modules	Applications of these five companies have been approved in-principle to set up PV cell manufacturing plants in Fab city (at Hyderabad) Fab city has now been accorded the status of a Special Economic Zone, land has already been allotted.
Solar semiconductors	40 000	Solar modules	50 acres of land allotted at the Fab city
Titan Energy Systems	33 750	Solar modules	50 acres of land allotted in Fab city for setting up its second PV manufacturing unit
XL Telecom and Energy Ltd	3375	Solar cells	Proposal cleared, 50 acres of land allotted in Fab city
KSK Energy Ventures Ltd	3150	Solar cells	Same as above
Embedded System Solutions	225	Solar modules	Proposal cleared, 10 acres of land allotted
Moser Baer Photovoltaics	90 000	Solar cells	Proposal under active consideration of the Ministry of Information Technology and Communications
Signet Solar India	90 000	Thin-film solar modules	Proposal to set up 3 manufacturing facilities each with a 300-MW capacity
Reliance India Ltd	200 000	Polysilicon, solar grade wafers, solar modules	Expression of interest made to set aside 1-GW capacity for modules at Jamnagar, Gujarat





The LaBL campaign is slowly reaching out to many villages in India





Lighting a Billion Lives

A total of 1.6 billion people in the world lack access to electricity, and 25% of them live in India alone. TERI has embarked upon a campaign – LaBL (Lighting a Billion Lives) – wherein it commits to brighten the lives of one billion people by replacing 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 levels.

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 programmes 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 terms of carbon benefits. Each solar lantern from the campaign will save 40–60 litres of kerosene each year, thereby reducing 319 lbs (145 kg) of carbon dioxide emissions per year.

The LaBL 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 to 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 LaBL. For this contribution, TERI provides the organization solar torches, which it can use as corporate gifts for its associates and employees!

For more information, contact
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Serving from the Front

Solar energy development in Ladakh

The Ladakh province of the state of Jammu and Kashmir is surrounded by two of the world's mightiest mountain ranges—the Karakoram in the north and the Great Himalayas in the south. It lies on an altitude ranging from about 9000 feet at Kargil to 25 170 feet at Saser Kangri in the Karakoram range. The total population of Ladakh is barely 245 000, spread over the two districts of Leh and Kargil. The summer temperatures seldom cross 27 °C in Ladakh, as against 20 °C in Leh. The thin air at high altitude makes the heat of the sun even more intense compared to the lower altitudes. It is an often said that a man basking in the sun with his feet in the shade can run the risk of getting a heat stroke and a frost bite at the same time. Such a situation is possible only in this picturesque location of Ladakh, which presents many challenges.

Taking such a challenge in its stride is the Ladakh Ecological Development Group, or LEDeG for short. It is an NGO (non-governmental organization), which came into being in 1983 and has been actively involved in awareness generation programmes related to the environment and sustainable development.

Practising what it preaches

LEDeG is a firm believer in the dictum of 'practising what you preach'. This is proved by the fact that it has installed a 960-W SPV (solar photovoltaic) plant on the roof of its office at Leh. Solar power thus produced is being used to run lighting systems, computers, and fax machines besides video systems. The underlying philosophy of this organization is to put in place a more decentralized approach of energy production based essentially on freely available renewable energy resources like sun and water.

Achieving milestones under duress

LEDeG has successfully developed various technologies like Trombe (solar) walls and direct gain system for solar space heating. In addition to this, it has been instrumental in demonstrating the usefulness of the following systems.

- Solar ovens
- Solar water heating systems
- Solar parabolic reflector cookers (both for family and community use)
- Improved water mills
- Micro hydroelectric installations
- Solar dryers
- SPV lanterns and home-lighting units
- Hydraulic ram pumps

The big change

There are many rural blocks in the Ladakh region, which have no conventional power. In a few areas, DG (diesel generators) have been at work, though at the cost of the ecological balance of those areas. Besides, it has not been an easy affair to run and maintain the DG sets in such difficult terrain. The LEDeG has been trying to

Practising what it preaches, LEDeG has installed a 960-W SPV plant on the roof of its office replace such generators gradually with solar power systems. It has been successful in installing a 100-kWp SPV power plant in place of a generator, thus signalling a major transformation in an otherwise ecologically disturbed habitat. Yet another major achievement of this group has been the installation of about 57 micro-hydro units in far-flung areas of Ladakh. The capacity of these systems varies from 0.5 kW to 15 kW.

Think global, act local

One of the major objectives of LEDeG is to increase the penetration of SHS (solar home systems) across the vast geographical terrain. The Dubruk block is a noteworthy example of the change brought about by the use of solar lighting systems. The LEDeG has made many efforts to popularize the use of locally manufactured technologies based on an effective utilization of solar energy. It also includes a small-scale water power system for grinding grains. It is a common but pleasing sight today to see solar energy technologies in use in nearly every village in Ladakh. Many parts of Ladakh face the problem of water scarcity. LEDeG has remedied this situation by introducing technologies like Hydram.

Using renewable energy for heating

People in the hilly areas have to combat severe cold weather when the temperature dips to as low as -40 ºC. The way out is to use Bukhari for room heating on a very large scale. However, the fallout is the overexploitation of scarce natural resources besides a rise in health-related problems like respiratory diseases. Realizing this, LEDeG has been taking the following measures to combat these problems.

- Use of solar energy for space heating
- Use of local resource based insulation techniques
- Efficiency improvements in cook stoves
- Incorporation of improved architectural designs

The group has innovated a simple looking system, that is, the Trombe system developed around the concept of solar gain, and minimized heat loss through use of various design and insulation techniques. It is a perfect example of how a successfully experimented technique can be replicated on a large scale. LEDeG had installed about 75 solar passive systems barely a year after its inception on the Ladakhi horizon. Of late, solar passive architecture has found quite a few takers, ranging from individuals to more rigorous users like the Indian army units stationed in Ladakh. Experimental observations point to a temperature gain of nearly 16–20 ºC above the ambient temperature through the use of Trombe wall—quite a pioneering effort by this NGO. Other outcomes are reduced dependence on heating fuels by as much as 66% and better environmental and health conditions.

One major objective of LEDeG is to increase the penetration of solar home systems

Reaping the rewards

This upcoming organization has been rewarded in the past with the prestigious Right Livelihood Award—deemed as an alternative Nobel Prize. The SESI (Solar Energy Society of India) also conferred on it the SESI-NGO award in 2005 in view of its path-breaking practical transformation of rural communities living in the inhospitable terrains of Ladakh.

The endeavours taken by this NGO should be replicated in other remote areas of the country as well. Only then will there be a renewable energy revolution, which would bring about global sustainable development. ■

With inputs from LEDeG and the research team

Cooking under the Sun: The Gadhia Experience

Deepak Gadhia, Managing Director, Gadhia Solar Energy Systems

Global warming and climate change, primarily due to the emission of greenhouse gases like CO_2 (carbon dioxide), are the two major concerns facing the world today. If only 3% Indians were to cook with solar cookers, we would save 3.2 MT (million tonnes) of wood per year and reduce CO_2 emissions by 6.7 MT per year.

Gadhia Solar has been on the forefront of identifying appropriate technologies in the solar thermal area and indigenizing them. The company introduced Seifert Parabolic Solar Cookers for domestic cooking and Scheffler Parabolic Concentrators for community cooking. Slowly, catering to the consumer demand and need, Gadhia Solar, with the help of inventors, improved upon them. It is also working on newer applications of solar concentrators not just for cooking but also for industrial applications such as desalination, waste-water evaporation, incineration, drying, and food processing.

Scheffler concentrators/dishes are the building blocks for solar steam generation. The unique feature of Scheffler dish is that it has stationary focus, which is achieved by changing the curvature of the dish in different seasons using seasonal adjustment bars at its back.

Initially, Scheffler dishes were used for community cooking that had a mechanical counter weight driven tracking system, which moved the dish in the east–west direction and followed the sun. Thus, irrespective of the position, the sun rays are focused at a fixed point.

For direct solar cooking systems, solar rays are reflected through a small opening in the north-facing wall of the kitchen and further deflected and bundled onto secondary reflector placed below a blackened cooking vessel placed in the kitchen. This enables cooking within the comforts of the kitchen. The temperature at focus is about 400 ºC. Therefore, practically, all items can be cooked. A single dish can cook for 50 persons per meal time.

Evolution of solar steam cooking system

It has been 10 years since the first solar steam cooking system was developed by Gadhia Solar Energy Systems Pvt. Ltd for the Brahma Kumari's in cooperation with Mr Golo Pilz of Brahma Kumari's, Mr Wolfgang Scheffler, and HTT company of Germany. Brahma Kumari's needed a system to cook for 1200 persons for their Mt Abu Ashram.

The company's initial idea was to offer a series of Scheffler dishes for direct cooking ,to be aligned in rows in the conventional east–west direction. This was not found to be feasible since it would have meant a large kitchen and many cooking vessels. Thus, it was decided to generate steam with solar concentrators and supply it to the kitchen. Fortunately, Brahma Kumari's were already cooking with steam, but it was generated with diesel-fired boilers. Therefore, it was proposed that they use solar generated steam.

The technology for generating steam with Scheffler dishes was provided by Ms HTT GmbH of Germany, where Deepak Gadhia had worked before returning to India in 1985. The funding agency GATE of GTZ, Germany provided funds under its prototype funding scheme. All these factors, together, helped the world's first and largest solar steam cooking system (in 1997) to be installed at Brahma Kumari's, helping them save 70 litres of diesel per day.

A solar concentrator in a village in Ladakh

Working of solar steam cooking system

- Parabolic solar concentrators are arranged in pairs of sleeping and standing dishes in parallel modules, aligned in a perfect east–west direction.
- Receivers (heat exchangers painted black) are placed in the focus of each pair of dishes.
- Above the receiver is a header pipe half-filled with water.
- Cool water enters the receiver through the inner pipe coming from the header.
- Solar rays falling onto the dishes are reflected and concentrated onto the receivers.

At present, there are more than 23 solar steam-generating systems installed by Gadhia Solar

- Due to the high temperatures achieved (450–650 ºC), the water within the receiver is converted into steam.
- Steam is stored in the upper half (empty portion) of the header pipe, and if the steam is not drawn, the pressure keeps on increasing.
- This steam is then drawn/sent to the kitchen through insulated pipelines to the steam cooking vessels for fast and hygienic cooking in a clean environment.
- There are two types of steam cooking vessels: (1) vessels in which steam is injected directly into the food to cook items like dal, vegetable, and rice; and (2) double-jacketed vessels in which steam circulates through the outside jacket of the vessel heating the food inside. It can help boil milk, tea, soup, and so on, since injecting steam into the food would dilute it.
- On cloudy days, during monsoon, and at night, conventional fuel can be used in the boiler house as a back-up system.
- Depending on the quantity of food to be cooked, the number of pairs of dishes and number of modules will vary.
- All the dishes are connected with a metal wire rope, and the wire rope is connected to a winch, which in turn has a DC motor connected to a timer mechanism which keeps on moving the dish, aligning it with the movement of the sun. This type of tracking system is called central tracking.
- To ensure that food is cooked even when the sun is not there (at night and on cloudy days in monsoon), the solar steam-generating system is connected with a fuel-fired boiler that acts as a back-up system.

Some prestigious systems installed

Since the first system installed in 1997, solar steam generation has found more and more acceptance in India. At present, there are more than 23 solar steam-generating systems installed by Gadhia Solar, and many more are in the pipeline. These systems are of various sizes and configuration and for different target groups, depending on the quantity of food to be cooked and space availability on the terrace or on the ground near the kitchen. The size of the cooking systems varies with the number of people, from 250 persons to 15 000 persons per day, and for varied user groups such as temples, ashrams, *mutts*, industrial canteens, schools, hostels, hospitals, and even defence institutions. Some of the many solar thermal systems installed by Gadhia Solar are as follows.

- World's largest solar steam cooking system at TTD (Tirumala Tirupati Devasthanam), which cooks 30 000 meals per day. The system was installed on 12 October 2002 and has been working for more than five years. On an average, it saves 200 litres of diesel every day. TTD has recovered its investment in approximately four years. The system is expected to run for another 15 years, with only reflector plates to be replaced every five years.
- World's highest solar steam cooking system for the Indian Army to cook for 500 *jawans* in Leh Ladakh, at a height of more than 3000 metres above sea level.
- Shri Saibaba Sansthan Temple at Shirdi has a solar cooking system, which cooks 7000 meals per day. The system has been working for the last seven years and the performance is improving day by day. Now the Shirdi Temple Sansthan is planning for a system to prepare food for 20 000 people, equivalent to 40 000 meals per day.

Gadhia Solar has also installed the world's largest steam cooking system at Tirupati

Gadhia Solar has learnt from its experiences. It offers and undertakes not only AMC (annual maintenance contract) but also the operating and maintenance contract, wherein its team is placed permanently at the clients' site to run the system. At present, such teams are located at Shirdi Baba Temple site and Tirupati Balaji Temple for hassle-free operation and maintenance of their systems.

Getting clean development mechanism benefits

Gadhia Solar has bundled its solar steam cooking system projects and registered the same with the UNFCCC (United Nations Framework Convention on Climate Change) under the Gold Standard project. Thus, its clients are now able to sell the carbon credits produced due to the saving of fuel by using solar cookers.

