The SOLAR QUARTERLY

The Complete Solar Magazine

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combining together for a collective purpose

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Educational and trade publishers: business perspectives on ecological practices

Session III
Sustainable practices in the non-traditional publishing sector: analytical viewpoints on the stationary industry and corporate publishing

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Our readers who keep a track of the annual analysis of the PV sector would be delighted to learn that despite the economic downturn, the sector is ready to post an impressive growth. They would also be noticing that these analyses, mostly done by reputed international groups, include data and information collected directly from the Indian PV industry. We also get to know about our own achievements from these international reports. I often wonder, as a researcher myself, whether there should be a single reliable source of information on manufacturing base, expansion and upgradation plans; production figures and shipments; technology acquisitions and strategic tie-ups; and so on, on the Indian PV industry. Such an information base, built upon year after year would not only provide a valuable repository on the Indian PV sector, but would also be a good reflection of our strengths to the rest of the world.

The Solar Quarterly has embarked upon this exercise in two parallel streams. The first one traces the history of the Indian PV industry since its inception after the oil shock of 1970s and attempts at building the learning curve of the past four decades. We plan to complete this exercise by mid 2009. The second stream initiates an annual survey on the performance and achievements of the Indian PV industry, beginning January 2009. The sample questionnaire is given on page 71 in this issue, which would be administered by our team in the month of January 2009 to all Indian manufacturers of wafers, cells, and modules. Your cooperation is extremely important to get authentic results of the survey. I also encourage you to register with us to participate in the survey so that we don't miss out on any member of the Indian PV industry. This is our first attempt and we strive to make it a success.

Akanksha Chaurey
Director, TERI

Owned, printed, and published by Dr R K Pachauri from The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003, Tel. +91 (11) 2468 2100 or 2468 2111, E-mail teripress@teri.res.in, Fax +91 (11) 2468 2144 or 2468 2145, Web www.teriin.org/pub, and printed by him at Batra Art Press, A-41, Naraina Industrial Area, Phase-II, New Delhi – 110028. © The Energy and Resources Institute. All rights reserved.

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

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

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

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

R K Pachauri
Director-General, TERI

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Solar energy teaming up with natural gas

GHG (greenhouse gas) abatement through all possible means is catching the imagination of every one around the world. Don't be surprised to see a hybrid combination of solar energy and natural gas trying to do just that. This solar facility is believed to be quite an innovative step in this direction. FLP (Florida Light and Power) Company has taken the cudgels to reduce the carbon footprint in Florida. The plain idea is to combine a solar thermal field with a combined-cycle natural gas power plant and thus attain the objective of using less fossil fuel. Here, the heat from the sun will be available to help produce the steam needed to produce electricity.

This Florida-based solar facility will comprise of nearly 180 000 mirrors over roughly 500 acres of land. Thus, each sunrise will be the equivalent of easing our foot off the gas pedal as solar power is being produced. Such power is expected to serve the needs of about 11 000 homes and thus lead to avoided emission of almost 2.75 million tonnes of GHG over a period of 30 years. Solar thermal technology use may ultimately reduce the fossil fuel consumption by about 41 billion cubic feet of natural gas in addition to more than 60 000 barrels of oil.

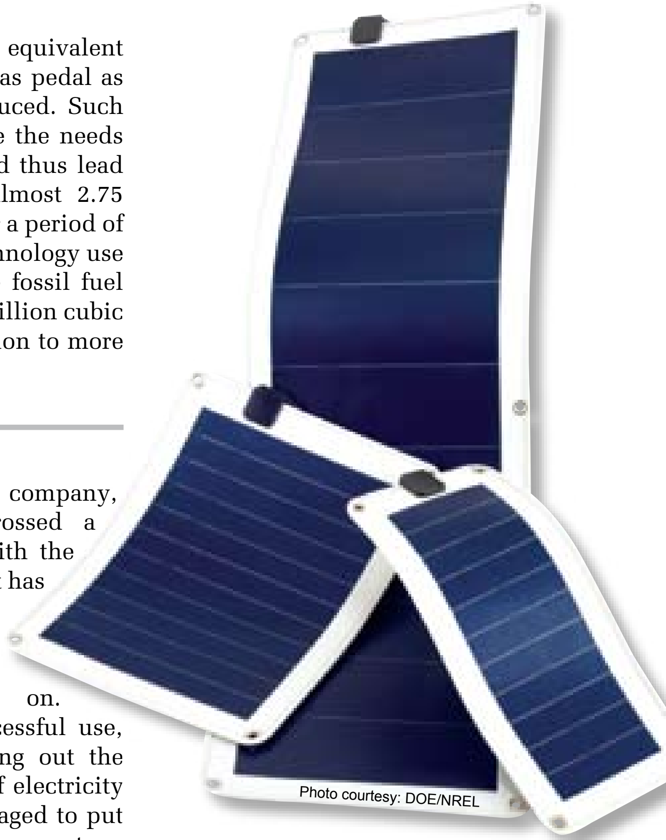


Photo courtesy: DOE/NREL

The fruitful sun

A California-based company, Mariani Packing, has crossed a century old association with the sun for a fruitful purpose. It has been using solar energy since then to nurture apricots, blueberries, apples, plums, and so on. Amazed with such a successful use, the company is now trying out the sun for a bigger purpose of electricity generation. It has just managed to put in place a 1.1-MW solar power system. You may like to ask as to what is so unique about this solar facility? Well, the partnership efforts of groSolar and SunEdison constructed and financed the system at no cost to Mariani. As a part of a long-term solar power services agreement, SunEdison will take care of the system and sell the electricity thus produced by it to Mariani at costs less than retail rates for the traditional energy sources. The company officials brand it as a unique example of how being environmentally sensitive can also accrue financial savings.

