The SOLAR QUARTERLY

The Complete Solar Magazine

Volume 1 • Issue 3 • April 2009

Rs 200

TURNING THE HEAT ON
Solar thermal power generation

GRIHA
transforming passive features into active gains

BRINGING LIGHT TO RURAL INDIA
Greenathon: India's first 24-hour telethon for the environment

teri

The financial year 2008 has ended on a sunny note for the SPV (solar photovoltaic) industry—one of the fastest growing industries in the world. Statistics are indicating that global production of PV in 2008 is in access of 6 GWp (gigawatt peak) as compared to 3.7 GWp in 2007. While Europe leads the sector in grid-connected PV market, the off-grid and distributed generation market has acquired significance in India. If you recall, I wrote in my editorial of October 2008 issue that PV is for all of us who depend on diesel-based captive power plants for meeting our domestic, institutional, and commercial demand. Well, I am happy to say that MNRE (Ministry of New and Renewable Energy) has announced a new scheme for rooftop PV systems for abatement of diesel and other fuel oil with attractive incentives given to residential, institutional, and commercial establishments to switch to PV systems and reduce their dependence on fuel-based generators. This scheme is important because it opens up a new market of rooftop PV in India. This might also usher in the BIPV market further incentivized by initiatives such as GRIHA (Green Rating for Integrated Habitat Assessment).

While the rooftop PV scheme is catering to the urban market, another important scheme for tail-end grid-connected PV power plants to be connected at LT or 11-kV grid is also very timely, as it would promote markets for distributed generation. One also sees synergies at the national level where this scheme could support the Decentralized Distributed Generation component under the Rajiv Gandhi Grameen Vidyutikaran Yojana. Schemes such as Solar Cities will further give a boost to the solar market in India. The solar industry is expected to provide the best technological solutions to these emerging markets so that they survive and thrive. This magazine will provide a platform to the solar industry to reach out to the key stakeholders and get them engaged towards working for a common goal of making India the sunniest country.

Akanksha Chaurey
Director, TERI

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When you get up in the morning, the first thing you face are the sunrays, you wash your face with water and when you come out the first thing you feel is the air and the natural environment. All these are renewable energy sources and are playing a great role in resolving our energy problem. Think of a remote village which has never seen electricity and where no grid can reach. This means that the villagers will never enjoy television, the children cannot hope to study at night, and life virtually comes to a standstill after sundown. Can you imagine your life without electricity? Perhaps not. But as they say, 'there is light at the end of the tunnel'. With the help of renewable energy sources, electricity can reach these far-flung villages as well. Today solar energy is lighting more than 6000 remote villages in our country and the efforts are on to cover more such villages.

Among the other renewable sources, solar energy based systems and devices are on the forefront of resolving our day-to-day energy demand. Solar water heating systems, solar cookers, solar home lighting, solar generators, solar lanterns, solar air heaters, solar traffic lights, solar road studs, solar blinkers, and so on are the most common devices and systems that are commercially available in the market. Use of solar passive techniques in buildings designs has started and few such buildings are already visible in India. Many states have issued orders on mandatory use of solar water heaters, construction of solar efficient buildings, promotion of solar streetlights, solar holdings, and so on. Few have even announced rebates in electricity tariff and property tax.

The Solar Quarterly is the first-of-its-kind magazine in India that covers topics exclusively on solar energy. This is a tool, which keeps you abreast with the latest happenings on solar energy in the world. The articles are laid out in an attractive manner so as to catch even the general reader's interest. Today, when climate change and global warming have become the 'hot' topics for discussion, this magazine offers the readers insights into the research and development being carried out in the field of solar energy. I request all our readers to encourage this publication further by providing their inputs in terms of their feedback and also contribute more research articles, and so on.

I am sure that you will find the material presented in this issue informative and useful as well. *The Solar Quarterly* team gratefully acknowledges the contribution of its writers.

Happy reading

Dr Arun K Tripathi
Director
Ministry of New and Renewable Energy
Government of India

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Letters to editor

I had an opportunity to read *The Solar Quarterly* and found it very informative for people concerned with energy in general and solar energy in particular. Every one has to be conscious of the energy scenario and the need for renewables. I am sure your magazine will prove a point in this direction by making people more aware of the benefits of renewable energy. I am also interested in contributing articles for the magazine. I wish the magazine and the team behind it all success for future.

S S Verma, Punjab

This is an upcoming solar energy magazine dealing with problems of national interest. A highly interesting magazine.

Dr Malhotra, Freelance energy consultant, Mumbai

I am doing research in solar passive buildings and the magazine is beneficial for me. It is a great way of making people aware of the benefits of renewable energy sources.

Vineet Tyagi, Research Fellow, School of Energy and Environment Studies

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We congratulate the team that publishes *The Solar Quarterly*. We are sure it will motivate people and organizations to adopt solar energy for their energy needs.

S L Surana, New Delhi

The Solar Quarterly is very informative. This shows the progress of the country in developing solar energy for power generation to face the energy crisis. This magazine will create awareness about the potential of renewable energy for power generation and utilization.

D S Joshi, Thane

India is giving a very good example to the world in terms of utilization of renewable energy sources. *The Solar Quarterly* will definitely be a very helpful medium in conveying the importance of renewable energy in meeting energy requirements of the current as well as future generations.

Omar Guillén Solis, Mexico

VITS (Vindhya Institute of Technology and Science) is a private engineering college recognized by DTE, Bhopal, approved by the AICTE, New Delhi, and affiliated to RGPV, Bhopal. The college was established in 2002. We want to set up a library, infrastructure, and renewable energy club for non-conventional energy systems in the college. We came across an issue of *The Solar Quarterly* and found it to be a very useful source of information on all aspects related to renewable energy. It provides valuable information on the developments in the field of renewable energy and thus, would prove beneficial in our endeavours. Keep up the good work.

Prof. R C Srivastav, Principal, VITS

We had the opportunity of going through a copy of *The Solar Quarterly*. We heartily congratulate the team for publishing this magazine. We shall be highly obliged if you could let us know about the projects on renewable energy generation, which may be commercially viable in the districts of South Bengal, especially in Burdwan, Bankura, and Purulia.

G R Khaitan, Chief Adviser, Raniganj Chamber of Commerce

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

Editor
The Solar Quarterly

Guarding the sun

Tripura is one of the seven states in the north-eastern region of the country. Here, the country's frontline border force, that is, the Border Security Force or BSF for short has undertaken a novel initiative to distribute solar lanterns. The location under description is New Chandra Para in Gandacherra in Dhalia district. The initiative has been largely catalysed by the poor affording capacity of the villages to pay even the bare minimum rent for getting the solar electricity. It is important to mention here that about 518 habitations have already been covered through solar electrification so far.

Concentrating on leather

Solar energy is making its presence felt in most parts of the country. Kanpur, known for its leather works, is going to receive the energy of the sun on a megawatt scale. To make this happen, a private company by the name of Power Cube Pvt. Ltd has just approached the UPPCL (Uttar Pradesh Power Corporation Ltd). It plans to set up a 10-MW solar thermal power plant in the neighbouring district of Unnao, once the decks are cleared for the purpose at various levels.

Photo courtesy: DOE/NREL

Walking the solar initiative together

At times, when everything else fails, people settle it on their own terms. A perfect example of this is the initiative taken by the residents of Union Park in Khar area of Mumbai. The hitherto neglected Union Park is expected to wear a new look by embracing sun in all its forms. It will soon have a space for children to play, a rainwater-harvesting centre, walking track, and a compost pit lit solely by solar modules. This park will be aptly renamed the Eco-Garden and will have water, manure, and all other material input needs generated on-site. In fact, the project is a striking part of the Jago Mumbai campaign taken up by the residents themselves. The sum of 40 lakh will not go down

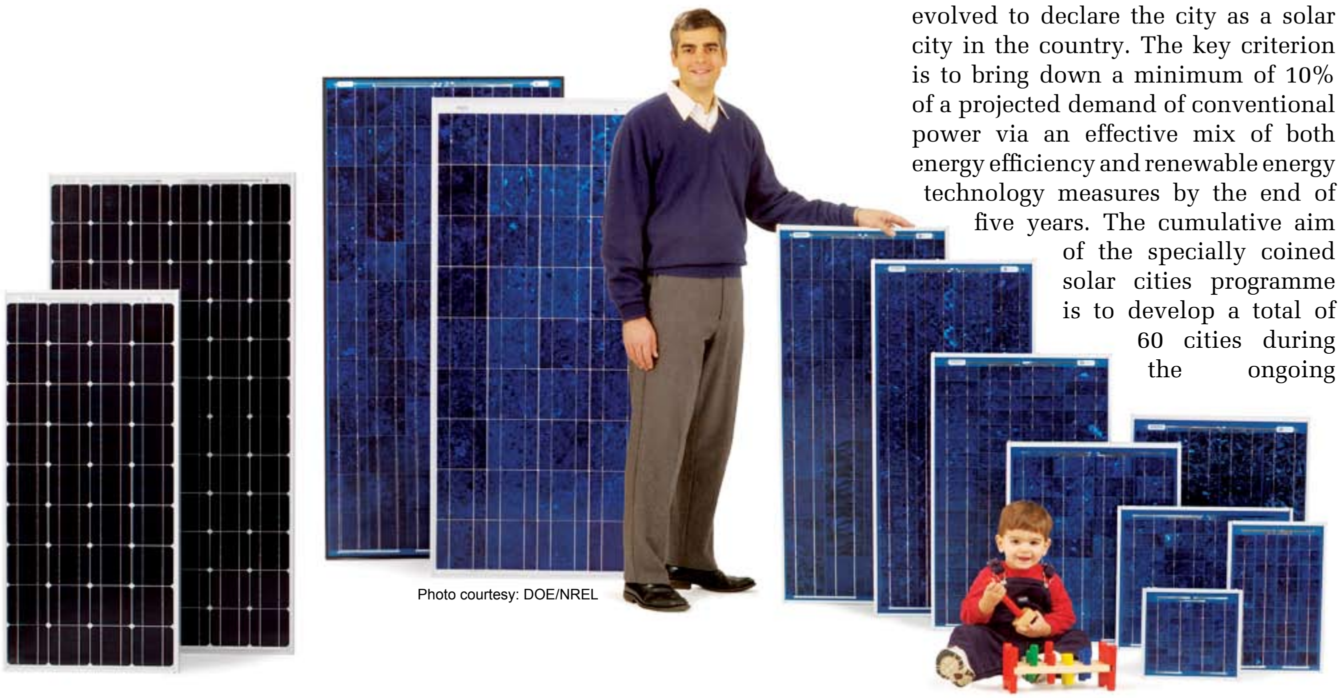


Photo courtesy: DOE/NREL

the municipal drain here, but will help give the park its newfound look that has been possible through the funds earmarked under the MLA fund. The core objective of this socially relevant scheme is to motivate the residents to use solar energy in addition to following safe waste water recycling practices, and so on.

Sun to intensify more in Nagpur

The city of Nagpur heats up more in comparison to few other neighbouring places. Now, it will become brighter under the gaze of the all-powerful sun and will be christened as the first solar city in India. In fact, the MNRE (Ministry of New and Renewable Energy) has given in-principle approval for setting up 14 other cities housing a population of about 0.5–5 million or more for special category states. These will come up in Agra, Rajkot, Moradabad, Gandhinagar, Kalyan-Dombiwali, Indore, Imphal, Kohima, Dehradun, Chandigarh, Gurgaon, Coimbatore, Visakhapatanam, and Thane. A special criterion has been evolved to declare the city as a solar city in the country. The key criterion is to bring down a minimum of 10% of a projected demand of conventional power via an effective mix of both energy efficiency and renewable energy technology measures by the end of five years. The cumulative aim of the specially coined solar cities programme is to develop a total of 60 cities during the ongoing Five-year Plan (2007–12). The two-fold purpose is to meet an increasing electricity demand of the cities and thus promote an enhanced use of renewable energy sources. The MNRE is expected to bear about 50% of the estimated project cost of Rs 190 million with the remaining coming up from the state governments. Types of solar systems destined to shine in the city ambience are as follows.

- Outdoor lights
- Garden lights
- Traffic lights
- Solar hoardings
- Solar water heating systems

A special feature of the solar cities will be a large-scale promotion of energy efficient green buildings.

Sun and wind waving together

How about the sun and wind coming at a handshaking distance from each other to meet a genuine purpose after all? Suzlon, India's frontline wind turbine manufacturer

Photo courtesy: DOE/NREL

has deployed solar power at a wind farm site in Adwadi, Nasik in Maharashtra. Such sites are normally very remotely located since they are part of the underdeveloped regions as well. Solar power thus produced is now being used to run site-specific operations hitherto met occasionally through the use of small backup diesel generators. Suzlon also cut down on even the minimal carbon emissions by putting up a pilot project of this type. To meet this objective, it tied up with Tata BP Solar for its supply of 20 solar panels, which lend power both to the site office and project yard. Following few are the distinct advantages.

- No need for any generators
- No diesel consumption
- No carbon emissions
- Greener outlook
- Secure energy supplies
- Addressing climate change concerns

24 × 7 with the sun

The state of Haryana has attained the distinction of making Iqbalpur its first fully solar-powered village. It has become possible through the collaborating efforts of Bhartiya Vikas Trust, Manipal (Karnataka) and Gurgaon Gramin Bank. The technical partner in this case too is Tata BP Solar. Now, every single household in Iqbalpur boasts of a solar home lighting system. Do not be surprised as the Gramin Bank has offered 100% loan facility for such installations and has fixed a target of setting up 5000 such solar systems by the end of 2009.

Making the sun reach one and all

Winter sends shivers in everybody's spine irrespective of one's means. However, the under privileged more often than not are not lucky to enjoy a hot water bath. Taking a cue from it, a Pune-based renewable energy company by the name of Shimshon Energy has evolved a novel idea. It proposes to replace the use of environmentally damaging material like cow dung, wood, and other waste matter with solar water heating system. Now you may like to ask if these people can really afford it. Yes, it is going to happen for sure akin to the practice of renting

out solar lantern to poor villagers in far off places. Shimon Energy intends to encourage one of the slum families to install a solar water heating system. The system capacity envisaged for the purpose is 1000 litres per day, which could be distributed to the needy at a nominal price for every bucket of water delivered.

Shining the sun on diamonds

Are you trying to trace any connection, even a distant one, between solar energy and diamonds? Yes, there is no such link excepting the fact that the sun is visiting the city of diamonds, that is, Surat in the state of Gujarat. The solar company, which is inclined to do so is MBPV (Moser Baer Photovoltaics), which plans to set up one of India's largest rooftop SPV (solar photovoltaic) installations there. In fact, it has just been assigned the responsibility by the Roads and Buildings Department of Gujarat government. The SPV system likely to come up would be of about 135-kWp capacity and will operate a 40-kW load for a daily duration of 10 hours. A battery bank of 6000-Ah capacity fits the solar system design scheme. MBPV is to take care of the O&M needs of this plant for seven years thus helping it to run in a smooth manner.

Photo courtesy: DOE/NREL

Swearing by the magic wand of $1/Wp

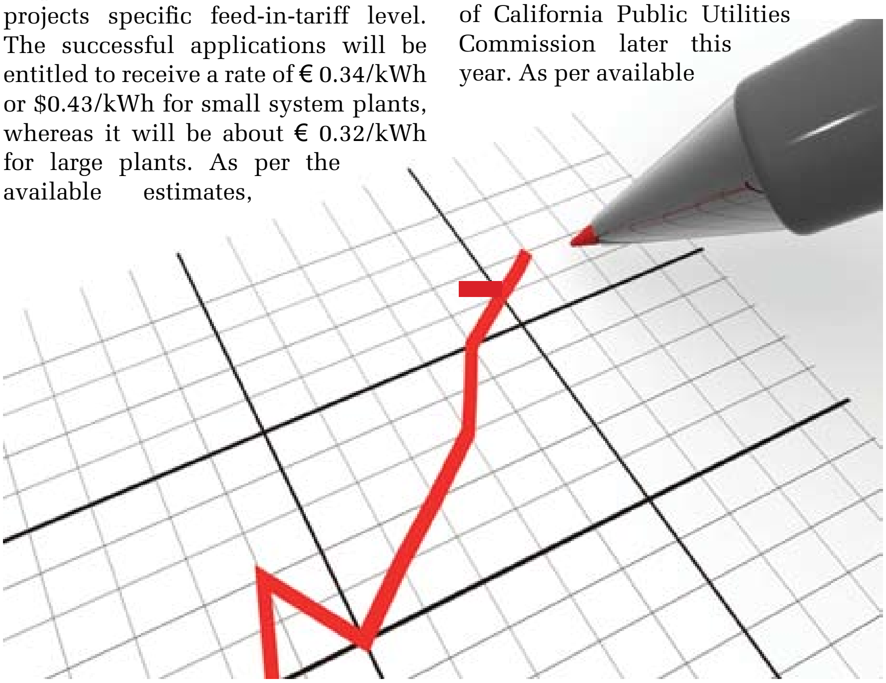
First Solar, as the name suggests, may well be on its way to finally achieve a revolutionary selling price of less than $1 per peak watt for modules some day. The company is now quite upbeat about having reduced its manufacturing cost for solar modules in the fourth quarter to $0.98/Wp. It aims to showcase a growing capability of the thin-film technology to rival the conventional power producing technologies more so for tackling a key challenge of climate change. This innovative manufacturing initiative came into being in late 2004. Between then and now, the manufacturing capacity has grown 2500% with a capacity of 2500 MW achieved in 2008. Its annual capacity is expected to double in 2009 to about 1000 MW. The positive gain has been in terms of bringing down the manufacturing cost considerably. In fact, the company has managed to cut down its costs by two-thirds from over $3/watt to less than $1/watt. Further reduction is expected on the basis of further changes in the production process.

Spain setting up a new feed-in-tariff

The National Energy Commission of Spain has received a huge response from about 392 applicants who wish to qualify for the country's new solar projects specific feed-in-tariff level. The successful applications will be entitled to receive a rate of € 0.34/kWh or $0.43/kWh for small system plants, whereas it will be about € 0.32/kWh for large plants. As per the available estimates, nearly 3000 MW of solar power projects were connected to the national grid between January and November previous year. The overwhelming response to the renewed tariff scheme is being seen as a sure indicator of its being attractive and stable too. In terms of the actual market growth, the country's solar market expanded three-fold going well past the estimates made by the market analysts. Till date, only about 2000 MW of the total installations have been grid connected and stand registered with the Spanish government.

Majoring with a mega solar power initiative

The PG&E (Pacific Gas and Electric Company) has recently made public its plans of a five-year initiative to develop about 500 MW of SPV power. The northern and central California service areas have been chosen for the purpose. The proposed programme involves setting up of 250 MW of utility owned PV generation, which is its first direct investment in renewable generation in over a decade. Another 250 MW of the capacity is intended to be built and owned by independent developers under a streamlined regulatory process. These plans have to go through the approval process of California Public Utilities Commission later this year. As per available



projections, more than 1000 GWh of power is expected to be delivered by 2015. These may well fulfill the needs of nearly 150 000 homes.

In totality, it may help to meet about 1.3% of the PG&E's electric demand. The company programme focuses on mid-sized projects, typically 1–20 MW capacity set up either on ground or using available roof space. One of the unique features is that the projects are earmarked at sites (that is, land), which PG&E already owns. If not, it is possible that these are put up in the vicinity of sub-stations to cut down the cost and time of interconnecting them to the power grid. It had already announced its intention to purchase the outputs of two SPV power plants with an aggregated capacity of 800 MW.

Sunshine to cheer about in US

Not everything is getting costly—at least not the cost of SPV systems installed in US. The installed costs have taken a dip of more than 28% in the last decade or so. It is based on a just released study of the LBNL (Lawrence Berkeley National Laboratory). As per the study, the cost of solar systems meant for commercial applications are declining faster than those for the residential purposes. The cost of installing such systems dropped from $10.50 per watt in 1998 to $7.60 per watt in 2007. The percentage reduction has amounted to nearly 3.5 per year with the costs having remained relatively flat in 2006 and 2007. These calculations do not include any cash rebates or tax credits as such. The research group of Ryan Wiser, Galen Barbose, and Carla Peterman used data from about 37 000 grid-connected SPV systems spread over 12 states. Arizona recorded the lowest cost in the capacity range of 10 kWp followed up closely by California and New Jersey. These findings are reported in the document, *Tracking the sun: the installed cost of photovoltaics in the US from 1998–2007*.

It is important to mention here that the solar panel prices made a little contribution to cost reduction. Instead, the cost on account of inverters, labour, and marketing amongst others made these installations cheaper. In figurative terms, the non-module costs came down from $5.7 per watt in 1998 to $3.6 per watt in 2007. It has also been observed that states with strong incentive programmes also tend to have more companies competing for providing installation and other services. Of all the states, Arizona, California, and New Jersey offer more generous tax and cash incentives. This resulted in Arizona recording the lowest cost (in the 10 kWp category) of $7.60/Wp followed up closely by California ($8.10/Wp) and $8.40/Wp for New Jersey. For 10-kWp systems deployed during 2006/07, thin-film panels cost on average $0.5/Wp more than those using crystalline silicon panels. However, the difference was not significant for system sizes in excess of 10 kWp. Other key summary results are as under.

- The net cost of putting up a residential PV system (taking into account all available private, state, and federal incentives) touched an average of $5.1 per watt in 2007.
- The above cost is about 7% less than the 2001 levels.
- The net cost for a commercial system averaged $3.9 per watt in 2007—a sizeable 32% less than the 2001 levels.
- Costs for all types of systems remained flat between 2005 and 2007.
- Cost reduction of 5%–20% or even more expected in the solar module prices in the current year.

Ring in the solar mobile phone please

Mobile telephony is making waves all around especially in this part of world. To add a new dimension to it, a China-based company ZTE has just unveiled the world's first low-cost solar-powered cell phone. It is going to be marketed under the brand name Coral-2000 and uses a small solar panel on the back of the phone. This way, it gets its energy with the charge time-to-

talk time ratio being 4:1. Simply put, you can chat on for 15 minutes after exposing it to the sun for 60 minutes. As per the company officials, its niche market is going to be two billion people having limited or no access to basic electricity as such. The first-year sales alone may be nearly 300 000 in virgin markets of Papua New Guinea, Samoa, and Haiti. This initiative may well spur the market introduction of several other models from companies of repute like Samsung.

Tunnelling in solar

SPV use is growing by the day with newer applications coming to the front. A good example of this type is the construction of a landmark SPV installation on the roof of a tunnel of Germany's A3 highway. This 2.8-MW facility about to be completed utilizes more than 16 000 ribbon technology panels of Evergreen Solar. It is being seen as one of the country's largest and the first system to be positioned on a public highway. The installation located near Aschaffenburg occupies 2.7 km of the A3 tunnel roof and is expected to light up more than 600 average houses annually. The projected outlay is about Euro 11 million intended to be paid back via cost savings over 16 years. Perhaps, this installation may provoke many companies around the world to use large areas of free space on the highway bridges and tunnels via the SPV route.

Bharat hot on solar cookers, new energy

This is one announcement that Pranab Mukherjee ought to have made on the floor of the house, but did not do so. At a time when the country is trying to increase its power generation capacity and a large part of the rural areas being unelectrified, Mukherjee has set aside Rs 1346 crore for new and renewable energy. And topping that list would be provision of solar cookers for villages. The MNRE (Ministry of New and Renewable Energy) would deploy 25 000 solar cookers in villages during the year. The ministry's allocation in the interim budget has been increased to Rs 1346 crore from Rs 1147 crore in the revised budget.

According to the annual budget for 2007/08, a total of 616 500 solar cookers including over 608 500 box-type solar cookers and about 8000 dish solar cookers were deployed during 2006/07. Extending its VESP (Village Energy Security Project), which was under test mode, the minister has allocated the project to be deployed in 70 villages/hamlets. VESP seeks to meet total energy needs for cooking, electricity, and motive power through various forms of biomass material.

Vihaan Network unveils world's first solar-powered GSM system

Vihaan Network Ltd, a group company of Shyam Group launched the world's first zero opex GSM systems powered by solar energy rather than conventional sources. The system is expected to save at least 50% of the capex currently involved in setting up base stations, which would lead to further reduction in mobile tariffs. There would be no operating expenditure in running the system. Setting up a solar-powered base station would cost one-tenth the amount currently spent on setting up a base station. Presently it costs as much as Rs 50 lakh to set up a base station.

Apart from saving costs, the system is environment friendly and cleaner. The system is also extremely simple to deploy, is compact, modular, and could be assembled very easily by even illiterate workers.

Speed breakers to go green

'Green' speed bumps that will generate electricity as cars drive over them are to be introduced on Britain's roads. The hi-tech 'sleeping policemen' will power streetlights, traffic lights, and road signs in a pilot scheme in London that could be rolled out nationwide. Speed bumps have long been the bane of motorists' lives, but these will capture the kinetic energy of vehicles. Peter Hughes, the designer behind the idea, said, 'They are speed bumps, but they are not like conventional speed bumps. They don't damage your car or waste petrol when you drive over them—and they have the added advantage that they produce energy free of charge.

The ramps, which cost between £20 000 and £55 000, depending on size, consist of a series pf panels set in a pad virtually flush to the road. As the traffic passes over it, the panels go up and down, setting a cog in motion under the road. This then turns a motor, which produces mechanical energy. A steady stream of traffic passing over the bump can generate 10–36 kW of power. The bumps can each produce between £1 and £3.60 of energy an hour up to 16 hours a day, or between £5840 and £21 024 a year. Energy not used immediately can be stored or fed into the national grid. Hughes claims that 10 ramps could generate the same power as one wind turbine.

First carbon-free polar station opens

The world's first zero-emission polar research station opened in Antarctica and was welcomed by scientists as proof that alternative energy is viable even in the coldest regions. Pioneers of Belgium's Princess Elisabeth station in East Antarctica said of a station could rely on wind and solar power in Antarctica – mostly a vast, icy emptiness – it would undercut arguments by skeptics that green power is reliable. 'If we can build such a station in Antarctica we can do that elsewhere in our society. We have the capacity, the technology, the knowledge to change our world,' Alain Hubert, the station's project director said.

Global warming, spurred by greenhouse gas emissions, has prompted governments to look for alternative energy sources. And renewable energies are gaining a foothold in Antarctica, despite problems in designing installations to survive bone-chilling cold and winter darkness. Constructed over two years, the steel-encased station uses micro-organisms and decomposition to enable scientists to re-use shower and toilet water up to five times before discarding it down a crevasse. Wind turbines on the Utsteinen mountain ridge and solar panels on the bug-like, three-storey building ensure that the base has power and hot water. Even the geometry of windows helps conserve energy.

Turning the heat on

solar thermal power generation

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Introduction

Solar energy is an inexhaustible and non-polluting source of energy capable of reducing the GHG (greenhouse gas) emissions too. Earth's upper atmosphere receives 174 PW (petawatts) of incoming solar radiation. Out of this nearly 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The solar energy thus absorbed by atmosphere of earth, oceans, and land is approximately 3 850 000 EJ (exajoules) annually. Photosynthesis captures approximately 3000 EJ per year in biomass formation. The solar spectrum at the earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near ultraviolet. In fact, the amount of solar energy reaching the surface of the planet is about twice as much as will ever be obtained from all of the earth's non-renewable resources of coal, oil, natural gas, and mined uranium put together.

Laying the ground for solar thermal power

Solar radiation is the largest renewable energy resource on earth. Solar thermal power is logically one of the main candidates for providing a major share of the renewable and clean power in future. Solar thermal collector (unglazed, liquid flat plate, air collectors, evacuated tubular, concentrating, and so on) is a technology for harnessing solar radiation for thermal (heat) energy applications. These are basically categorized on the basis of their maximum temperature attainability as under.

- Low-temperature collectors are flat plates generally used for domestic and industrial applications.
- Medium-temperature collectors are also usually flat plates or evacuated tubular but are used for commercial applications as well.
- High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production.