Gadhia Solar has also found a buyer for the carbon credits, who has agreed to buy the CERs (certified emission reductions) at € 11.50 per tonne of CO_2 saved. Thus it's a win-win situation, as the client saves precious fuel cost and gets paid for CO_2 not emitted into the atmosphere as well.

Newer applications of solar steam systems

Besides cooking, Gadhia Solar has developed and supplied solar steam generating systems for other applications, such as the following.

- A system for process heating to Jaipur Sadi Kendra, where the steam is being injected into water for fastening of colours.
- A system for food processing to Tapi Food Industries, Surat, where the system is being used for manufacturing tutti fruity and concentrates.
- Value addition and employment generation in the food Industry with solar concentrator offers to be a vehicle and backbone for changing the economy of our country by creating wealth in rural areas.
- Waste-water evaporation and desalination to get drinking water from sea water as also desalinated and contaminated water.
- Air conditioning, where the solar-generated steam is used to run a 100-TR vapour absorption chiller. The MNRE (Ministry of New and Renewable Energy) has sanctioned the subsidy for the Muni Seva Ashram, Goraj, which has placed the order for the same with Gadhia Solar. The plant is under installation, and once installed, it will become the world's largest solar air conditioning system.

Like food processing, solar air-conditioning too holds a bright future for India, as there is a perfect match between the need of cooling and availability of sun.

Gadhia Solar is at present testing a thermic fluid system at Muni Seva Ashram, where instead of steam, synthetic oil is being circulated in the solar loop, heating the oil to about 250 °C. This will help in storing energy for cooking not only during day but also at night and early morning. Thermic fluid systems are also widely used in textile and other process industry and offer immense potential.

Now with the MNRE support in place for Rs 3500/m^2 of concentrator area for commercial institutions, which can avail an accelerated depreciation benefit of 80% in the very first year and for Rs 5000/m^2 of solar concentrator area for NGOs, and so on, the use is bound to spread.

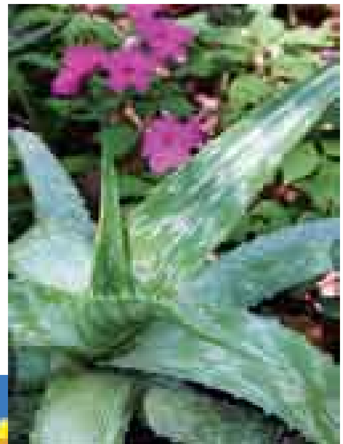
Gadhia Solar, through its NGO Eco Center ICNEER, in cooperation with MNRE and GEDA (Gujarat Energy Development Agency), conducted a training programme for dissemination of the technology, in which 18 industries participated. ■

Solar drying in Uttarakhand

Ishan Purohit, Research Associate, TERI

Uttarakhand is endowed with rich medicinal and aromatic plants, herbs as well as cash crops, and is, therefore, called the 'herbal state'. The topography of the state and its varying climate are suitable for the growth of medicinal plants and cash crops. The growing demand for herbal products offers tremendous possibilities for Uttarakhand.

A research project, 'Potential assessment of solar drying in the hilly regions of Uttaranchal', was carried out by the Department of Physics, H N B Garhwal University, Srinagar, Uttarakhand, under the supervision of Prof. G C Joshi and Dr Gunjan Purohit in 2005. This project was sponsored by the Ministry of New and Renewable Energy. It was started with a solar radiation resource assessment exercise. A weather station was installed in Srinagar (latitude 30.13 °N, longitude 78.47 °E, altitude 532 m) for periodic measurement of solar radiation, ambient temperature, relative humidity, wind speed, and so on, and a solar radiation map of the state was also developed. Through a field survey of farmers, NGOs (non-governmental organizations), research centres, and government bodies in all districts of the state, the production data for medicinal plants and produces, aromatic plants, herbs, and cash crops was collected.



Experimental investigations and testing were carried out with the help of two prototype models of solar dryers (one simple cabinet type and the other convective cabinet type), which were designed and manufactured locally for the purpose. Both the dryers were capable of achieving an internal temperature of up to 80 °C. A number of locally grown and cultivated medicinal produce and cash crops, such as *amla*, *bahera*, *harda*, ginger, turmeric, plash, mint, lemon slices, orange slices, and chilli, were dried under various loads, and climatic and operating conditions, and their thermal performance parameters (drying rate, moisture removal, drying efficiency, and so on) were investigated at Srinagar under stagnation as well as load test conditions.

There has been good response to the solar drying technology in Uttarakhand

These were compared with the test results obtained from traditional sun drying, which was carried out simultaneously. It was found that the solar drying option is more efficient as compared to the open sun drying method.

The financial and energetic evaluation of the solar drying systems has also been carried out. The solar drying approach has been found suitable in all the locations where the production of medicinal plants was highest. In order to check the nutrition level of the dried products, the HPLC testing of some samples was also carried out.

There has been a good response to this technology from the local industries despite the fact that it was the first attempt at exploring the feasibility of solar energy technology in Uttarakhand. Research work towards development of high-capacity solar drying systems is still going on in H N B Garhwal University for higher capacity solar drying systems. ■

India's first solar housing complex

Rabi Rashmi Abasan

S P Gon Chaudhuri, Managing Director, WBREDA

Green buildings are being seen as an emerging business opportunity in India. The construction industry is estimated to contribute about 10% of the GDP (gross domestic product). India Green Building Council (which is part of CII–Godrej Green Building Council) has undertaken the initiative of promoting the green building concept in the country. Today, a variety of green building projects are coming up in the country—residential complexes, exhibition centres, hospitals, educational institutions, laboratories, IT parks, airports, government buildings, and corporate offices. Many of these may use technically well-proven solar technologies in different ways. One of these is the BIPV (building integrated photovoltaic) application, which is well suited to such ambiences. By 2010, about $100 million would be generated through the use of solar PV in green buildings in India. Of late, the use of both solar PV and solar thermal systems in urban buildings is gaining momentum. A common practice is to connect solar PV system to the grid.

PV grid system

The solar PV technology involves direct conversion of available solar energy into some useful electrical energy. It can realistically contribute to greater global sustainability in the medium to long term. PV is becoming more and more accessible, both in urban and rural areas, due to declining costs. One common PV application today is to connect a PV system with the conventional grid. This is called grid-connected PV. A grid-connected system works in parallel with the conventional grid network and offers the following advantages.

- Supplies energy to loads at the point of generation
- Exports power when there is excess energy
- Allows the import of energy if there is a shortfall

Building integrated photovoltaic

Recently, there has been a worldwide focus on the architectural integration of PV modules in the building envelope. Such type of modules can effectively replace conventional building materials like roof tiles, shingles, façades, and normal glazing. PV building materials can be manufactured in such a manner that they are quite similar to the conventional building products, blending well with the surrounding environment. Integration of PV materials means that the costs of the replaced building products can be offset against the PV system cost, thereby improving the economics of the project. Such PV systems are often termed as BIPV. Today, there are a large number of houses with such built-in features in countries like Germany, Spain, Japan, and California. The regulators also provide clear tariff orders for construction of such houses. This mainly relates to export of surplus solar power to the grid against a tariff structure fixed for the purpose.

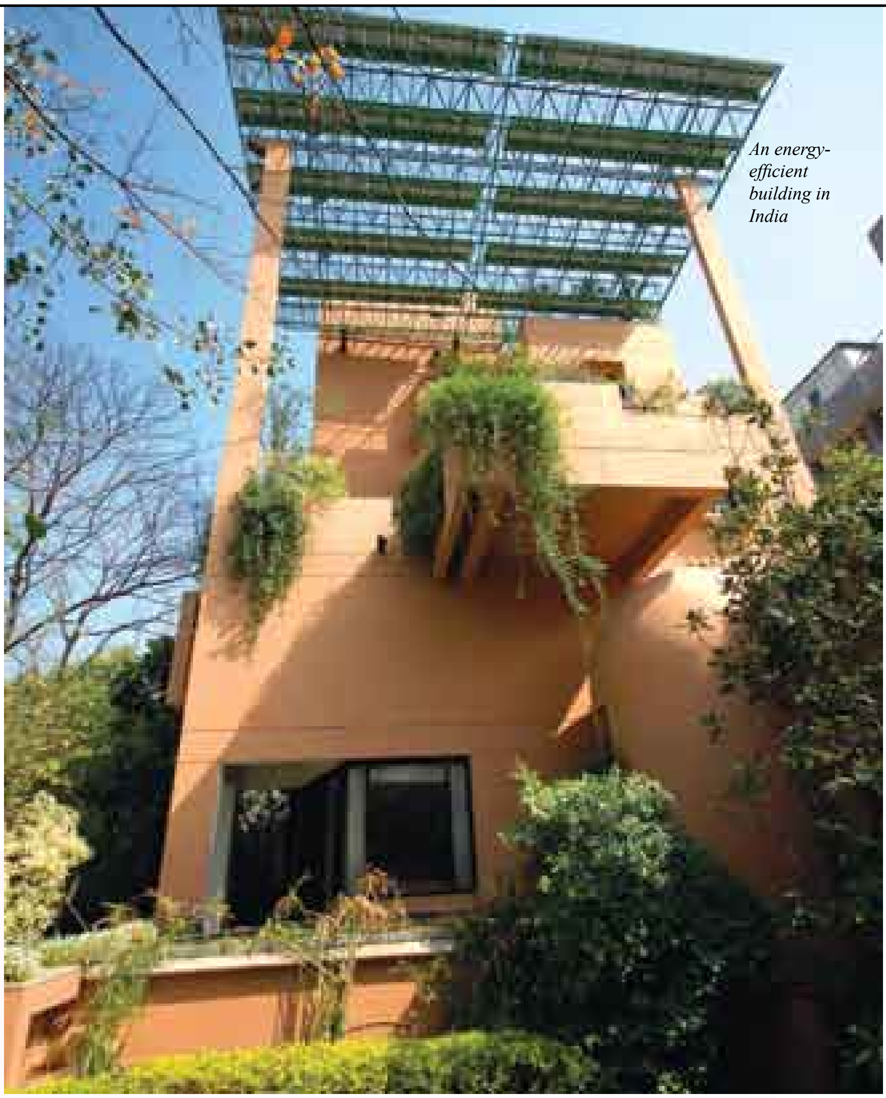
The Indian scenario

West Bengal is the first state in India to come up with a well-formulated tariff order for promoting the use of small-capacity BIPV systems. The SERC (state electricity regulatory commission) of the said state issued such an order on 5 March 2008, which had the following salient features.

- Rooftop solar PV systems with 2-kWp capacity can be put up for delivering power into the distribution system of a licensee.
- Institutional consumers comprising government hospitals, health centres, schools (including aided ones), academic institutions, offices, and organizations, besides any housing complex already promoted for the purpose by the government or any government agency (includes local bodies like municipalities,

panchayats, and cooperative societies) for development of renewable sources, are eligible for the specially announced tariff structure.

- Such injection from rooftop solar PV sources of the above-mentioned consumer(s) shall not be more than 90% of the consumption from the licensee's supply by the above-mentioned consumer(s) in a financial year. It shall be settled on net energy basis at the end of each financial year.
- Any excess energy injected by the above-mentioned consumer(s) from the rooftop solar PV sources more than the 90% of the consumption of energy by that consumer(s) from the licensee's supply in each billing period shall be carried over to the next billing period within that financial year.
- Slab tariff, as per tariff order, shall be applicable for the net energy supplied by the licensee in a billing period if the supplied energy by the licensee is more than the injected energy by the rooftop solar PV sources of the consumer(s). It will be so after taking into account the quantum of energy, if any, carried forward from earlier billing period(s) of that financial year.
- If in a billing period, the supplied energy by the licensee is less than or equal to energy injected by the rooftop solar PV sources of the consumer(s) after adding



An energy-efficient building in India

TERI RETREAT at Gual Pahari, Gurgaon

the cumulative carried over injected energy from previous billing period(s) of that financial year the billed amount for energy will be nil for that billing period(s).

- At the end of the financial year, if the total energy supplied by the licensee to the consumer(s) for that financial year is found to be less than the energy injected by the rooftop solar PV sources of that consumer(s) for that financial year, the licensee shall not pay any charge to the consumer(s) for that net energy, injected by the consumer(s), in excess of 90% of consumption of that consumer(s) from the licensee's supply in that financial year and the same shall be treated as unwanted/inadvertent injunction.
- At the beginning of each financial year, the cumulative carried over injected energy will be reset to zero. Payment in a billing period by the consumer(s) (owning

A solar photovoltaic array

Degree College and Hill Complex, Leh

rooftop solar PV sources) to the licensee shall be guided by the provisions of the regulations made by the Commission under section 50 of the Act.

- For each billing period in a financial year, the licensee shall show the quantum of injected energy from rooftop solar PV sources in the billing period, supplied energy from its source in the billing period, net billed energy for payment by the consumer(s) for that billing period, and net carried over energy to the next billing period separately.
- Any delay in payment shall attract surcharge at the agreed rate. The MoU/PPA to be signed between the licensee and developer of rooftop solar PV sources shall include necessary terms and conditions of meter reading, billing, payment, payment of security arrangements, rate of delayed payment surcharge, and so on.