The solar facility spread on seven acres is comprised of more than 5800 PV panels. It is expected to produce about 1.9 million units of useful electricity per annum. The system will produce enough electricity to power 3230 homes over a period of 20 years. The carbon emissions will be less than 30 million pounds—a significant number indeed.

Photo courtesy: DOE/NREL

Venturing out in the sun

As per the available estimates, the VC (Venture Capital) investment has moved up from a modest trickle to a roaring inflow during the last four years or so. To give you an idea, VCs made a total investment of almost \$200 million in solar startups in 2005. However, between 2005 and 2008, this is expected to surge beyond \$4.5 billion. In the process, 150 new startups may well begin their onward solar journey.

New ways of extracting greater cell efficiency

A team of physicists and engineers at MIT are using computer modelling and a host of advanced chip-manufacturing techniques to obtain more efficiency from the cells. They have applied an AR (anti-reflection) coating to the front and a novel combination of multi-layered reflective coatings in addition to a tightly spaced array of lines also known as a diffraction grating to the backs of ultra-thin silicon films to enhance the cell output by as much as 50%.

In practice, the carefully designed layers deposited on the back of the cell cause the light to bounce around longer inside the thin silicon layer. Thus, it prolongs the time to deposit its energy and produce an electric current. If these coatings are not present, the light would just be reflected back into the surrounding air. Ideally, the vexing issue is as to how far does light have to go (within silicon) prior to its high probability of being absorbed for producing some useful current. The MIT team started off by carrying out thousands of computer simulations in which they tried out variations in the spacing of lines in the grid, thickness of silicon and importantly, the number and thickness of reflecting layers deposited on the back surface. In fact, this work is just a step forward in the direction of producing an economically viable solar cell. It is important to mention here that the MIT Deshpande Center selected the project for an 'i-team' study to evaluate its business potential. The team analysed the potential impact of this efficient thin solar cell technology and found significant benefits in both manufacturing and electrical power delivery for applications ranging from remote off-grid to dedicated clean power.

Photo courtesy: DOE/NREL

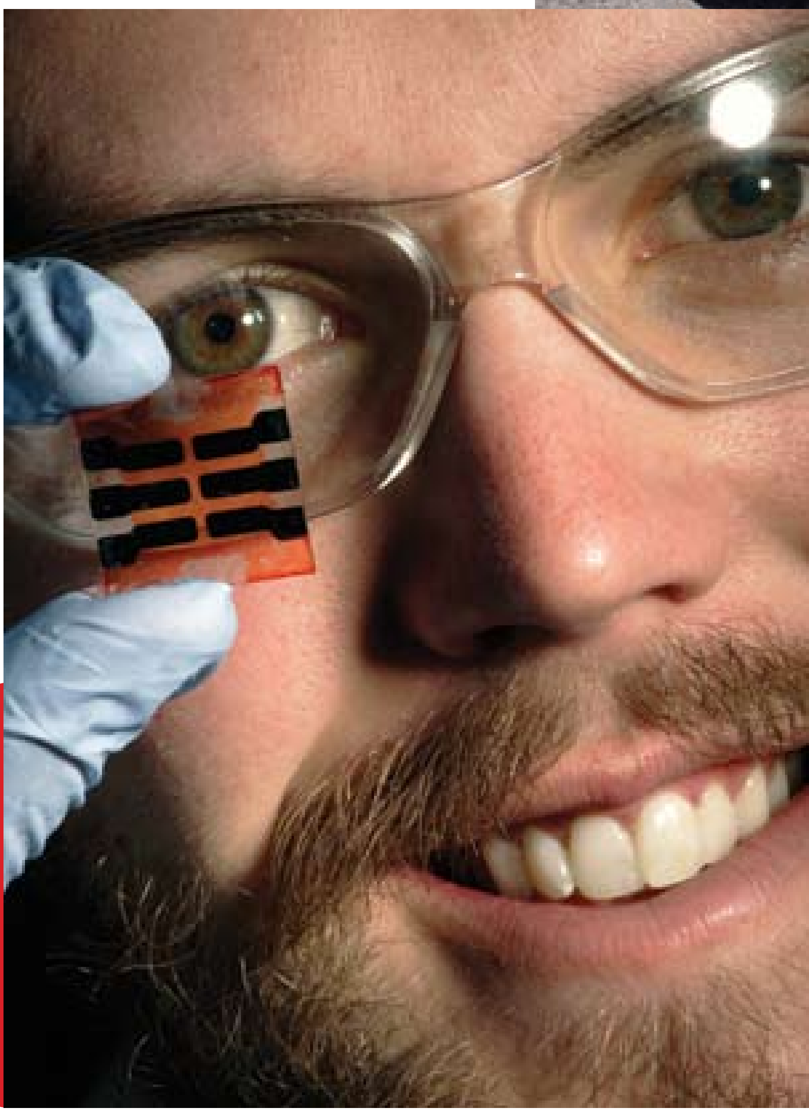


Photo courtesy: DOE/NREL

Trapping solar heat in concrete

The prestigious US DOE (Department of Energy) has just awarded a whopping amount of $770 000 to engineering researchers at the University of Arkansas for developing a novel technique of storing thermal energy in concrete. It is with the aim of developing low-cost energy storage of solar power. The trick is to transfer heat cheaply from the solar collectors and holding it before routing it to generators.