The big canvas of solar thermal electricity

Solar thermal electricity is obtained on changing directly available solar radiation into electricity via some conversion device. In solar thermal power plants, the incoming radiation is

Photo courtesy: DOE/NREL

tracked by large concentrators/mirrors field and concentrated onto absorbers. These then transfer it thermally to a working medium (that is, fluid). The heated fluid operates as in conventional power stations directly (if steam or air is used as medium) or indirectly through a heat exchanging steam generator on the turbine unit, which then drives the generator.

Concentrating solar power technologies

Concentrating solar thermal power plants produce electricity by converting the solar radiation into high-temperature heat using various reflector and receiver configurations. The heat is then channelled through a conventional generator. The plants essentially consist of two parts: one that collects solar energy and converts that into heat (that is, solar field) and another that converts heat energy to electricity, (that is, power block). Solar collectors are the vital components of a solar system, which collect and/or concentrate solar radiation on to the receiver, which contains the HTF (heat transfer fluid). It carries the heat from receiver/absorber. CSP technologies are flexible and are appropriate for a wide range of applications including dispatchable central-station power plants and distributed modular power plants.

STPP (solar thermal power plants) use the high-temperature heat from concentrating solar collectors to drive conventional types of engines turbines. Some plants generate just electricity, but others use the combined heat and power cycle to generate electricity and process heat at the same time. In this way, a solar thermal power plant can simultaneously meet the following few important requirements.

- Produce electricity
- Provide cooling by means of absorption chiller
- Generate industrial process steam
- Produce drinking water with a seawater desalination plant

In this way, about 85% of the absorbed solar thermal energy is converted into some useful energy.

Positioning of solar thermal power plants

Suitable sites for solar thermal power plants are mainly located in the sun-rich regions of the world south of the latitude. This is mainly because only the direct share of the radiated solar radiation can be concentrated by the mirrors. Considering the solar radiation on a global scale following distribution can be made with different optimal effects on CSP (concentrated solar power) technologies.

- 0–15 deg: The equatorial belt is a moderately favourable area for CSP because of cloud coverage and humidity, which reduces the amount of direct radiation.
- 15–35 deg: This is the most favourable area for CSP because of good sunshine and limited cloud coverage.
- 35–45 deg: This is the least favourable area for CSP because higher latitude reduces the amount of solar radiation

The all-important yield

Almost half of the radiation is in the form of diffuse radiation, which does not work well for CSP. The high production of diffuse radiation and the overall lower irradiation levels limits their economic feasibility at northern latitudes. In 2003, solar thermal electricity production in OECD (Organization for Economic Cooperation and Development) countries was nearly 548 GWh (gigawatt hour). The average capacity factor for a solar power plant, which is a function of tracking, shading, and location, is about 20%, meaning that a 50-MW capacity power plant will typically provide a yearly output of

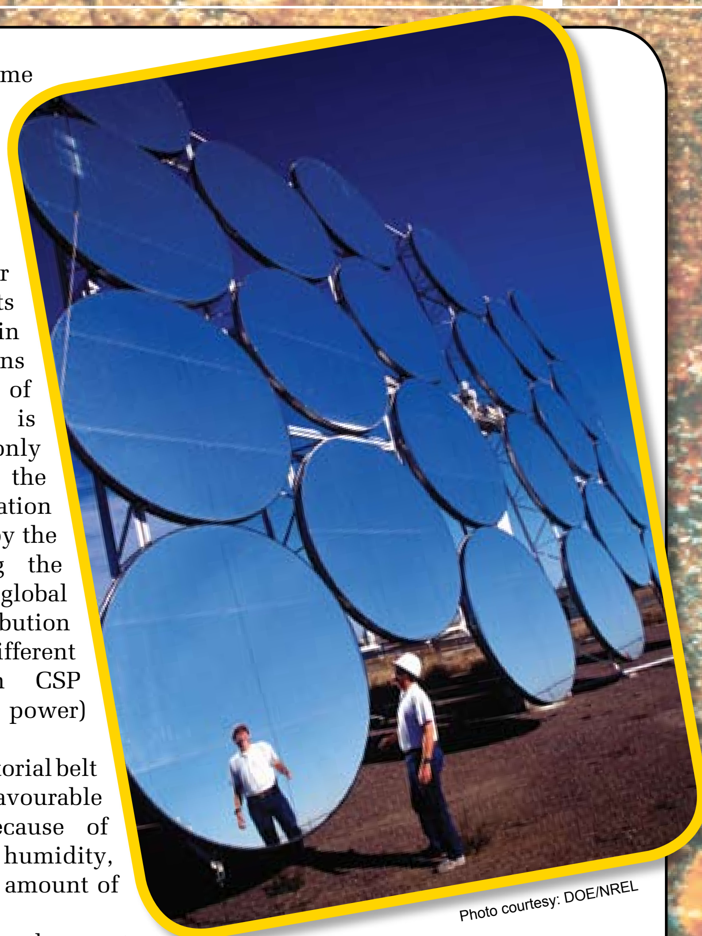


Photo courtesy: DOE/NREL

50 MW × 24 hours × 365 days × 20% = 87 600 MWh/year, or 87.6 GWh/year.

Solar thermal power generation technologies

As of now, solar thermal power generation is a proven and demonstrated technology. More than 100 years of accumulated operating experience demonstrate the soundness of the concept. The STPG plants installed in 1985 in USA have generated more than nine billion units of solar-based electricity.

Almost all the solar thermal technologies (with the exception of solar chimney and solar pond) are based on four basic sub systems: collector, receiver (absorber), transport/storage, and power conversion. Concentrator capturers direct solar radiation, which is then delivered to the receiver/ absorber. The receiver absorbs the concentrated solar radiation, transferring its heat to a working fluid and the transport–storage system passes the HTF fluid from a receiver to the power conversion system. Following few are the representative STPG technologies.

- Parabolic trough solar electric generating system (PTC)
- Power towers or central receivers
- Parabolic dishes (dish-engine system)
- CLFR (concentrating linear Fresnel reflectors)
- Solar chimney
- Solar pond

Out of these many, the parabolic trough, central receiver, and parabolic dish technologies have reached a certain commercial maturity.

Parabolic trough collector system

Parabolic trough power plants are line-focusing solar thermal electric power plants. Trough systems use the mirrored surface of a linear parabolic concentrator to focus direct solar radiation on an absorber pipe running along the focal line of the parabola. The HTF (heat transfer fluid) inside the absorber pipe is heated and pumped to the steam generator. This in turn, is connected to a steam turbine. A natural gas burner is normally used to produce steam during low insolation conditions.

The major components in the system are collectors, fluid transfer pumps, power generation system, and the controls. This power generation system usually consists of a conventional Rankine cycle reheat turbine with feedwater heaters de-aerators, and so on. The condenser cooling water is cooled in forced draft cooling towers.

These types of power plants can have energy storage system. The essential components of a PTC plant are mirrors, receivers, and turbine technology. The receiver consists of a specially coated absorber tube which is embedded in an evacuated glass envelope. The absorbed solar radiation warms up the HTF flowing through the absorber tube to almost 400 °C. This is conducted along a heat exchanger in which steam is produced and generates power.

While using the direct solar steam generation, the HTF and water heat exchanger will no longer be required. This may result in improvement of the efficiency and a higher overall efficiency of cycle too.

Photo courtesy: DOE/NREL

ANDASOL-1: 50-MW solar parabolic trough plant with thermal storage, Spain

The 'Andasol-1' solar thermal power plant of the capacity of 50 MW is located in Granada Spain, using parabolic trough collectors and a molten-salt thermal storage system. Due to its altitude of 900–1100 m, the Andasol project has one of the best direct solar radiation resources in Spain. Without thermal storage, the solar resources in the Granada are only allowed about 2000 annual equivalent full-load hours. The thermal storage system increases the annual equivalent full-load hours to 3589. The power plant has 7.5-hour storage capacity and consists of 510 120-m2 receiver geometry (that is, SKAL-ET parabolic trough). The 624 SKAL-ET collector units that make up the Andasol-1 solar field are controlled from a control room by a central computer. The total ground area covered by the power plant is 200 hectares and annual electricity production is approximately 179 GWh.

The efficiency factor

The efficiency of a solar thermal power plant is a product of the collector efficiency, field efficiency, and steam-cycle efficiency. The collector efficiency depends on the angle of incidence of the sunlight and the temperature in the absorber tube. It can reach an efficiency value of up to 75%. Field losses are usually below 10%. Altogether, solar thermal trough power plants can reach annual efficiencies of about 15%. In contrast, the steam-cycle efficiency of about 35% has the most significant influence. Central receiver systems such as solar thermal power plants can reach even higher temperatures and therefore achieve higher efficiencies too.

The commercial transformation

PTC systems were commercialized in 1980s in California, USA and were commonly known as SEGS (solar electric generator systems). LUZ Company installed nine such plants between 1980 and 1989 with an aggregate capacity of 350 MWe.

SEGs use oil to take the heat away; the oil then passes through a heat exchanger, creating steam. This in turn runs a steam turbine. The following two major technological developments are under way alongside focused research on components and materials.

- Integration of parabolic trough power plants in combined cycle plants.
- Direct steam generation in the collectors' absorber tubes.

Power tower system

In power tower systems, heliostats (a heliostat is a device that tracks the movement of the sun which is used to orient a mirror of field of mirrors, throughout the day, to reflect sunlight onto a target-receiver) reflect and concentrate sunlight onto a central tower-mounted receiver where the energy is transferred to a HTF. This energy is then passed either to the storage or to power-conversion systems, which convert the thermal energy into electricity. The major components of this system are as follows.

- Heliostat field
- Heliostat controls
- Receiver
- Storage system
- The heat engine (which drives the generator)

For a large heliostat field, a cylindrical receiver has definite advantages when used with Rankine cycle engines, particularly for radiation from heliostats at the far edges of the field. Cavity receivers with larger tower height to heliostat field area ratios are used for higher temperatures required for the operation of Brayton cycle turbines. The key elements of a solar tower system are the heliostats—provided with a two-axis tracking system – the receiver, the steam generation system, and the storage system. The number of heliostats will vary according to the particular receiver's thermal cycle and the heliostat design.

These plants are defined by various options chosen for a HTF, thermal storage medium, and for the power-conversion cycle. HTF may be water/steam, molten nitrate salt, liquid metals or air, and the thermal storage may be provided by PCM (phase-change materials). Power tower systems usually achieve concentration ratios of 300–1500 and can operate at temperatures up to 1500 ºC. To maintain constant steam parameters even at varying solar irradiation, two methods can be used.

- Integration of a fossil back-up burner.
- Utilization of a thermal storage as a buffer.

By the use of thermal storage, the heat can be stored for few hours to allow electricity production during periods of peak need, even if, the solar radiation is not available. The modern R&D efforts have focused on polymer reflectors and stretched-membrane heliostats. A stretched-membrane heliostat consists of a metal ring, across which two thin metal membranes are stretched. A focus control system adjusts the curvature of the front membrane,

Photo courtesy: DOE/NREL

PS-10: an 11-MW solar thermal power plant in Southern Spain

The plant concentrates the sun's rays onto the top of a tower 115 m high using mobile mirrors that are faced towards the sun by a control system. The solar receiver on top of the tower produces saturated steam and circulates it to a conventional steam turbine that generates the electricity. The annual electricity generation is approximately 23 GWh. The PS-10 features a large solar field of 624 heliostats. Each heliostat is a mobile 120 m² curved reflective surface mirror. The receiver on the tower – based on a cavity concept to reduce radiation and convection losses – is designed to produce saturated steam at 40 bar–250 °C from thermal energy supplied by concentrated solar radiation flux. It is formed by four vertical panels 5.40-m wide and 12-m high, each one making up an overall heat exchange surface of about 260 m². During operation at full load, the receiver will receive a thermal power of about 55 MW of concentrated solar radiation with peaks of 650 kW/m². For cloudy periods, the plant has a saturated water thermal storage system with a thermal capacity of 20 MWh (50 at 50% load). When energy is needed to cover a transient period, energy from saturated water is recovered at 20 bar to run the turbine at a 50% partial load.

CESI EuroDish solar generator: paraboloid concentrating technology

Dish-stirling solar generators represent a new alternative way to produce electricity at a small scale. CESI, which acts in support of the Italian power sector on behalf of the Italian Authority for gas and electricity, installed a sample of EuroDish, the unique dish-Stirling generator fabricated and proved in Europe. EuroDish is a solar thermal generator with a nominal electric power of 10 kWe at 1000 W/m² of direct normal insolation. The power is delivered at 400 V, three phases, 50 Hz by means of an asynchronous generator running at 1500 RPM suited for grid connection. The EuroDish is comprised of a reflecting parabola, which concentrates the direct normal solar radiation on the receiver of the stirling motor placed on the focus. By means of the heat supplied to the receiver at temperatures in the range of 650 °C, a gas (helium) drives a closed Stirling thermodynamic cycle inside the motor, producing mechanical work, which is converted in electricity by means of asynchronous generator. EuroDish consists of five main components; the concentrator, the rotating turn table, the SOLO 161 stirling solar unit, the tracking system, and electronic control. It has a diameter of 8.5 m, a focal length of 4.2 metre, and can rotate along the vertical plane following the elevation of the sun during its path. When the dish is pointed to the sun a flux of reflected radiation equivalent to more than 2000 sun, strikes the flat tubular receiver of the stirling motor. The receiver absorbs the radiation and is warmed at more than 800 °C.

which is laminated with a silvered-polymer reflector. It is done usually by adjusting the pressure in the plenum between the two membranes.

Examples of heliostat-based power plants include the 10-MWp Solar One and Solar Two demonstration projects in the Mojave Desert. These have now been decommissioned. The 15-MW Solar Tress Power Tower in Spain builds on these projects with storage option. In Spain, the 11-MW PS10 Solar Power Tower was recently completed. Likewise, in South Africa, a solar power plant is planned with 4000 to 5000 heliostat mirrors, each having an area of 140 m².

Parabolic dish system

Dish systems use parabolic reflectors in the shape of a dish to focus the solar radiation on to a dish-mounted receiver at the focal point. The parabolic dish system uses a parabolic dish shaped mirror or a modular mirror system that approximates a parabola and incorporates two-axis tracking to focus the sunlight onto receivers located at the focal point of the dish. It absorbs the energy and converts it into thermal energy. This can be used directly as heat for thermal applications or for power generation. The thermal energy can either be transported to a central generator for conversion, or can be converted directly into electricity at a local generator coupled to the receiver.

The mirror system typically is made from a number of mirror facets, either glass or polymer mirror, or can consist of a single stretched membrane using a polymer mirror of thin metal stretched membrane. The dish technology is applicable to off-grid power generation. The parabolic dish collectors track the sun on two-axes, and thus are the most efficient collector systems. Their concentration ratios usually range from 600 to 2000, and they can achieve temperatures in excess of 1500 °C.

Concentrating linear Fresnel reflector technology

CLFR power plants offer reduced costs amongst all the elements of solar array. Rival single-axis tracking technologies include the relatively new LFR (linear Fresnel reflector) and CLFR (compact-LFR) technologies. CLFR uses many thin mirror strips instead of parabolic troughs to concentrate sunlight from a large field onto just two tubes of working fluid.

This is because it uses cheaper flat mirrors and not costly parabolic mirrors. These also allow for a greater density of reflectors in the array thus

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL

maximizing the use of sunlight. Further, the system is characterized by a simple and cost-effective modular construction of up to several hundred megawatts capacity.

CLFR is a single-axis tracking technology but differs from a parabolic trough in that the absorber is fixed in space above the mirror field. Also, the reflector is composed of many long row segments, which focus collectively on an elevated long receiver running parallel to the reflector rotational axis. The LFR collectors have begun to attract significant attention due to the following few reasons mainly.

- Low structural support
- Cost of reflectors
- Fixed fluid joints
- Receiver detached from the reflector system
- Long focal length feature (allowing use of conventional glass)

The global outlook

Worldwide parabolic trough collector and tower technologies have gained maturity. Dish sterling systems have high efficiency but are not recommended for high-capacity power generation. Thus, these are mainly used for decentralized power supply. CLFR technology is one of the emerging technologies with a potential to replace PTC collector-based systems ultimately.

Solar chimney

In a solar chimney, three well-known physical principles – the flat-plate air heater, the tall chimney, and the vertical axis turbine – are combined in a novel way. Incident solar radiation heats the air in a large collector roof. The difference between the temperature of the air under the roof and thin ambient air causes a pressure drop over the height of the chimney. Ambient air is drawn into the glass collector. This is warmed by solar energy and rises up the chimney. The current of rising warm air drives a turbine. This pressure drop is converted into kinetic energy-the upwind. It passes through the turbine and then between the two layers of glass to ground level, entering the solar collector from underneath the absorber. The ascent of hot air drives the wind turbines installed at the base of the chimney thus generating electricity. The following well-known physical effects are thus combined.

- Greenhouse effect, causing the air under the glass roof to heat up.
- Chimney effect, causing the air heated under the glass roof to ascend through the chimney.
- Turbine, which removes energy from the air flowing in the chimney and converts it into electrical energy through a generator

Solar pond

Solar pond is an effective and cost-effective technology to harness the solar thermal energy for industrial applications namely, process heating, water desalination, refrigeration, and solar thermal power generation. A solar pond is a large-scale solar energy collector with integral heat storage for supplying thermal energy. It essentially contains layers of salt solutions with increasing concentration and density to a certain depth, below which the solution has a uniform high salt concentration. The gradient of density prevents heat in the lower layers from moving upwards by convection and leaving the pond in the process if absorption of radiation. This shows that the temperature at the bottom of the pond will rise to over 90 °C, while the temperature at the top is usually about 30 °C. The trapped heat in salty bottom layer can effectively be used for many applications namely, heating of buildings or industrial hot water or even to drive a turbine for generating electricity.

Financial estimates

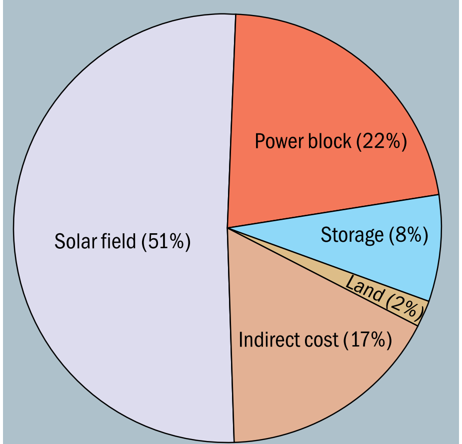
Solar thermal power is amongst the most cost effective renewable energy technologies and offers the lowest-cost solar electricity worldwide. Key cost projections are as under.

- Power generation costs are expected to be in the range of \$0.075/kWh to \$0.19/kWh.

- Grid parity is expected in the near future.
- The capacity factor for power towers and parabolic troughs has been estimated to be 72.9% and 56.2%, respectively.
- A cost reduction of 14% is expected for parabolic trough technology based large-capacity (say 400 MW) power plants.
- Economies of scale will come into play via installation of above mentioned power plant but of 600 MW capacity and expecting a cost reduction of about 17%.

Photo courtesy: DOE/NREL

COST BREAK UP OF A SOLAR THERMAL POWER PLANT BASED ON PTC



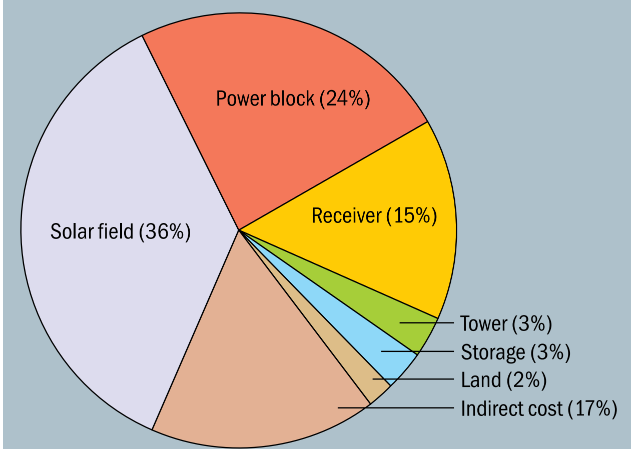
Indian outlook on solar thermal power generation

Solar thermal power generation technology scenario is currently gaining momentum worldwide. A number of such power plants are either under construction or are in the pipeline. The European Commission has recently launched a global initiative called 'Solar Paces', which aims to establish 5-GW capacity of solar thermal power plants around the world. Additionally, plans are underway to integrate European grid and extend it to the North Africa where large-capacity solar thermal power plants can be established. These plants can then provide electricity to Europe and Africa. As part of the national climate change policy, the solar mission targets 10 000 MW of installed capacity by 2020.

Tracing the past

India despite being soaked in sunshine has very limited experience with regard

COST BREAK UP OF A SOLAR THERMAL POWER PLANT BASED ON POWER TOWER TECHNOLOGY



to solar thermal power generation. In fact, it has just experimented with a 50-kW capacity thermal power plant installed at Solar Energy Centre (MNRE [Ministry of New and Renewable Energy]) in late 1980s. This facility uses the parabolic trough line focusing technology. A 140-MW integrated solar combined cycle power plant conceptualized on a fuel mix of solar energy and naptha is still not a commercial reality. This despite the fact that GEF has approved a grant of $40 million accompanied by few more positive indicators. Leaving this behind is a renewed initiative to set up Asia's largest solar thermal power plant of 10-MW capacity at Nagpur in Maharashtra.

Few recent initiatives

The MNRE has recently announced a GBI (generation-based incentive) scheme for the megawatt-capacity grid-connected solar thermal and PV power generation. Various states like Rajasthan, Haryana, Punjab, and West Bengal have announced tariff policies and other incentives for solar power generation systems. MNRE policy is currently under review as it has capped the total installed capacity by a project developer to 5 MW. This makes solar thermal power generation non-attractive in financial terms. Thus, attaining economies of scale holds the key to make such projects economically viable. This fact is now being realized by the Clinton Foundation, which has announced an ambitious plan to set up 5-GW capacity solar power plants in India.

The emerging possibilities

The state government of Gujarat has just announced an innovative policy aptly called the Solar Power Policy 2009. A minimum project capacity of 5 MW each has been earmarked both for solar thermal and SPV power generation. A unique feature of this policy is setting up of a 500-MW capacity target realization during its operative period (that is, up to 31 March 2014). It is important to note here that use of any fossil fuel source such as coal, gas, and naptha has been disallowed under the solar thermal power projects. The following tariff structure has been approved for a period of 25 years.

- Rs 10 per kWh during the first 12 years for projects commissioned before 31 December 2010.
- Rs 3 per kWh during the first 12 years for projects commissioned before 31 December 2010.
- Rs 9 per kWh during the first 12 years for other projects commissioned before 31 December 2014.
- Rs 3 per kWh during the first 12 years for projects commissioned before 31 December 2014.

As per the available reports, a massive expression of interest has been witnessed since the time of announcement of this policy. A sizeable number of projects are expected to mature through a collaborative route between the experienced foreign companies and Indian companies.

Conclusion

Selective few locations in India are bestowed with a very high direct solar radiation availability of more than 2200 kWh/m^2 annually. Serious efforts are needed to transform such resource availability into a few functional power plants at least. The immediate gains may accrue by way of establishing demonstration experience and thereby a path forward for a commercial foothold. With climate change concerns riding high, solar thermal power generation may ride a national solar wave in the time ahead.

Photo courtesy: DOE/NREL

Box 1: List of solar thermal power stations

1 Operational

Name	*Country*	*Location*	*Technology*	*Capacity* (MW)	*Notes and references*
Solar Energy Generating Systems	United States	Mojave desert California	Parabolic trough	354	Collection of nine units
Nevada Solar One	United States	Las Vegas, Nevada	Parabolic trough	64	Third largest
Liddell Power Station	Australia	New South Wales	Fresnel reflector	35	Electrical equivalent steam boost for coal station
PS10 solar power tower	Spain	Seville	Solar power tower	11	Europe's first commercial solar tower

2 Under construction

Name	*Country*	*Capacity (MW)*	*Technology*
Andasol – 1	Spain	50	Parabolic trough with heat storage
Andasol - 2	Spain	50	Parabolic trough with heat storage
La Risca 1 solar power station	Spain	50	Parabolic trough design
Solnova 1 solar power station	Spain	50	Parabolic trough design
Solnova 3 solar power station	Spain	50	Parabolic trough design
PS20 solar power tower	Spain Seville	20	Power tower design
Beni Mathar Plant	Morocco	20	Technology unknown
Solar Tres Power Tower	Spain	17	Power tower design with heat storage
Keahole Solar Power	Hawaii	1	Micro CSP parabolic trough design

3 Planned/announced

Ivanpah Solar	California, USA	500 MW + 400 MW optional extension	Power tower design
Mojave Solar Park	California, USA	553 MW	Parabolic trough design
Pisgah	California, (near Pisgah north) USA	500 MW	Dish design
Unnamed	Florida, USA	300 MW	Fresnel reflector design
Imperial Valley	California, USA	300 MW	Dish design
Solana solar power plant	Arizona southwest of Phoenix, USA	280 MW	Parabolic trough design
Beacon Solar Energy Project	California, USA	250 MW	Parabolic trough design
Negev Desert	Israel	250 MW	Design will be known after tender
Antelope Valley	California, USA	245 MW	Power tower design
Carrizo Solar Farm	California near San Luis Obispo, USA	177 MW	Fresnel reflector design
Coalinga	California, USA	107 MW	Parabolic trough design, hybrid with biomass
Upington	South Africa	100 MW	Power tower design
Shams	Abu Dhabi Madinat Zayad	100 MW	Parabolic trough design
Yazd Plant	Iran	67 MW steam input for hybrid gas plant	Technology unknown
Barstow	USA California	59 MW, with heat storage and back-up	Parabolic trough design
Kuraymat Plant	Egypt	40 MW steam input for a gas-powered plant	Parabolic trough design
Hassi R'mel	Algeria	25 MW steam input for gas-powered plant	Parabolic trough design
Cloncurry solar power station	Australia	10 MW with heat storage	Power tower design
NA	India	10 MW with heat storage	Parabolic trough design

4 Out of commission

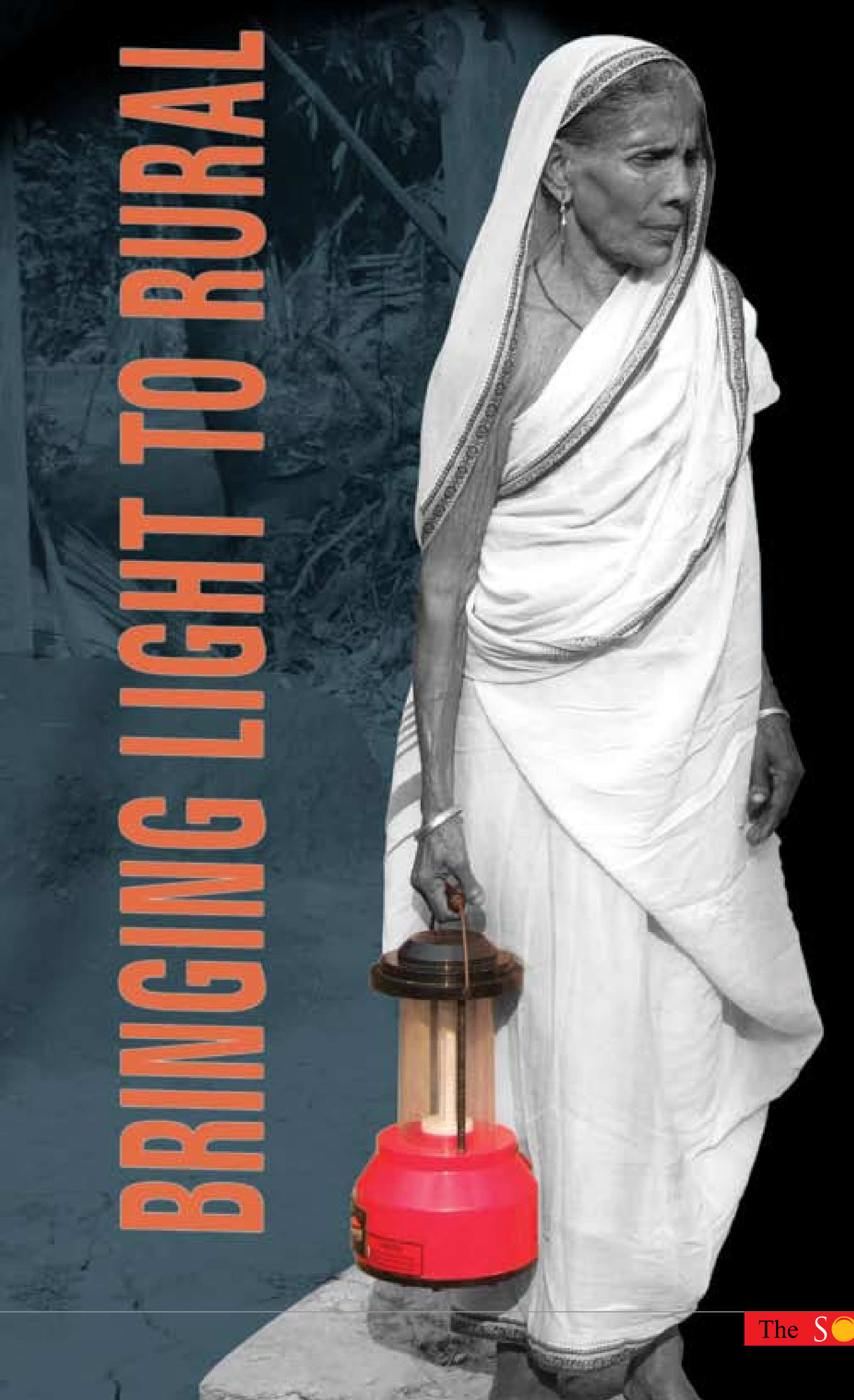
- Solar One (converted into Solar Two), USA California, 10 MW, power tower design
- Themis (under rehabilitation), France, 2 MW, power tower design

BRINGING LIGHT TO RURAL INDIA

GREENATHON

INDIA'S FIRST 24-HOUR TELETHON FOR THE ENVIRONMENT

AMBIKA SHANKAR, Editor, TERI Press <ambika@teri.res.in>



Suddenly the environment is everywhere. Of course, it always was but we seem to have noticed it only recently. Not so long ago we were happily ignorant of the trail of destruction in our wake. We polluted with gay abandon. We wasted gleefully. We mined, chopped, and plundered enthusiastically. Then, from our plastic-wrapped bubble of carbon emissions, we looked proudly into the future. The future looked back at us. It didn't look happy. Sadly, we cannot reverse the damage now. We cannot close the hole in the ozone layer and we cannot reanimate the dodos. But there is some light, admittedly dim and probably running on solar energy, at the end of this long, dark tunnel. We cannot renew, but we can recycle. We can reduce pollution and conserve energy.