The birth of Rabi Rashmi Abasan

Rabi Rashmi Abasan (meaning a solar housing complex), India's first solar complex, came into being mainly due to the above-mentioned tariff order. This complex conceived by WBREDA (West Bengal Renewable Energy Development Agency) is located at New Town Kolkata and is spread over an area of 1.76 acres. Each house owner within the complex will produce his own power for domestic use and feed any surplus power into the local grid. He can also draw power from the grid as and when needed. The utility will pay the house owner and vice-versa on net monthly metering.

Solar systems at the complex

There are 25 independent apartments in the complex, each of which has been provided with a rooftop solar PV system of 2-kWp capacity. Sixteen single crystalline silicon modules of 125 Wp have been put up in each case. These will produce power during the day, and any surplus power that is not consumed by the individual household will be supplied to the local grid. In addition, each household has a 100-litre solar water heating system. Seventeen solar street lights have been installed to light up the entire area. The stree tlights are unique in the sense that batteries are placed on the top with a proper, nicely designed, colourfully fabricated pole. The community centre has a solar swimming pool and an 8-kW BIPV in the southern side of the building.

This specially designed complex not only uses active solar systems but also incorporates solar passive features.

Passive solar components

About 25% of the total commercial energy in India is spent on lighting, air conditioning

Solar panels at the WBREDA building

Front view of the TERI RETREAT complex, Gual Pahari, Gurgaon

and ventilation, and so on. The Rabi Rashmi complex incorporates several features specific to solar passive architecture. This keeps houses cool during summer months and also reduces the daily peak demand. A unique feature is the use of solar chimney. A small lily pool in the southern side, with proper ducting arrangements, has been kept in the building for smooth flow of hot air in and out of the building. This also ensures proper ventilation inside the room. Natural lighting has been arranged in all rooms as far as possible.

Insulated walls and windows

Thermal comfort of the buildings is enhanced through insulation on the walls of south, west, and east sides of each individual unit in the housing complex. The insulation material used here is extruded polystyrene block of 50-mm thickness inside walls that are 250 mm thick. Double-glazed windows have also been provided in the openings on such walls to exercise radiant energy control in the buildings. Double-glazing has been done, maintaining complete vacuum inside.

Intelligent water supply system

The housing complex has also been provided with energy-efficient hydro pneumatic pumping arrangement to supply pressurized water. This intelligent system design based on auto-start/auto-off mode and installed centrally is expected to match the end-user requirements fully. The underlying idea is to do away with the conventional individual household pumping arrangement and, thus, save some energy in the process. The system comprises a pump-motor set, micro processor/controller-based control unit, pressure gauge, pressure transmitter, pressure tank, and different control valves. There is also an emergency tank for each house.

Clean ride: electric vehicle

Two battery-powered vehicles will be available to the residents to commute within the surrounding areas. The basic idea is to showcase the green spirit of the complex in every possible manner.

Present status of the Rabi Rashmi project

This aesthetically done solar complex is expected to be completed by June 2008. It would be handed over to the residents after a formal inauguration. The solar systems will be maintained by the system supplier for a period of five years from the date of its commissioning, and thereafter, the resident's body is expected to care for it.

Conclusion

Rabi Rashmi Abasan is expected to serve as an example of transition to the sustainable use of energy. Use of both active and passive solar devices will lead to energy savings of about 60%. It will prove to be a role model for upcoming housing complexes and encourage them to adopt clean energy technologies for a sustainable future. ■

Harnessing the power of the Sun

The development of megawatt-capacity solar power plants

Dr Sunil Deambi, Consultant, TERI

The total installed power capacity in the country, as on 31 March 2008, is 143061 MW. Out of this, the respective shares of thermal power and hydropower are 64.2% and 25.1%. The share of power from renewable energy technologies is about 7.8%, which is incidentally more than double the share of power obtained from nuclear energy. A capacity addition of nearly 78 520 MW has been planned by the Ministry of Power during the Eleventh Five-year Plan period (2007–12). As of now, about 52.5% of the total power production takes place in the state sector, while the central and private sectors produce 34% and 13.5%, respectively. There is an urgent need to increase participation from the private sector in the area of power generation from all possible sources. The all India AT&C (aggregate technical and commercial) losses are pegged at 34.54%, which is no small number, considering an increasing gap between the demand and supply of conventional power.

Presently, a total of 487 338 villages (82.1%) stand electrified. There is a target of increasing the per capita power consumption to about 1000 units from the existing 681 units. Importantly, there is a need for large-scale power generation from both the non-renewable and renewable energy sources to sustain a targeted GDP (gross domestic product) annual growth of about 8%–10%. Considering all this, there is a need to exploit solar energy for power generation through financial and fiscal measures as far as possible.

Renewable power targets

Wind energy continues to be the dominant source of renewable power in the country. About 8000 MW of wind power capacity has been created in the country so far. As against this, the share of solar power is abysmally low, mainly due to its high initial capital cost and, thus, a higher cost of per unit power generation. The MNRE (Ministry of New and Renewable Energy) has drawn up an ambitious plan of adding about 14 500 MW during the current plan period. Out of this, the grid-interactive power derived from the wind, biomass, and small hydro will account for 13 500 MW. The share of distributed renewable energy power will be somewhere around 1000 MW. Expectedly, the share of renewable power will cross the 10% mark of the total installed power capacity by 2010. However, just a very small percentage of it will come through solar power.

The private sector investment of about 97% has been the mainstay of power generation through the renewable energy route so far. It has mainly been possible through the nearly favourable policies of both the central and the state governments over the last decade or so.

Of late, solar power investments in the country are registering a fast increase. In fact, India is becoming a chosen destination for many national and international bigwigs for setting up large-scale PV manufacturing facilities. There is a growing optimism on the fact that solar power may well attain the much-needed grid parity within the next few years or so.

Status of PV-grid power systems in India

India has limited experience in the demonstrational use of solar PV-grid interactive power plants. In all, about 33 such power plants have been established solely with government assistance. These plants have a cumulative capacity of 2.12 MW and are expected to produce about 2.55 million units of electricity per annum. Compare this with an off-grid use of PV, where about 1.45 million decentralized systems (that is, for lighting, water pumping, and battery charging) installed across the country have a potential of producing about 150 million units annually. The capacity of the largest PV power plant in the country is just 225 kWp, which is definitely lower in comparison to the installed capacities of wind and small hydropower plants, for example.

Rationale for large-capacity solar PV power plants

Large-scale PV-manufacturing facilities are now being planned by many big names in the PV industry. These may subsequently provide the oft spoken benefit of economies of scale. The most recent example is of MBPV (Moser Baer Photovoltaics), which is optimistic of achieving the much-needed grid parity of solar power within the next few years. Till such time, it has become absolutely essential to gain some useful experience by using megawatt-capacity power plants. It also makes sense to feed the PV-produced power to the grid directly minus the presence of an expensive battery bank. One of the major benefits is that the cost of replacement of the battery bank, after a period of four to six years, is avoided, and it is easy to maintain the system on a year-round basis. Also, a centralized control system can help in keeping a close tab on several key performance indicators under the actual field operating conditions. In cumulative terms, the MNRE policy of encouraging the use of megawatt-capacity solar grid power seems to be a well-timed move aimed at some long-term gains.

Summary indicators of 1-MWp PV grid power plants

It is quite clear from the box that a megawatt-capacity PV power plant does not come cheap. The cost per unit of producing power through this route is much more than the power produced from either coal or water or even wind for that matter.

The moot question is why should PV power be considered at all? Well, there are several compelling reasons favouring its use—the abundant sunshine available being the predominant reason. There is also a growing recognition of the fact that cost of PV technology is sure to tumble down more as new capacities based on the most modern processing techniques come up. However, there is no denying the fact that the support from the government is a pre-requisite to push forth the newly emerging concept of generation-based incentive for solar power. Prior to examining such a scheme in its entirety, let us take a look at the existing promotional measures for the market development of solar energy sector in the country.

The generation-based incentive announced for the first time by the MNRE is a well-timed policy measure. It is oriented towards a bigger role for solar power and is based on some gainful insights into the actual operation of megawatt-sized solar power plants.

Issues concerning solar PV

The solar PV grid power segment has just been a very small component of the

Promotional measures

The government has taken several measures to stimulate the growth of the solar energy sector in the country. These mainly include the following.

- **Subsidy on many solar energy systems**
- **Interest subsidy to provide soft loan to users and manufacturers**
- **Concessional or zero import duty on some of the raw materials, components, and products**
- **Excise duty exemption**
- **80% accelerated depreciation in the first year**

overall countrywide PV programme so far. This has kept the interest of electrical and electronic companies at a subdued level as far as the commercial production of high-capacity PCUs (power conditioning units) is concerned. Market volumes have not been attractive in this regard.

There are hardly any indigenous manufacturers of PCUs (higher-end capacities). This could also mean full compatibility of this vital sub-system component with the locally prevalent weather conditions at a given site apart from some cost reduction features as well. There is a lack of field data from the traditional small-capacity PV grid power systems (25 kWp mainly) to know how well such systems generate power in a real time situation.

Issues concerning solar thermal

Unlike solar PV, there is no established experience vis-à-vis the use of solar thermal power generation in the country. The SEC (Solar Energy Centre) of the concerned ministry has so far experimented mainly with a 50-kW imported parabolic trough based solar thermal power system. The much talked about 140-MW solar thermal power system planned at Maithania in Rajasthan has still not seen the light of the day due to one reason or the other.

Salient features of the incentive scheme

Large-capacity (megawatt-scale) solar grid power generation has not been high on the agenda of the MNRE till very recently. However, it is now actively promoting the establishment of such systems by providing generation-based incentive for the first time. The purpose is to develop and demonstrate the technical performance of grid-interactive solar power generation so as to bring down the cost of the grid-connected solar systems. Following this, the cost of solar power generation in the country is expected to come down. The financing arm of IREDA (Indian Renewable Energy Development Agency) will manage funds earmarked for the purpose besides being involved in the monitoring-cum-evaluation activities alongside MNRE.

A plant with a minimum capacity of 1 MWp at a single location will qualify for the above-said incentive. However, such capacity may be installed in modular units of at least 250 kWp so as to achieve a capacity of 1 MWp per location. A sum total capacity of 10 MWp of grid-interactive solar PV power generation projects can be established in a state. Any project developer is allowed to install PV power generation projects up to a maximum of 5-MWp capacity within the country.

Some additional issues in the sector

• Solar thermal power generation equipment is not manufactured indigenously.

• Fully imported solar thermal power system may not be a techno-economically viable proposition.

• There is little or no solar radiation data available with respect to the diffused component of solar radiation. Solar thermal systems do not use the diffused light, but the direct component.

Key objectives of the MNRE's generation-based incentive scheme

The MNRE (Ministry of New and Renewable Energy) has evolved a generation-based incentive scheme with the specific objective of achieving the following.

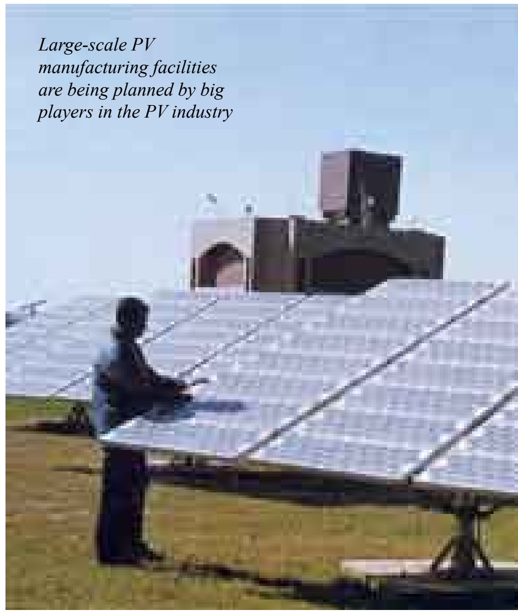
• Motivate project developers to establish solar power plants across the country so as to showcase their viability.

• Gather field performance data on power generation in relation to the available solar radiation.

• Assist the regulatory commissions in determining suitable tariff for solar power.

• Inculcate the required awareness among utilities regarding the purchase of high tariff based solar power keeping in view of its long-term benefits.

Expectedly, these measures may very well result in reduced cost of solar power generation in the country.



Large-scale PV manufacturing facilities are being planned by big players in the PV industry

Type of project developers

• Any company duly registered is at liberty to avail the generation-based incentive.

• Any public/private sector PV power project developers, who have set up or propose to set up a registered company in India, also qualify for such a concession.

• Both the central and the state power generation companies are also included in the category of eligible project developers.

• NGOs (non-governmental organizations), societies, financial institutions, individuals, and other unorganized investors fall outside the ambit of this innovative incentive scheme.

of that tariff to the solar PV grid-interactive power projects within their respective states. However, if no such tariff orders are available, the utilities will offer the highest tariff being offered by the utilities for purchase of power to the project developers in their respective states on a medium term—or the highest tariff being provided for the purchase of power from any other energy source vis-à-vis the orders/guidelines already issued for that state.

Technical requirements

As far as possible, higher power output solar modules should be used and these should conform to BIS Standards or IEC 61215 certification or any other international certification. Optimized generation of undertake an inspection of all eligible projects prior to feeding of power to the grid. The incentive will be approved only after the demonstration of the satisfactory commissioning of the plant at the project site and its interfacing with the grid of the utility. A dedicated electronic meter or any other meter as specified and approved by the utility will be installed at the point of power evacuation and/or any other point as specified by the utility. The purpose is to monitor the quantum of net electricity being fed to the grid from that project.