Thermal storage via a concrete medium is a fairly well established practice in Europe. However, it is yet to take off in countries like the US. In Europe, energy has been stored at a maximum operating temperature of 325 °C at an estimated cost of $25 per kilowatt-hour. Storing heat at a higher temperature is a sure way of bringing down the cost. Therefore, the researchers are now experimenting with storing heat up to an operating temperature of 500 to 600 °C. Actually, storage of power in concrete begins with the collection of heat in solar panels. The heat thus collected is then transferred through steel pipes into concrete. It absorbs the heat and stores it till the time it can be transferred to the generator. This new initiative is expected to result in more suitable and efficient ways of such heat transfer. DOE is aiming to achieve thermal energy storage at about 5 cents per kWh for up to 16 hours by 2020 from about 13–17 cents per kWh at present.

Organic solar cells wish to live longer

The Germany's Federal Ministry of Education and Research (BMBF) is currently supporting a development project through a consortium headed by Konarka. The major objective is to work towards an extended lifespan of organic solar cells. These relatively lesser-known cells are expected to rule the roost in the times ahead. The financial outlay earmarked for the purpose is about $3.16 million over the next three years. The project named, 'OPV Stability' will investigate the ways and means to increase the lifespan of OSCs (organic

Photo courtesy: DOE/NREL

US Solar Industry Association sets out 2009 agenda

Solar Energy Industries Association or simply SEIA is a strong body of more than 800 companies engaged in production, distribution, marketing, designing, installing, financing, and so on of solar power plants and systems. It has just outlined the key policies that President-elect Obama and the Congressional leadership must address to ensure an expanded use of free-flowing solar energy. This policy enunciation has been aptly named as 'Solar Energy: a blueprint for job creation and economic security'. SEIA has recommended a quick implementation of the following few policies and programmes with an ultimate objective of creating more than one million clean energy jobs in the US alone.

- Improve solar tax credits
- Increase government procurement of solar power
- Create tax incentives for manufacturing
- Pass a national renewable portfolio standard with a solar provision
- Expand and update transmission infrastructure
- Improve access to federal lands to harness our vast solar resources
- Create a federal clean energy bank
- Create the office of renewable energy development
- Establish national standards for interconnection and net metering
- Increase DOE solar appropriations
- Enact climate legislation to reduce carbon emissions and stimulate solar generation

solar cells) for purely commercial use. OSCs are flexible, semi-transparent, and inexpensive to produce. However, they are short-lived. The trick of the trade is to combine high-quality encapsulation with high intrinsic stability of photoactive materials.

Trio agrees on solar energy purchase

RIL (Reliance Industries Ltd) has just entered into an agreement to sell solar energy to three power companies of Rajasthan. These include Jaipur Discom, Ajmer Discom, and Jodhpur Discom. Basically, RIL is embarking on a major plan to set up a 5-MW solar power generation plant at Khimsar village in Nagaur district. It is being deemed as the first-of-its-kind initiative to tap solar energy for the direct benefit of consumers in the state. This specific agreement entitles RIL to obtain Rs 15.78 per unit of electricity. The power purchase rate would be Rs 3.67 for 10 years while IREDA (Indian Renewable Energy Development Agency) will pay Rs 11.33 per unit (during the first year) as per the directives of RERC (Renewable Energy Regulatory Commission). Thereafter, it will go down by 4 paise per unit each year. In addition, the discoms will pay 78 paise per unit to the power generation company. However, the underlying benefits will be applicable only for plants commissioned by December 2009.

BHEL: looking towards the land of rising sun

BHEL (Bharat Heavy Electricals Ltd) took an early lead alongside other major public sector unit (CEL [Central Electronics Ltd]) to develop solar technology in the country. However, its initial enthusiasm did not keep pace with the solar companies, which took a plunge into solar business much later. BHEL is now embarking on a major investment drive of about Rs 30 000 million in the solar energy sector. It is in negotiations with a Japanese technology partner under its plans to establish an integrated solar facility preferably in West Bengal or Gujarat.

Vehicular solar fridge in rural India

Have you ever thought about use of commonly used car parts to produce refrigerators? It seems unbelievable but true, as an Indian multinational has offered support to Promethean Power (US company) both for manufacture and distribution of the refrigerators. Majority of the commercial refrigerators run on diesel generators in the rural areas. The plain intention is to facilitate an easy repairing within rural areas. The system was created by the STG (Solar Turbine Group), a non-profit organization formed by students from the MIT (Massachusetts Institute of Technology). STG has already built some of its solar turbines in the African country of Lesotho. These are being used to produce hot water and electricity.

In practice, the solar refrigeration system makes use of parabolic troughs to generate the heat from sunlight to heat a liquid. In turn, it creates steam to turn a turbine to make electricity.

According to Promethean Power, a sizeable market potential exists for this fridge in developing countries like India. The ultimate objective of the company is to operate the fridge by combustion of natural gas or biomass—a definite advantage in terms of availability in rural areas.