As dusk slowly lapses into night, it is time for millions to call it a day. For, before the night falls, farmers with their cattle have to be at home, children have to finish studies, and housewives have to finish the household chores, as life comes to a standstill once it is dark. India is gasping for energy—and mind you there are 76 million rural households that are yet to switch on their first light bulb. By 2030, the Planning Commission estimates that India will need to generate at least 700 000 MW (megawatt) of additional power to meet the demands of its expanding economy and growing population. However, generating power will not be the end of the story. It has to come from cleaner sources. India receives about 5000 trillion kWh (kilowatt-hour) equivalent of energy per year through solar radiation. Just one per cent of the country's land area can meet its entire electricity

requirements till 2030. In 2007, solar energy production in India was 80 MWp (megawatt peak) power, a mere 1.7% of the world total of 4700 MWp. Despite a fairly strong start, India's solar energy movement failed to gather pace. But now with increasing costs of oil and the threat of climate change, the buzz is back.

A revolutionary change is required in the field of renewable energy generation, which would bring substantial benefits to some of the poorest citizens living in rural India. TERI (The Energy and Resources Institute) has launched a programme called LaBL (Lighting a Billion Lives), which addresses the sad situation of 1.6 billion people globally who have no or normal access to electricity. The campaign is spearheaded by Dr R K Pachauri, Director General, TERI. Unfortunately, 25% of these – about 400 million – live in India. Yet, this problem can be addressed and solved, if required, through provision of solar lanterns.

Celebrities are increasingly coming forward to voice their opinion on environmental problems and do their bit for the cause. Taking forward its 'Open Up Tomorrow, Today' campaign to save our planet, NDTV supported by Toyota, telecast first of its kind 24-hour non-stop programme 'The Greenathon', urging Indian citizens to take a pledge towards a greener tomorrow. The NDTV-Toyota Greenathon saw a plethora of stars performing for the environment and advocating the cause of going green. The well-thought-out television extravaganza saw these stars backing NDTV's efforts to raise money for TERI's LaBL campaign and adopting villages themselves as also encouraging people to do the same. For those who take the light in their homes for granted, the Greenathon was certainly an eye-opener into how many people still don't have that one speck of light in their homes.

Spearheading the Bollywood bandwagon was Preity Zinta, the bubbly, dimpled actor who is also the NDTV Greenathon brand ambassador. She felt that the government needs to be pushed. She said Indians are good people but what is needed is education at every level. The Greenathon started across the NDTV network on 7 February 2009 at 7 pm and ended at 7 pm on 8 February 2009. The telethon was even extended by an hour on request from Dr Prannoy Roy, President, NDTV; and Dr R K Pachauri. There was overwhelming response to the whole event from the entire world.

Giving their support to the cause, cellphone giant Nokia adopted three villages in the tribal state of Jharkhand—places that have only seen the natural light of the sun. Dr R K Pachauri, in his closing remarks said, 'This is just

the beginning of a long pathway to sustainable development'.

NDTV's Greenathon was a raging success in terms of raising money for TERI's LaBL campaign as well as creating awareness about the environment. However, there are those who say the carbon footprint of the event was immense. Well, we now weigh in the pros and the cons. The event was grand but not grander than the aim of saving the planet. So has all the sweat and blood, the muse and the music paid off? Was the cost of emissions to host an extravagant gala worth the impact for a greener future? The facts are all before us. The Greenathon helped in raising funds for the LaBL initiative, which aims to provide solar lanterns to villages that have never seen electricity.

About Rs 2 crore 40 lakh was pledged in just 24 hours! Thousands of Internet users donated online to replace the kerosene and paraffin lanterns with solar lighting in the villages. While cleaning of Yamuna and beaches in Mumbai went on simultaneously, celebrities joined in to spread awareness and gave green tips on living. In 24 hours, participants committed donation to light 45 villages in the poorest of regions. Schools across the country kick-started their own initiatives taking lead from Greenathon. Many schools in Orissa, Bangalore, and Delhi made paper bags. Schools in Pondicherry held Quizathons on environment. Facebook and YouTube created fan groups committed to green initiatives.

In short, 24 hours of Greenathon was perhaps a first day towards a much greener tomorrow.

At the end of each day, when we go back to our soft beds in the comfort of our homes, on the other side of the town, lies another bed in a village, in a place called home. Sleep comes without an effort, overshadowing the unspoken dreams of those 'few others' who await another morning that would bring light and hope into their lives—and the LaBL is a step towards that direction.

MAKING THE SUN MORE AND MORE VISIBLE AT NIGHT

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Introduction

Are you mistaken at the thought of the sun making a brief appearance at night nowadays? Certainly not since the sun happens to be the most powerful entity breathing life into anything and everything. A quick detour along the countryside brings alive the role of sun at night. The rural homes cheer about the presence of solar light, the young student studies by the side of a solar lantern, and an artistic hand somewhere weaves dreams of change. That is not all. The use of solar energy is now moving into new frontiers, some as varied as illuminating the billboards. Perhaps the sun is becoming brighter as the day progresses more so in the rural landscapes and lately within the urban ambiences too. The moot question that remains is whether there is a compulsive need to use solar energy for urban uses like advertising? This article delves deep into a few such reasons finally leaving the choice of use with the end-user itself.

It has been well said that take business to people rather than taking people to the business. There is nothing wrong with this proclamation excepting the fact that power is playing hide and seek with those who try to enforce this maxim. To remedy this situation, the generators are there as a standby option, but offend the sensibilities of quite a few for the following few reasons mainly.

- Encroach on the limited space available (within the commercial complexes like office buildings, shopping malls, and so on)
- Lead to noise and smoke pollution (not all the generators work in a silent mode)
- Use the vital import dependent commodity (that is, outflow of precious foreign exchange)

Why use the solar canvass

It would not be out of place to mention here that the sun has been advertised in the open for many years now. The most well known example is that of solar street lighting systems in the sense that it stood out when everything else failed on the road. However, it cannot be taken as a concrete example of solar advertising. Before we delve deeper into issue, let us try to mention a few compelling reasons in support of using solar-powered advertising. These mainly include the following few.

- Conventional power is not available in a full measure for meeting the basic needs.
- Power used for advertising in a large measure drains the already limited supply of power.
- There may be a public appreciation to look at such glowing signages, but a section of public opinion is surely against use of grid power for such purposes.
- Solar power is a clean source of power and works in a silent mode without slicing any share of the power that may have been intended for any community use.
- Solar-powered advertising can well be taken care of by the elite corporate entities, keeping in view its high initial capital cost.

- Solar offers immense environmental gain as against the conventional power.

Trailing the past

There is nothing new per se in the concept having been put into action more than a decade back. However, what is certainly new is a renewed liking and thrust to make it happen on a more visible scale. Let us analyse some of the most tried out solar mediums of advertising here.

Solar signboards

These systems akin to a normal solar street lighting system were initially put up at selective few places. For example, one could see an array of such sunlit boards along the Lady Shriram College stretch in New Delhi. These worked well for some time before fading into memory not necessarily for want of any repairs and so on.

Solar bus shelters

The garden city of Bangalore in particular experimented with the solar power lit bus shelters. In fact, a still role was conceived for such locations.

Solar on-line news

A private news channel came up with a bright idea of displaying the news as it unfolds on the solar-operated panels close to the busy traffic intersections. This proved to be of a good news value mixing both the ancient and modern source of energy together. There are still quite a few such systems installed in places like Delhi and Noida in the NCR region.

Solar traffic kiosks

Manning traffic on the congested roads of a metropolis like Delhi always poses its own difficulty. The traffic personnel, often very few in numbers, struggle to direct such traffic. Solar kiosks put up on a few intersections were a true delight to watch for some time at least. One could for example feel satisfied watching a traffic policeman guiding traffic through solar-operated public address systems. The kiosk offered succour to the occupant by way of a solar run light and fan. However, what one saw after a while was the open vulnerability of such systems put up by a reputed south-based solar manufacturer. These were vandalized though standing in a full public view by perhaps those who liked to bask in the winter sun, but unaware of its great roadworthy promise.

Solar bus route panels

An upcoming company in New Delhi tried to sell the concept of illuminating the bus route number plates fixed at numerous bus shelters in the capital city. The sheer logic was that a large number of commuters fails to read the bus route numbers when more often than not, streetlights fail at night. A few such systems were put up on a trial basis to be dispensed with after a very limited period of demonstrated use.

A typical conventional advertising hoarding

Large-sized hoardings are in full display across big cities and towns in

Table 1 Description of various hoardings

Lamp Type	High-intensity halogen lamps
Average number of lamps used	4–12 lamps
Average hours of operation	10–12 hours
Average energy consumption	Few kilowatts
Likely benefit of avoided power use	May well be used to light up small towns and villages still reeling in darkness especially between 6 pm and 10 pm every night.

the country. These can be described briefly in Table 1.

A possible technical option is to bring in solar power to take care of small hoardings in the first instance. These may well be operated during the peak hours from 6 pm to 10 pm. To meet this objective, it may well suffice to install a 1-kWp solar power system.

Case specifics

Let us take the example of a conventional advertising hoarding publicizing some product or service. Each such hoarding uses at least a couple of halogen lamps of 460 watts each. This brings its daily energy consumption to nearly 1 kilowatt. Let us assume that it runs for just 5 hours a day meaning thereby an average power consumption of 5 units per day. Thus, a single hoarding is going to consume about 1825 units in a year and this number multiplied by a fairly large number of hoardings in a city like Mumbai for example takes the power consumption to new heights at least not in that sense of connotation really.

Is solar power the real alternative?

The figures projected above point to an alarming need for saving such misuse of power for other more productive purposes. Even if any viable alternative like solar power could lead to savings of just about 10% or so, it could well spell immense overall gains in the real sense. Few most distinct advantages that solar mode of advertising could offer are as under.

- Substitute high power lamps with minimal power LED lamps.
- Offer automatic timer-based operation, which sense the available sunlight and accordingly switch on/off the system.
- These do not produce heat and thus have no carbon emissions associated.
- Can be used practically with any type of hoarding.
- Need minimal maintenance on a daily basis.

The ministry outlook

The MNRE (Ministry of New and Renewable Energy) has embarked on an ambitious plan to enhance the visibility of solar power in the urban areas in terms of supporting the demonstration of various end-use applications like solar advertising. According to ministry sources, the street lighting and outdoor advertisement panels in the country amounted to a power consumption of about 20 000 MW. The intention is to make state governments see sense of purpose in moving towards the use of solar power for such applications. In fact, the honourable minister himself has already undertaken wide-ranging deliberations with the state governments of Andhra Pradesh, West Bengal, Maharashtra, and Karnataka.

The response to this proposal has been by and large positive with even hope of advertisers being ordered to experiment with the use of solar power instead of conventional power. If implemented, it could signal a big

change in the urban landscape, which is struggling hard not only to meet its power needs, but also to keep it clean. In fact, the MERC (Maharashtra Electricity Regulatory Commission) has already banned the use of conventional neon signs that illuminated hoardings and floodlights in the city of Mumbai between 5 pm and 11 pm. The obvious choice is to use solar power at least for a small number of such hoardings to begin with.

Supporting the initiative

The concerned ministry is finally supporting the use of illuminated hoardings as per the details given in Table 2.

The renewed thrust

SPV systems have been widely demonstrated in the rural landscapes with a fairly good degree of success with each year of experience gained. The time has come to replicate the success at least in a small measure within a chosen few cities in the country. MNRE has just announced that Nagpur in the state of Maharashtra is going to be the first solar city by 2012 followed up by a well-designed plan to build 60 more such cities.

The intention is to have at least one city in each state to a maximum of five cities in a state during the ongoing Five-year Plan period (that is, 2007–12). The distinct reasons for doing so are the following few.

- Minimize dependence on the use of fossil fuels and expensive oil and gas.
- Encourage the use of renewable energy.
- Generate all round awareness for stimulating the interest of potential buyers of solar systems for example.

Table 2 Ministry's efforts on the initiative

PV module capacity	Up to 1 kWp
Threshold area under illumination	2 square metre
Daily hours of operation	About 6 hours
Grant available from the ministry (that is, MNRE)	50% of the total cost or Rs 15 000/100 Wp, whichever is less
Total number of hoardings to be supported per year	Maximum of 500 (limited to just 20 hoardings per corporation)
Implementing agency	Municipal corporations

A variety of systems are going to be introduced in the solar cities coinciding with a larger aim of generating requisite awareness amongst the public at large. These mainly include the following.

- Solar hoardings
- Street lights
- Garden lights
- Traffic lights
- Solar water heaters
- Energy-efficient green buildings

Quite clearly, the solar way of advertising may receive the much-needed fillip so as to be increasingly visible.

The impact out in the open

It is quite logical to assume that those using solar power daily for their bare minimum lighting needs (say for example in the rural areas) are more aware of the immense power of the sun and thereby the solar technology.

However, that is not exactly true with the urban dwellers. There are several key reasons for this.

- Major chunk of the population relies on grid power
- Solar systems are switched on mainly at night, when it's the time to rush for home
- More often that not, the solar use of the system is not properly and clearly highlighted (solar module is not always instantly recognized by a majority as being a power generating device)

However, there is more than what meets the eye on road. The advertisement panels seem to blink as time advances for whatever reasons. Amongst the few possible reasons could be the following.

- The system is mostly installed on roads with a high traffic density. It leads to accumulation of atmospheric impurities like dust on the surface of panels.
- The panels go without regular cleaning for many days at a stretch and thus lead to low power generation and hence less storage capacity of the associated battery.
- The battery needs to be topped up at regular intervals, even if it is a low maintenance tubular plate battery partly due to being positioned in that kind of ambience.

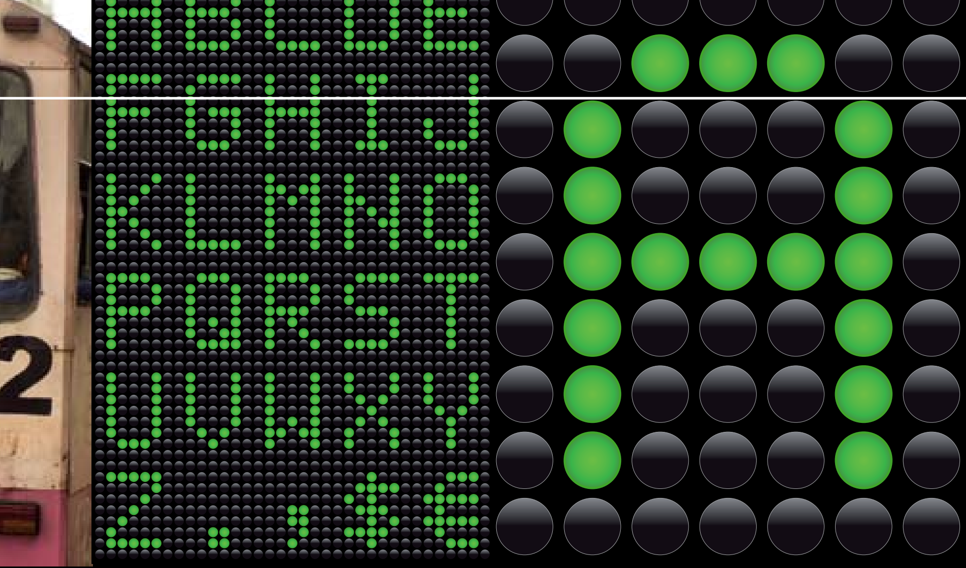
In view of above, the roadside perception of the general viewers does not emerge very favourably.

Is solar advertising needed anywhere and everywhere?

Youth is fun (pun unintended) makes a very good target segment for use of solar advertising. Colleges in particular can be ideal spots to popularize such new generation systems. A few solar-powered advertising companies, though in a limited manner, have been able to display the messages of corporate houses in the premises of both educational and professional institutions. However, it may not be economically viable to use solar power for advertising anywhere and everywhere. Nonetheless, one could think of few ideal spots for solar power use as mentioned below.

- Eco-tourism cottages, where visitors could get across the message of using solar power crisp and clear. They may also not be reluctant to part with some part of their earning for such a cause.
- Pathways of famous mall roads be it Shimla, Mussoorie, or any such place in the country. The product appeal in those type of serene surroundings may be a thing to watch, when the message to use solar power is loud and clear.
- Hotels, motels, and dhabas, which act as stop points during a long outstation journey on the highways offer a definite scope for embracing solar advertising.
- All major places of pilgrimage, which people throng in lakhs could be given a serving of solar advertising. Quite often, such devotees queue up for long hours and thus could imbibe and admire the concept of sun being there at night as well—be it flashing of token numbers on the panels or announcements displayed.

- Majority of commercial complexes, where roof space is available and could be utilized for the purpose of advertising.
- Popular heritage sites and monuments, and even parks and gardens, could find solace with solar power messaging.



Inside out of advertising through solar

The moot question is whether solar power can lift up the spirit of people while they go out. For example, why do we see so little of it even in this age of high environmental consciousness? There seem to be a few compelling reasons to do that, which may be mentioned as under.

- A conventional power hookup still seems to be an easy way out.
- Not all locations are well suited for using solar power.
- Solar system vulnerability in the outdoor environment is still an issue to reckon with.

- The high initial capital cost consideration does not seem to fade away especially when it comes to having large number of sun-powered hoardings.

The solar advertising way forward

We now have a glaring example of how solar power is gradually replacing the use of diesel generators for a critical application like running of base transmitter stations for mobile telephony. Till just recently, such an option was being ruled out on various grounds—some flimsy too. The same type of situation could be witnessed for a variety of the following few considerations.

- Someone has so well said that if people cannot come to business, take business to the people. This clearly means that advertising is going to stay here for long. So, it does need power all the time.
- There is an increasing gap between the demand and supply of conventional power. It surely leaves a window of opportunity for solar power to peep in.
- The standby mode of power, predominantly the generators especially those being used in a haphazard manner and with little regard to noise and emissions are lately being viewed as high-risk elements too.
- The price of conventional power is moving way up and it may not be long before solar power actually prices itself competitively.
- A section of population, even though still small in number, has developed a certain fervour for eco-friendliness and they would like to view it in all ways possible.
- The issue of climate change is now receiving attention at the highest level and solar power is an in-thing now waiting for a green signal to take it places—a good advertising medium indeed.

The big onus on solar community

It is crystal clear that the sun can come out in the open at night too. There seem to be various niche areas of its presence during those odd hours as well, not to talk of beaming breaking news on panels through the day at busy crossings for example. It is in the fitness of things here to lay bare the expectations from the solar power community, that is, all those who are votaries of this clean source of power.

- Design, develop, and demonstrate truly well performing systems, which will work flawlessly over long periods of time.
- Small is beautiful maxim may well apply in this case, as it is somewhat easy to make someone (even a corporate entity) pay up for solar power use.
- A bigger system is not necessarily the best for quite a few reasons. More often than not, it becomes a huge burden to mobilize resources for replacement of battery bank. Thus, the idea should be to go for small systems mainly.
- The trick of the trade seems to be in garnering support from every possible quarter and not just the corporate sector alone.

The final advertisement

The solar way of reaching out to the masses is possible in more ways than one. However, what is certainly needed is to instill confidence in such systems and leave the rest wide open for others to rejoice at.

GRIHA transforming passive features into active gains

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Introduction

The existing development patterns are having a negative impact on our environment. It is imperative to make a judicious use of our remaining resources accompanied with a search for alternatives with no potentially dangerous side effects either in the short or medium term. Simply put, it is essential to be far more sensitive towards the preservation of environment. Climate change may throw up disastrous consequences if not addressed immediately. Climate change is mainly caused by GHGs or greenhouse gases that are released into the atmosphere. Buildings and related activities like construction, operation, maintenance, and demolition account for as much as 40% of the global GHG emissions. These four processes are energy intensive meaning thereby a huge power consumption too. A lot of waste is also generated via these processes as by-products. The additional concern is in terms of an ever-increasing number of urban buildings owing to moving mass of people from the rural areas. As per available projections, about 47.1% of the Indian population will inhabit the urban areas by 2030. The moot question is if, there is a solution in sight to curb the growing menace of GHG emissions. Surely, we can make the existing buildings more energy efficient while adopting similar practices for the new structures.

Green buildings

Most of the human activities are centred around buildings. Migration of people from rural to urban areas puts a heavy demand on the power availability and so on. Consequently, the occupants get the desirable living conditions at a none too affordable price.

The most recent trend is to design a green building that offers all the comforts of, if not more than a conventional building. At the same time, it minimizes the negative impacts of the building on the surrounding environment. The following few technologies/systems are incorporated into such green buildings.

- Renewable energy sources
- Recycling technologies
- Water and waste management systems

The possible gains

Various studies are available to quantify the gains from implementation of energy-efficient measures in the buildings. These can be put down as follows.

- Up to 20% energy savings in existing residential buildings.
- Up to 30% energy savings in existing commercial buildings.
- Up to 30% of energy savings in new residential buildings.
- Up to 40% energy savings in new commercial buildings.

Green buildings generate electricity using solar power and wind power where available in abundance. Any surplus power thus available can be fed to the grid. It is also possible to bring down the heating and cooling load to just about 15% via the following few measures.

- Proper North–South orientation (a passive architecture design feature).
- Proper optimization of HVAC systems.
- Use of less power-intensive technologies.
- Use of optimized lighting in tandem with proper day lighting feature (possible energy savings of about 15%).
- Use of new building materials and proper insulation
- Use of water conservation and rainwater harvesting techniques for irrigation and other purposes.

Further, waste products can be reused in useful ways to reduce both the energy consumption and embodied energy of the building.

In fact, a variety of techniques are available for making both old and new buildings, more efficient. These usually translate to a marginally higher capital investment, but in an O&M cost saving of as much as 50%.

Green Rating for Integrated Habitat Assessment

TERI (The Energy and Resources Institute) has recently developed a building rating system keeping in view the specific needs of the Indian construction sector. It is aptly named as the Green Rating for Integrated Habitat Assessment or GRIHA for short. This has now been adopted by the MNRE (Ministry of New and Renewable Energy) as the National Green Building Rating System for India. In fact, GRIHA assimilates the key features of the following few building codes and guidelines.

- National Building Code
- ECBC (Energy Conservation Building Code)
- Construction specific clearances of the Ministry of Environment and Forests
- Pollution Control Guidelines (issued by the Central Pollution Control Board)

The point system

GRIHA is a rating system that assesses the environmental performance of buildings on a scale of 0–104 points. A minimum count of 50 points is required for a building to be certified as a GRIHA building. On the basis of the number of points scored, a building can be rated with between 1 and 5 stars. Here, 1 star indicates the lowest rating, while 5 stars stand for the highest level of environmental performance. GRIHA evaluates green building performance on the basis of following few aspects.

- Water and waste management
- Energy use
- Site preservation
- Indoor comfort and air quality
- Degree of innovation

CESE Building, IIT Kanpur

The maximum weight is given on the points for energy—43 out of a total of 104 points are dedicated towards energy. There are three broad aspects within energy, which are tackled in GRIHA.

Embodied energy

This is the energy that goes into the construction of the building and building materials. It usually forms almost 20% of the total energy consumed by buildings over their complete life cycle. Thus, using locally available low energy materials for construction with low embodied energy leads to energy savings.

Operational energy

This constitutes almost 80% of the total energy consumed by buildings over their entire life. Currently, most of the initiatives undertaken by various stakeholders are dedicated towards reducing the operational energy requirement of buildings via various energy efficiency measures. Various features like solar passive building design and mechanical systems with high energy efficiency can help in reducing the amount of energy required during the operation of the building.

Renewable energy

Once the energy requirement of the building is reduced, the next step is to ensure that this energy has the least possible carbon footprint. Renewable sources of energy like solar power and wind power supply some useful amount of power to the buildings. These lessen the dependence on the use of conventional energy sources, thus resulting in reduced carbon footprint and GHG emissions.

TERI Gram, Gual Pahari, Gurgaon

The next most important aspect of GRIHA deals with site preservation and reduction in the negative impacts of site interventions. The process of constructing buildings has a negative impact on the site and its surrounding habitat. It may lead to destruction of habitat, loss of fertile soil, felling of trees, and so on. There are various criteria within GRIHA dedicated towards ensuring that the impact of constructing the building on a particular site is minimized. Various aspects like site selection, topsoil preservation, air pollution control, tree plantation, and reduction of heat island effect are taken into consideration.

Doon School, Dehradun

Other important aspects

GRIHA also covers a few other aspects of green buildings like waste and water management. There are various standards to follow in order to reduce building water consumption while simultaneously recycling water and recharging ground aquifers. GRIHA lays emphasis on various national water quality standards as well. Waste is required to be managed, recycled, reused, and appropriately and sensitively disposed.