Some existing initiatives

- The incentive for generating 50 MW of solar power is assessed close to Rs 900

Generation-based incentives

- **MNRE may provide, via IREDA, a generation-based incentive of maximum Rs 12 per kWh to the eligible projects, which are successfully commissioned by 31 December 2009. This will be done after taking into account the power purchase rate (per kWh) provided by the SERC (State Electricity Regulatory Commission) or a utility for that project.**
- **Any project that is commissioned beyond the above date would be eligible for a maximum incentive with a 5% reduction and ceiling of Rs 11.40 per kWh.**
- **Further, the incentive will continue to decrease, as and when the utility signs a PPA (power purchase agreement) for power purchase at a higher rate. The proposed annual escalations agreed with the utility, as in force, should be reflected in the PPA.**
- **The incentive approved for a project may be available for a maximum period of 10 years from the date of approval and regular power generation from that project. This will be subject to the condition that the utility under consideration continues to purchase power from that grid-interactive power plant.**
- **The project developers are not entitled to avail accelerated depreciation benefit under Section 32 of the Income Tax Act 1961.**

Operational status

The grid-interactive solar PV power generation projects will be built on a BOO (build, own, and operate) basis. Setting up of such power plants in a captive mode is not permitted, as is the captive utilization of solar PV power. Simply put, only sale of power to the grid is allowed. These plants will run minus the use of any other source of power and will in no case be transferred to any new management or sold to any other company without prior written approval from the MNRE.

Tariff fixation

In case of availability of a separate tariff for solar power from the SERC, or if the tariff gets fixed during the period of availing the incentive, the utilities will offer a minimum electricity in terms of kilowatt-hour generated per megawatt-peak of PV capacity installed with regard to available solar radiation at the site is required. The grid-interactive PV power plant may be preferably connected to a 33-kV grid line to reduce the losses during power transfer. Key field performance data on daily solar radiation availability, hours of sunshine, duration of plant operation, and amount of power fed to the grid has to be maintained and provided to IREDA as and when reimbursement is needed.

Monitoring and evaluation

A full-fledged team comprising officials from the MNRE, IREDA, concerned state nodal agency, and the state utility will

million. Taking this as an advantage, some states like Rajasthan and West Bengal have already evinced keen interest. Expectedly, such projects may also come up in more states like Maharashtra and Madhya Pradesh. Ideally, west and central India, which receive the maximum sunlight, are well suited for such type of projects.

- MBPV, a wholly owned subsidiary of Moser Baer India, has signed an MoU (memorandum of understanding) with the Government of Rajasthan for setting up of a large solar power project in the state with an estimated generation capacity of 1–5 MW. The project entails an investment of about $25 million

(Rs 100 crore) at $4.5 million per megawatt and will be the largest grid-connected solar farm in India.

- PEDA (Punjab Energy Development Agency) has just allocated letters to four project developers (Moser Baer, Power Quality and Electrical Systems Inc., India Bulls Electricity, and Azure Power) for setting up solar PV projects with a capacity of about 17 MW on a BOO basis at various locations in the state. Nearly 20 bids were received from both national and international agencies for the said purpose. These projects are expected to be completed and commissioned before December 2009, and the power thus generated would be fed into the grid.

The RERC (Rajasthan Electricity Regulatory Commission) has proposed the following tariff for solar power generation

• Solar PV power plants (covered under the Government of India policy) = Rs 15.78/kWh (commissioned up to 31 December 2009)

• Solar PV power plants (not covered under the policy) = Rs 15.60/kWh (commissioned up to 31 December 2009)

• Concentrated solar power plants (covered under the policy) = Rs 13.78/kWh (commissioned up to 31 December 2009)

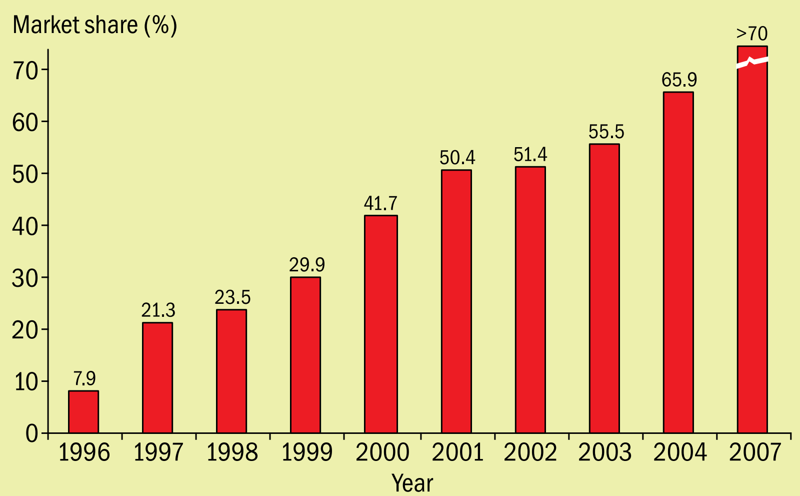
• Concentrated solar power plants (not covered under the policy) Rs 13.60/kWh (commissioned up to 31 December 2009)

*** In case of plants commissioned after 31 December 2009, but before 31 March 2010, the above tariff shall be reduced by 60 paise/kWh**

In all, there are more than 800 PV plants worldwide with capacity greater than 200 kW

Of the top 10 largest PV power plants in the world, 50% are operating in Spain

This graph shows the percentage of share of PV grid-connected application during 1996–2007



A unique feature of these projects is that these would be eligible for carbon credits under the CDM (Clean Development Mechanism) and may ultimately pave the way for reduced cost of power generation, building up enhanced capacities and attaining economies of scale.

Feed-in-tariff

One of the major reasons for solar power projects not making much headway so far has been the absence of a proper feed-in-tariff policy from the concerned ministry (that is, MNRE). Solar projects have to be treated at variance from those of wind and small hydro due to their higher initial capital cost. For example, in Germany, solar grid-connected rooftop systems have been put up in huge numbers, mainly due to higher

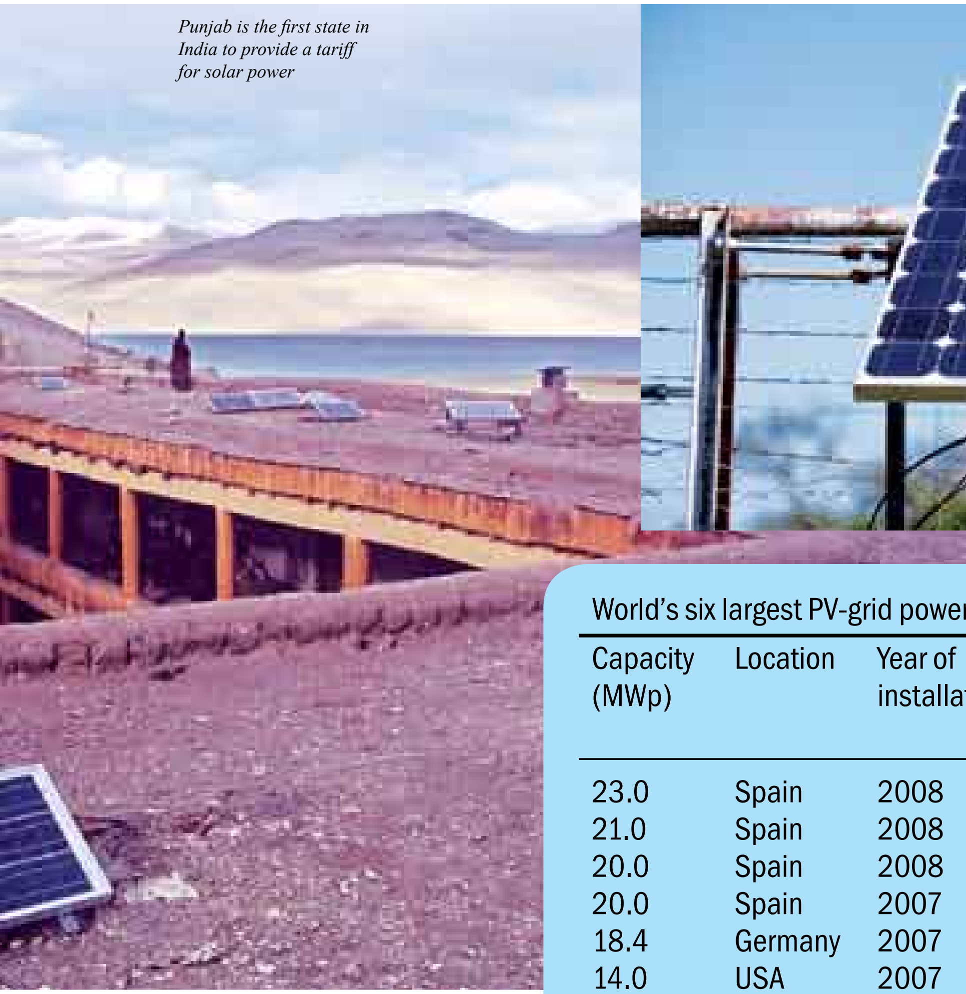
Facts and figures

- **Between 2005 and 2008, the annual growth of large-scale PV (photovoltaic) power plants, with an average peak power of 200 kWp or more, has been nearly 100%. The trend is expected to continue, as more growth will be possible in 2009.**
- **In all, there are more than 800 PV plants worldwide, with capacity greater than 200 kW and at least nine plants with capacity larger than 10 MW, in Germany, Portugal, Spain, and the US.**
- **Almost half of the global installed large PV power is connected to the German grid. Eight per cent of all large PV plants (power related) are installed in Europe (700 MWp).**
- **Germany, Spain, and Italy lead the market of large-scale PV power plants in Europe. Almost 60% of all European large PV plants (power related) are located in Germany (403 MW), followed by Spain (245 MW; 35%) and Italy (17 MW; 24%).**
- **Eight per cent of the world's large PV plants are situated in Europe, 16% in the US, and 4% in Asia. The most dynamic market is Spain, where a steep increase in installed power has been observed in 2007.**
- **The rest of the world (that is, Africa, South America, and Australia) represents less than 1% of global installed PV power but shows significant potential for future solar energy use.**
- **Germany leads with more than 400 MW, followed by Spain (almost 250 MW), putting the US (140 MW) at third position. Italy and Japan (each about 17 MW), Korea (13 MW), and Portugal (12 MW) managed to reach two-digit figures.**
- **Countries with less than 1-MWp installed capacity are Thailand, France (without overseas territories), United Kingdom, Malaysia, Saudi Arabia, Luxembourg, Rwanda, and Mexico.**
- **Primary PV world markets are Germany (with about 45% of the installed power), followed by Spain (28%), and the US with 16% market share.**
- **The average installed capacity of a single large commercial power plant has increased from 400 kWp in 1997 to 1.64 MWp in 2007. The average capacity of sole commercial PV plants accounts for 1.14 MWp.**
- **Amongst the top 10 largest PV power plants, 50% are operating in Spain.**
- **At the end of 2007, almost 70% of all large PV power plants (power related) were mounted on ground. Twenty-nine per cent were installed on roofs.**
- **Other types of plants (about 1%) include PV power plants integrated into building envelopes (BIPV), noise barriers, and other similar applications.**
- **Twenty-seven per cent of the large power plants (power related) have tracking arrays (single- or double-axis trackers) and 73% have fixed arrays.**

feed-in-tariff rates. There is already hope for solar power gaining grid parity within the next few years, and the MNRE scheme may well be a precursor to that.

Punjab is the first state in the country to provide a tariff for solar power, which starts from Rs 7 per kWh (base year 2006/07) and peaking up to Rs 8.93 per kWh (base year 2011/12), with annual escalation of 5%. A tariff order providing this tariff was given by PSERC (Punjab State Electricity Regulatory Commission) on 13 December 2007. It is in accordance with the NRSE Policy 2006 and PSERC tariff order, with peaking rate for sale of power from these projects being Rs 8.93/kWh from 2011/12. The power purchase agreements shall be signed for a period of 30 years.