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL

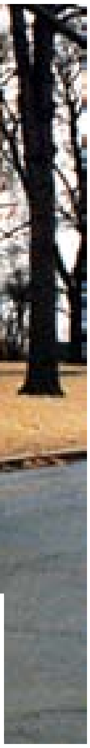
Taking the sun along for a cause

There is an urgent need to look for some effective solutions to the increasing threat of climate change. However, what is equally needed is to make everyone aware about this new global menace. Taking a strong cue from it, ten dynamic individuals from across India and around the world are about to focus on local solutions to the climate change issue. Conceived as a journey of a lifetime, these youths are fired with an immense passion of sheer hope. Aiding their mission are three solar-electric REVA vehicles, a solar biofuel bus, and a solar-powered rock band and even dancers from Shiamak Dawar's Victory Arts Foundation.

These youthful agents of change are set to go out on a journey, aptly named as Climate Caravan, in January 2009. The primary focus of the project will be to create solutions in the form of moving through college campuses and launching groups. It will also put into sharp focus the potential for availability of green jobs. Finally, the climate solutions road tour will mark the beginning of a long-term project that will support a database of climate change solutions of all kind.

Aiming big with solar thermal power

Solar energy usage for power generation is evolving at a very fast pace. The latest potential entrant to think of producing solar power on a megawatt scale is Acme Energy Solutions. It is planning to establish a 100-MW capacity thermal power plant either in the state of Rajasthan or Gujarat in the coming year. The company is optimistic about producing the cheapest available power anywhere in the world at Rs 8.33 per unit. Arid or desert areas are usually the preferred areas to accommodate a large assembly



of mirrors or lenses for power generation.

A factory that uses green lighting

G P Tronics, a Kolkata-based company entered the Indian domestic inverter market way back in 1978. Today, it makes sine wave inverters for industrial applications as well. The company has just gained the envious distinction of becoming India's first 100% factory using green lighting. Associated with it is a zero carbon emission vis-à-vis its lighting load. The entire area of 5500 square feet area is lighted up only by the LEDs (light emitting diodes). Binay Opto Electronics, also based in Kolkata came into being much earlier in 1950s and specialized in an indigenous production of filament indication bulbs. Binay executed this turnkey project for G P Tronics using specially designed LED lighting project inaugurated on 29 November 2008.

The complete lighting load takes up just 1200 W (watts) in direct contrast to originally envisaged load of 4200 W using traditional CFLs (compact fluorescent lamps). It is important to mention here the BEE (Bureau of Energy Efficiency) norm of using a maximum of 11.5 W/square feet lighting load. In the present case, it just works out to about 4.5 W. The positive outcome of all this is the presence of 100% solar-operated lighting—a first of sorts in the country.

XL Telecom and Energy establishes 1.6-MW solar farm in Europe

XL Telecom and Energy Ltd has announced the establishment of the first of its series of solar power plants in Europe. It has been a pioneer in solar module manufacturing for over 15 years and has been working on to capture the complete value chain of the solar industry. As part of this strategy, the company is in the advanced stages of implementing the 120-MW solar cell manufacturing facility in SEZ, Hyderabad with a capital outlay of Rs 360 crores. Looking at the demand for power generation from renewable energy sources, XL, as part of its strategy to be a serious player in the field, has decided on embark on forward integration in the solar value chain, by entering into the EPC segment of solar farm establishment and also power generation using solar technologies.

The company is looking at establishing a series of solar farms generating about 300 MW of power over a period of three years. The first solar farm has been established in Majorca, Spain, with an installed capacity of 1.6 MW and capital outlay of 9.5 million euros. XL has signed the power purchase agreement for 25 years with the Spanish Utility Company. The project is expected to generate about 19 million euros over its initial life with almost negligible maintenance cost. XL is looking at continuing to explore the opportunities to establish a solar farm in Italy, Southern France, and other European countries in the next three years totalling a capacity of about 300 MW.

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL

SOLAR TECHNOLOGIES
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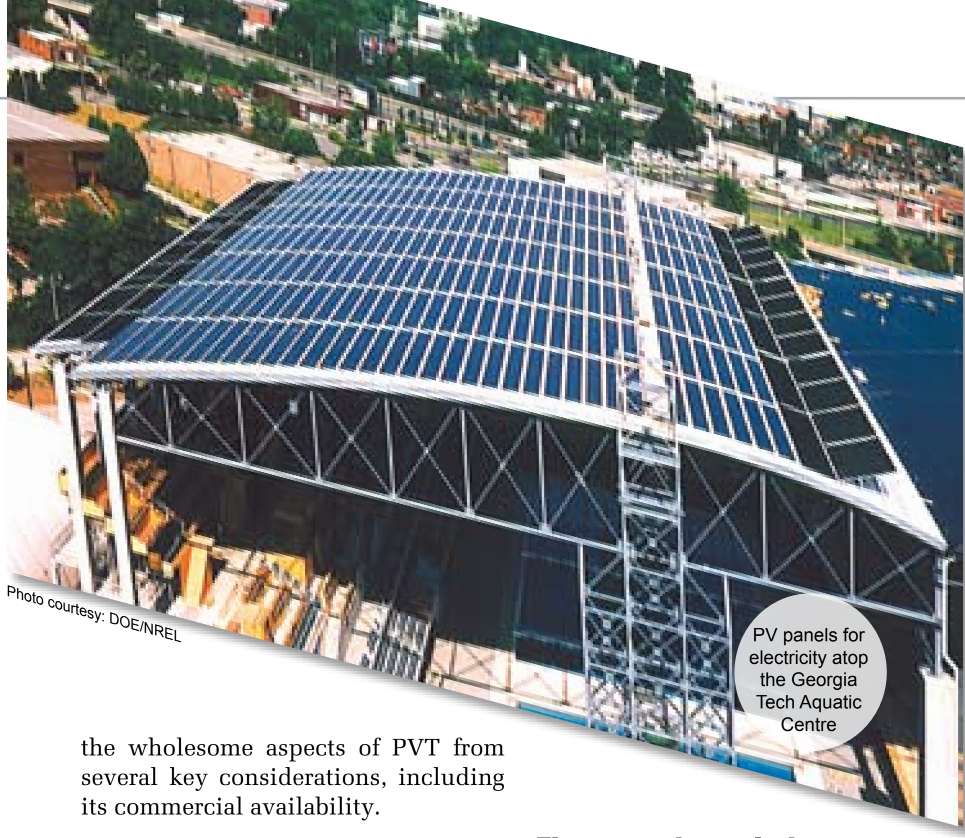
Introduction