A green building that is unable to provide good comfort levels to its users and creates an unhealthy environment for them is not desirable. Thus, GRIHA has criteria dedicated towards maintaining good indoor comfort levels and air quality. GRIHA as a rating tool emphasizes upon using traditional construction techniques and knowledge base in order to construct green buildings. This promotes and encourages the principles of traditional building systems, which have been gathered and refined over centuries. Another unique feature of GRIHA is that it rates non air-conditioned, semi air-conditioned as well as fully air-conditioned buildings. This promotes the use of natural ventilation as a design strategy and thus breaks the paradigm of green buildings being necessarily air-conditioned.

Solar passive architecture and GRIHA

The sun plays a major role in the building designs. For ages together, people never had the luxury of mechanical systems to control the comfort conditions inside buildings. Thus, all traditional buildings around the world have been suitably adapted to the local climate, which is in turn primarily governed by the sun. Design principles, in most of the traditional buildings, revolve around the position of the sun during a given time of the year. GRIHA understands the importance of these traditional principles of design and encourages architects to adopt them while designing their buildings.

The level playing field for solar architecture

There are various levels at which green buildings can adopt solar passive design techniques. The interventions begin from site planning and landscape design and proceed towards the building envelope and interior design of the building. The specific role of various enlisted criteria is as follows.

- Criteria 4, 13, and 14 of the GRIHA rating system emphasize upon adoption of solar passive principles in building design.
- Criterion 4 encourages incorporation of existing site features in building design, one of which is building orientation.
- Criterion 13 of GRIHA rating places great emphasis on solar passive design of buildings. Its objective is 'to apply solar passive measures, including day-lighting, in order to reduce the demand on conventional energy for space conditioning and lighting systems in buildings'.
- This particular criterion also has a direct impact on Criteria 14, which measures the reduction in energy demand of a building. Buildings designed on solar passive principles tend to consume much less energy as compared to the conventional buildings.

Key solar passive design considerations

A special design feature of a solar passive building is to orient the building correctly according to the local sun path. The correct building orientation ensures that there is no excess heat gain (unless required). It thus helps in positioning the windows to allow for maximum daylight penetration in the building. After the building is appropriately oriented, external landscape can further assist in reducing the heat gains into the building. In composite climates like Delhi, warm and humid climates like Mumbai, and hot and dry climatic regions like Jaipur representing almost 80% of all the regions in India, reducing heat gain from the east and west sides is quite crucial. The northern façades in regions like Delhi do not require any shading from the sun. The east and the west façades get sun at quite low angles. This results in harsh light levels as well as high heat gains. Thus, it is recommended to completely cut off the sun on the eastern and western sides for composite climates. On the south side, the sun can be easily cut off during summers by designing appropriate shading devices and thus proper sunlight can penetrate during winters as well. This is because the sun is low in the sky, which allows it to penetrate deeper into the building. It thereby results in heating of the internal spaces and reduces the need for mechanical heating devices. This forms part of the Criteria 4 of the GRIHA rating which requires incorporating existing site-specific features into the building design.

Landscaping

Landscape design around the building helps in reducing the energy requirement of any given building. As in the case of composite climates, planting evergreen trees on the eastern and western sides of a building will ensure that it is appropriately shaded throughout the year. This way minimum heat gains result from these two sides. On the southern side, deciduous trees are recommended to be planted. The idea behind planting deciduous trees on the south façade is that these trees shed their leaves during winters and retain them during summers. Thus, they help shade the building during summers and allow sunrays to penetrate through during winters.

Role of shading devices

A properly oriented building calls for the next important intervention in terms of the following.

- Design of the building envelope
- Use of shading devices
- Internal layouts

The maximum amount of sunlight and heat enters a building through its glazed area (windows). In regions where one wants to prevent sunlight from entering the building, the glazed area of the façade is minimized. However, in colder regions, sunlight is allowed to enter the building thus reducing the demand for mechanical heating. Hence, in such regions, the glazed area of the façade is increased. Windows are also the source of natural light and ventilation for a building. Having insufficient window area would result in increased dependence on artificial lighting systems. This is because the amount of natural daylight entering the building would get reduced. Thus, the glazed area of the façades has to be balanced in accordance with the amount of day lighting entering the building.

The natural variants

There are two ways in which sunlight enters a building after the openings are designed, directly and indirectly. Direct sunlight brings with it light as well as heat components while the indirect or diffused sunlight brings sufficient light. This reduces the amount of heat getting transferred into the building. In cold climatic regions, direct sunlight is a desirable feature. In composite and tropical climatic zones, diffused sunlight is more desirable. In order to prevent direct sunlight from entering a building, appropriate shading devices and optimum window areas must be designed. The shading devices are designed such that they cut off direct sunlight from entering the building while simultaneously permitting maximum natural diffused daylight inside the building. This reduces the heat gains inside the building while reducing the need for artificial lighting.

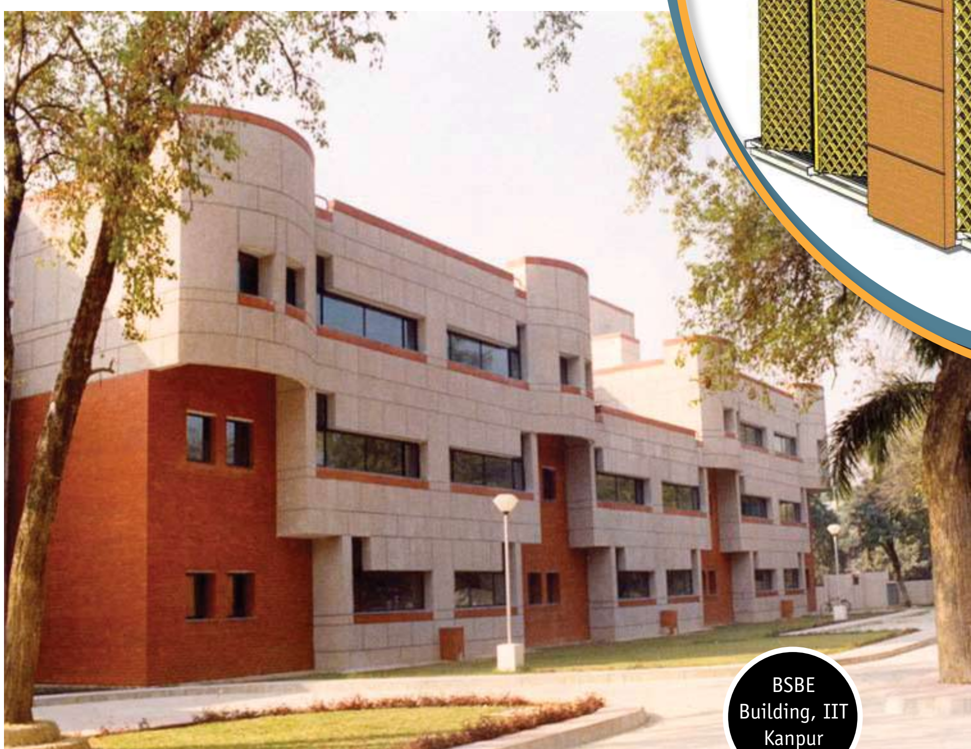
The internal layouts of a building can also be designed in response to the local sun path. This can be done by organizing the service areas within a building towards the direction, which needs to have a thermal buffer. A thermal buffer acts as a space between two sides of a building and leads to reduced heat transfer. Thus, in a climate like Delhi, having toilets and staircases on the west side of a building would ensure that extreme heat from the west does not enter the living spaces. Such interventions affect a reduction in the amount of energy required to cool the living areas like bedrooms. Adopting these solar passive design features can lead to a reduction of up to 15% in the operational energy requirement.

Case specific examples

Centre for Environmental Sciences and Engineering Building, Indian Institute of Technology, Kanpur

The IIT Kanpur CESE (Centre for Environmental Sciences and Engineering) building is the first GRIHA rated building in the country. It has achieved the highest rating of 5 stars. The building houses laboratories, seminar rooms, classrooms, and so on and has been able to achieve high energy efficiency and rating. It is by virtue of a design that is extremely sensitive towards the local climate. The climate of Kanpur city falls under the composite climate typology.

The building has been aligned along the east–east axis. This



BSBE Building, IIT Kanpur

ensures that the longest façades of the building face north and south. As discussed earlier, the northern façade in regions like Kanpur does not receive direct sunlight and the direct sun can be cut on the southern façade with some interventions. Besides the correct orientation on site, various trees have been preserved and planted such that they shade the building thereby reducing heat gains.

The building envelope has been appropriately designed keeping in mind the WWR (window–wall ratio) as recommended in the ECBC (Energy Conservation Building Code). The overhangs have been designed according to computer simulations such that majority of the windows do not receive any direct sun. Various material properties like SHGC (solar heat gain coefficient) and U-values were followed as mentioned in the ECBC to strike a balance between natural daylight and heat gains.

The internal spaces have been organized such that spaces catering to services like staircases, AHU rooms, and toilets occupy the eastern and the western façades. These act as a buffer between the regularly occupied areas by building users and outside. This ensures that the direct heat from the east and the west does not enter the regularly occupied spaces like classrooms and seminar rooms thereby reducing their cooling energy requirement.

The resultant gain

Following these interventions, the EPI (Energy Performance Index) of the building fell from a base case value of 240 kWh/m^2 (kilowatt hour per square metre) per annum to 208 kWh/m^2 per annum. Subsequent interventions lead to further reductions in the EPI. The final EPI of the building dropped to about 98 kWh/m^2 per annum. Thus, by adopting various interventions, the building has reduced its energy and water consumption by almost 60% and 62%, respectively.

Additionally, the building uses solar water heating systems and SPV systems that reduces its energy dependence on the central power grid.

Conclusion

Solar passive architecture adopts such principles as are a direct adaptation of traditional architecture of various regions. These principles have been refined over centuries and are known to be energy efficient. A solar passive building when coupled with optional water and waste recycling strategies, adoption of low embodied energy materials, and RETs can yield a building as close to the sustainable model as possible. GRIHA attempts to mainstream these features in order to enrich the country not only with environment-friendly green buildings but also with aesthetically rich buildings.

WIDENING THE REACH OF solar energy new initiatives

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A. KEY FEATURES OF SOLAR POWER POLICY 2009 OF GUJARAT GOVERNMENT

Background

Climate change concerns are taking everyone by sheer surprise and are forcing everyone to think loud and clear about a long-lasting alternative. Many see it as a grim reflection of extended fossil fuel use for virtually anything and everything. Added to this is the much visible complexity of a growing demand for power, which does not keep up with the available supply. The moot question is we will continue to be plain watchers or do something concrete and meaningful. With this in view, the state government of Gujarat announced a major Solar Power Policy Initiative 2009 on 6 January 2009. In fact, the Energy and Petrochemicals Department formulated it with an extended sense of purpose. Solar power seems to be an alternate technology of choice.

Why Gujarat

The state of Gujarat is blessed with high solar insolation levels with about 300 days of clear sun and conducive arid conditions and a minimal need for sun tracking. The immediate region of interest is the large tract of barren wasteland, which can get transformed as a means of socio-economic development. These may further lead to being integrated solar generation hubs for a country-wide outreach. It is important to mention here that Gujarat offers an overall conducive business environment always drawing the investor interest to the hilt.

The solar experience in the state

A number of SPV systems have been demonstrated so far with an aggregate installed capacity of about 1 MW till the end of the Tenth Five-year Plan. Now, the stage seems set for roping in the project developer's interest by putting up megawatt-scale solar power plants. To attain this objective, the concerned department has put

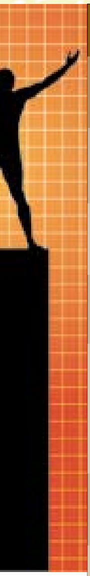


Table 1 Solar experience in the state of Gujarat

Item	Description	For SPV power projects (under MNRE GoI scheme)
Effective period of operation	Up to 31 March 2014	Up to 31 March 2012
Capacity of the installed system	A maximum of 500-MW solar power generation to be allowed	Maximum capacity of 50 MW earmarked
Capacity limit per project	Minimum project capacity to be 5 MW each	1 MW, but projects in a modular fashion also allowed
Eligible units	Any company or body corporate or association (whether incorporated or not) can set up an SPG facility	All existing registered companies, central and state power generation companies and public/private sector project developers
Type of use allowed	For self use or for sale of power to grid/sale to third party Captive use is not allowed	—
Wheeling charges	To be allowed at a wheeling charge of 2% of the energy fed to the grid (till the wheeling charge is determined by the state electricity regulatory commission)	Wheeling not allowed
Exemption from electricity duty	To be exempted in case of self use of power/sale to third party/sale to licensees	Not available
Exemption from demand cut	To be allowed to an extent of 50% of the installed capacity of SPG assigned for captive purpose	—
Metering of electricity	To be metered on a monthly basis jointly by GEDA (Gujarat Energy Development Agency) and GETCO (Gujarat Energy Transmission Company Ltd) at the sending station of 66 kV or above	Dedicated electronic meter to be installed for the purpose
Grid connectivity and evacuation facility	To be provided from the solar sub-station/switch yard to the GETCO sub-station by GETCO after a system study	Yes, to be made available
Open access for third party sale	For any developer/beneficiary being granted open access, open access charges to be paid for	—
Renewable Purchase Obligation	To be restricted to about 10% from all renewable energy sources put together	—
CDM benefit	Project developer to pass on 50% of the gross benefits of the CDM to the distribution licensee (with whom PPA is signed)	—
Miscellaneous	GEDA and GPCL (Gujarat Power Corporation Ltd) to help in arranging water supply, right of way, and in obtaining clearances and approvals from the state government. Encourage R&D activities for cost effective, sustainable, and environment-friendly technologies in due collaboration with national and international institutions of repute	State agencies to help in obtaining the set of procedural clearances on various accounts like for example land, pollution, and water.

in place a favourable technical, policy, planning, and programme implementation framework. The broad features of this are summarized in Table 1.

Allowable tariff

As per the policy statement, the energy produced from a solar power project shall be sold to the distribution licensees in the state at a levelized fixed tariff per unit. It will be permitted for a period of 25 years under a duly signed PPA (power purchase agreement). The finer points of this will be enunciated by GUVNL and/or distribution licensee. Table 2 shows the tariff structure under this special scheme as under.

Expected inferences

- New generation technologies may receive special attention under this scheme for technology demonstration.
- Foreign companies may be permitted to set up PV grid-interactive power plants of 1-MW capacity for testing-cum-evaluation purpose.
- Foreign companies setting up

Table 2 Tariff structure

Description	Tariff for PV projects (rupees/kwH)	Tariff for thermal projects (rupees/kWh)	Tariff for PV projects (under MNRE scheme) (rupees/kWh)	Tariff for thermal projects (under MNRE scheme)
Projects commissioned before 31 December 2010	Rs 13 (for first 12 years) Rs 3 (from 13th to 25th year)	Rs 10 (for first 12 years) Rs 3 (from 13th to 25th year)	Rs 12 (for a maximum period of 10 years)	Rs 10 (for a maximum period of 10 years)
Other projects commissioned before 31 March 2014	Rs 12 (for first 12 years) Rs 3 (from 13th to 25th year)	Rs 9 (for first 12 years) Rs 3 (from 13th to 25th year)	—	—

manufacturing facilities may be specially encouraged to set up their operations within the state and sell their produce also outside the country.

- The technical criteria stipulated for the purpose may be a limiting factor for those having experience in areas other than solar energy. Thus, any infrastructure-related experience may have to be considered.
- The financial criteria stipulated for the purpose may not necessarily be related to solar operations. Instead, any company interested in infrastructure development is welcome to participate.
- The project is expected to breakeven in the 13th year and the payment of Rs 3 for every unit generated may well take care of the O&M (operation and maintenance) needs of the solar plant between the 13th and 25th year.
- The project appraisal process is expected to be very quick thus leading to lower project lead periods as well.

B. NEW POLICY GUIDELINES FOR VILLAGE ELECTRIFICATION THROUGH DECENTRALIZED DISTRIBUTED GENERATION UNDER RGGVY IN XITH PLAN

Background

Majority of India resides in villages, which need to be strengthened from all possible considerations. Energy is a basic driver of our activities, but is not available in the same proportion everywhere. Rural areas of the country are mostly devoid of energy availability in a desired measure. Many villages do not have any electricity at all. To redress this situation, a special scheme for creating rural electricity infrastructure and complete rural electrification was put in place some years back. It is more commonly known as the Rajiv Gandhi Grameen Vidyutikaran Yojana or simply RGGVY. The scheme was launched to meet the commitment of the NCMP (National Common Minimum Programme) of completing the household electrification in five years besides modernizing the rural electricity infrastructure. Few facts needing a special mention here are given in Table 3.

The renewed policy focus

The Ministry of Power has issued a fresh set of guidelines for village electrification through DDG (Decentralized Distributed Generation) on 12 January 2009 under the above-mentioned RGGVY vide scheme no. 44/1/2007-RE dated 12 January 2009. The major objectives to be achieved are highlighted in Table 4.

- The REC (Rural Electrification Corporation) would be the nodal agency for the scheme and would take care of the capital subsidy distribution too for the projects found eligible. Should a project fail to perform satisfactorily, the capital subsidy would be changed into interest bearing loans.

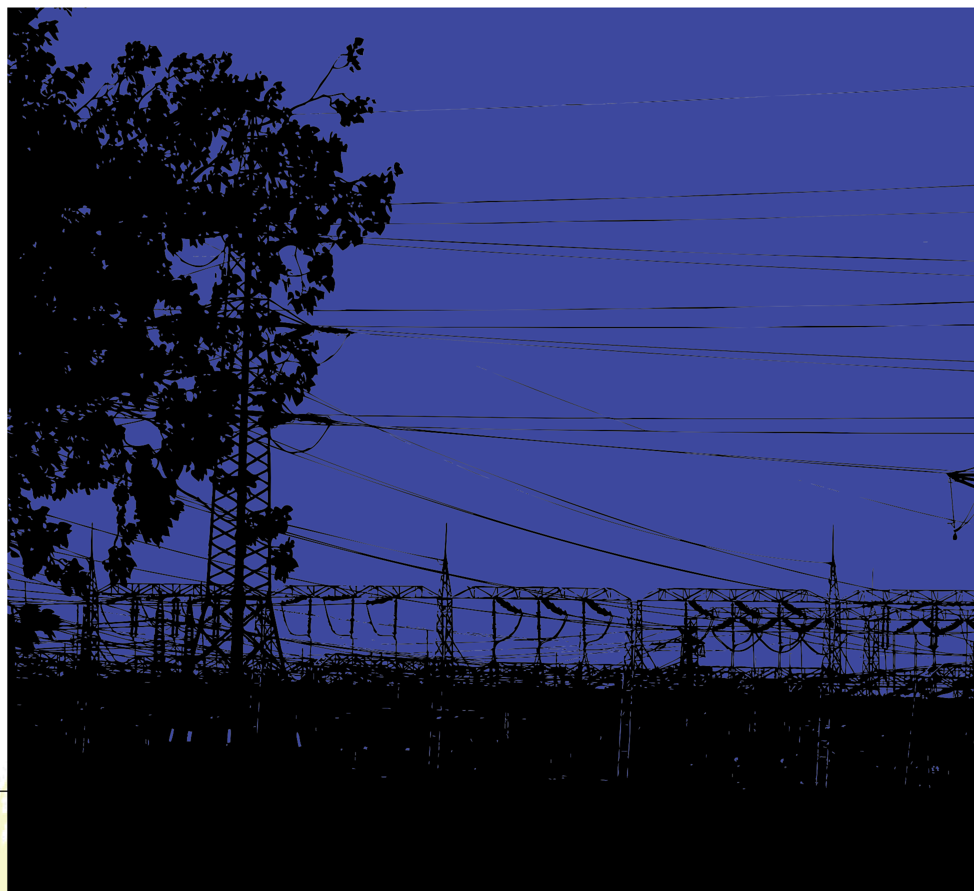
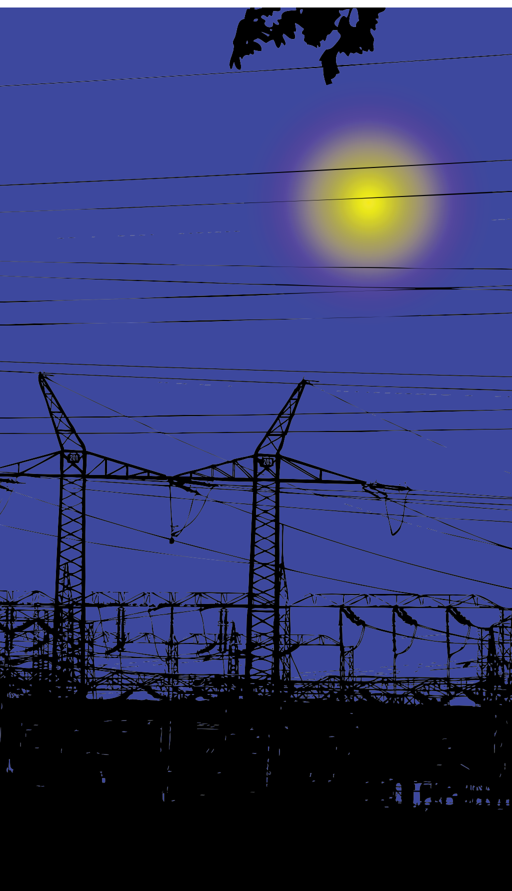


Table 3 Facts pertaining to RGGVY

Number of households electrified since independence	44%
No. of villages yet to be electrified	100 000
Targets under newly formulated scheme	To provide electricity to about 78 million households in five years
Programme implementation agency	Rural Electrification Corporation
Percentage amount as grant	90% of the capital cost of the programme to be provided as grant by the central government
Infrastructure development (via above grant)	▪ Rural Electricity Distribution Backbone with at least one 33/11 kV or 66/11 kV substation in each block ▪ Village Electrification Infrastructure with at least one distribution transformer in each village/ habitation ▪ Decentralized Distributed Generation systems in cases where grid supply is not feasible or cost-effective
Connection charges	Free of cost connection to all rural households living below poverty line
Key gain in sight	▪ Availability of good quality power for running of small industries, khadi, and village industries in the rural areas. ▪ Enabling accelerated rural development, employment generation, and poverty.
Total estimated cost of the scheme	Rs 160 000 million



- The DDG projects would be owned by the implementing agencies of the state government such as nodal agencies for renewable energy or departments promoting renewable energy or state utilities or the identified central public sector units within the respective states.
- The above-mentioned agencies will be paid service charges ranging between 8%–9% of the project cost as charges for implementing the scheme, and so on. REC will be given 1% of the project cost as fee for setting up frameworks for implementation, and so on.
- Supporting activities will incur a cost of 1% and would be in the form of capacity building, awareness generation, franchisee development, and undertaking of pilot studies and projects complementary to the rural electrification scheme.
- CPSUs (central public sector units) (like NTPC, Power Grid, NHPC, and DVC) will assist the states in the smooth execution of rural electrification projects in a purely need-based manner.
- The selection of villages/hamlets is to be carried out in a cluster mainly to derive maximum possible advantage of the clustering effect as far as possible by the state nodal agency/departments responsible for renewable energy promotion in due consultation with the state utilities and MNRE.
- Such villages as have little chance of getting grid connected in the next 5–7 years will be taken up first. A threshold size of 100 people will be necessary for consideration under the DDG scheme.

Table 4 Major objectives to be achieved

Operational period	2007–12 (that is, Eleventh Five-year Plan)
Major goals	▪ Provide electricity access to all households ▪ Electrification of about 1.15 lakh un-electrified villages ▪ Electricity connections to 2.34 below poverty line households by 2009
Total amount of capital subsidy involved	Rs 5400 million for decentralized distributed generation during the Eleventh Plan
Total capital subsidy available for RGGVY in Eleventh Plan period	Rs 280 000 million
Decentralized distribution generation technologies (under consideration)	Can be from conventional or renewable energy sources such as biomass, biofuels, biogas, mini-hydro, and solar (in areas where grid connectivity is either not feasible or not cost effective)

- Such villages as are presently benefiting through solar home lighting for example may also be considered. Grid compatibility of the villages will be built up to the stage where it becomes possible to connect to the grid finally.

Choice of technology

Such technologies as have either attained commercial maturity or exist with a proven technical viability qualify for implementation under this scheme. The following are few such options.

- Diesel generating sets powered by biofuels such as vegetable oils like jatropha and pongamia.
- Diesel generating sets run by producer gas obtained through biomass gasification (that is, use of 100% producer gas engines).
- Solar photovoltaic modules.
- Small hydro power.

Few other possible options

These are mainly such as are expected to have near-term relevance.

- Diesel generating sets run on biogas (obtained from animal waste).
- Wind-hybrid systems.
- Any other new technology/hybrid system.
- Diesel to be kept only for standby uses or in such cases triggered by temporary.

Project financing

It is quite important to understand the project financing mechanism. The project cost would be met on account of the following.

- Capital cost: for all plant equipment, auxiliary systems, and accessories needed for a smooth plant operation
- Civil works: includes all associated civil works
- Cost of land: to be borne by the state government
- Distribution network: includes necessary control equipment
- Initial capital cost for plantation to ensure a sustainable supply of bio-energy (related to projects on biomass gasification/biofuel projects)
- Initial capital cost of setting up non-domestic loads as specified by the implementation agency
- Revenue cost: includes cost of spare parts for five years after commissioning
- Cost of providing power for a period of five years from the date of commissioning as identified in DPR after taking into account recovery from village households and as per tariff to be decided by the concerned agencies
- Soft cost comprising of preselection of villages, preparation of DPRs, cost of social engineering, and so on.

Payment scheme

- Ninety per cent of the total project cost (includes capital cost and soft cost) to be provided to the implementing agency as subsidy.
- Balance 10% cost to be arranged by such agency either by themselves or via loan from REC, and so on.

Who all can set up projects?

These mainly include the following few.

- State agencies
- Technology suppliers
- Corporate entities
- Equipment manufacturers and contractors
- Voluntary agencies
- Individuals
- Registered societies, cooperatives, panchayats, local bodies, user associations, and so on.

The projects will be taken up on a BOMT (build, operate, maintain, and transfer) basis for a period of five years. Thereafter, a fully functional plant will be handed over to the state government. It will be the responsibility of the project developers to collect the tariff from villagers. An added incentive may be in terms of earning carbon credits via the CDM (Clean Development Mechanism).

Conclusion

Improved and innovative policy regimes may well go hand in hand with initiatives aimed at achieving lower costs via technology upgradation/ modernization efforts.

Gaining optimally *from the* sun

SPV 'Maximum Power Point Tracking'

Photo courtesy: DOE/NREL

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Introduction

Sun and humankind share a special relationship with each other. There is an added reason factored in such an association-that is, sun being used to light up our houses at night. That is not all, as solar energy based applications have progressed much beyond the early days of lighting and water pumping. The technology of converting sunlight into useful electricity is better known as solar photovoltaics or simply SPV. It has the potential of becoming one of the key alternate sources of electricity for urban and rural areas. However, before it takes charge of that, a good change is needed in the efficiency of such a conversion. No doubt, solar cell efficiencies have improved over the last decade or so, but a higher efficiency cell is still a distance away. Today's commercially available crystalline silicon solar cells are generally 15%–20% efficient which transforms into moderate power output for the running of any load. The moot question is, whether in the existing siyuation, there is an option at hand to tap the maximum power that the solar panel/array is capable of producing at a given atmospheric condition.

Rationale for maximum power point tracking

Broadly, there are two ways that can be adopted in order to improve the performance of the SPV based system under all conditions. A SPV system can work at its best if the two techniques are implemented in conjunction with each other. However, not many commercial systems use both simultaneously.

Sun tracking: Solar modules or panels produce power when exposed to the sun. These get exposed to other atmospheric conditions too, which change throughout the day. It leads to decreased power output too, if, solar panel is not aligned in the path of sun always. The trick is to keep it facing the sun in a process commonly known as sun tracking akin to tracking someone's movement on the road or elsewhere. Single- and double-axis sun-trackers tilt the modules mechanically. The immediate purpose is to obtain the maximum possible sunlight on the module surface and thus realize a higher power output.