The RERC (Rajasthan Electricity Regulatory Commission) produced a concept paper on the determination and declaration of promotional tariff from solar power generation plants. This was done



Punjab is the first state in India to provide a tariff for solar power

World's six largest PV-grid power plants

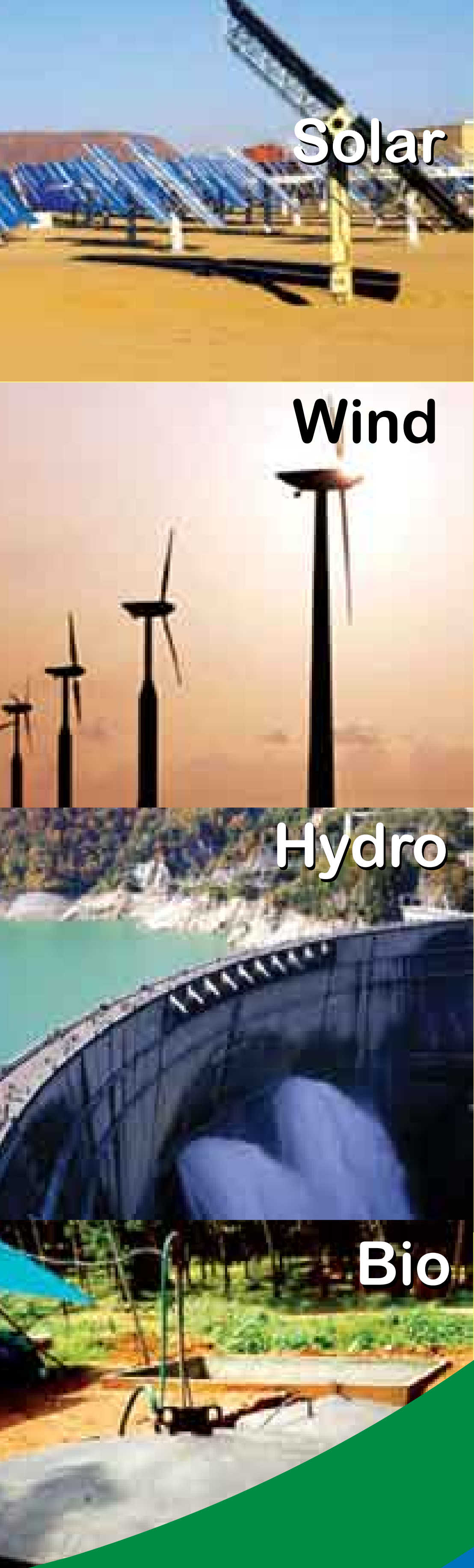
Capacity (MWp)	Location	Year of installation	Power generation (MWh)	GHG abatement (tonnes of CO_2 displaced)
23.0	Spain	2008	41 600	42 000
21.0	Spain	2008	40 000	
20.0	Spain	2008	42 000	
20.0	Spain	2007	30 000	30 000
18.4	Germany	2007		
14.0	USA	2007	30 000	23 000

with a clear objective of harnessing the available solar power generation potential in the state of Rajasthan. Accordingly, a public notice in this respect was issued on 15 February 2008 in a few prominent newspapers, seeking comments from all interested stakeholders in the field. Following this, a public hearing was held on 4 March 2008, wherein representatives of several government organizations and the solar industry put forth their views. There were many key points raised during these deliberations.

The recently announced policy on solar grid power generation is peculiar in that more incentive would have to be made available to the power producer in case of the commission specifying a lower tariff. On the other hand, the higher tariff fixation would put the burden on the consumer, but the incentive available from the ministry would be lower or even negligible. In view of this, reasonable tariff should be put in place so as to protect the investor's interest together with a suitably evolved compensation for the distribution of solar power at a higher cost. A different opinion was that a maximum of 5% of the power purchase cost by the discom should be considered. Simply put, this incentive should be passed on to the discom instead of the project developer.

A few members felt that the proposed tariff was reasonable, though it must be operationalized for a longer period to make the project viable. Further, the depreciation benefit should be allowed for the solar projects in this case too. Some members also demanded extension of the applicability date of the promotional tariff vis-à-vis the power plants commissioned up to March 2012. At present, the promotional tariff for solar power project is for 10 years only, but the PPA (power purchase agreement) can be executed for 20 years or life of the plant. The aim of the promotional tariff is to attract solar power generation, and, therefore, the tariff has to be for a limited capacity and for a limited period. For setting up of a solar power project, the developer may get the provisional tariff determined on a case-to-case basis, that is, specific for site, technology, and financial package. The tariff can be within the financial parameters of the RERC tariff determination regulations or there can be a competitive bidding.

There was an important observation as per which there is no restriction on allowing an open access to non-renewable and renewable power. Interestingly, a suggestion was mooted with regard to integrating the solar power at places endowed with wind power. Further, the evacuation capacity already in place can be used optimally. ■



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EVALUATING RENEWABLE ENERGY PROJECTS

A REVIEW OF RETScreen SOFTWARE

The RETScreen International Clean Energy Project Analysis Software is a unique decision-support tool for renewable-energy-based project evaluation. The RETScreen International Clean Energy Decision Support Centre seeks to build the capacity of planners, decision-makers, and industry for implementing projects related to renewable energy and energy efficiency. The software essentially helps the user feed appropriate inputs for designing and costing a project in situations where space and water heating are the primary loads, along with a critical range of financial indicators, for assessing the viability of project. These include simple payback period and the net present value of total savings.

This user-friendly software helps the user identify the inputs and suggests acceptable value ranges. An accompanying manual provides a detailed description of the software as well as a substantial background on renewable energy technologies. The software carries out a preliminary analysis of renewable energy projects anywhere in the world. This includes projects on wind energy, small hydro, photovoltaics, biomass heating, solar air heating, solar water heating, passive solar heating, and ground-source heat pumps.

The latest version of this software also helps in static simulation of buildings. If measured values are not available, the software is linked with the NASA (National Aeronautics and Space Administration) Satellite to calculate meteorological parameters (for example, solar radiation, wind speed, ambient temperature, relative humidity, and so on). Thus, a user can get the values of required meteorological parameters by providing latitudinal and longitudinal data of the project site.

The software is available free of cost and can be used worldwide to evaluate the energy production and savings, life-cycle costs, emission reductions, financial viability, and risk for various types of energy-efficient and renewable energy technologies. The software also includes product, cost, and climate databases, and a detailed online user manual. The help section of the software carries many case studies, a training course, an engineering electronic textbook, and so on. These tools are available free of cost in English and French, with many of the tools available in other languages as well.

In RETScreen Version 4, the software's capabilities have been expanded from renewable energy, co-generation and district energy, to include a full array of financially viable clean power, heating and cooling technologies, and energy efficiency measures. The international appeal of this decision-support tool has been improved through the expansion of climate data, required by the tool, covering the entire surface of the planet, including central-grid, isolated-grid, and off-grid areas, as well as through the translation of the software into 30 languages that are spoken by roughly two-thirds of the world's population.

The key outputs of this significant effort are as follows.

- Development of a suite of new models to evaluate energy efficiency measures for residential, commercial, and institutional buildings; communities; and industrial facilities and processes.
- Expansion of the RETScreen Climate Database to 4700 ground-station locations around the globe and incorporation of the improved NASA Surface Meteorology and Solar Energy Dataset for populated areas directly into the RETScreen software.
- Integration of the existing RETScreen models for renewable energy (for example, wind energy) and combined heat and power, along with the new models for energy efficiency measures, all into one software file, and expansion of the capabilities of existing models to evaluate emerging technologies, such as ocean current and wave power.
- Translation of the integrated single software file and databases into 30 languages (for example, Chinese, French, German, Hindi, Italian, Japanese, Portuguese, Russian, Spanish, and so on).
- Broad dissemination of the tool via the RETScreen Website and CD-ROM, with locally targeted training and dissemination by an international network of RETScreen trainers and outreach partners.

The expected outcome of this work is that by the end of 2012, an estimated 300 000 planners, professionals, and decision-makers will have been empowered to make better energy decisions as a result of the knowledge transferred and by the subsequent use of the improved decision-making tools.

The RETScreen software carries out preliminary analysis of renewable energy projects anywhere in the world

RETScreen is developed and maintained by a core team at CETC-Varennes, with a large network of experts from industry, government, and academia providing technical support on a contracted or task-shared basis. This approach provides RETScreen International with access to a broad array of expert skills, which are needed for specialized tasks. The software has been developed by Natural Resources Canada in association with NASA, UNEP (United Nations Environment Programme), GEF (Global Environment Fund), and REEEP (Renewable Energy and Energy Efficiency Partnership).

Two versions are available online on the link *http://www.retscreen.net/ang/home.php*. Various RET case studies are also available in a standard format on *http://www.retscreen.net/ang/12_case.php*.

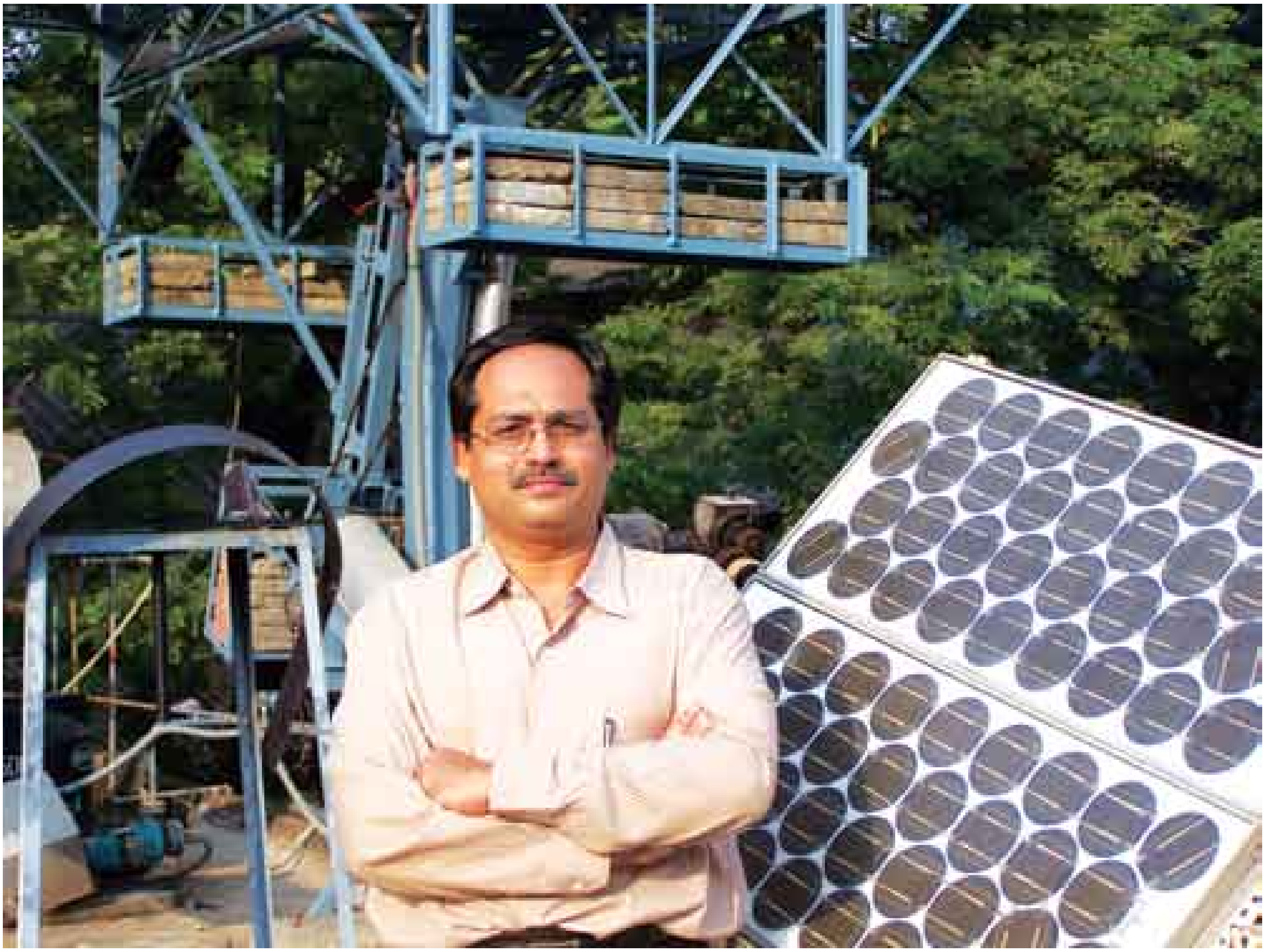
A sustainable future for India...

Dr Shireesh Kedare, Director, Clique Development Pvt. Ltd, talks about thin-film photovoltaic technology, and the strengths and weaknesses of the solar energy industry in India

Indian R&D efforts in the area of thin-film technology development have been quite intensive across several well-known academic and research organizations. However, there is no established history of any successful commercial venture based on such a technology. What are your thoughts on this issue?

My field is solar thermal technology and I am not an expert in SPV (solar photovoltaic). However, I can see that the thin-film technology is coming up, and the commercial ventures in this technology are taking shape. In about two years, we should get thin-film PV in the market. It should be mentioned here that thin-film cells are less efficient (efficiency is only about 7% compared to 12%–15% in case of crystalline silicon technology). So, they will require almost double the area for the same power output. But, the cost for the same power output will be lesser than that of crystalline silicon technology, of course excluding the land cost.

There is now a fairly well established production base for the manufacture of solar cells and modules in the country. The newly announced generation-based incentive for the solar PV power generation is a step in the right direction. But, does it call for strengthening the R&D base in the area of power conditioning units, for example, when we look at an increasing number of imported electronic control units still being used in India?



I will say it is a good beginning. And yes, it will also indirectly boost the R&D base. This policy has sent a message that we need to work in the solar field, and the government support is going to come in because utility needs power. This will certainly attract more research students to this field. This will encourage the research institutes and teachers. New courses in solar and allied field will start. There will also be some activity in allied industries.

What according to you are the major strengths and weaknesses of the solar energy industry in India?

I would like to interpret this question on the background of solar thermal field and answer accordingly, as I am more conversant in the activities in solar thermal field, especially the concentrators.