Solar energy technologies are quite capable of doing much more than what has really been achieved till now. The issue is not solely of managing a wider programme outreach, but also of maximizing the gains from the freely flowing solar energy. One such approach deals with integrating PV (photovoltaic) and T (thermal) technologies into a single module. This is what is typically known as a PVT system. The real focus on the PVT collector development began as early as the 1970s with a clear-cut objective of enhancing the energy efficiency. The key market segment was perceived to be the domestic application with a well-understood requirement of both electricity and water heating for example. The glazed collectors – both air and liquid type – gained prominence during the formative years joined soon by the idea of developing unglazed collector in tandem with a heat pump. Thus, small air collectors mainly for autonomous applications like for instance the ventilation of cottages came into being. However, research was stimulated on development of autonomous PVT collectors more specifically to take care of developing country needs. The onset of early 1990s witnessed the market worthiness of large PV facades and soon the issue of ventilating these so as to bring down the PV temperature gained ground. Heat thus available was deemed to be useful for heating the rooms.

The existing PVT market continues to be quite small, but can garner multi-level support as conventional power gets costlier and less available too. This article attempts to look at



PV panels for electricity atop the Georgia Tech Aquatic Centre

the wholesome aspects of PVT from several key considerations, including its commercial availability.

The solar scenario

A universal initiative of sorts is presently going on to lessen our dependence on the use of fossil fuels. Quite a few companies are beginning to repose their newfound faith in the PV panels. Catching every available moment of sunshine for free, these panels are now finding their way into the design of homes, offices, government buildings, industrial complexes, and large commercial spaces in a varying measure. As known already, PV needs very less maintenance and is a silent worker in itself. A quite obvious question is why PV is not very widespread as it should be, though sunshine happens to be so.

Well, there are three compelling reasons for their subdued visibility at this point of time. The PV modules are just about 10% efficient, the initial capital cost is high, and the payback is slow often running into years and years. The commercially produced cells are not more than 10%–15% efficient and the panels release far more heat than electricity. The fact remains that for every 1 °C increase in the PV panel temperature, there is a 0.4%–0.5% drop in efficiency. As is well known, many such panels sit pretty on roofs in the temperate climates. So, it can represent a significant loss of effectiveness.

The emerging solution

Perhaps a more worrisome situation is that the heat build-up can damage the PV cells, allowing them to live shorter only. At times, roof temperatures may get hot to the level of damaging the underlying roofing materials. It is not an uncommon sight to record such temperatures of over 85 °C on bright summer days. The moot question is if a solution or two is in sight to remedy this type of situation? Surely, simply by keeping air circulating evenly around the modules, a sizeable portion of the heat can be isolated. This can bring the combined PVT efficiency to about 50% or even more. The resultant effect could be in the form of an increased electricity generation and lower heating energy requirements. As per available estimates, payback time may be sliced by as much as two-thirds.

What is a photovoltaic–thermal system?

It is now a common practice to refer to a PVT system as a total energy system or even a co-generation system. A PVT module is a combination of solar cells with a solar thermal collector. Thus, it forms a device that can convert solar radiation into electricity and heat simultaneously. The excess heat that is generated in the PV cells is eliminated and changed into a usable form of thermal energy. This is for the simple reason that besides change of sunlight into useful electricity, it collects the residual heat energy. Thus, a user stands to gain by simultaneous delivery of both usable heat and electricity. Following few are some of the most important pluses of a PVT system.

- Increased energy production per surface area
- Diminished manufacturing and installation costs
- Lower payback time as compared to PV
- Homogenous appearance of roof and façade
- Improved PV aesthetics
- Single solar product for holistic energy needs of a consumer

Simple working of a PVT system

Just think of a simple PVT module within which PV cells are fixed to a heat exchanger with either air or water as a heat transport medium. Here, heat available to the extent of about 70% can be used quite effectively. There are many different ways of combining the different PV and solar thermal technologies into a PVT collector. These typically include the following few.

- Crystalline or thin-film cells/modules
- Liquid or air collectors
- Flat plate or concentrating technologies (with or without a transparent cover).

Types of PVT collectors

As of now, a number of PVT collectors falling under the following few types are available in the marketplace.

- PVT liquid collector
- PVT air collector
- PVT concentrator
- Ventilated PV with heat recovery

Quite a few manufacturers have joined hands in an initial effort related to the development, production, and marketing of the PVT collectors.