Maximum power point tracking: In addition to the method described above, there is another way to enhance the power drawn. This is related to the load that is connected to the array at a fixed position. This purely electronic system is known as Maximum Power Point Tracking or simply MPPT. It is basically regarding optimization of the operating point (optimal point on the voltage versus current curve) of the connected PV array. There is no technical barrier as such to use MPPT for any PV application.

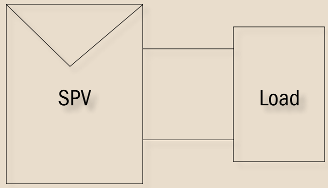


Figure 1(a) DC load directly connected to SPV

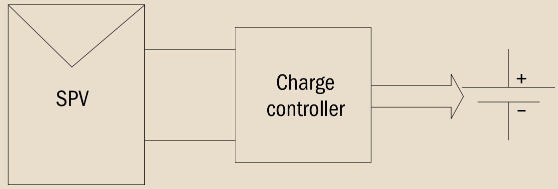


Figure 1(b) Direct battery connection to SPV

MPPT working with the sun

The power output of a SPV source maximizes at a particular output voltage. The magnitude of this power and also the corresponding voltage keep varying with insolation and temperature conditions. Following few types of situations can arise:

- Generally when a load is directly connected to a solar array (Figure 1(a) and 1(b)), there is a load mismatch.
- This occurs due to the operating point of the load not coinciding with the optimal operating point of the SPV array (see Figure 2).
- The power and the voltage corresponding to MPP keep varying with varying insolation and temperature. (see Figures 3 and 4).

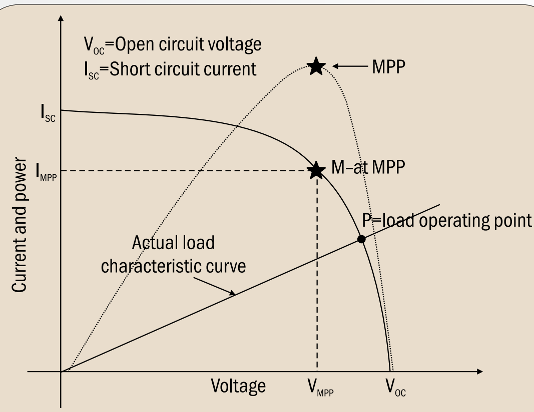
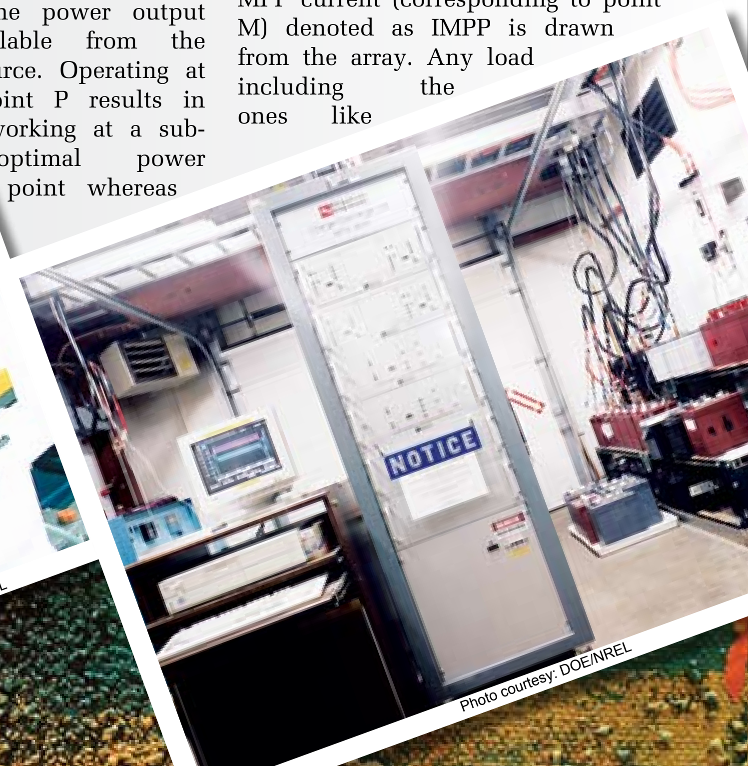


Figure 2 PV characteristic curves and concept of MPP tracking

Referring to Figure 2, it can be observed that under ideal conditions, the load characteristic curve should have intersected the I-V characteristic at the MPP. That means it should have operated at point M (corresponding to MPP) in the figure rather than point P (direct load operating point). The key difference is in terms of the power output available from the source. Operating at point P results in working at a sub-optimal power point whereas working at point M would ensure that the peak power is utilized by the load.

The possible gain

MPP trackers help to electronically manipulate the operating point to virtually reach the optimal current and voltage value on the SPV characteristics. It ensures that current equal to the MPP current (corresponding to point M) denoted as IMPP is drawn from the array. Any load including the ones like



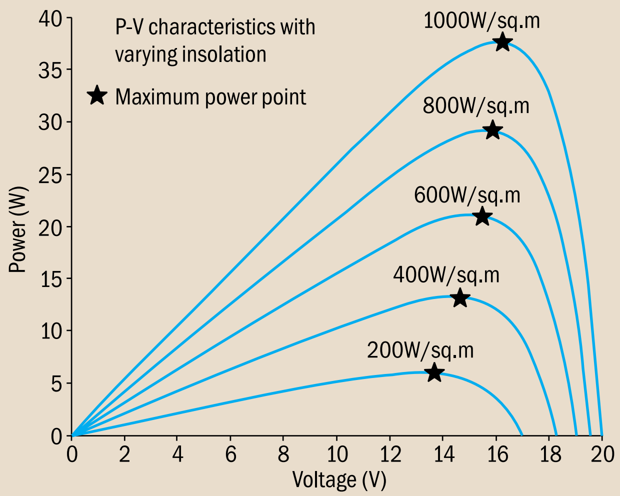


Figure 3 Varying power versus voltage characteristics with varying insolation

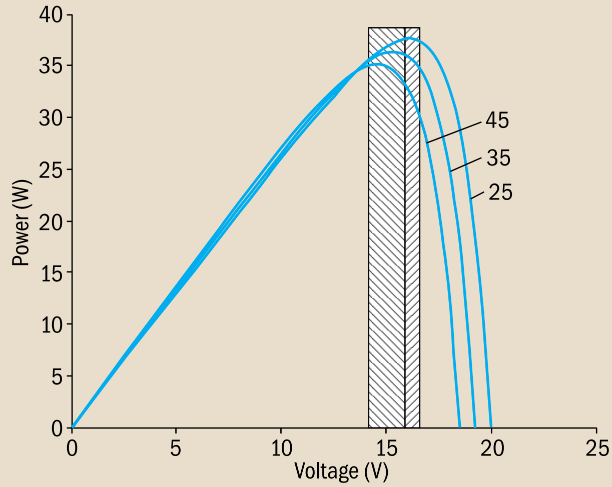


Figure 4 Curve showing changing power and voltage at the MPP with variation in temperature

batteries can be delivered with maximum obtainable power thus ensuring optimal performance of the system.

As is observed from Figure 3, the optimal operating point corresponding to the maximum power keeps varying with solar irradiation. The MPP tracker must track the changing optimal operating points continuously. The same argument holds true for varying temperature.

Let us take a quick look at the shaded regions of Figure 4. The operating voltage and peak power increase with the falling temperature. Using an MPPT will help gain more in such a condition where the array has the capability of producing more power. So, a MPP tracker is a boon especially in winters when the power requirement is greater.

Case specifics- MPPT

A most commonly used standalone application is that of water pumping. It makes use of a DC motor. Experimental observations point to water output gain of around 20% via use of a tracking system. As per a IEEE Published report, a digitally controlled simple MPP tracker enhanced the PV power output to a DC load by nearly 15%. This is in direct comparison to the fixed duty cycle condition for maximum power at STC.

Sensing such gains, most battery charge controllers are now being manufactured with MPPTs. The cost of MPPT's is easily offset by the following few benefits mainly:

- More power is transferred to the load.
- System becomes economically viable.

However in low-power systems, one needs to vie for a cost-effective MPPT option.

Most commercial MPPTs are more than 95% efficient. High efficiency MPPTs can even be coupled with individual modules. However, these are ideally useful for system capacities of a few kilowatts and above.

Photo courtesy: DOE/NREL

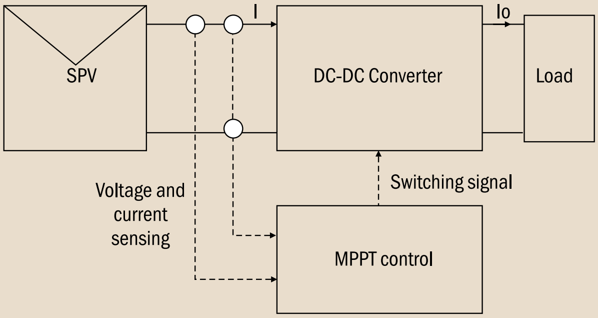


Figure 5 Block diagram of Maximum Power Point Tracker catering to a DC load

The topology

Basically, a MPPT is a converter connected between the PV source and the load (see Figure 5). The PV array 'power' can be said to be the 'target parameter' to be maximized. The converter topology is chosen much in accordance with the load voltage requirement or the battery voltage (in case of battery charging). Buck (Voltage Step down) and Buck-Boost (Step down-Step up) topologies are most widely preferred. As the control circuit, either analog or microcontroller/Digital Signal Processor based systems are employed Use of such microcontrollers facilitates the implementation of robust P-V curve tracking algorithms. Simplicity in software implementation where every computational step adds to the code complexity is also an important issue. This is so during the designing of MPP tracking algorithms.

Understanding the algorithms

The tracking algorithm is at the core of the performance of an MPPT. Several algorithms are employed depending upon the robustness and allowed complexity of implementation.

Constant Voltage Ratio method: Generally VMPP lies in range of 70%–80% of the open circuit voltage (VOC). Knowing the ratio, many trackers sense the VOC and compute the VMPP. This helps the operating point to reach its vicinity for an optimal performance. It can be used in low-power systems having cost-constraints and need for simple circuitry.

I-V curve sweep method: Another simple tracking mechanism is to sweep the entire voltage range at particular intervals to locate where the power peaks out. This may then help in identifying the value of the MPP operating voltage. Although simple, this method incurs occasional power-loss due to sweep. However, some well-known manufacturers such as Xantrex do not use the sweep method. Rather, they prefer continuous tracking (as implemented in their MPPT model Xantrex XW Solar Charge Controller). as per the manufacturers claim, the robust method implemented in their model tracks the optimal point continuously even during cloudy conditions and fast changing solar conditions.

Perturb and Observe (P&O) Algorithm: The most common method of tracking is called the 'Perturb and Observe' algorithm. Within which, the SPV power values in two sampling instants are compared. It then manipulates the switching signal to the converter for driving the operating voltage towards increasing power. It can be carried out by using a voltage reference loop or by directly controlling the duty cycle. This method is also called 'Hill-climbing'.

Incremental Conductance Algorithm: Drift is a situation that occurs during fast changing atmospheric conditions wherein the P&O method occasionally fails to track the fast changing MPP points in the correct direction. This is where a more efficient but complicated alternate method called 'Incremental Conductance' comes in. Here the algorithm recognizes the side of the peak power at which the system is operating at a particular instant. It then takes the correct tracking direction, thus avoiding drift during such conditions.

Curing the shading effect: Partial shading results in a drastically low power output from a PV array. It is clear from figure 6 that even nominal shading on a part of a cell can sometimes cause local maxima to occur. In such a case, a general tracking algorithm can confuse the local peaks for the actual global peak thereby tracking a sub-optimal operating point. The net impact may be further loss of power. Interrupting the global tracking algorithms at regular intervals and sweeping the voltage range is the most common solution to this problem.

Talking further on the present R&D efforts, researchers are envisaging a possibility to use only one sensor that is, either the voltage or current sensor for tracking purposes. This is expected to improve the reliability besides reducing the circuitry cost. Such algorithms having sensor-reduction without compromising on tracking precision shall be hugely beneficial to the MPPT market.

Market Savvy MPPT

High power, high efficiency MPPT battery charge controllers are available

Photo courtesy: DOE/NREL

Table 1 Different MPPT Models

Manufacturer	Model	Specifications	Other details
Outback Power Systems	FLEXmax 80 (MPPT Charge Controller)	■ Works in a wide temperature range ■ Less than 1 W standby power consumption ■ Max PV voltage = 150 V ■ Max output current = 80 A ■ Charges batteries with nominal voltages equal to 12 V, 24 V, 36 V, 48 V, and 60 V	Claimed increase in power as compared to non-MPPT systems is about 30%
Morningstar	SunSaver MPPT Solar Charge Controller	■ Upto 36 V solar array can be used to charge 12 V or 24 V battery ■ 30 days of data-logging ■ Current battery current = 15 A (max.) ■ 35 mA self consumption	—
Phocos	MPPT 100/20	■ Used with 12 V or 24 V off-grid systems ■ Max 95 V solar input ■ Nominal battery charge current = 20 A ■ Standby power consumption < 80 mW for 24 V system	■ Uses method of sweeping the voltage range every 2 hours ■ Energy gain of upto 30% (with average gain of 10%–25%)
Steca Solarix	MPPT 2010	■ Power = 250 W/500 W ■ Can be used for 12 V/24 V systems ■ Maximum charging current = 20 A	Can be deployed in conjunction with thin film module
Xantrex	XW Solar Charge Controller	Used for batteries of 12, 24, 36, 48 and 60 V systems	• Does not use voltage sweep technique • Continuously tracks MPP even with moving clouds and quickly changing solar condition
MSTE	MPT 330	• Battery voltage = 12 V • Power = 330 W • Maximum charging current = 26 A • Maximum solar voltage = 28 V	—

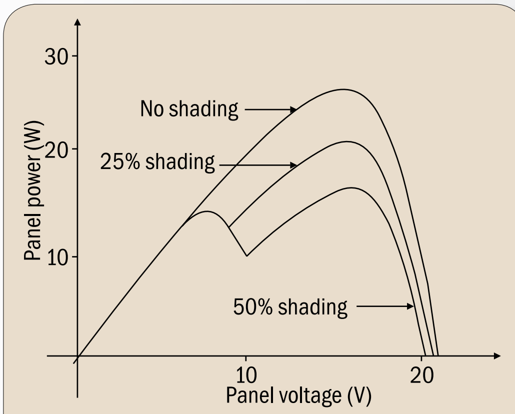


Figure 6 Local maxima due to partial shading

from some well-known manufacturers. Some of the established models are listed in Table 1 in terms of their present wattage, voltage ratings and operational capabilities. Updated numbers can be found on the respective latest datasheets.

Conclusions

The Maximum Power Point Tracker is one sure way of producing more power from within the same panel. However, it is a high time to establish indigenous capabilities both with regard to actual manufacturing as well as gauging their long-term field performance.

SunSaver MPPT from Morningstar

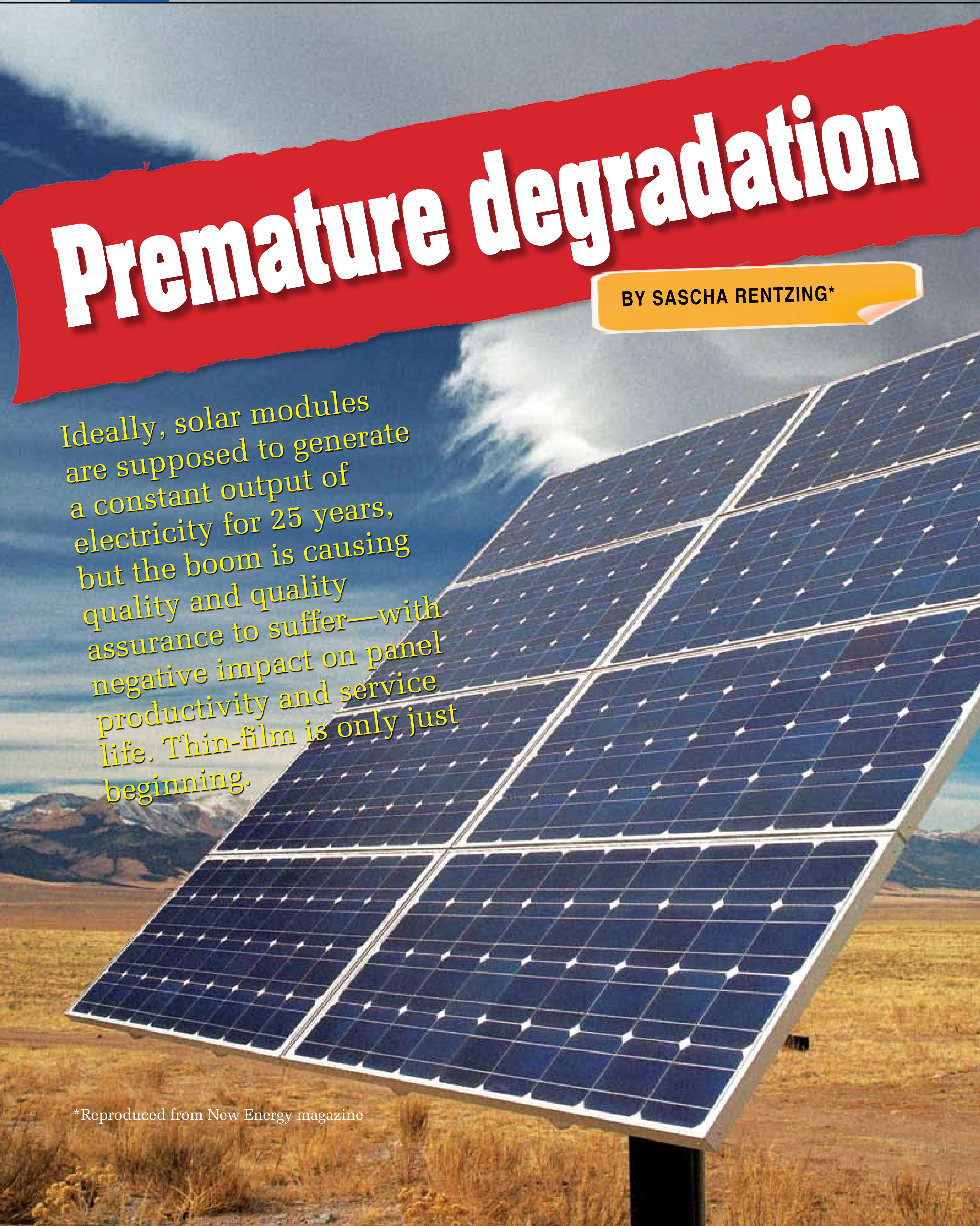
MPPT from MSTE

MPPT 100/20 from Phocos

Premature degradation

BY SASCHA RENTZING*

Ideally, solar modules are supposed to generate a constant output of electricity for 25 years, but the boom is causing quality and quality assurance to suffer—with negative impact on panel productivity and service life. Thin-film is only just beginning.



*Reproduced from New Energy magazine

The DLG (German Agricultural Society) has a plan that sounds rather peculiar. The organization, which describes its mission as bridging the gap between agricultural and food theory and practice, wants to study whether and to what extent animal ammonia vapours, such as those that arise in pig farms, corrode the glass and wiring of PV (photovoltaic) plants. Winfried Gramatte, DLG's test lab man responsible for renewable energy, says that also this issue still isn't heeded in internationally standardized testing procedures, there is indication that modules degrade faster when exposed to odour and ammonia emissions. The society recently spent € 220 000 on a new test bed, a kind of time machine, in which modules are exposed to an ammonia atmosphere with accelerated temperature and climate fluctuations. In this way, the DLG testers are simulating the ageing process, or degradation, of solar modules in agricultural environments. The project is set to begin at the end of 2008. Gramatte says DLG wants to provide its expertise to testing institutions and PV manufacturers.

Corrosive swine gas

The solar industry has indicated little interest so far. There are no concrete cases of ammonia corrosion, is the reply from companies and machinery syndicates, from whom many farmers get their solar systems. But farmers could rise up when the first agricultural power stations start getting up in years. Experts estimate that in Germany, more than 1500 MW (megawatt) of solar electricity capacity was installed by landowners over the past four years alone. That's the biggest group of customers for the solar business. Even if only a fraction of those installations start to act up, the industry would face a lot of claims for damages and see its image take a nose dive. Premature module degradation is an issue that will probably concern companies in future for other reasons. Demand for thin-film solar installations is growing fast because they cost less than conventional silicon modules. But it's uncertain how the technology will perform over the years.

Experts say that the performance claims made by manufacturers are based less on knowledge than on estimations. 'We don't yet fully understand the behaviour of thin film,' says Dieter Geyer, Director of the Test Centre for thin-film solar modules at the Centre for Solar Energy and Hydrogen Research (ZWS) in Stuttgart. There's also inherent danger in the fact that in times of a demand boom and mass production, quality, and quality assurance often tend to slide. Ingot and wafer producers complain about impure silicon, cell producers about poor wafers, and module builders about faulty cells. Perhaps few years from now, a bunch of operators will be complaining about prematurely degraded solar installations and lower output. The accusations made by industry insiders are serious: in boom time many manufacturers stop caring about quality. Sometimes even inferior parts are wittingly waved through to keep production at rolling and costs down, they say. Their criticism isn't only directed at the usual suspects – newcomers and companies from the Far East – but also to big brand names from Europe, Japan, and the US.

Every tenth wafer is flawed

Solar make Sunways, for instance, has been experiencing problems with the quality of wafers it buys in. 'Five years ago, we had virtually no rejects. Nowadays we sometimes have to discard 10%,' says management board chairman Roland Burkhardt. The underlying problem, he says, lies with the ingot manufacturers who don't use only high-grade silicon but often mix varying qualities in these times of commodity scarcity and high productivity pressure. This results in low-resistance wafers that degrade more than good, high-resistance material. So as to not aggravate its customers, Sunways plays it safe with the performance values of its modules. Before they are shipped out, their efficiency characteristics are determined and adjusted downward by a few per cent, says Burkhardt.

At the end of the solar value added chain there is also reason to grumble. Dresden-based module builders Solarwatt have received several deliveries of poor-quality EVA (ethylene vinyl acetate) sheets used for cell encapsulation. 'We give very precise specifications but sometimes what we get isn't suited to our technological process,' says Dietmar Jakob, Sales Director for German speaking countries. With high international inspection demands, it's hard to imagine how low-quality modules make it onto rooftops. They are supposed to withstand at least 25 years and degradation test is accordingly tough. An especially high hurdle to pass is the moisture–heat test in which modules have to endure a month of 85% humidity and 85 °C heat. If during that, a panel's performance drops by more than 5%, it fails the test. If it passes, it goes through a stress test involving 200 temperature cycles. In between the test runs, the panels go through visual, performance, and insulation tests. Only the modules that weather all procedures unharmed are certified.

Some that are not long-life premium products nonetheless get sold. Three years go by from the base certification of module types till a re-audit by TÜV Deutschland Group, for example. In that time, the performance values of a module type can drop by a lot of several cells contain impure silicon. Not all manufacturers, word has it, adjust the module efficiency numbers downward to accommodate the stronger degradation effect.

Great unknowns

Besides that, the established tests can't simulate exactly the real-life conditions of modules out in the sun. Thus, it can come to pass that a module performs really well on the test bed but not so well in the great outdoors. 'Although we have learned a lot about degradation over the last few years, it's hard to predict how quickly a module will suffer fatigue,' says Jörg Eylert, Director of TÜV's test lab for PV. At least the inspectors know the main reasons for performance losses: dust and dirt deposits that corrode the glass can lead to fatigue, physical effects in the cells such as irreversible recombination, in other words the negation of charge carries, which means they don't contribute to electricity generation.

Due to the gaps in degradation research, scientists and corporations have come to accept a simple formula. For crystalline solar modules, they generally assume a performance loss of half a per cent per year, amounting to 12.5% after 25 years of operation. This vague assumption also explains the manufacturers' performance claims. The bulk of them guarantee that with

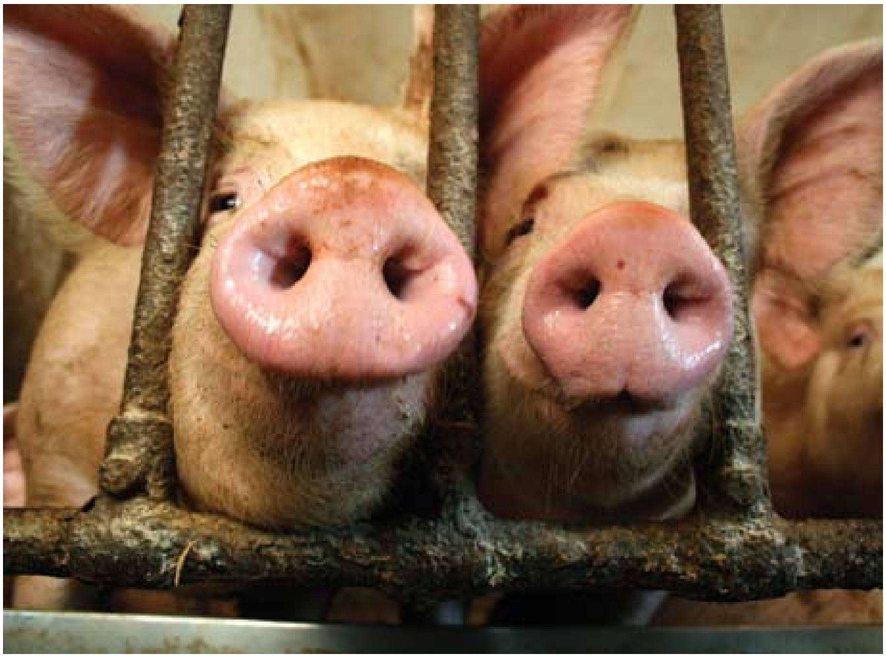
GETTING THE LOW-DOWN ON DEGRADATION

Up to now, the solar industry knows little about solar module service life. There's been hardly any systematic research into questions like: Which factors cause degradation and how much? What can be done to slow it down? That's set to change. In several projects, institutes are taking a close look at modules. In 2007, the Fraunhofer ISE and TÜV Rheinland started a project called 'Reliability of PV Modules' sponsored by the German environment ministry. Various German brand name systems were installed on the Zugspitze, Germany's highest mountain, in the Negev desert in southern Israel, in the high-humidity heat of Indonesia, and on the rooftop of TÜV's building in Cologne, Germany, where the climate is moderate. Readings of the solar systems will indicate how material characteristics such as diffusion and heat emission change from degradation. The scientists want to use the results to develop new testing methods and to build a new climate chamber with accelerated weathering to better evaluate new materials. A status report is scheduled for the end of this year and there is talk of continuing the project.

The German Agricultural Society (DLG) is studying the effects of lifestock ammonia vapours on the service life of modules. The DLG invested in its own test laboratory and will begin measurement in six months. It hopes to have gained insight into the problem of ammonia degradation in two or three years. Then it wants to cooperate with manufacturers to develop ammonia-resistant modules suitable for farm applications.

The Bavarian Centre for Applied Energy Research (ZAE Bayern) is seeking encapsulation materials that best prolong the operating life of modules. Various contaminants are exposed to great heat and high humidity and then readings are taken. By measuring the electroluminescence of modules, the Photovoltaic Institute Berlin, is trying to identify weak spots. Screenings reveal defects that don't show up in other quality tests. Inspections and manufacturers' tests that include such measurements could stop faulty modules getting into circulation in future.

The Centre for Solar Energy and Hydrogen Research (ZWS) in Stuttgart focuses predominantly on thin film. It researches methods of reliable efficiency measuring of CIS modules and studies the mechanism of degradation during simulated ageing. This is valuable groundwork for CIS modules because so far it's unclear how they behave over periods of years. Some material compounds even become more efficient the older they get.



the given definition of solar irradiation, 80% of the capacity rating of a new module will still be achieved after 20 to 25 years of operation. The 7.5% difference is a kind of safety net that the suppliers factor in to account for any unexpected degradation effects.