The major strength of the Indian solar energy industry is that it is in a country where solar energy is abundant almost everywhere. But that's not all. We also have an advantage of small and medium industry, wherein ground and roof installation of solar devices of about 500–2000 square metre contribute to significant amount of heat being used in that industry, thus, making significant dent in its fuel consumption. This is more so with the concentrators developed and being commercially installed in India, which can handle medium temperatures (100 °C to 150 ºC by Scheffler systems for cooking) to high temperatures (120 °C to 350 ºC by Arun Solar Paraboloid concentrator developed by Clique Developments Pvt. Ltd, Mumbai for wide-scale industrial process heat applications). The concentrators can now replace steam being used in the industry with solar steam. The Arun Solar Paraboloid concentrator by Clique is specifically designed for industrial process heat applications, and it comes with optimized integration needed for industrial applications.

Further, the increasing costs of liquid fossil fuels in India make solar thermal systems more economical day by day. Based on the record of last 10 years, we can say that the costs of materials going into the making of solar thermal devices increased at a rate of 10% annually, whereas the cost of liquid fossil fuels that they save increased at an annual rate of 20% in India. This is an advantage for solar thermal industry in India.

But, then, there are weaknesses too. We are not well organized and are not able to reach the market in a united way to make a bang. We are slow in innovating and adopting new technological concepts and slow in convincing the market about our capabilities.

What can the Indian solar industry learn from the advances being made across the world, especially in Europe?

I think India is different. Its solar thermal energy market economics is different from that of Europe. The texture of manufacturing capabilities of Indian entrepreneurs is different. The technologies, which are costlier in Europe, like paraboloid dish technology, are comparatively cheaper here because of the manufacturing processes used and the scale of production. On the other hand, technologies like parabolic trough require the back-up of large-scale dedicated manufacturing units, which are not available in India. This affects the choice of technology in India.

> The major strength of the Indian solar energy industry is that it is in a country where solar energy is abundant almost everywhere. But that's not all. We also have an advantage of small and medium industry wherein ground and roof installation of solar devices of about 500–2000 square metre contribute to significant amount of heat being used in that industry, thus, making significant dent in its fuel consumption...

Still, what we can learn from European entrepreneurs and industry is their sustained efforts over many years, integration of university research into products, and their ability to dream!

The Indian renewable energy industry is showing a remarkable growth rate over the last few years, particularly with the wind energy segment taking it to new heights. However, there is still not a definite yearning to make a career in this industry for one reason or the other. Are you taking a close look at this hitherto subdued human resource development sector too vis-à-vis renewable energy?

The situation is fast changing. I know a few examples. IIT-Bombay has started MSc-PhD in Energy (science) as well as BTech (energy)-MTech (energy systems) dual degree. Many schools and institutes have started UG and PG courses. WISE (World Institute of Sustainable Energy), Pune, conducts short courses for manpower in the renewable energy industry, especially wind; and I think they will also conduct similar courses in solar PV and solar thermal. And you are aware of TERI's plans better than me.

But, I may agree that we may be slow—considering the estimated requirement of about 10 000 to 20 000 qualified personnel in the solar sector in the next five years and almost the same in the wind sector, if not more. If I add biomass, the number will increase further.

Would you like to give any special message to a growing community of stakeholders through *The Solar Quarterly*?

I will say that we should take a broader view and see that the renewable energy sector does not comprise a single or few technologies. It is a combination of many technologies in the basket. India can address its energy issues, with a combination of different renewable energy technologies and devices appropriate for different applications, in different regions in different cost brackets. Multiple solutions will lead to a stable and sustainable future.

A sustainable energy future for India is possible only if we act today and act in many directions.

As told to Roshni Sengupta, TERI

Subsidy for solar power inevitable

Mr V Subramanian, former Secretary, Ministry of New and Renewable Energy

The need to generate power from renewable sources of energy is being increasingly emphasized due to growing awareness about climate change. The initial response to the subsidy scheme for solar power is very positive. V Subramanian, former Secretary, Ministry of New and Renewable Energy, feels that the cost of solar power generation would come down over time due to technological improvements.

How would you rate the performance of your ministry during 2007/08?

The progress of the ministry has been very commendable, although there is still a long way to go. As of March 2008, the installed capacity of solar photovoltaic systems in the country has increased to 125 MW in various applications like lighting, rural telecom, and offshore oil-well-head platforms. We have street lighting systems, lanterns, home lighting systems, and pumping systems run on solar power, apart from stand-alone units. Installed capacity in the case of wind energy has increased to 8757 MW, followed by 2180 MW in the case of small hydro projects, 800 MW in the case of bagasse co-generation, and 606 MW in the case of biomass conversion. In the short-to-medium term, we can generate more power, from renewable sources as compared to nuclear power. We have set the ball rolling with subsidy scheme for solar power and the initial response is very positive. There are people who do not want their investments restricted to 50 MW, but we have kept in mind the need to keep the window open for opportunities from various parts of the country.


As much as 97% of the power generation capacity based on renewable energy is built on the strength of incentives and government policies

Why should the government subsidize solar power?

The estimated cost of generating solar power is about Rs 15 per kWh (kilowatt-hour). This is the cost of supplying PV (photovoltaic) power to the grid, without involving any batteries for storage. Since the unit cost of power generated through conventional sources is far lower, and the cost at which power is bought by state electricity boards is cheaper, the government has decided to subsidize solar power generation. The incentive is up to Rs 12 per kWh for electricity generated from solar photovoltaic and a maximum of Rs 10 per kWh for electricity generated through solar thermal power plants. We need to provide subsidy in order to encourage generation of clean energy. This subsidy is only for power supplied to the grid. It is not applicable for any private supply or captive use.

How will the subsidy, once awarded, go down?

The initial cost of solar PV systems is high because raw materials like silicon wafers are imported. We expect costs to come down over a period of time due to advances in technology. In the next four to five years, we expect conversion efficiency of solar power plants to improve to 18% as compared to 14% or 16% now. The industry, on its part, is trying to reduce consumption of silicon wafers. As a result of these measures, cost of solar cells and modules should come down by about 33%. Therefore, the subsidy component can be reduced over a period of time. There is a built-in provision to bring down maximum subsidies by 5% each year for capacities commissioned from 2010/11 onwards if the current programme is not reviewed in 2009/10.

Do you believe the subsidy offer would attract a large number of investors?

As much as 97% of the power generation capacity based on renewable energy is built on the strength of incentives and government policies. This includes wind energy, power from waste, bagasse co-generation, and biomass conversion programmes. For the sake of clean energy, incentives have been provided. We are confident of the solar power scheme since it is a direct, upfront subsidy. The programme would be implemented through IREDA (Indian Renewable Energy Development Agency), and there is no chance of bureaucratic red tape coming in the way of the delivery system. State electricity boards will not feel any disincentive since they are buying power at commercial rates, similar to what is paid to other electricity producers. Moreover, we are also providing state electricity boards with an incentive of 10 paise per unit sourced from solar power generation.

Can we quantify the projected benefits from the subsidy for solar projects?

Every solar plant with 1-MW capacity would produce 2 million kW of electricity, taking care of 5000 families if we go by the government's commitment of providing at least 1 kW of power to each rural household. Apart from this, each of these plants would create 25 to 40 jobs directly and another 400 indirectly. ■

Interview courtesy: Akshay Urja

Solar Thermal Power Generation

New Initiatives

Solar energy is increasingly being utilized for a variety of end-use applications. Of these, SPV (solar photovoltaic)-based applications are outnumbering the solar thermal uses. The MNRE (Ministry of New and Renewable Energy) has just announced a generation-based incentive for power generation via the solar thermal route as well. However, there are many issues to be addressed before solar thermal power gets a foothold within the country. On the international front, a few countries like the US and Spain have already established multi-megawatt solar thermal power plants hooked to the grid.

Algeria and Germany have recently signed a joint research agreement for the development of large-scale, low-cost thermal power plants. This is based on the assumption that such power plants will be more successful because of their cost-effectiveness. The project will be participatory in the true sense, sharing data and expertise, and will aim at speedy introduction of large-scale thermal power plants in the market. These plants could supply up to 200 MW of electricity and desalinate water for the consumption by about 50 000 people.

Site selection

The German organization has used weather data from the last several years to select countries that receive maximum sunlight. In Algeria, an average of 2200 kWh (kilowatt-hour) of solar radiation is incident on each square metre, with about 2650 kWh falling on the Sahara desert region. Compare this with a 1000 kWh of solar radiation touching 1 m^2 in Germany and about 1500 kWh in India. Estimates point to the fact that solar energy harnessed just from Algeria could fulfil 60 times the electricity needs of Europe.

System optimization

There is a 150-MW hybrid solar-gas plant located 420 km south of Algiers at Hassi R,mel. It has a capacity of 25 MW, with a parabolic trough design, and is likely to start operating in 2009. According to an agreement between DLR in Germany and the NEAL (New Energy Algeria Ltd), complete data access would be provided to the German researchers from this plant. The aim of such an exercise is to optimize the design and manufacture of the system components besides the efficiency of the collectors and absorbers. The research teams will also look at the thermal storage technology aspect.

Desalination use

Solar thermal desalination plants could turn as much as 100 000 m^3/day of sea water into fresh, clean water. This would increase the agriculture yield and secure the supply of drinking water in a usually drought-hit region. As per a German study, there is a shortfall of about 50 BCM (billion cubic metres) of fresh water already in the region. It is expected to reach an alarming 150 BCM by 2050.

Transporting the power

A 1875-mile high-voltage direct current cable is proposed to be built between Algeria and Germany, which will run through a few countries like Sardinia, Italy, and Switzerland. Hopefully, small quantities of electricity can be imported into Germany by 2010. DLR, the German organization, is also looking at the possibility of starting a research project on a pilot scale with a 1.5-MW capacity solar tower power plant in Julich in northern Germany.

Partnership of purpose

DLR possesses nearly 30 years of rich experience in solar thermal power technology. In contrast, Algeria has the most suitable sites for such plants. The technology is thus intended for captive use and for export to Europe at a later stage. DLR has used satellite imagery to locate best possible sites for the purpose.

Feed-in-tariff

In several parts of the world, solar power generation is now facilitated by a feed-in-tariff route. Algeria has already introduced a feed-in-tariff for electricity from solar thermal plants so as to catalyse the use of technology. NEAL is determined to build thermal plants running purely on solar energy. A typical future solar thermal power plant could have capacity as high as 200 MW. It could then supply power to nearly 0.25 million people and fresh water to 0.05 million people.

Project finance

Almost 80% of the project finance is expected to come from private investors in expectation of the best possible return. In technical terms, it means looking for nearly cloud-free sites.

Economic estimates

Electricity obtained from solar thermal power plants may cost as little as €0.04/kWh ($0.06/kWh) by 2015 to 2020, according to Mr Bernhard Millow from the German Aerospace Center (DLR). Further, using solar thermal power to desalinate sea water could cost the same. Currently, electricity from solar thermal plants costs €0.20–0.30/kWh ($0.31–0.47/kWh), depending on the location of the plant and the amount of sunlight it receives.

However, with improvements in the performance of plants and better sites, solar thermal electricity could soon be cheaper than coal. This may well pave the way for generating large amounts of reliable, clean electricity in hot desert regions. As per DLR, 1 kWh of electricity could still be as low as €0.06–0.07/kWh (US $0.09–0.11/kWh) if the power plants are built in prime locations. Taking it further means that by 2050, about 10%–25% of Europe's electricity needs could be supplied by North African solar thermal power plants.

Global status of solar thermal power plants

Solar thermal power plants have been in commercial use in southern California since 1985. In 2007, a 64-MW capacity parabola trough Nevada Solar One plant began operation. In Spain alone, about 10 new solar thermal plants are being plant. Spain went ahead with a 25-year guaranteed feed-in tariff of €0.26/kWh ($0.40/kWh) for solar thermal electricity. It is currently constructing Europe's two largest parabola-trough-based solar power plants, namely, Andasol I and II in Andalusia. Prior to this, the 11-MW PS10 solar power tower also started operating close to Seville in southern Spain. As per the available information, several new plants are also being conceptualized in countries like Egypt, Iran, Israel, Mexico, Morocco, and Abu Dhabi. The Red Sea region may also be used to derive power through wind energy and solar energy.

India has also set the ball rolling by offering generation-based incentive for the solar thermal power route as well. A few wide ranging deliberations have taken place so far amongst the potential project developers and the MNRE. There is a broader view that solar thermal plants with a capacity of 1 MW may not be techno-economically feasible. Therefore, the ministry should look into the possibility of according its approval to the setting up of 15–20-MW capacity thermal power plants. ■

DLR is planning a research project on a pilot scale with a 1.5-MW capacity solar tower power plant in North Germany

With inputs from the research team

Cold storage goes solar

Battery-less solar PV refrigerator

This project, under which a battery less refrigerator was developed, is best known as a Solar Chill Project. It has witnessed a unique partnership amongst key international organizations, NGOs, and private sector manufacturing companies.

- OzonAction (UNEP)
- UNICEF
- WHO
- Greenpeace
- Path
- Danish Technology Institute (research organization)
- GTZ Prokilma (development agency)
- Danfoss
- Vestfrost

This showcases the power of such a diverse partnership for the first time that can produce a product with an ability to improve the health of children in the developing countries. It is expected that the solar chill will ultimately replace a sizeable number of kerosene oil and electricity dependent refrigerators in use today across the world for cooling vaccines.