Concentrating collectors at the Adams County Detention Centre

However, the hard fact is that there is still a very limited availability of collectors in the market. It is equally true that operational experiences vis-à-vis these collectors is just not enough.

The energy yield of a PVT collector

The electrical yield of a PVT can either be used directly or be supplied to the grid. Since storage is not required, it is straightforward to determine the annual electric yield. For the annual thermal yield, the situation is different. The PVT device is part of larger heat supply equipment containing other equipment such as a thermal storage and piping. In addition, the user determines how much heat is needed.

Factors influencing the yield

- The effect of temperature is appreciable and amount of primary energy saved per unit of collector area is about twice as high between two different locations.
- The seasonal variation in demand may reduce the annual thermal yield significantly.
- The effect of temperature level on electrical PVT performance is relatively small.
- The effect of temperature level on thermal output is substantial, although this trend is reduced due to corresponding change in the PVT design.
- Façade integration reduces both the electrical yield and thermal yield.
- For most applications, the thermal yield is substantially higher than the electrical yield, which shows that a conventional PV laminate generates a large amount of untapped heat.

Characterization of PVT modules

It is a fairly common practice to characterize PVT modules in terms of type of PV, glazing and fluid utilization. Water, glycol, and air are amongst the most commonly used collector fluid mediums. The availability or otherwise of concentration is also of some significance besides the type of module design. In totality, a sound relation exists between the module type required and the type of demand under consideration.

Specific issues in collectors

To bring down the thermal losses, PVT collectors may often have a glass cover over the absorber. In case such a cover is present, it is normally referred to as the glazed collector otherwise an unglazed one. The terms glazed and unglazed as such do not refer to the glass substrate that may be a part of the PVT absorber. Quite often, the glazed collectors are associated with smaller thermal losses moreso at higher collector fluid temperatures. However, for medium- to high-temperature applications, this results in a much higher thermal annual yield. Glazed collectors may result in high stagnation temperatures and in turn these may be critical for certain types of PV encapsulant. The immediate risk is that of yellowing and delamination. The glazing makes the module more prone to hot spots. Additionally, bypass diodes may get overheated due to the additional insulation. Similarly, reflection losses at the glazing reduce electrical performance. Increased temperature levels lower the electrical yield. These are some of the engineering challenges that surfaced during the process of commercial development of PVT collectors. Table 1 shows the type of PVT collector suited to a specific user demand.

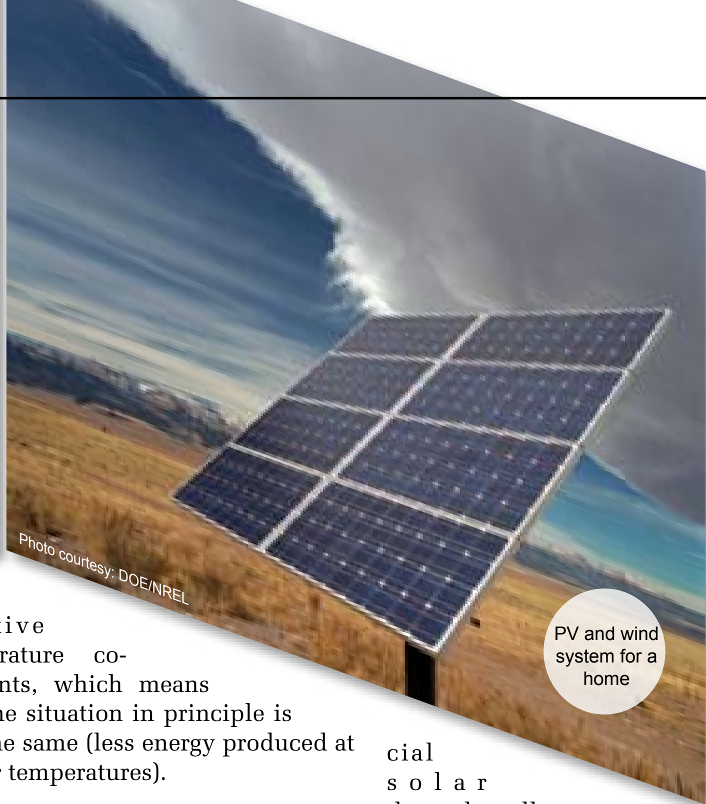
The additional thermal output that is provided from the PV/T systems make them cost effective compared to separate PV and thermal units of the same total aperture surface area. Generally, in PV/T system application, priority is given to producing electricity. Therefore it is important to operate the PV module at low temperature in order to get higher electrical efficiency from the PV module. As far as the applications of PV/T systems are concerned, they can be used for various applications, which need heat in medium (60–80 °C) and low temperatures (<50 °C) because in these ranges both electrical and thermal efficiency of the system remain in an acceptable level.