But it's precisely in that great unknown where danger lurks. No one can say today whether swine gases might render modules completely inoperable. It's also unclear whether physical processes occur in purified metallurgical silicon over the course of years. Some manufacturers, like Q-Cells, are making long-term plans to use this newfound solar material because it's much cheaper to make than standard silicon and because it delivers decent cell efficiency rates of 14%–16%.

The thin-film variable

Determining the performance and electric behaviour of thin-film technology is even trickier than with crystalline modules. For panels with amorphous silicon, for example, it's assumed that they lose about 20% performance during the first 1000 hours of sunshine. But after that they are still not stable and ready for performance measurement. For one thing, the degradation in amorphous material continues at a slower pace after a thousand hours and for another, it slows down during cold spells and converts more light into electricity when the temperature rises. The fickleness of amorphous modules makes it very difficult for researchers and companies to determine the best time to measure its characteristics. If done at the wrong time, the result might be a capacity rating that is too high and falsely raises customer expectations of production.

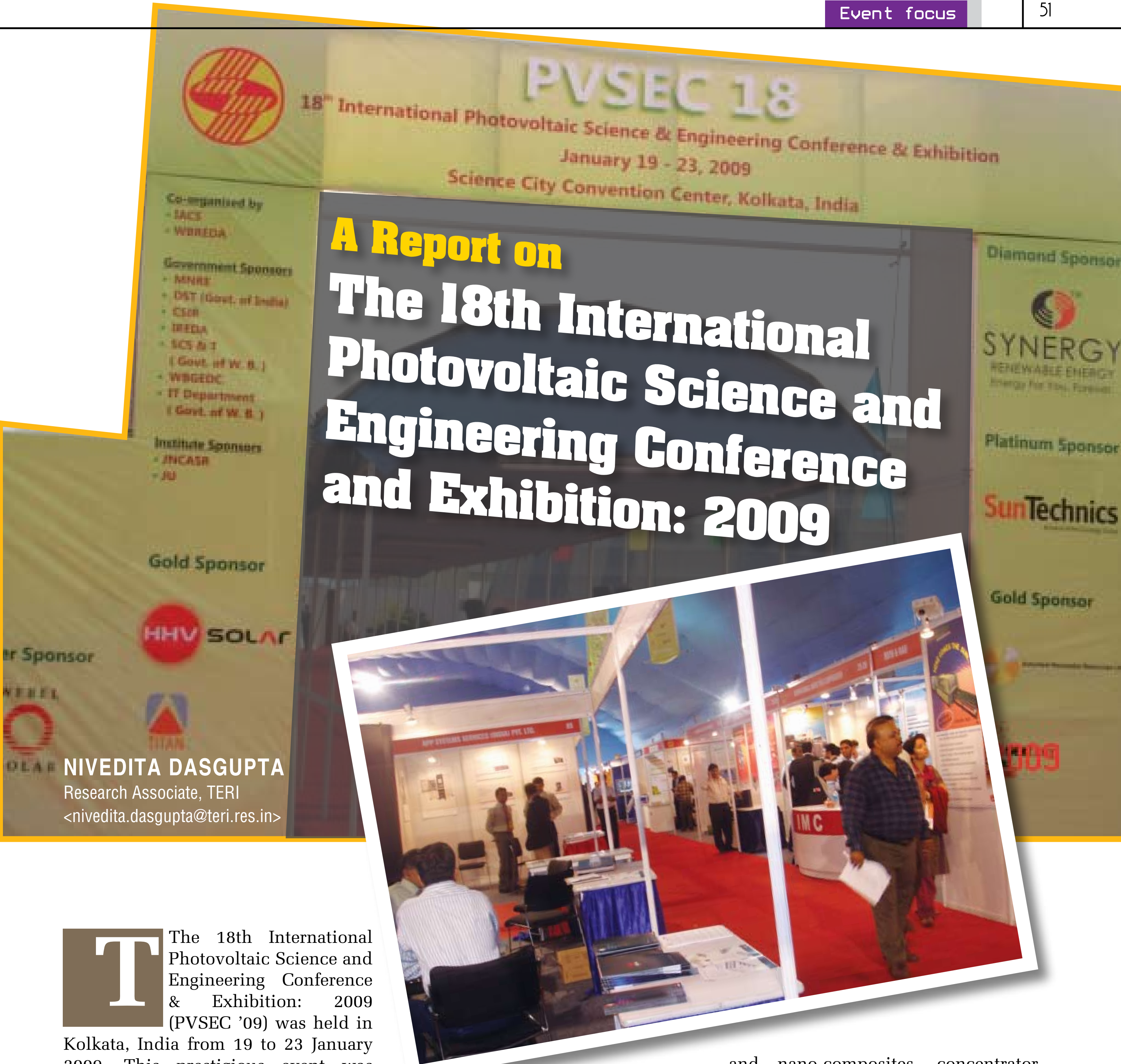
It would be even more aggravating if on top of that there were unforeseeable or previously unknown ageing pains. It's possible. Nowadays amorphous silicon is increasingly being used in combination with microcrystalline silicon in tandem and triple-junction cells. But for how long do the compounds work effectively? There is no clear answer to that yet.

It's equally difficult to predict the degradation process in copper modules combined with indium gallium selenide and sulphur (CIS) and CdTe (cadmium telluride). Unlike amorphous silicon modules, the performance of CIS modules for instance, can first increase under light but then during a dark phase they can become electrically unstable and lose a lot of their effectiveness. Depending on the given CIS technology, these effects can be more or less serious. Beyond that, all CIS modules perform better in sunlight than in the laboratory. So, it's difficult to get a handle on this material and establish a uniform measuring routine. 'If a manufacturer were to sell you a CIS module with a 110-W rating today, it could turn out that the module produces only 100 W or 125 W,' says ZSW's Geyer. It's a problem.

Working on better tests

The solar industry is still getting by with the vague performance data it gives its customers. Photovoltaics are trendy and solar systems are a hot item. In such boom times, there are rarely questions about possible weaknesses later on. Especially since there is hardly any bad news about prematurely degrading arrays because the first utility scale power plants haven't yet reached a critical age. But there are signs that in the future not only price and efficiency of modules but also their robustness will be key. More than a few experts perceive the solar market on the verge of switching from a suppliers' to a buyers' market. It's possible that 80% efficiency guarantees will then no longer be enough. It's also unlikely that potential investors will put up with production estimates; they'll want to know what exactly are the risks of degradation and what concrete impact they might have. In the post-boom period, it could lead to serious sales problem especially for the thin-film providers.

But the mindset of researchers and manufacturers is changing. For a long time, the solar industry talked it down; now degradation is becoming more and more an issue. A project called 'Reliability of Solar Modules' sponsored by the German environment ministry is proof of that. The Fraunhofer Institute for Solar Energy Systems, TÜV, and German manufacturers have cooperatively installed modules in the most varied regions of the world to learn how they behave in various climates. The readings are to be used to develop laboratory tests that go beyond today's standards. The DLG's ammonia project might also help to avoid disappointment in the future. But so far hardly anyone has shown any interest.



A Report on The 18th International Photovoltaic Science and Engineering Conference and Exhibition: 2009

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The 18th International Photovoltaic Science and Engineering Conference & Exhibition: 2009 (PVSEC '09) was held in Kolkata, India from 19 to 23 January 2009. This prestigious event was organized by the 18th International PVSEC Organizing Committee, co-organized jointly by IACS (Indian Association for the Cultivation of Science) and WBREDA (West Bengal Renewable Energy Development Agency) after a long interval of around 16 years. The sponsors included well-known brands such as Synergy, Titan, Hindhivac, Suntechnics, Webel Solar, and Moserbaer Photovoltaic.

Paper presentation (s) on solar cell technolgies

Technical papers were presented both in oral and poster sessions in the broad areas of crystalline silicon solar cells and technologies, PV modules and system components, CIGS-II-VI and related thin films, amorphous and nano-composites, concentrator PV systems, testing and field performance reliability PV policies, economics and environmental issues, PV architecture, and other PV systems. One of the presentations was related to the understanding of material related performance limits in multi-crystalline solar cells. The conference proceedings having the full version of papers mentions work on hetero-junction solar cells and a simulation model that can be applied to study the kinetics of the surface defects. We can also find a comprehensive outline on Sanyo company's thin-film solar cell research during the last 30 years. Amongst several other papers on solar cell materials, there was a separate section on the relatively new technology developments vis-à-vis concentrator cells. Scientists presented their work on super high-efficiency multi-junction concentrator cells; quantum structures in concentrator cells and improved tandem solar cells.

Paper presentations on solar modules/arrays

There were several interesting presentations made on the key aspects of SPV systems. This section covered the aspects mainly related to the electrical characteristics and the electrical/electronic components such as converters, inverters, batteries etc. that make for complete grid-interactive and/or standalone PV systems. In a solar cell which is a p–n junction diode, there are several electrical parameters that are governed by its structure. A presentation on the solar cell electrical characteristics explained, on the basis of experimental results, as to how the diode parameters vary with intensity. This in-turn helps us to understand the variation of typical parameters such as open circuit voltage and short circuit current with solar intensity. Another presentation dealt with the comparison of a low capacity concentrator module with the common flat-plate silicon module under Indian conditions. Although the newly developed module yielded 24% lower energy than the silicon-based one, its lower cost may offset this effect to some extent. Work on, a cost-effective DC-AC inverter was also presented. It is ideally suited to small scale standalone PV systems in remote places involving only one panel.

Sufficient measures must be taken to install solar PV arrays in shade-free area. However, there can be cases where partial shading on whole or a part of the module cannot be avoided at specific times in a day. In such cases, the characteristic curves of the solar module may get distorted and it may also lead to lower current output. A specific research paper focused on the effect of partial shading on the internal resistances. These can in-turn help in understanding the distortion of the voltage versus current curve of a cell.

Presentation (s) on Test Standards etc.

Within a section based on test standards and other such issues, there were several enlightening presentations. SPV is a relatively expensive option and its viability is based upon its long term performance. However, SPV modules are subjected to degradation due to atmospheric exposure, and so on. A presentation was made based on the field observations on the degradation and possible damages to single crystalline silicon modules. It dealt with the degradation aspects like cell de-lamination, corrosion of cell grid, corrosion of end-strip connected in the terminal box, failure of bypass diode, and detachment of terminal box. These findings are a result of continuous exposure of modules for 10 years under the Indian conditions. Some of the modules showed more

deterioration in performance than what was normally expected. Thus the authors proposed that considerable modifications must be made in the test standards in terms of specifications for the modules to perform well under harsh Indian conditions for 20–25 years. Another work suggested the methods of electrical fault detection and location methods in PV strings.

Presentation(s) on SPV systems

Amongst the various solutions presented on SPV systems, one work apprised the participants about various kinds of battery charge controllers alongwith their advanatages and limitations. We know that a SPV module sources maximum power at a particular operating point. A researcher from Japan presented his novel work on using a special mathematical technique called Neuro-Fuzzy Network to locate this maximum power point quickly and accurately too. Other papers on global Maximum Power Point Tracking and those under partial shading were also presented. Work on the ever popular topic of solar home systems was also discussed.

Presentation (s) on Policy issues

There was a separate section covering the policies and economics related to the PV market from all over the globe. There were reports, amongst others, on the current status and prospects of PV market in Japan, US Department of Electronics' (DoE) solar programme, the role of next generation PV cells in Korea's national vision of 'Low Carbon, Green Growth', and so on. From India, a paper on Sustainable Photovoltaic Roadmap and Policy Initiative in Gujarat was presented.

Product Exhibition

PVSEC 18 offered significant insights into the fast emerging world of SPV technology and its accompanying developments. Prominent personalities from the PV industry and academia participated in the plenary lectures and other technical presentations. A solar product exhibition had been put up during this event and familiarized the delegates and visitors with the latest available trends in the PV market. Solar products on display included both crystalline and thin-film modules, lanterns, grid-tied inverters, power-conditioning unit, batteries,, module testers, charge-controllers and a few other products too. The exhibitors included the likes of Evans Analytical Group (USA), Spire, Green Energy Technology Inc., Optimal Power Solutions India, Waaree, APP systems (India) Pvt. Ltd, Titan Energy Systems Ltd., Agni Power (India), Solid Solar (India), Indo Solar, and so on.

Summary observations

The technical digest published as an outcome of the academic presentations is worth possessing. Overall, the conference and exhibition proved to be immensely informative. It was indeed an apt platform for interaction amongst SPV researchers, manufacturers and enthusiasts at large. It apprised the participants of the state-of-the-art in photovoltaics and the future possibilities of expanded use of PV applications and markets.

Carving a niche in solar power

The vibrant state of Gujarat is all set to take the lead in generation of power from renewable energy. Various initiatives and policies taken in this direction have helped the state to achieve the pioneer status in renewable energy. *Mr S Jagadeesan, Principal Secretary, Energy and Petrochemicals Department, Government of Gujarat and Chairman, Gujarat Energy Development Agency, Gandhinagar* talks about the various policies and more in an interview with *Dr Suneel Deambi.*

Q. The state of Gujarat is well known for a very conductive business environment. To what extent has it actually catalysed the growth of various renewable energy technologies within the state?

Gujarat is the leader and a pioneer as far as development of renewable energy business is concerned. It boasts of successful experiments in decentralized energy supply models especially for solar cooking and solar water heating systems in the domestic and industrial sectors. Its decentralized power generation projects are successful case studies that have to be replicated from large- to small-scale levels. The name of Bardoli in Surat district is not only synonymous with Satyagraha but also with the rapid technology advances that the country has made in renewable or green energy sources. Incidentally, the first solar cooker was designed in Bardoli. It subsequently led to the launch of a national solar cooker programme. Gujarat won a national award for overall best performance during the Tenth Five-year Plan in the market development/dissemination of solar cooker programme.

But this is just a tip of the iceberg. A series of innovative green energy initiatives by Gujarat have gone a long way in expanding the country's green energy base and creating energy conservation awareness too. Amongst Gujarat's renewable energy initiatives that have made a mark are the following.

- The first joint sector wind farm (that is, Pavanshakti).
- 500-kW grid-connected biomass-based power generating system.
- Large-scale promotion of solar water heating systems.
- Community biogas programmes.

The state's success in creating awareness about green energy has also won wide acclaim. The BURD (Bal Urja Rakshak Dal) – a state-wide school energy education programme – is motivating a force of 50 000 children annually since 2004/05. This is to inculcate energy skills as life skills and spread conservation awareness in the budding young minds. This initiative is by now a big hit. It won't be an overstatement if, I say, that Gujarat is the green energy capital of India, particularly after it announced the path breaking and incentive-based policies for solar and wind power generation recently.

Q. The MNRE's (Ministry of New and Renewable Energy) GBI (generation-based incentive) scheme is being seen as a massive success at least in terms of the number of project proposals received so far. In what ways is your solar policy initiative different from the one undertaken by the union government?

The Gujarat government policy has looked at a larger canvas of technology development. The centre's incentive scheme for solar energy has a cap of just 50 MW while the Gujarat government in its new solar generation policy has taken a historic step. A minimum of 500 MW and an eligibility period of 25 years has been offered to attract large-scale, hundreds to thousands of megawatt capacity installations. However, initially the developer will be free to install pilot-scale demonstration facility. The pay back calculation will actually attract investments initially for a period of 12 years from financial institutions. If one looks at the front-end cost, it is definitely attractive, as after the 12th year, the operation and maintenance cost will work out to be merely 2%–3% of the total system cost. The rate of return is at 14% equity.

The investor-friendly state policy fares quiet well, when compared to the centrally-sponsored scheme, wherein, the buy back rate is Rs 12 per unit for SPV while that offered by us is Rs 13 for the first 12 years and Rs 3 for the next 13 years. Similarly, in case of solar thermal power, Gujarat has offered a tariff of Rs 10 per unit for first 12 years and Rs 3 for next 13 years, as against Rs 10 offered by the Government of India for 10 years only that too without the benefit of accelerated depreciation.

The expected broad impact of this policy is that it will encourage research and development in solar energy generation. Additionally, it aims at expanding the manufacturing capacities for solar energy technologies along with power generation too.

Q. What do you think will be the precise, overall impact of the packages?

The special packages announced by the Gujarat government on the eve of the last Vibrant Gujarat summit for solar and wind power generation have given a historic boost to green energy in the country. It was evident in the quantum of green energy proposals that were received at the summit.

The green energy projects' capacities, when installed, will generate 20 000 million units of electric power annually. The power generated from the renewable energy sources will offset 12.53 MT (million tonnes) of coal and reduce carbon emissions levels to 18.43 MT annually. What better initiatives can be expected from a state government?

> *"The new solar policy is expected to increase the global demand of SPV products and silicon cells in particular... the envisaged capacities of the products installed are expected to reduce the price of such products by almost 50% in a few years from now."*

Q. Gujarat and Rajasthan are deemed as the two best locations in the country especially for solar power generation. Have the project developers been essentially waiting for the just announced solar power policy to take shape?

Yes, the developers were essentially waiting for the buy back rates announced in our policy.

Q. GEDA was adjudged the best wind power developer in the state during 2007/08. Has something similar materialized in the area of solar energy technology sector as well so far?

None can deny that Gujarat has been a model state in implementing the renewable energy alternatives. Power generation projects / programmes in the state from wind, SPV (solar photovoltaic), and biomass have successfully demonstrated that renewable technologies are here to deliver grid-quality power. The Gujarat government has chalked out a very sustainable pathway when it comes to utilization of renewable energy resources and techniques.

Q. What according to you should count in the scheme of things, when it comes to making the renewable energy products and systems truly affordable, more so solar based?

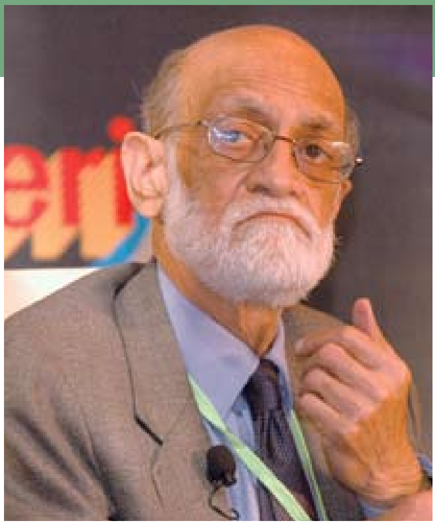
The new solar policy is expected to increase the global demand of SPV products and silicon cells in particular. Consequently, the envisaged capacities of the products installed are expected to reduce the price of such products by almost 50% in a few years from now.

Q. How relevant do you find the need for capacity building and training both within your organization and particularly at the end user level?

Capacity building, training, and sensitization are imperative at all levels because what we are developing is an area where the technological development and state-of-the-art are either in the third or fourth stage of implementation. Commercialization prospects of almost the full range of renewable energy technologies in the Indian scenario have to be estimated.

Q. Finally, could you kindly share your renewable energy specific vision for India as a whole and Gujarat in particular? Where will things stand in 2014?

Gujarat is a pioneering state for renewable energy promotion and will continue to remain so. The Gujarat government has a vision that is all encompassing. Looking to the fossil fuel scenario and the burgeoning challenge of climate change, the country has no other option but to move faster in the direction of green energy. By announcing its new solar and wind energy policies and separate department of Climate Change, Gujarat has already set the tone in keeping with its much cherished vision of sustainable development.



Awareness is the answer

Renewable energy is definitely the in thing and will power the energy needs of the future. India is a country with abundant sunshine and a potential to utilize the sun's energy—more so in states like Jammu and Kashmir. However, what is needed is exploiting them in the right manner and putting the best foot forward in fuelling the shift to solar energy in every sector. *Mr Ashok Jaitly, Distinguished Fellow, TERI and former Chief Secretary, Jammu and Kashmir* talks about this and much more in an interview with *Ambika Shankar*.

Q. You have served with great distinction in the volatile state of Jammu and Kashmir. Could you kindly enlighten us about your main achievements in putting the state on the map of Indian renewable energy movement?

A. Yes, I did have a long association with the state including serving there as chief secretary for five years. But quite honestly, I don't think we can take too much credit for having done enough on the renewable energy front. Our focus was mainly on hydro energy, which is of course renewable, but we were looking at the larger hydel projects. During my tenure we had at least three of those hydel projects, which were commissioned. But that is still not enough because the potential in the state is about 15 000 MW. What needs to be done is persuade the state government to allow the private sector to come into the micro hydel sector.

Q. Jammu and Kashmir is endowed with immense hydropower resources. Do you feel that other renewable energy sources like for example solar energy have some important role to play there?

Definitely, solar energy has potential in the state particularly in the Ladakh region, which has sunshine almost round the year including in winters. It has very little precipitation and is a cold desert, as you would know. There is no reason why we can't have much more of solar energy being tapped in Jammu and Kashmir as a whole. The state is mountainous and has scattered villages. Therefore, decentralized generation is really the answer for a large part of the state, especially for the poor people. I think there is tremendous scope for solar energy as well as some wind. However, wind energy can't be exploited to that great an extent. And micro hydel is of course all over the state.

Q. Which renewable energy source in particular is closer to your heart and for what special reasons?

I think all of them. I don't think I have anything particularly close to my heart. However, because of my association with the state, I would say solar for Ladakh. When you go there, you feel why is this not being developed? It is so obvious that the state has a huge potential. And of course I have a great passion for micro hydel, also because of its viability. Solar still has a high capital cost. Micro hydel also perhaps generates a little more employment. But having said this, I do not have any favourite as such. I think exploitation of all renewable energy sources especially what is the most viable in a given location must happen. Renewable energy is the answer for the future.

Q The Ladakh region stands out for having the maximum possible solar insolation in the country. Has this unique feature been put to some large-scale use of solar energy in Ladakh by now?

There are two NGOs who have done very good work in Ladakh. One is SWRC in Tilonia managed by Mr Bunker Roy. This organization has done good work in SPV primarily in household individual systems. Then there is another organization called LEDeG, which is a local NGO in the sense that it is managed by Ladakhis. They have done some good work as well. They have also partnered with organizations like Gadhia Solar Systems. The younger civil servants who have been posted there have also done some good work—both in terms of PV as well as using solar energy for greenhouses. This has developed in a very big way in the Leh Valley. Almost every home has little vegetable gardens that use the greenhouse technology. The other thing is buildings. At least one room in a house would have glass windows for trapping the heat of the sun. This is a good and spontaneous development happening there. It hasn't really been organized by anyone and has developed over the years. There is a great scope for better architecture using solar energy.

Q. SPV products are still deemed to be costly at least from the viewpoint of high initial capital cost. But do you think these can be put to an effective use by developing more and more eco-tourism sites aptly suited to states like Jammu and Kashmir and Himachal Pradesh?

"At least one room in a house would have glass windows for trapping the heat of the sun. This is a good and spontaneous development happening in Leh. It hasn't really been organized by anyone and has developed over the years. There is a great scope for better architecture using solar energy."

Definitely. I think for the tourist sites there is a good potential to use solar energy. For instance, why don't the households in Srinagar use solar energy for heating water, since the potential in the valley is more for heating than for lighting? Though there are clouds, snow, and rain in winter, but I think there is enough sun too. I am not a technical person but I feel there is enough sunshine to at least get warm water if not hot water. And the households are ideally suited for using that energy rather than using traditional conventional energy.

Q. The famous Dal Lake in the beautiful valley of Kashmir has mesmerized one and all so far. However, of late, it has shrunk considerably as well as lost its clean clear water ability to a good extent. Did you make any efforts to have solar-powered motorized boat in this lake as a ready replacement to the diesel-operated boats commonly known as motor launches in the local parlance?

The Dal Lake is definitely threatened. It's one of the heritage lakes identified by the UNESCO. The size is shrinking and it's polluted. A great deal of effort has gone into trying to clean up the lake though without much success. This is because it also perhaps needs a much more imaginative effort. No, I don't think there has been any effort to switch to solar-powered boats. But that's not really the problem of the lake. It's more related to the catchment and sewage of the city rather than diesel boats. I think there are only about four or five diesel boats that ply on the lake. That's not really the problem area, though of course the existing ones should be converted.

Q. You have been associated with a large number of development-sector organizations, including TERI currently. Do you feel such organizations have contributed effectively to enhance the capacity-building skills in the state nodal agencies for renewable energy like for example JAKEDA?

I don't think there has been too much of capacity building. What I think is needed in states like Jammu and Kashmir and in Himachal Pradesh is awareness—a lot more capacity building. JAKEDA is just a nodal institution. Lots of other institutions including the mainstream engineering institutions, the power department, and the electricity department itself need to get sensitized and become more aware of the potential of these sources. I don't think we should be living in compartments as we do. Even in the Government of India, we have a Ministry of New and Renewable Energy and a Ministry of Power. I don't think they should be separate. There has to be a handholding among these people. You can't have the mainstream engineers in one direction and the others propagating non-conventional energy or solar energy. There is a need for awareness generation, sensitization, and capacity building of a lot many other institutions including educational institutions. Renewable energy has to become part of our lives and not just something that is 'different'. It has to be mainstreamed.

Q. Do you envision a future form of living that relies to a sizeable extent on the actual utilization of various renewable energy products and systems and at what level of intervention likely?

I can't say that I envision a future. What I do believe in is that the future has got to have much more of renewable energy. I don't see this massive change happening in the near future because it's still expensive. Though what we are doing, for example in TERI, with solar lanterns and solar torches is a very important step especially for rural and remote areas. Things like these need to be propagated on a large scale. But otherwise I think solar appliances, for instance solar heaters, have tremendous potential that must be exploited on a larger scale. In the future, there should be and will be a switchover provided of course the pricing is right. If we stop subsidizing the conventional sources of energy as we are doing currently, the whole balance will shift—as we say, we will have a level playing field.

Q. Public activism in the form of sounding an alert on climate change concerns and advocating the use of renewable energy technologies is making its presence in India too. Could you please tell us about a few most important plans of action that could have a multiplying effect to achieve the desired objectives?

I think it's just a question of roping in the education sector in a big way. TERI has actually taken a lead in it. Then there are the NGOs. Earlier there was a great movement among the NGOs for things like watershed development. There hasn't been that kind of a movement for solar energy or renewable energy per se. That's one area, which should be able to generate a lot of activity and public interest. If the government gets into the act and is able to mobilize and incentivize the NGOs into this field in a much bigger way, it would stir much more interest. I think the media is already doing a good job. There is a lot of awareness in the media and people to write about it; we see programmes on the television also. But a lot more can be done.

> *"There hasn't been that kind of a movement for solar energy or renewable energy per se. That's one area, which should be able to generate a lot of activity and public interest. If the government gets into the act and is able to mobilize and incentivize the NGOs into this field in a much bigger way, it would stir much more interest."*

There is also this factor that renewable energy systems are large and require a lot of space for installation. However, there are two aspects to this. One is that technology has to make them smaller. When there is nanotechnology, there is no reason why this can't be achieved. The second aspect is that if it uses a lot of space, it needs to be made more community oriented. For instance, such a thing is being done in Delhi but for diesel generation unfortunately! Colonies are putting up their captive diesel generating electricity units and people are paying high rates for the energy generated. Why can't we have similar community based solar or gasifier units? These will then be cheaper at least in terms of per unit cost. In the long run, these will be much more viable in every way.

Q. What message would you like to send across to the readers of *The Solar Quarterly*?

I think it's a wonderful magazine and will do a great job in spreading the message that we really want to—using renewable energy as the future energy source.

Annual Review and Analysis of PV Cell and Module Production in India, 2009

The Solar Quarterly, the flagship magazine of TERI on solar energy, is undertaking the Annual Review and Analysis of PV Cell and Module Production in India, 2009. The survey intends to capture latest production data and expansion plans of the PV cell and module manufacturers in India. For this purpose, we rolled out a survey questionnaire to all PV Cell and Module manufacturers enlisted with us in the January 2009 issue of this magazine. We anticipate receiving your valued response by May 2009 and the findings would be published in the July 2009 issue of the magazine.