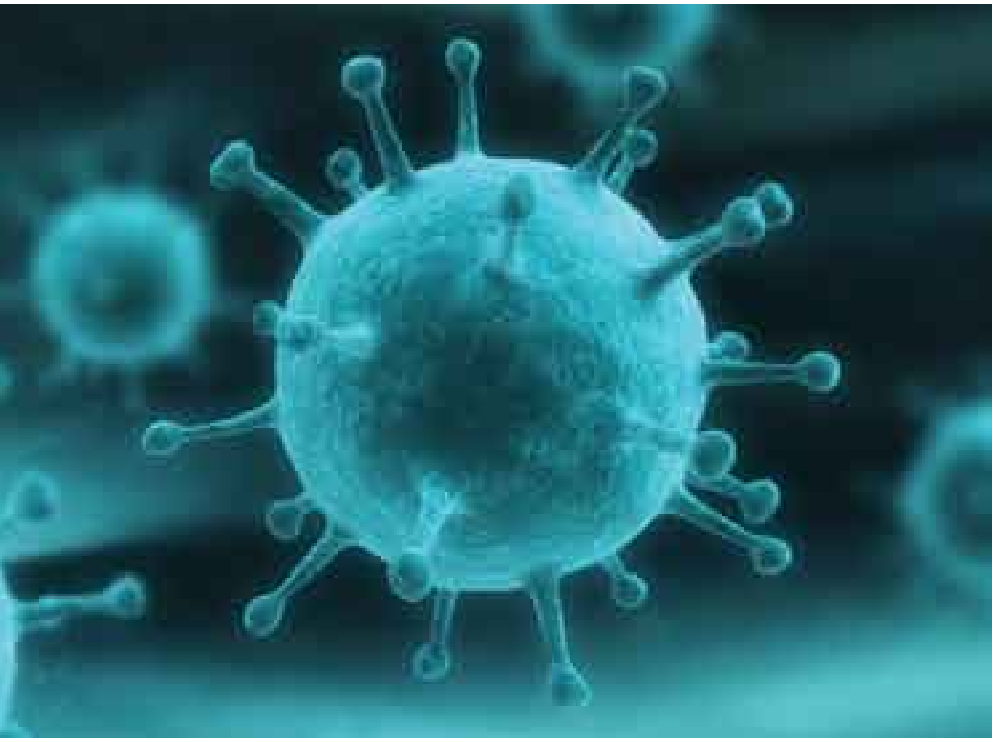
Technology in brief

It is a new technology, where the appliance is solely driven by solar energy from solar panels. A unique feature is that it uses no batteries at all. In this case, the energy is stored in the ice packs through the use of direct current compression power of the solar panels. The temperature control is via natural convection between the ice storage component and vaccine component. This unit does not involve the use of any electronic controls.

The reason for choosing energy storage in ice was to avoid a lead battery for energy storage. Lead batteries tend to deteriorate, especially in hot climates, or they are misused for other purposes. This makes it necessary to install a new battery after a couple of years, and has in practice been an obstacle for the use of solar powered refrigerators. In addition to that, some pollution resulting from lead might be expected from the batteries. Instead, kerosene or gas powered absorption refrigerated coolers are widely used in areas with poor or no grid electricity. Absorption coolers are used for both vaccine storage and for household applications and obviously need regular supply of fuel. Furthermore, they are difficult to adjust, which does often result in destructive freezing of the medicine.

Another unique feature of the solar chill is that there is no contribution to ozone depletion since it uses hydrocarbon Danfoss compressor and cyclopentane blown insulation foam.

The vaccine cooler cabinet is built by Vestfrost, and is based on a highly insulated standard cabinet. The net volume of the vaccine compartment is about 50 litres and is separated from the ice storage of about 18 kg, made by a number of standard plastic containers. The evaporator is integrated into the ice storage end during daytime forced convection is cooling the vaccine. If the temperature in the vaccine compartment gets to cold during daytime, a small electrical heating element is keeping the vaccine above freezing temperature. A thermostat controls the heater. At night, the vaccine is kept cool by natural convection from the ice department.



Other key features
- Self regulating temperature control
- Zero fuel cost
- Little or no maintenance
- Environment friendly

Field testing and evaluation

This refrigerating unit has been developed in a record period of six years through a multi-organizational partnership. It has been extensively tested in a few countries like Cuba, Senegal, and Indonesia under actual field operating conditions. Currently, it is awaiting the much-needed approval from WHO (World Health Organization) so as to gain global acceptance.

Even after an expected WHO approval, there is still basis for optimization, such as the following.
- Minimization of the module area for specific climatic regions.
- Optimization of the control strategy in order to minimize the needed PV-power.
- Further simplification and cost reduction of the construction.

Some obvious future applications for this product could be milk chilling, vending booths for food and beverages, recreational purposes or as a grid-independent household refrigerator.

Key system specifications
- Solar panel capacity: 150–180 Wp
- Vaccine storage capacity: 40 litres
- Temperature range: 2–8 °C (at 10–27 °C ambient temperature)
- Backup time (without any sun at all): 20 hours at 27 °C
- 3 storage baskets
- 3 separate ice packs
- Dimensions: 850 mm × 720 mm × 600 mm
- Make: Vestfrost (Denmark)
- Approximate cost: 2000 euros

Indian distributors

In India, this product is being marketed by Celsius Refrigeration Pvt. Ltd, which is located at the following address.
7th Floor, Udyog Minar
Udyog Vihar Phase-V
Gurgaon – 122 016
Haryana

New Book Information

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

Authors (s) Falk Anthony, Christian Durschner, Karl-Heinz Remmers

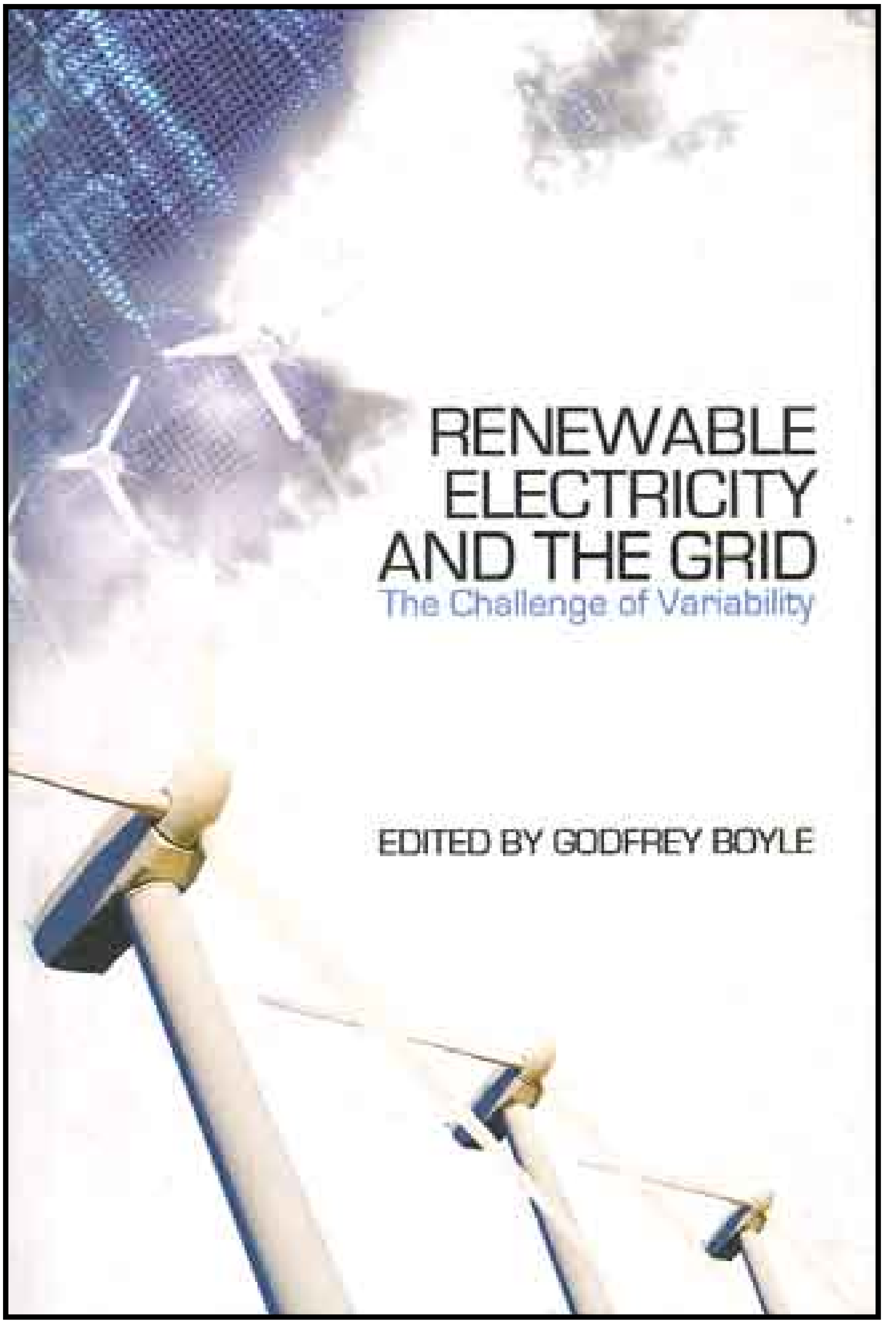
Publisher Solarpraxis AG in association with Earthscan

Year of Publishing 2007

Price £42.75

About the book

This book primarily focuses at imparting practical knowledge to designers and installers of SPV (solar photovoltaic) systems through easy to understand, step-by-step examples. With PV use growing by the day worldwide, the book comes across as an easy reference to understand the nuances of PV technology from a variety of end-use considerations. The book offers quite a few useful tips so as to make the experience of PV system design, installation, maintenance, and trouble-shooting as exact as is possible. Coloured illustrations of product applications enrich the well-chosen contents further. ■



Title Renewable Electricity and the Grid: the challenge of variability

Edited by Godfrey Boyle

Publisher Earthscan

Year of publishing 2007

Price £60.00

About the book

Renewable energy sources like the wind are proving to be significant contributors to the overall installed conventional power capacities across several countries including India. However, this is also accompanied by a certain degree of variability in electricity supplies. This edited volume of articles written by acclaimed experts in the field investigates the importance of the issue of variability of renewables. It offers technical-cum-operational solutions besides quantifying the impacts of such variability. The outcome spells out a more positive outlook on wind and solar energy sources, which beyond any doubt are not present in the same measure every now and then. ■

Forthcoming renewable energy events

Renewable Energy India 2008 Expo
21–23 August 2008
Hall 7, Pragati Maidan, New Delhi

International Congress on Renewable Energy 2008
16–17 October 2008
Hotel Le Meridien, Chennai
info@sesi.in

Renewable Energy Asia 2008: international conference and fourth SEE forum meeting
11–13 December 2008
Dr Virendra Kumar Vijay
Centre for Rural Development and Technology, IIT Delhi
www.iitd.ac.in

19th International Photovoltaic Science and Engineering Conference
19–23 January 2009
Science City, Convention Centre, Kolkata
ersr@iacs.res.in

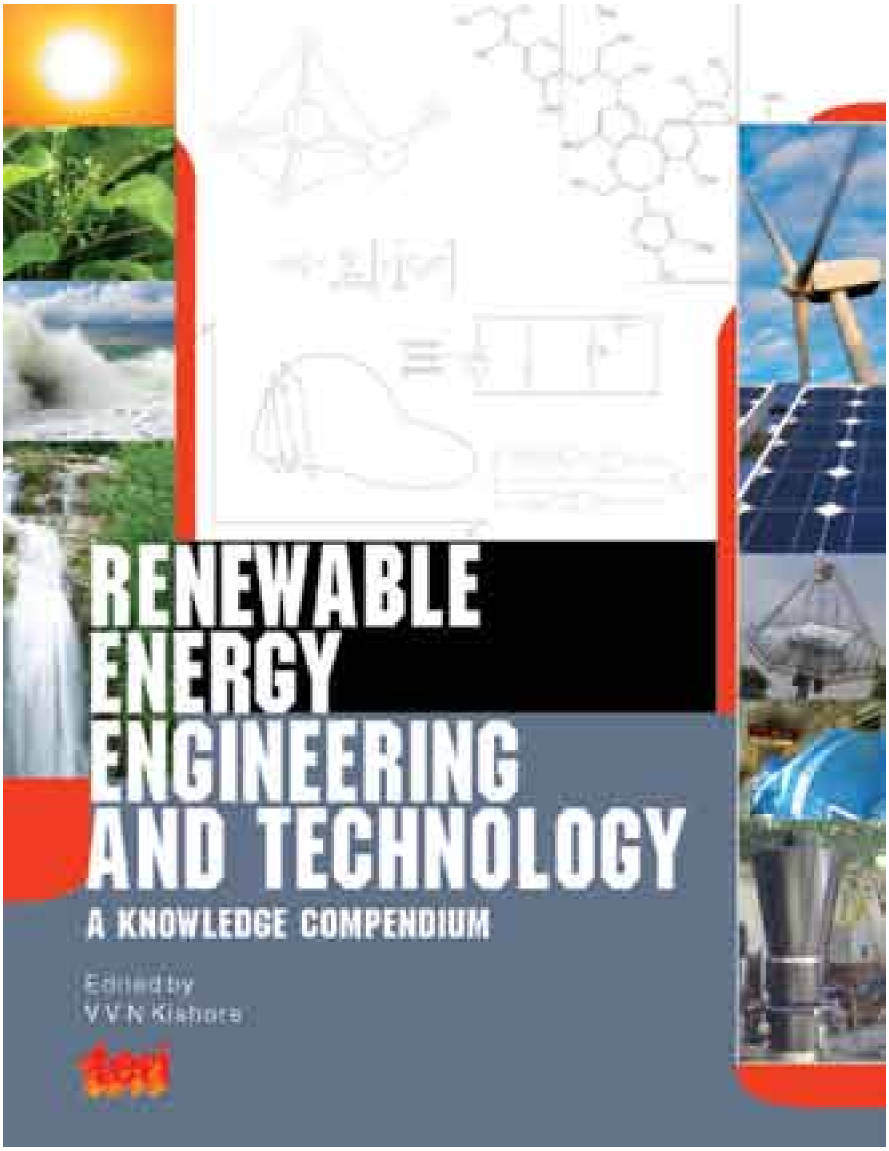
Renewable Energy Finance Forum 2008
20–21 November 2008
Euromoney Energy Events
Nestor House, Playhouse Yard, London

Wind Power 2008
1–4 June 2008
1001 Avenida de las Americas
Houston, TX 77010
http://www.houstonconventionctr.com

Energy Ocean 2008
24–26 June 2008
Technology Systems Corporation
P O Box 1096, Palm City, Texas
info@energyocean.com

The 10th World Renewable Energy Congress and Exhibition
21–24 July 2008
P O Box 362
Brighton, Glasgow, UK
asayigh@netcomuk.co.uk

23rd European Photovoltaic Solar Energy Conference
1–4 September 2008
WIP-Renewable Energies
Sylvensteinstr. 281369 München, Germany
pv.conference@wip-munich.de



Renewable Energy Engineering and Technology: a knowledge compendium

Edited by V V N Kishore

Publisher: TERI Press. 925 pp.