Temperature coefficients

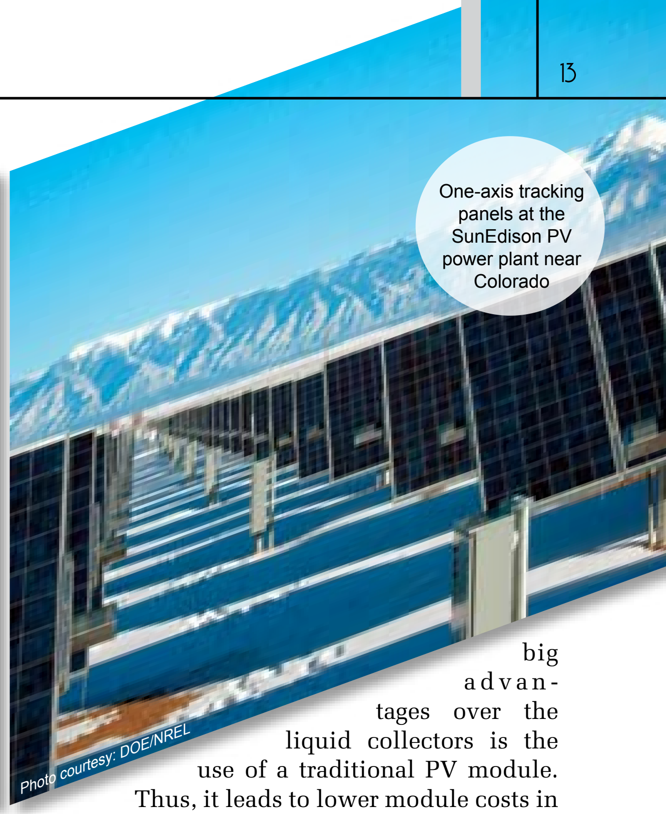
For most thin-film cells, the temperature coefficient is smaller than that for crystalline silicon cells. So, the losses may only be about half the losses compared to crystalline cells. However, all cells

Table 1 Type of PVT collector by user demand

Type of demand	Recommended type of PVT collector
High-temperature water	Use glazed liquid collector, glazed air collector with heat exchanger or concentrator. Unglazed collector is possible as source for heat pump.
High-temperature air	Use glazed collector or unglazed collector/ventilated PV as a source for a heat pump
Low-temperature water	To meet just the summer requirement use unglazed liquid collector and for the winter demand, make use of glazed liquid collector.
Low- temperature air	In case of summer demand or high irradiation in winter, use unglazed air collector or ventilated PV. For meeting the winter demand and low irradiation in winter, use unglazed air collector or unglazed collector as a source for heat pump.



PV and wind system for a home



One-axis tracking panels at the SunEdison PV power plant near Colorado

have negative temperature co-efficients, which means that the situation in principle is still the same (less energy produced at higher temperatures).

X-Si	0.4%–0.5%
a-Si	0.2%
CIS	0.36%
CdTe	0.25%

The effect of power dependence on the temperature should not be overestimated. During operation, that is, enough sunlight X-Si PV module has an average temperature of about 30–40 °C over the year (depending on the amount of ventilation of the module). In contrast, a glazed PVT may have an average temperature between 30–50 °C (depending on the solar fraction). Under such a situation, the electrical power loss may generally be less than 10% of the total electric yield.

PVT collectors: the inside view

Liquid collector

Initial efforts to develop the PVT liquid collector were kick-started during the early 1970s. It is primarily an absorber with a series of parallel risers onto which PV has been laminated or glued. Simply put, it is almost identical to a conventional flat-plate liquid collector. A number of PVT prototypes have been designed so far with collectors configured on sheet, tube, channel, plastic absorbers, and thermosyphon. In most of the cases, the PVT prototypes were constructed by the connection of a commercial PV laminate to a commercial solar thermal collector.

In water/liquid PVT collectors, water is used as heat-transfer fluid and the PV cells are pasted either directly on the absorber or interior on a cover plate with a dielectric material. Hence, the only contact between the PV cells and the absorber or the cover plate is high thermal contact. The heat-transfer fluid flows inside the ducts on the absorber and collects heat from the absorber. If the PV cells are pasted to the absorber, heat is also extracted from the PV cells. This often results in a higher electrical efficiency of the PV cells. The heat-transfer fluid can be circulated by either a pump or by the difference in specific gravity of the heat-transfer fluid.

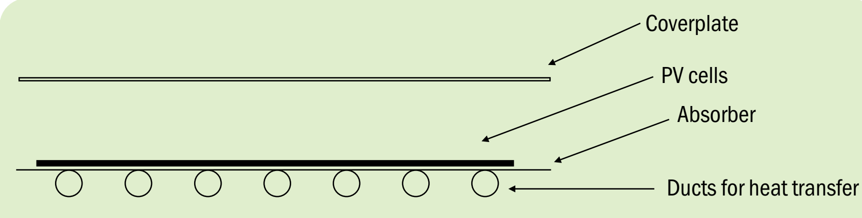
PVT air collector

This type of collector is almost identical to a conventional underflow air collector with a PV laminate acting as the top cover of the air channel. One of the big advantages over the liquid collectors is the use of a traditional PV module. Thus, it leads to lower module costs in comparison to the liquid type. Air collectors are either of glazed or unglazed type. The limited market share of the solar air heating systems is a pointer towards the initiation of selective few studies on these systems so far.

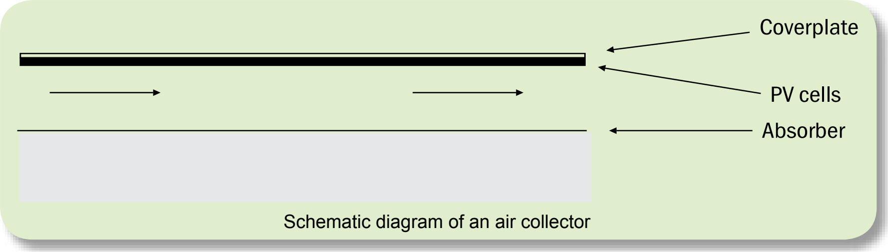
In air-based PV/T system, air is used as heat-transfer fluid instead of water. Solar PV cells are either pasted to the interior of the cover plate or to an absorber or the PV cells and act as an absorber or cover plate by itself. Air can be circulated by either natural ventilation or forced ventilation.