SUN KNOCKING FASTER AT THE RURAL FRONT

GURJIT BHARARA, Reliance India Ltd, Gurgaon <gurjit.bharara@ril.com>

Solar technology comes forward as a proven alternative that allows an electricity infrastructure network of local-grid clusters with distributed electricity generation or stand-alone solar solutions. Reliance Industries formed a Solar Group in 2007 to harness PV (photovoltaic) technology with a key purpose of lighting up the rural lives. It implemented a large electrification programme at the community and village level in Maharashtra in 2007/08. This project was awarded by MEDA (Maharashtra Energy Development Agency) for electrification of remote rural households in the state.

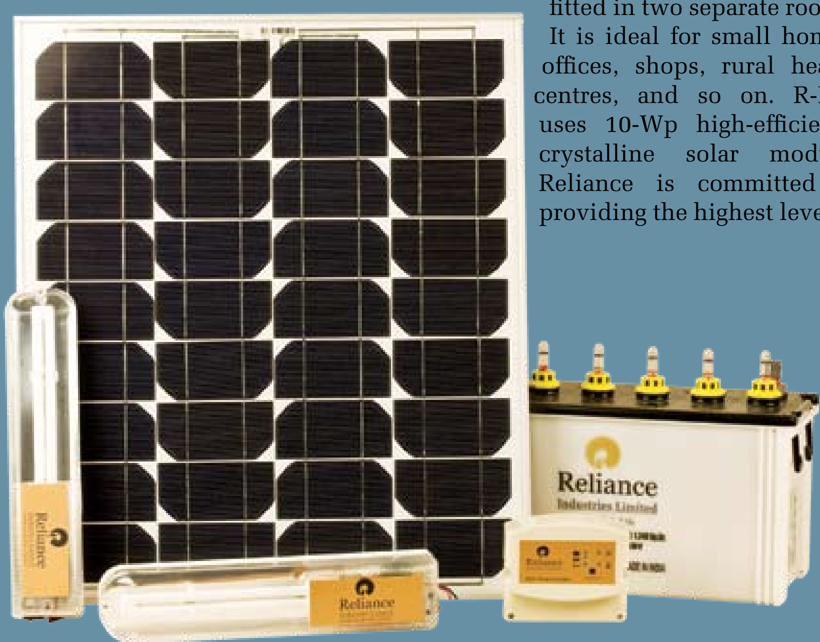
Project outreach

The solar project spanned different districts of Maharashtra namely Nandurbar, Thane, Dhule, Amravati, Nasik, Raigad, Kolhapur, and Chandrapur. It involved providing lighting for over 14 000 households spread over 84 villages in these districts. This has now taken the Reliance initiative further and it has been assigned the contract to light up a total of 15 000 households located in Arunachal Pradesh, Tripura, West Bengal, Maharashtra, and Chhattisgarh. On the technology front, the company has developed LED-based lamps under the trade names of Arushi and R-Lite in this year itself. These two products offer the following few advantages to the rural communities.

- Reduced cost as compared to the CFL based lamps.
- Efficient and reliable operation
- Bright lighting solution.

R-Lite: lighting up a bigger purpose

R-Lite–Home Power System has similar features and comes with two luminaries, which can be fitted in two separate rooms. It is ideal for small homes, offices, shops, rural health centres, and so on. R-Lite uses 10-Wp high-efficiency crystalline solar module. Reliance is committed to providing the highest level of quality and its products are warranted for five years (except battery). These products are cheaper than CFL products.



The expanding network

The company is also working out arrangements with various banks for cheap financing of its solar products. Efforts are underway to make them available through the existing and newly created networks. The role of NGOs and a few more agencies are currently being explored for product deployment and after sales services too.

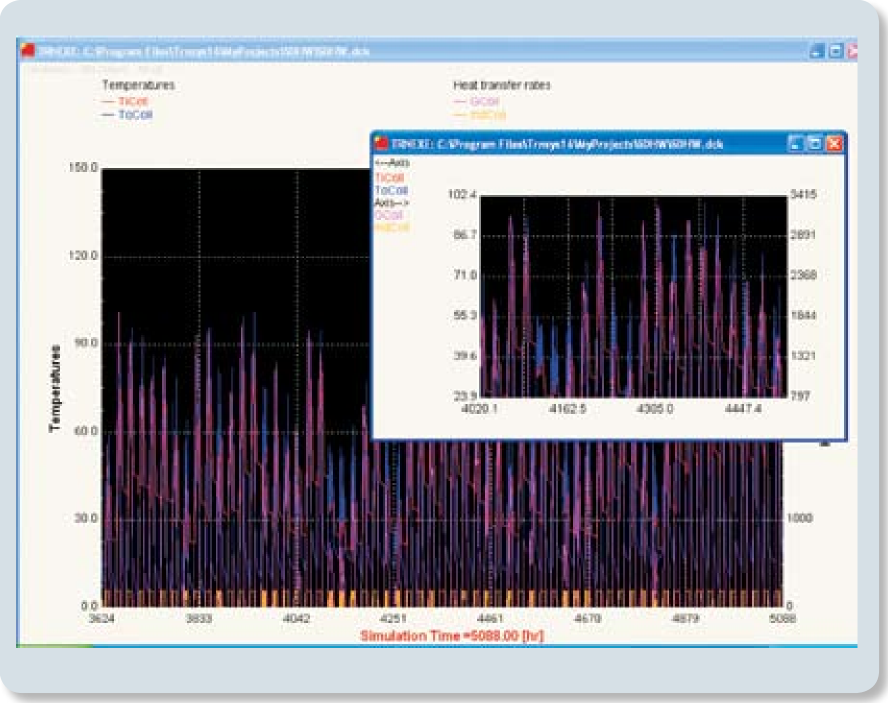
TRNSYS: A 'TRANSIENT SYSTEM SIMULATION PROGRAM' FOR THERMAL ENERGY SYSTEMS

Dr Ishan Purohit, Research Associate, TERI <ishanp@teri.res.in>

Introduction

TRNSYS (TRaNsient SYstem Simulation Program) is a simulation program primarily used in the areas of renewable energy engineering and building simulation for passive as well as active solar designs. It is an extremely flexible software tool used to simulate the performance of transient systems. It is a commercial software package (since 1975) developed at the University of WisconsinMedison, USA by internationally recognized scientists/path finders of solar energy engineering namely, J A Duffie, S A Klein, and W A Beckman.

One of its original applications is to perform dynamic simulation of the behaviour of a solar thermal or PV system for a typical meteorological year. This is basically done to ascertain the long-term cost savings of such systems. TRNSYS is written in the FORTRAN programming language. It recognizes a system description language in which the user specifies the components that constitute the system and the manner in which they are connected. TRNSYS can be conveniently used to model other dynamic systems such as traffic flow, or even the biological processes.



Key applications

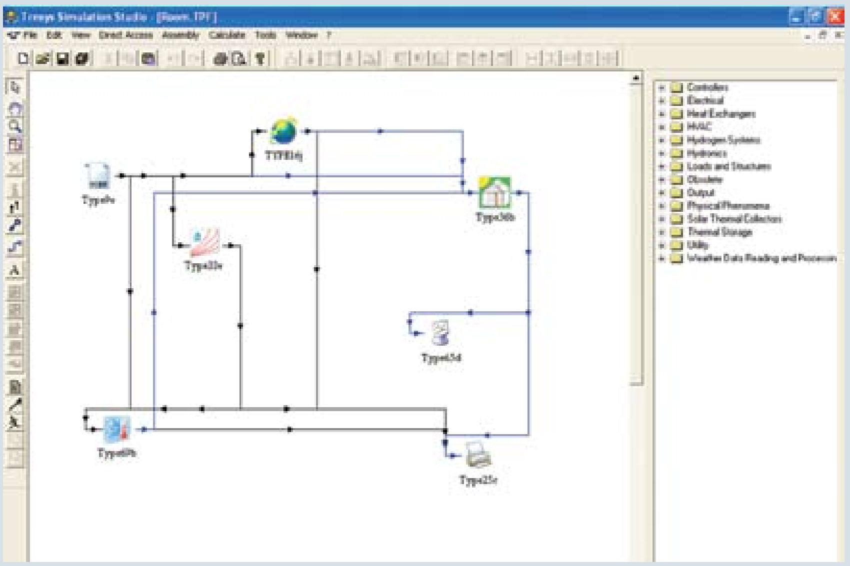
This simulation package has been in use for more than 30 years now mainly for the following applications.

- HVAC analysis and sizing
- Multi-zone airflow analyses
- Electric power simulation
- Solar design
- Building thermal performance
- Analysis of control schemes, and so on
- Concentrating solar power generation, and so on

Operational characteristics

TRNSYS is a transient system simulation program with a modular structure which gives the program tremendous flexibility. It also enables an addition to the program of mathematical models not included as such in the standard TRNSYS library. The software is well suited to undertake a detailed analysis of systems whose behaviour is dependent on the passage of time. It relies on a modular approach to solve large systems (or sets) of equations described by FORTRAN subroutines and each FORTRAN subroutine contains a model for a system component. For example, TYPE16 is radiation processor. The transient weather data file is provided as input and TYPE16 may calculate solar radiation on flat, inclined, vertical, and tracking surfaces. Unlike many other simulation softwares, TRNSYS allows users to completely describe and monitor all interactions between system components like for example, the user determines the connections amongst various system components. The modularity structure especially has enabled the TRNSYS users to write their own components. Such a feature allows the user to have pumps, chillers, cooling coils, and so on in any desired size and configuration.

TRNSYS is essentially a research tool, which has gained popularity in the recent years. Today, it is one of the major tools for simulating solar energy systems and thermal energy systems. It has thus become a reference software for researchers and engineers around the world.



TRNSYS library functions

The TRNSYS library includes many of the components commonly found in thermal energy systems, as well as sophisticated building models, component routines to handle input of weather data or other time-dependent forcing functions and output of simulation results. It includes graphical interface, simulation engine, and a library of components that range from various building models to standard HVAC equipment to renewable energy and emerging technologies. TRNSYS also includes a method for creating new components that do not exist in the standard package.

In totality, this immensely useful software package is being widely used for simulation and designing of solar energy systems, thermal behaviour (discomfort and energy required for heating/cooling) of buildings, solar thermal power generation, fuel cells, and so on.

TRNSYS is a well respected energy simulation tool under continual development by a joint team made up of the SEL (Solar Energy Laboratory) at the University of Wisconsin-Madison, the CSTB in Sophia Antipolis, France, Transsolar Energietechnik GmBH in Stuttgart, Germany and TESS (Thermal Energy Systems Specialists) in Madison, Wisconsin. TRNSYS currently boasts a graphical interface, a library of 80 standard components, add on libraries offering over 300 other components, a world wide user base and distributors in France, Germany, Spain, Sweden, Luxembourg, the US and Japan.

TRNSYS 16: an integrated package

After four years of development work, both the TRNSYS kernel and its graphical user interface have undergone significant evolutions.

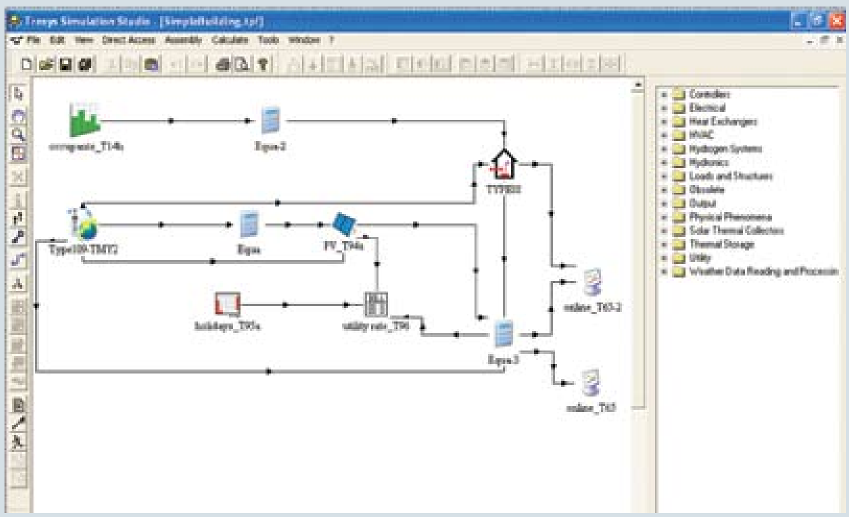
While the TRNSYS kernel has been restructured to allow for even easier integration of new components, communication with other programs and even higher performance, the graphical user interface has evolved towards an integrated development and simulation environment : the TRNSYS Simulation Studio.

The TRNSYS Simulation Studio is the next generation of the well-known IISiBat program, and the other programs in the TRNSYS Suite have also been renamed to reflect the higher level of integration:

- TRNBuild (formerly known as Prebid) is the visual interface of the multi-zone building model (Type 56)
- TRNEdit is the successor of TRNSHELL. TRNEdit is used to develop stand-alone distributable TRNSYS applications.

TRYNSYS availability in India

SESI (Solar Energy Society of India) has a long standing contract with the Solar Energy Laboratory, University of Wisconsin, USA to market this software package (Version 16) in the Indian market. In the process, SESI has become its Indian distributor and more than 10 such packages have been sold so far. Amongst the main buyers have been the engineering organisations (like colleges).



Expert Speak

Answers to questions on solar energy

Dr V V N Kishore
Professor
TERI University

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

Q1. How do PV systems work?

Akshay Sinha, Ranchi

Ans. 1 PV panels operate on the principle of the photoelectric effect. Electromagnetic radiation (solar radiation is part of the electromagnetic spectrum) can be thought of as a bunch of particles called photons, with different energy levels. Semiconductors have a characteristic energy band gap, measured in eV (electron-volts). When the photons have energy levels higher than the band gap, free electrons are released, which then contribute to the electric current. The more the intensity of radiation, the more the number of photons, and hence more the photoelectric current. Concentration of radiation by focusing increases the intensity; hence, more current can be generated by the same panel.

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

Mahendra Sharma, Bhopal

Ans. 2 To estimate the potential of solar power generation systems, one should clearly understand the following.

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

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

radiation falling on a surface. Hence, solar thermal power plants should be installed in relatively clear-sky locations, typically obtained in desert climates.

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

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

Q3. What is the methodology used to assess solar PV potential in India?

Sahana Vaidyalingam, Chennai

Ans.3 The amount of power produced by a solar PV panel is normally rated as Wp (watt peak), meaning that so many watts are produced under a specified set of conditions such as radiation intensity of 1000 W/m^2 at a cell temperature of 25 °C, and so on. The actual power produced will vary depending on the time and location. An important parameter for potential estimate is the annual energy generated, expressed in the units of kWh/(year) (kWp). The average value for Indian conditions is about 1360, but the exact value has to be obtained for a given location either by field experiments or by simulation methods. Once this number is known, the annual generation can be obtained by the kWp rating of the PV panels installed or proposed to be installed. The area required per kWp depends on the manufacturer, and is generally provided in the panel specifications.

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

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

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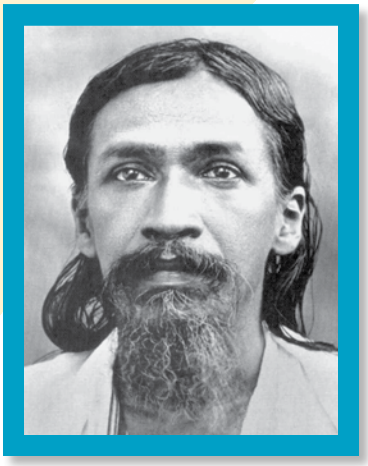
The Solar Quarterly
TERI, Darbari Seth Block, IHC Complex, Lodhi Road
New Delhi – 110 003
E-mail ambika@teri.res.in/smarcus@teri.res.in

Pioneering the Solar Energy Research

Jadavpur University

DR BISWAJIT GHOSH, Professor of Energy Science and Technology and Director, School of Energy Studies, Jadavpur University, Kolkata <bghosh3@gmail.com>

With the acceleration in industrial activities, there are tremendous advances in science and technology that are exacerbating the world's energy dependence. Over the past five decades, as the demand for energy has escalated and the consumption of fossil fuels has increased many folds, people have sought renewable sources as an alternative way to meet growing energy requirements. One promising and virtually inexhaustible source of energy is the sun. One of the many universities conducting research and helping utilize the power the sun is the Jadavpur University. Jadavpur University has its origin in the nationalist movement in Bengal against the British Raj, which led to the establishment of the National Council of Education, Bengal. With the funds coming from the landed



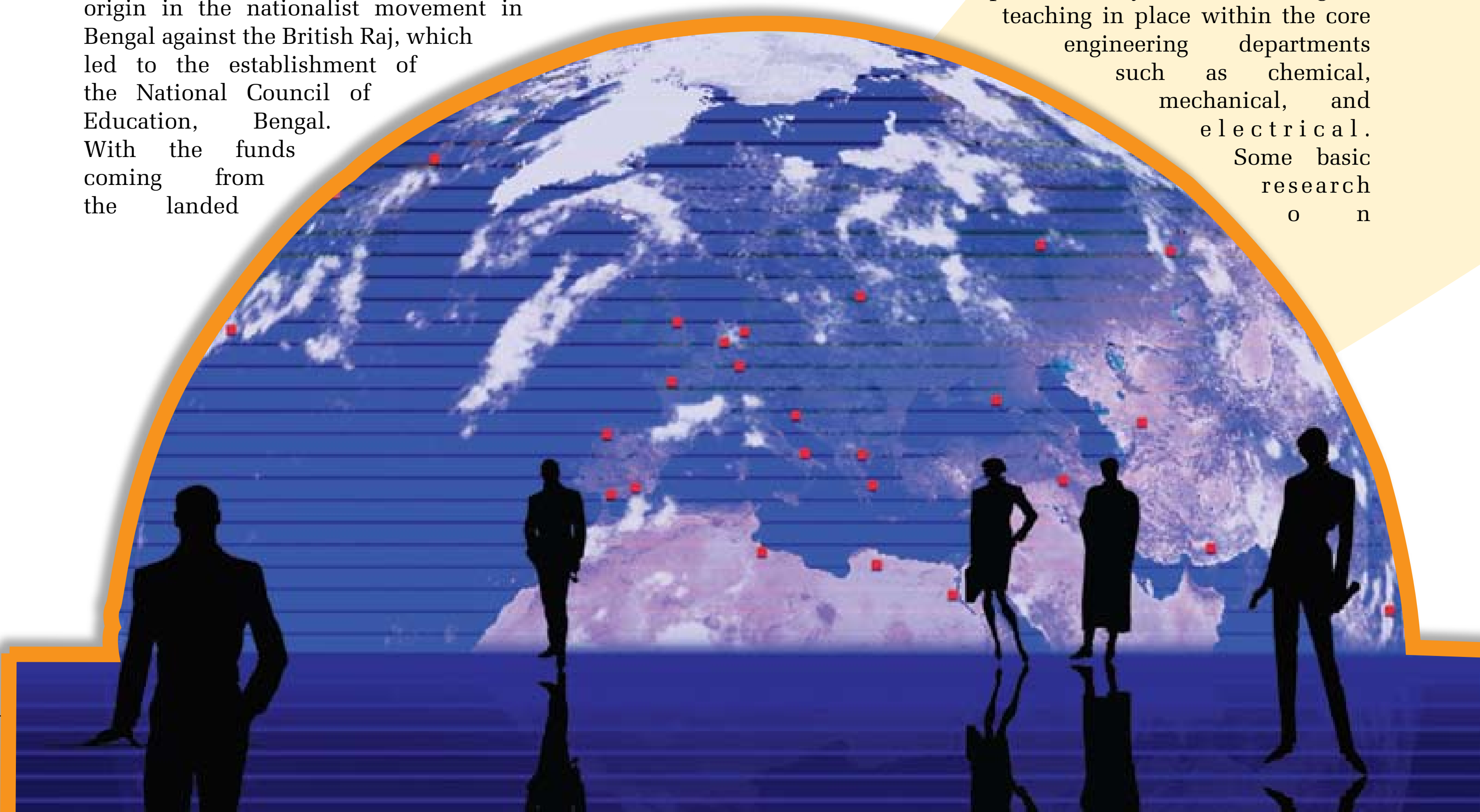
Sri Aurobindo Ghosh

gentry, the College of Engineering and Technology, Bengal was started in 1906 for the students who refused to attend the government-run institutions.

Sri Aurobindo Ghosh, later Rishi (Saint) Aurobindo, was the first principal of the college. Engineering and technology was given due importance for rightly carrying out the task of reconstruction of the country for attaining independence. 'The students serve their motherland,' Sri Aurobindo said and in 1956 the college was rechristened the Jadavpur University.

The good beginning

Jadavpur University (Kolkata) had regular teaching in place within the core engineering departments such as chemical, mechanical, and electrical. Some basic research on



energy technology was initiated in these departments. However, a new department of Electronics and Telecommunication was set up in 1963. The credit for this goes to Professor S Deb who initiated research on solar energy conversion devices in this newly created department at the university. In fact, he started the pioneering research work on CdS–Cu_2S (cadmium selenide–copper selenide) solar cells in the country. Initially, research work on ceramic-type CdS–Cu_2S was initiated. A few years later, that is, in 1966, Professor Deb and his colleague Professor M K Mukherjee published a paper on PV (photovoltaic) conversion entitled Response of a partially illuminated p–n junction cell, in the *International Journal of Electronics*.

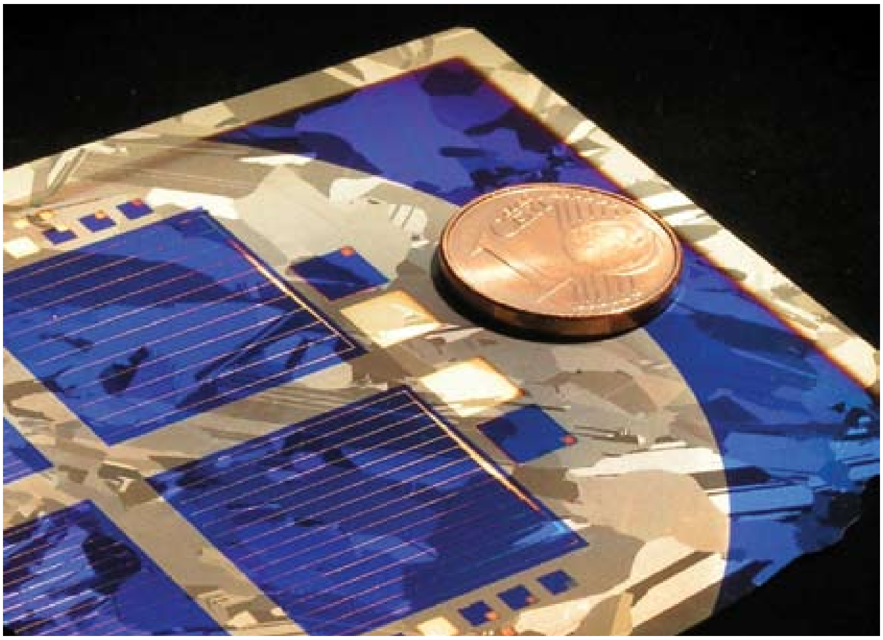
This was followed by one more visionary publication on Solar battery and agro-economy of developing nations in the Journal of Science and Research. In this paper, the authors discussed the integration of solar pump with agro-irrigation and strong sunshine demand for more water for vegetation. This was with relation to energization of solar pump to draw more water for meeting the desired demand. Such pioneering studies visualized the need for solar energy research in the developing countries.

The expanding frontiers

The worldwide oil crisis in 1973 stimulated some more research on solar energy at the international level and Jadavpur University was no exception. The group for solar energy research was expanded and an initiative was taken to establish the SESI (Solar Energy Society of India) as an Indian section of the ISES (International Solar Energy Society). Local- and regional-level seminars on solar energy utilization were organized across the country by some eminent personalities in this area. In 1976, the sum total of the research effort at the national level was presented at the first National Solar Energy Convention (NSEC-76) organized by the university under the leadership of Professor Deb. Soon after, a proposal for setting up a full-fledged academic unit called School of Energy Studies was submitted to the UGC (University Grants Commission).

Meanwhile, few more research activities were underway in the university. In 1975, Professor Mukherjee moved to the Institute of Physical Electronics, University of Stuttgart, Germany for carrying out research on thin film CdS–Cu_2S solar cells under the support of Alexander von Humboldt-Stiftung. In the same year, UGC instituted a major research project on 'Fabrication of Opto-Electronic Devices' under the supervision of Professor Deb. The main objective of the project was to develop thin-film CdS–Cu_2S solar cells. Mr Darbari Seth , the then chairman of Tata Chemicals, another pioneer in the promotion of solar energy research in the country, promoted TERI (Tata Energy Research Institute), presently The Energy and Resources Institute. In 1979, TERI funded a project related to 'Fabrication of CdS solar cells' at the Jadavpur University. It led to further interest on PV research and helped achieve 8%–10% efficient thin-film CdS–Cu_2S solar cells.

Innovative techniques like new top grid contact and magnetic field assisted bonding technique were introduced in this novel cell structure. Taking this as a very positive development, TERI funded the second phase of the project for the



fabrication of large area CdS–Cu_2S solar cells. Following this, solar cells with an efficiency of 6%–8% on large area (10 × 10 cm^2) were fabricated and the project was continued right up to 1984. However, a major lacuna was noticed in terms of poor stability in such CdS–Cu_2S cells. This turned off any further research efforts on this device structure. It was found out that thickness and structure of Cu_2S layer is an important factor in controlling the stability of cell performance. Thus, research was switched over from CdS–Cu_2S to CdS–CdTe (cadmium telluride).

The new dimensions

In 1982, the Academic Board of Jadavpur University decided to create the School of Energy Studies for carrying out advanced studies and research in the field of Energy Science and Technology. A four-semester masters degree programme, M Tech in Energy Science and Technology was introduced. Research work in solar energy was initiated in the following four distinct directions.

- Fundamental
- Strategic
- Applied
- Adoptive

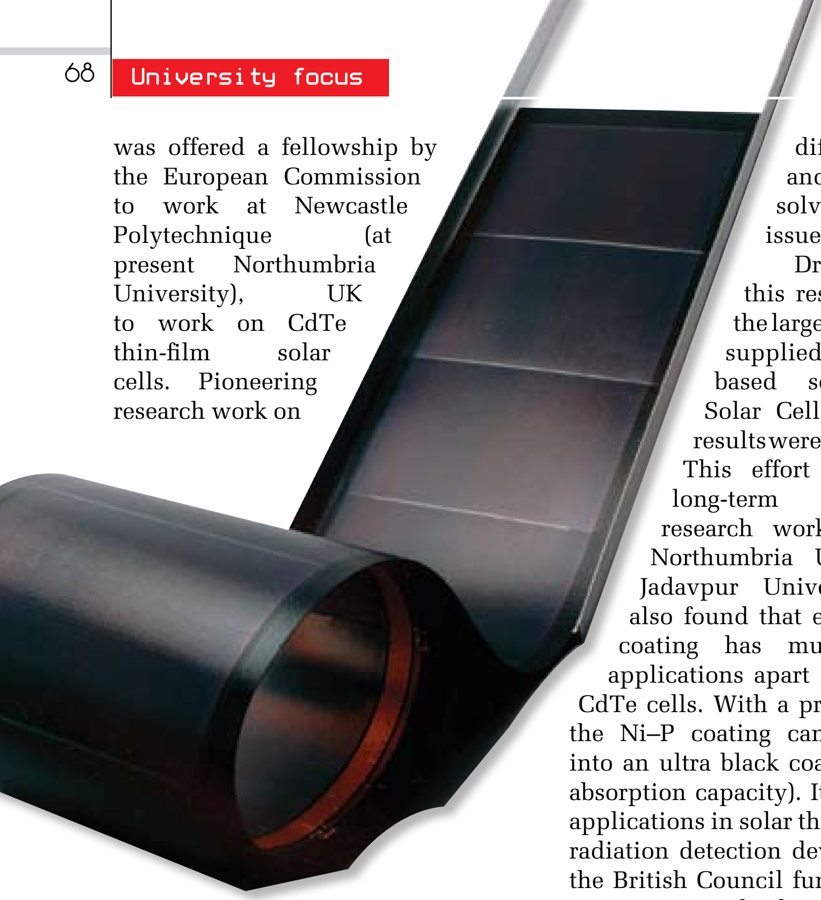
Roof-top solar power generation

The school started its full-fledged activities towards the end of 1984 with funding from Ministry of Human Resource Development, Government of India. In 1987, Dr B Ghosh, another member of the group, was invited by the Stuttgart University to carry out post-doctoral research on the quantum efficiency of thin-film solar cells. On his rejoining, the group was equipped with an enriched technical expertise in developing various measurement techniques for solar cells. During 1987–91, research work was concentrated on the development of thin-film CdS–CdTe solar cells. Special emphasis was given to developing electronic grade CdTe film using co-evaporation of elemental Cd and Te. Novel technologies like collinear and co-evaporation of elemental Cd and Te to form electronic grade CdTe was developed. The following few solar cell related developments deserve a special mention here.