ISBN: 81-7993-093-9

Price: Rs 2250

Energy is a key requirement for implementing any strategy towards increasing economic output and/or towards improving the quality of human life. During the 20th century, human civilization has essentially depended on fossil fuels with their per capita as well as gross consumption increasing considerably with time. The extraction, conversion, transmission/transport, distribution, and utilization of fossil fuels releases highly polluting emissions into the ecosystem. Their accumulation can have adverse impacts at the local as well as global levels. Large-scale harnessing of renewable energy resources is one of the potential strategies to reduce energy-related environmental emissions. Renewable energy utilization can help reduce dependence on gradually depleting fossil fuels and at the same time facilitate transition towards a low-carbon economy.

Recognizing the fact that availability of adequate manpower with required knowledge and skills is an essential prerequisite for large-scale dissemination of renewable energy technologies, a large number of academic institutions are offering teaching/training programmes in this area. Moreover, many organizations are engaged in the development and dissemination of these technologies. Unavailability of quality text and resource books and other teaching/learning resource materials has been a major handicap in imparting renewable energy education at all levels. This book is a timely and extremely valuable contribution towards providing a comprehensive teaching/learning resource material on renewable energy technologies and also a resource book for researchers, planners, policy-makers, and other stakeholders in the field.

The book covers all renewable sources of energy (solar, wind, small hydro, biomass, geothermal, OTEC, waves, and tides) and also has a chapter that deals with basic scientific and engineering principles relevant for harnessing the same. Each chapter provides a judicious mix of conceptual inputs, mathematical formulations, and practical considerations on resource assessment, design and performance characterization of respective technologies, and system integration aspects. The examples provided are of great help in assimilating the information provided in each chapter. The text is well written, is easy to understand, and provides tremendous amount of information useful for all the stakeholders in the development and dissemination of renewable energy technologies.

If priced moderately, this book has the potential of reaching the desks of all students of renewable energy. ■

Reviewed by
Tara C Kandpal
Centre for Energy Studies
Indian Institute of Technology Delhi
Hauz Khas, New Delhi – 110 016

Photovoltaic systems

www.pvresources.com
This website is devoted to promoting PVC (photovoltaic) applications and technologies. It was developed as non-commercial helpful information to serve teachers, students, and others interested in PV. The website provides many interesting information on PV technologies, systems, applications, and so on. Further detailed information and answers on the most complex questions about solar electricity use are accessible through links leading to websites of many different organizations and institutions.

Solar utilities network

http://www.solarnet.org/
The SUN (solar utilities network) is a not-for-profit informational website sponsored by the Caspar Institute in support of global efforts to reform energy use. The website provides practical information and strategies for saving energy and using renewable resources in the home. On this site are links to case studies describing the actual applications of sustainable energy technologies, do-it-yourself project ideas, and a schedule of 1996 training courses taught by experts from the SUN.

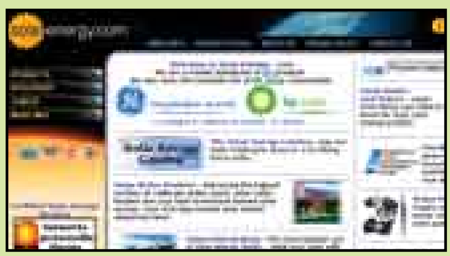
Photovoltaic Power

http://www.pvpower.com/
This website aims at the coordination and dissemination of information on global PV technologies, its applications, history, and resources. It also contains a searchable database of all the solar products including solar panels, solar heating systems, pumps, generators, and inverters.

Solar Energy International

http://www.solarenergy.org/
SEI (Solar Energy International) provides education and training to decision-makers, technicians, and users of renewable energy sources including practical use of renewable energy technologies, including electricity from sun, wind or water by conducting workshops, programmes, and so on. The site is a rich collection of books, videos, and softwares related to renewable energy and sustainable building technologies, online education, training, technology transfer programme, and project reports on renewable energy. It contains a newsletter and links to other related websites.

Solar energy marketplace



http://www.solarenergy.com/
Solarenergy.com is a web-based marketplace dedicated to providing information on solar products including solar panels, batteries, controls, pumps; PV; solar water heating; commercial products including water heating, control panel, air conditioning, commercial pool heating, power generation, and solar news. The site also provides pricing of a wide range of products and publishes a regular newsletter.

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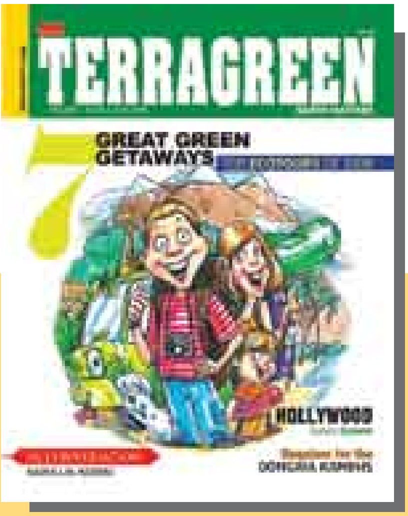
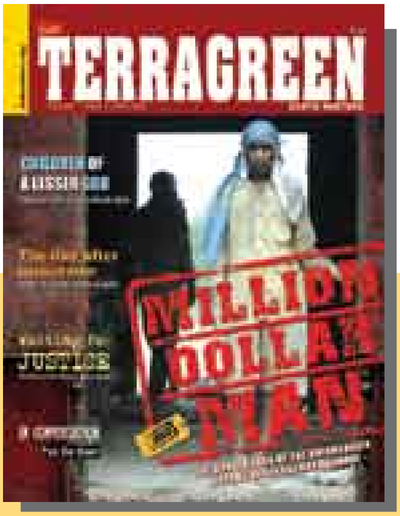
Earth matters





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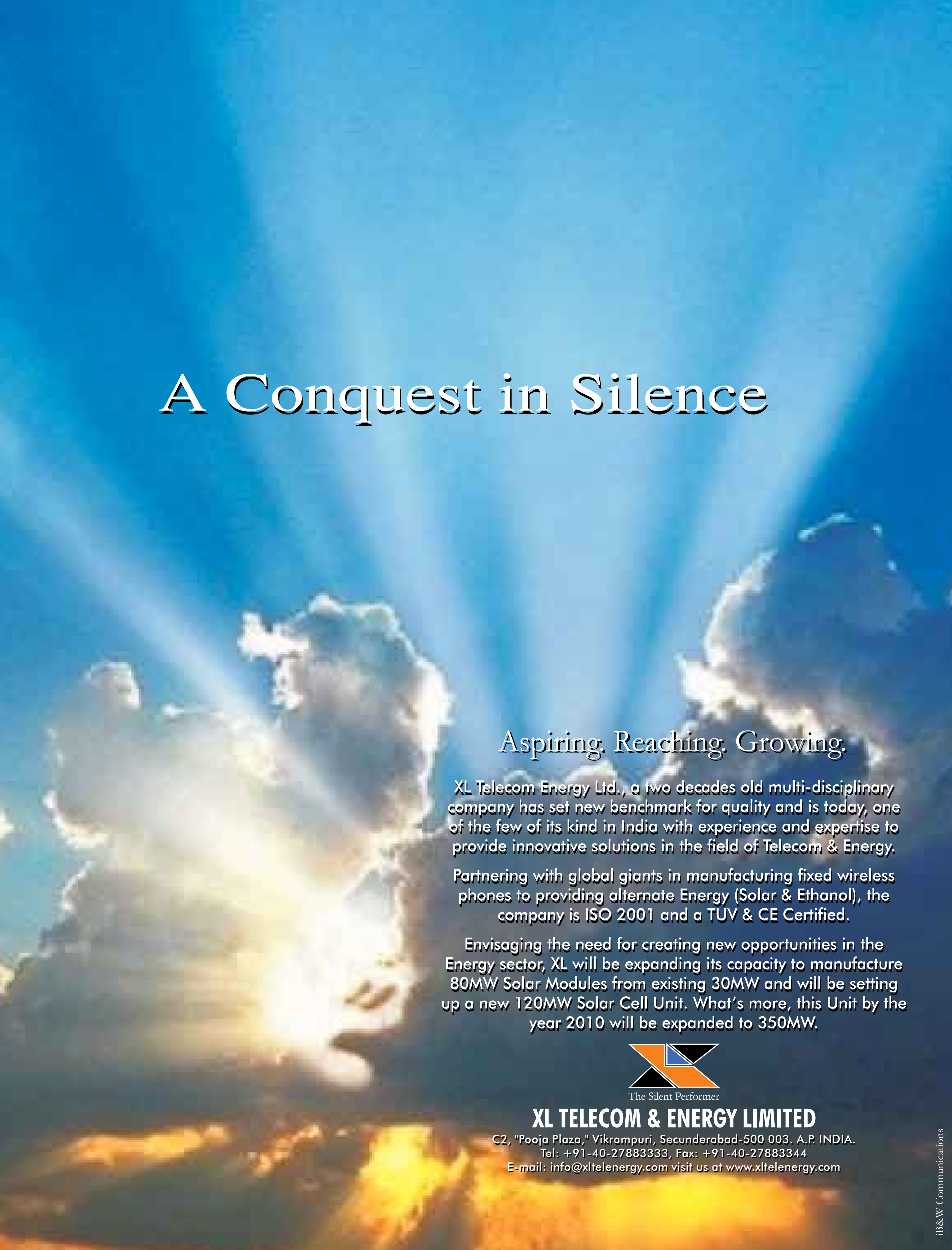
Renewable Energy: Indian scenario

S.No.	*Source/system*	*Estimated potential*	*Achievement as on 31 March 2008*
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	8757.00
2	Bio power (agro residues and plantations)	16 881	606.00
3	Bagasse cogeneration	5 000	800.00
4	Small hydro power (up to 25 MW)	15 000	2180.00
5	Energy recovery from waste (MW)	2 700	55.25
6	Solar photovoltaic power	–	2.12
	Sub total (A)	**84 776**	**12 400.37**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	–	95.00
8	Biomass gasifier	–	100.11
9	Energy recovery from waste	–	26.70
	Sub total (B)	**–**	**221.81**
	Total (A+B)	**–**	**12 622.18**
II	**Remote village electrification**	**–**	4 198 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	39.94 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MW_p
	i. Solar street lighting system	–	70 474 nos
	ii. Home lighting system	–	402 938 nos
	iii. Solar lantern	–	670 059 nos
	iv. Solar power plants	–	2.22 MW
	v. Solar photovoltaic pumps		7148 nos
12	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	2.30 million m^2 collector area
	ii. Solar cookers		6.20 lakh
13	Wind pumps		1284 nos
14	Aero generator/hybrid systems		675.27 kW
IV	**Awareness programmes**		
16	Energy parks	–	504 nos
17	Akshay Urja shops	–	269 nos
21	Renewable energy clubs	–	521 nos
22	District Advisory Committees	–	560 nos

MW – megawatt; kW – kilowatt; MW_p – megawatt peak; m^2 – square metre; km^2 – kilometre square


A Conquest in Silence
Aspiring. Reaching. Growing.
XL Telecom Energy Ltd., a two decades old multi-disciplinary company has set new benchmark for quality and is today, one of the few of its kind in India with experience and expertise to provide innovative solutions in the field of Telecom & Energy.
Partnering with global giants in manufacturing fixed wireless phones to providing alternate Energy (Solar & Ethanol), the company is ISO 2001 and a TUV & CE Certified.
Envisaging the need for creating new opportunities in the Energy sector, XL will be expanding its capacity to manufacture 80MW Solar Modules from existing 30MW and will be setting up a new 120MW Solar Cell Unit. What's more, this Unit by the year 2010 will be expanded to 350MW.
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