- Small area (1 cm^2) 6%–8% CdTe–CdS thin-film cells were developed successfully on the glass substrates.
- Large area (10 × 10 cm^2) CdTe–CdS solar cells with efficiencies of about 4%–5% were fabricated using this technique.

The foreign collaboration

Further enhancement in efficiencies was not attained due to the electrical contacting problem in CdTe. In 1992, Dr Ghosh, the key person of the group



was offered a fellowship by the European Commission to work at Newcastle Polytechnique (at present Northumbria University), UK to work on CdTe thin-film solar cells. Pioneering research work on contacting technology to CdTe was carried out by Dr Ghosh at the Northumbria University, Newcastle. Electrical contact to CdTe was developed through deposition of Ni–P (nickel–phosphorous) using an electroless technique. Ni–P coating deposited using electroless technique has many dimensions of applications. It was observed that P from Ni–P diffuses in CdTe and was able to solve contacting issue to CdTe.

Dr Ghosh applied this research work on the large-area CdTe cells supplied by the USA-based solar company Solar Cells Inc. and the results were very successful. This effort resulted in a long-term collaborative research work between the Northumbria University and Jadavpur University. It was also found that electroless Ni–P coating has multi-dimensional applications apart for electrode of CdTe cells. With a proper treatment, the Ni–P coating can be converted into an ultra black coating (very high absorption capacity). It has promising applications in solar thermal as well as radiation detection devices. In 1997, the British Council funded a research project to Dr Ghosh on the industrial applications of electroless technique and technology for developing UBC (ultra black coating). UBC was successfully developed during 1997/98. In 1998, Dr Ghosh was again invited by the Imperial College London to work there as the Academic Visitor on the development of contacting technology to TPV (thermo-photovoltaic) cells and concentrated solar cells. Electroless of Ni–P showed its potential applications as the electrode for TPV cells and diffusion barrier for the concentrated cells.

These tasks enabled research collaboration with Imperial College. In 2006, the Royal Society offered a visiting fellowship to Dr Ghosh to work on the contacting technology to CdTe-based high energy imaging devices at the University of Surrey, Guildford, UK. Accordingly, the expertise developed at Jadavpur University made possible electrical contacting technology from solar cell to high-energy imaging devices.

In 2007, a four-year exchange programme between UK and India under the UKIERI (UK–India Education and Research Initiative) programme of British Council was launched at Jadavpur University. This was specifically for developing human capital on 'UK–India Network for II-VI Sensor Technology.

Conclusions

Research work on thin-film solar cells and expertise in contacting technology of Jadavpur University has received good recognition at the international level so far. A large number of research papers have appeared in various reputed international journals and conference proceedings alongside filing of a good number of patents.

The Sun is 'indeed' Bright

PROF. ASHOK PARTHASARATHI*

SPV (solar photovoltaics) offer tremendous growth potential to a country like ours. Barack Obama has announced a programme to create five million new jobs by investing $150 billion over the next 10 years, to catalyse private efforts to build a clean energy future. Where does India stand in this field? As in so many areas of national endeavour, it was Nehru who was the pioneer protagonist of solar energy. Indira Gandhi gave a big push in the 1970s and 1980s, and Narasimha Rao in the 1990s. R&D (research and development) and prototype development on solar electricity generating systems (called solar photovoltaics, or SPV for short) had started at the NPL (National Physical Laboratory) as far back as 1955, at Nehru's instance. Small SPV lighting systems were developed and field proven, as were solar cookers. However, solar energy did not catch on till around 1975 because cost-effective materials and technologies for terrestrial applications did not then exist anywhere in the world. Till 1973, SPV power sources were only used to power earth satellites. It was the first 'oil shock' of 1973 that brought solar cells to earth! The early R&D and prototype development was undertaken by major international US oil companies — Arco Solar & Exxon Solar – with massive funding by the US government. Thanks to a major initiative by Indira Gandhi, an SPV R&D programme was also nucleated in our public sector company, CEL (Central Electronics Ltd), as early as 1976—just three–four years after Arco Solar. Over the last 30 years, we have undertaken a sustained scientific, technological, industrial, commercial,

*The writer is former Science Adviser to late Prime Minister Indira Gandhi and former Secretary of various scientific departments of the Government of India. This article has been reproduced from *Business Standard.*

and governmental effort to promote and build up SPV applications, industry and R&D. Consequently, we now have a large and diversified SPV industry consisting of 10 fully vertically integrated SPV manufacturers making solar cells, solar panels, and complete SPV systems, and about 50 assemblers of various kinds. Between them these companies make and supply about 200 MW per year of 30 different types of SPV systems in three categories: rural, remote-area, and industrial. We also have at least six centres of R&D in government laboratories and IITs.

CEL was the world's first – in 1985 – to design, develop, engineer, and manufacture SPV power systems for powering a large amount of electronics on the offshore oil well-head platforms of ONGC in Bombay High. Today, some 60 such platforms have been 'solarised' by CEL. The world's second manufacturer of such SPV systems was BP Solar of the UK in the Persian Gulf, but only in 1990. CEL has done likewise for special-tech, ultra lightweight SPV man-pack battery chargers for wireless communication sets for our jawans all over the country, but particularly in Siachen where they have to work continuously on a 'fail-safe basis' at temperatures as low as minus 40 °C and in the Thar desert where they have to do likewise at (plus) 55 °C. Over the years, CEL has supplied about 14 000 such solar chargers to our army and also selectively exported them. There is no other company making such chargers anywhere in the world and they have also been internationally patented.

Photo courtesy: DOE/NREL

CEL has also exported many types of its SPV systems to some dozen other developing countries. It has also exported its proprietary SPV technology and set up manufacturing plants in Syria, Sudan, and Kenya in competition with Western SPV companies and made substantial profits on those projects.

Taken as a whole, we are among the top five countries in SPV energy and number one in many areas. At 2.8 million as of 31 March 2008, the total number of stand-alone SPV systems of the 30 different types our companies have manufactured, installed, commissioned, and operationalized is by far the largest number of SPV systems set up by and installed in any one country—and almost all based on Indian technology. Most of these systems are installed and operating in a developing country's rural or remote areas. This uniquely requires that they be reliable and rugged enough from design to commissioning to operate on a 'fit and forget' basis.

Apart from such stand-alone SPV power sources meant for remote area rural and industrial applications, the MNES/MNRE programme has, over the last decade, involved a large number of public grid and local grid based SPV power plants having capacities ranging from 5 kW to 200 kW, for a diverse range of users—from the two buildings of the M S Swaminathan Research Foundation at Chennai where there is no conventional grid supply at all, to the main building of the R&D Engineers of DRDO at Pune, to the Maharshi Centre in Nagpur.

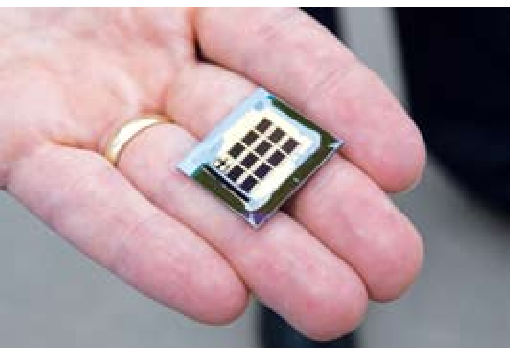
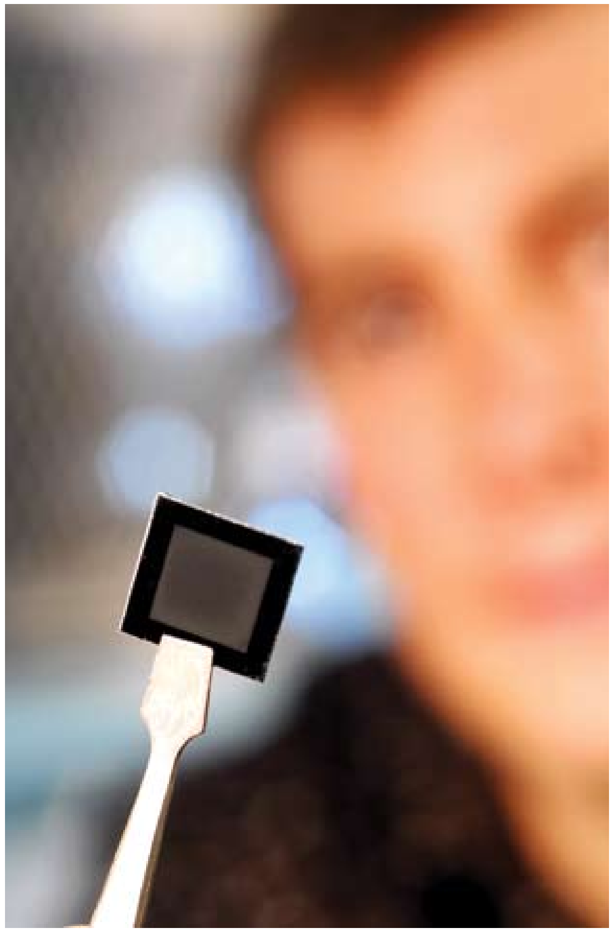
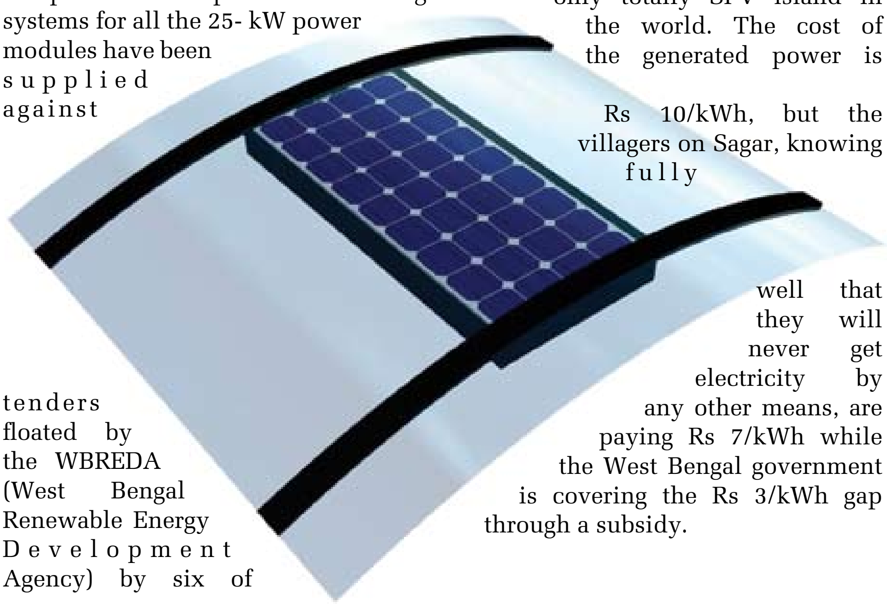


Photo courtesy: DOE/NREL

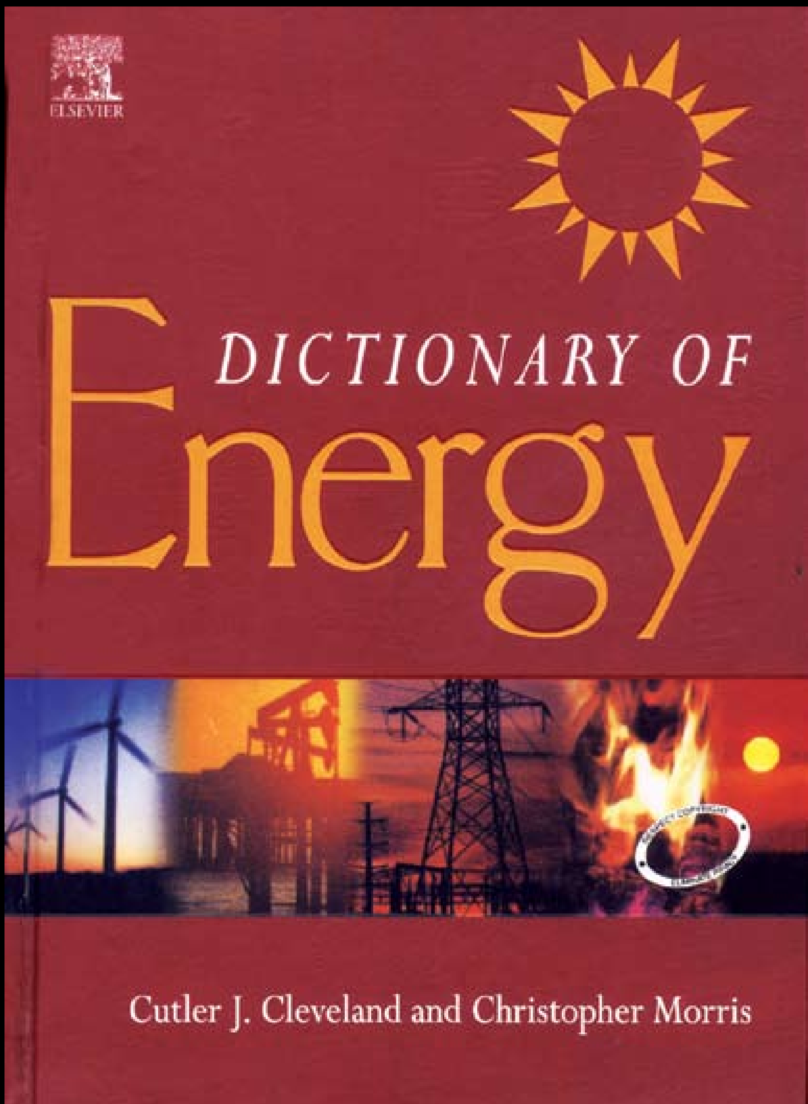
Several pilot projects have also been undertaken by our SPV manufacturers of specially designed, grid-connected 100 kW power plants at the front end of conventional grids for peak shaving and at the tail end for voltage stabilization. They are working well and generating valuable data for the design of future systems. The use of SPV for such applications is in its infancy even in the industrialized countries.



A major success story in the use of SPV power on a local grid is that of Sagar Island in the Sunderbans in West Bengal. The Mission, 'Sagar Island — Solar Island', was inaugurated in December 1996. It consisted of providing high-quality, 50-cycle 220-volt solar-derived electricity for home and street lighting and solar pumps to all the 12 000 homes on the island through a local grid, and powering a large fish freezing plant through a wind–SPV hybrid power plant. With a steady and sustained programme of adding modules from 20 kW to 120 kW, a solar power-generating capacity of 500 KW was operationalized by end-2000; another 500 kW has since been set up. The SPV panels and the complex electronic power conditioning systems for all the 25- kW power modules have been supplied against tenders floated by the WBREDA (West Bengal Renewable Energy Development Agency) by six of our major SPV manufacturers, based entirely on local know-how, while the overall system design and engineering was done by WBREDA. Sagar is the only totally SPV island in the world. The cost of the generated power is Rs 10/kWh, but the villagers on Sagar, knowing fully well that they will never get electricity by any other means, are paying Rs 7/kWh while the West Bengal government is covering the Rs 3/kWh gap through a subsidy.



Dictionary of Energy



Dictionary of Energy

Cleveland C J and Morris C. 2006

Publisher Elsevier, 502 pp.

ISBN 81-312-0536-3

Price Rs 1750

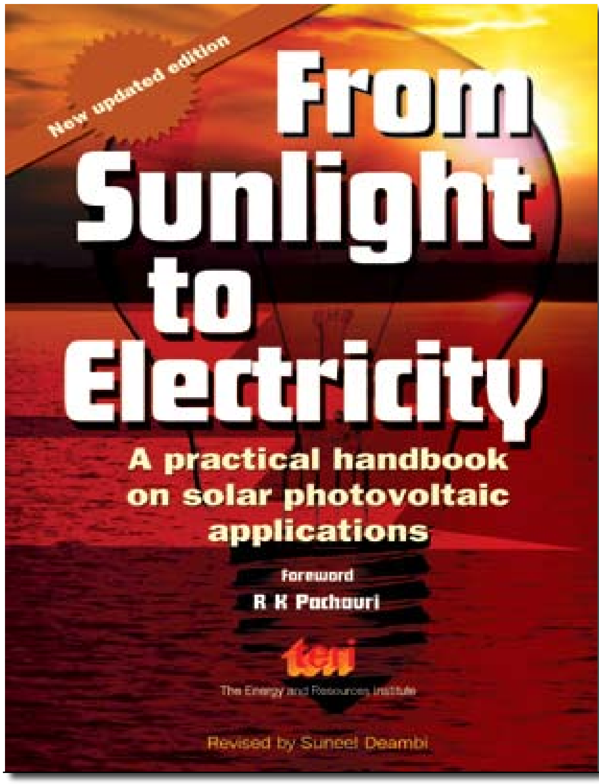
While energy has always been a driving force in the evolution of human culture, its importance has reached new heights in the first decade of the 21st century. Due to its overarching macroeconomic importance, energy is now a precious commodity in global financial markets. Energy issues pervade global geopolitics, and will continue to do so in light of the increasing concentration of oil supplies in the Middle East coupled with rising global energy demand. Energy is central to global environmental change as emissions from energy use contribute significantly to the human component of climate change. Finally, and most importantly, access to modern energy services is a fundamental prerequisite to alleviating poverty from the lives of the three billion people living below subsistence level.

A commonly agreed upon set of terms and definitions is essential to build communication among disparate groups, and to improving the general public's understanding of energy issues. This is especially true as new words are generated, and old ones are discarded, and as technologies, institutions, and behaviours change. An authoritative dictionary is important for an area in which identical words mean very different things. For example, 'efficiency' and 'elasticity' mean different things to an economist and an engineer.

This dictionary covers all the academic disciplines and multifaceted aspects of the concept of energy. The distinguishing features are its integration of the social, natural, and engineering sciences and its breadth of coverage. It uses an integrated approach that emphasizes not only the importance of the concept in individual disciplines, such as physics and sociology, but also how energy is used to bridge seemingly disparate fields, such as ecology and economics. The dictionary covers all the environmental, engineering, and physical science topics found in existing dictionaries. It also covers entirely new areas such as the economic and social aspects of energy use, energy flows in the biological realm, methods of energy modelling and accounting, energy and materials, energy and sustainable development, energy policy, net energy analysis, and energy in world history, among others.

Reviewed by
Ambika Shankar, TERI Press

New Book Information



From Sunlight to Electricity: a practical handbook on solar photovoltaic applications (second edition)

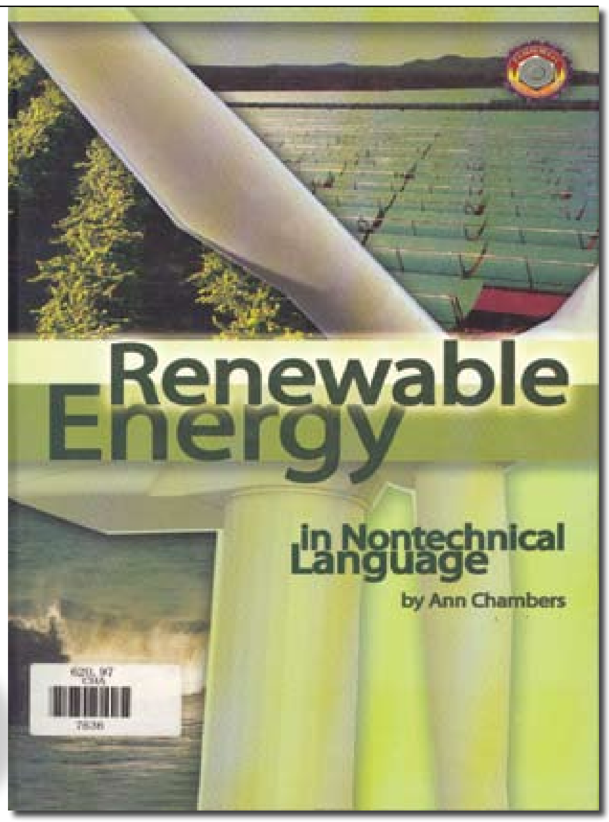
This book is a compilation of information that gives the readers an overall understanding of the PV sector in India, designs, and applications of specific devices and related benefits, finances, and policies. The book also discusses the PV technology programme in India, the issues therein, and its future directions. It serves the interest of all the stakeholders in the PV sector—policy-makers, government officials, non-governmental organizations, and academic and research organizations.

Deambi S (ed.). 2008
New Delhi: TERI Press. 121 pp.
Price: Rs 200
ISBN 978-81-7993-156-1

Renewable energy in non-technical language

In this book, the author draws from her expertise on energy matters to deliver an unparalleled guide to renewable energy resources. Using a non-technical approach, she introduces sources of renewable energy such as wind, solar, biomass, and hydro supported by several pictures, graphs, and charts showing the usage of each energy type state-by-state for the US (United States). The author also covers renewable energy usage around the globe. Next, she details out each energy type, providing case studies, market conditions, usage leaders, and more. A chapter on fuel cells has also been introduced in the book. Besides, a comprehensive coverage of renewable gasoline additives, alternatives, ethanol, and bio-diesel is also provided.

Chambers A. 2004
Tulsa, Oklahama, USA: PennWell Corporation. 244 pp.
Price: $69
ISBN 978-1-59370-005-08



Events calendar

National events

PowerGen India and Central Asia 2009
2–4 April 2009, Pragati Maidan, New Delhi
PennWell
Tel. 44 1992 656 610
Web www.pennwell.com

Renewable Energy India 2009 Expo
10–12 August 2009, New Delhi
Rajneesh Khattar
Exhibitions India Group
217-B, (2nd Floor)
Okhla Industrial Estate
Phase III, New Delhi – 110 020
Tel. +91 11 4279 5000/054
Fax +91 11 4279 5098/99
E-mail rajneeshk@eigroup.in

Third Renewable Energy Finance Forum
20–21 November 2009, Mumbai
Maria Ferreiro
E-mail mferreiro@euromoneyplc.com

International events

Fourth Asia Solar Photovoltaic Exhibition & Forum 2009
30 March-1 April 2009
China New Energy Chamber of Commerce of ACFIC, TC90
CCPIT Pudong Sub-Council
CCOIC
Aiexpo Exhibition Service Co.Ltd
Tel. 0086-21-6592-9965
Email info@aiexpo.com.cn

Gulf Solar Expo 2009
April 2009, Dubai, UAE
Ben Leighton
Tel. 00971 4214 9558
E-mail Ben.Leighton@greenpowerconferences.com; Ben.Leighton@greenpowerconferences.com

Organic Photovoltaics 2009
27-29 April 2009, Philadelphia
Doubletree Hotel Philadelphia
237 Broad Street
Philadelphia, PA 19107-5686
Tel. +1 207 781 9618
E-mail brian.santos@pira-international.com
Web www.philadelphia.doubletree.com

SNEC PV Power Expo 2009
6–8 May 2009, Shanghai, China
Tel. 86 159 21921158
Fax 86 21 511882-00
E-mail cathychu2007@163.com
Web www.snec.org.cn

Solar 2009
8–14 May 2009, Buffalo, New York, USA
Tel. 1 303 443 3130
Fax 1 303 443 3212
E-mail ases@ases.org
Web www.ases.org

Solar 2009
12–16 May 2009, Buffalo, New York
Tel. 1 303 443 3130
Fax 1 303 443 3212
E-mail ases@ases.org
Web www.ases.org

ESTEC 2009
25–26 May 2009, Munich, Germany
European Solar Thermal Industry Federation
Renewable Energy House
Rue d'Arlon 63-67
B-1040 Bruxelles
Belgium
Tel. 3 225 461 937
Fax 3 225 461 939
E-mail info@estif.org
Web www.estif.org

Intersolar 2009
27–29 May 2009, Munich, Germany
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Fax 49 7231 58598-28
E-mail info@intersolar.de
Web www.intersolar.de

Solar Taiwan 2009
10–12 June 2009
Taipei, Taiwan
Tel. 886 2 2351 4026 (Extn 805)
Fax 886 2 2396 8513
E-mail pamela@mail.pida.org.tw
Web www.optotaiwan.com

24th European Photovoltaic Solar Energy Conference & Exhibition (EU PVSEC)
21–25 September 2009, Germany
WIP-Renewable Energies Conference Secretariat
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E-mail pv.conference@wip-munich.de
Web www.photovoltaic-conference.com

Solar Power 2009
27–29 October 2009, Anaheim, California, USA
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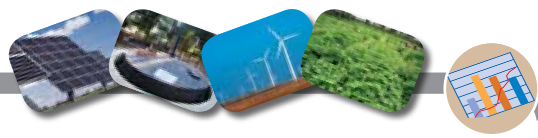
Renewable energy at a glance

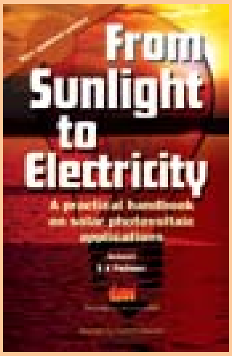


S.No.	Source/system	Estimated potential	Achievement as on 31 January 2009
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	9755.85
2	Bio power (agro residues and plantations)	16 881	683.30
3	Bagasse cogeneration	5 000	1033.73
4	Small hydro power (up to 25 MW)	15 000	2344.67
5	Energy recovery from waste (MW)	2 700	58.91
6	Solar photovoltaic power	—	2.12
	Sub total (A)	**84 776**	**13878.58**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	150.92
8	Biomass gasifier	—	160.31
9	Energy recovery from waste	—	31.07
	Sub total (B)	**—**	**342.30**
	Total (A+B)	**—**	**14220.88**
II	**Remote village electrification**	—	5410 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	40.90 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting system	—	70 474 nos
	ii. Home lighting system	—	434 692 nos
	iii. Solar lantern	—	697 419 nos
	iv. Solar power plants	—	8.01 MW_p
	v. Solar photovoltaic pumps		7148 nos
12	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	2.60 million m^2 collector area
	ii. Solar cookers		6.37 lakh
13	Wind pumps		1347 nos
14	Aero generator/hybrid systems		0.89 MW_{eq}
IV	**Awareness programmes**		
16	Energy parks	—	504 nos
17	Aditya Solar Shops	—	284 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

From Sunlight to Electricity

A Practical Handbook on Solar Photovoltaic Applications (Revised Edition)



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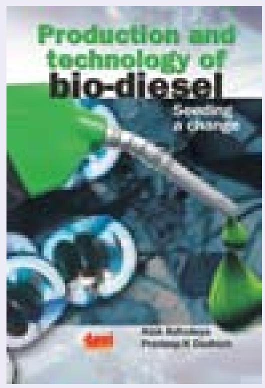

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