Ventilated PV with heat recovery

Building-integrated PV is a fast emerging PV application. PV facades or roofs are being put up within which an air gap is mostly present at the back to facilitate the airflow. It takes place via natural convection (ventilated PV). The heat, if recovered from the PV for use in the building, is better known as ventilated PV collector function.



Schematic diagram of a liquid collector



Schematic diagram of an air collector

In fact, such collectors are positioned to offer multiple uses like limiting the thermal losses from the building to the ambient. The mid 1990s saw the emergence of PV facades on the market scene, which also prompted research into ventilated PV collectors.

PVT concentrators

Concentrating light onto a small PV area is a time-tested demonstrated use. The plain intention is to replace a part of the expensive PV area by a relatively inexpensive mirror area. This ensures a faster payback period as compared to a conventional PV application. However, it brings in its fold a problem of substantial thermal energy generation in the solar cells. If left this way, it can result in very high operating temperature of the cells and thus far reduced solar cell efficiency. So, it becomes an absolute necessity to bring the cells to a much lower temperature via a PVT concentrator collector. Several research studies have focused to increase the PVT yield by means of reflectors or even parabolic troughs. A combined solar and heat power solar CHAPS PVT collector has been developed recently. It involves a parabolic trough of concentration ratio of 37 times with mono-crystalline silicon solar cells along with a tracking system. On the backside of solar cells, a tube with water and antifreeze is attached to collect most of the generated heat produced.

Performance of PVT collectors (energy balance)

The PVT collector essentially combines the functions of an FPC (flat-plate collector) and those of a PV module. It is possible to evaluate the thermal, electric, and combined efficiency of a PVT collector by considering the following sets of equations.

Solar flat-plate collector

The thermal efficiency ($\eta_{thermal}$) of a conventional flat-plate solar collector under steady state condition is given by

$$\eta_{thermal} = \frac{Q_{useful}}{G}$$

and Q_{useful} is given by

$$Q_{useful} = mC_p(T_o - T_i)$$

where Q_{useful} represents the useful energy collected by FPC, the fluid mass flow rate per unit collector area (kg/sm²), G the solar irradiance (W/m²), C_p the specific heat of fluid (J/kg K), T_o the outlet temperature(°C), and T_i the inlet fluid temperature (°C).

Photovoltaic module

The electric efficiency ($\eta_{electrical}$) of a solar PV module is given as

$$\eta_{electrical} = \frac{I_m V_m}{GA_c}$$

or given by en empirical relation

$$\eta_{electrical} = \eta_o(1 - \beta(T\ \ 25\ °C))$$

where I_m represents PV current at maximum power point (A), V_m the PV voltage at maximum power point (V), A_c the PVT collector area (m²), T the temperature of PV module (°C), and represents the cell efficiency temperature coefficient.

Efficiency achievements

Efficiency	PVT collector
Thermal	24%–28%
Electrical	6%–7%
Combined	30%–35%

Simple comparing the PVT collectors

Quite clearly, there are four different types of collectors each with some distinguishing feature or the other. Generally, any technology development and commercialization effort is to be viewed in the context of techno-commercial issues if not more. Table 2 summarises these issues in an effort to choose the best in accordance with a specific user demand.

International programme in PV/T

There is an enhanced focus on PVT technology development within the European countries. In this regard, a roadmap for the development and market introduction of PVT collectors was prepared and several priority actions identified for the purpose. Several issues related to technical, marketing, system integration, standardization, and financing were enunciated along with a concrete action plan to realize the key objectives of the PVT programme.

Leading research institutes such as Energy research Centre of the Netherlands, The Netherlands; Arsenal


Photo courtesy: DOE/NREL

Solar installation at the Desert Research Institute

Table 2 Technical and commercial issue in commercialization of PVT collectors

Type of collector	Commercial issues	Building integration issues	Technical issues	General remarks
Liquid PVT	Flat-plate are collectors very well suited to produce hot water. These collectors (both unglazed and glazed) constitute over 75% of the total installed solar thermal collector area worldwide. Cost of PVT system can be assumed to be similar to the cost of a solar thermal system plus the cost of PV laminates minus the cost of saved materials through integrated production/installation and reduced installed costs.	Building integration is applied successfully for solar thermal collectors and PVT collectors can be integrated in a similar way.	Special integrated PVT absorbers are also needed to avoid leakage or freezing problems.	Good enough possibility for an enhanced market penetration.
Air PVT collector	Limited application for hot air especially during the summer. Installed area of air collectors is about 1.5% of the total installed solar collector area globally. Difficult for these systems to compete with a liquid collector due to cost and the limited efficiency of an air/water heat exchanger.	Problem is the high air volume flow needed to obtain a good thermal efficiency. The large tubing may cause problems especially in retrofitting	No freezing and no boiling of the collector fluid plus no damage if, leakage occurs. Disadvantages low heat capacity and low heat conductivity result in a low heat transfer. High heat losses through air leakages.	Heating air to more than 60 °C is not recommended for direct heating of the living rooms.
Ventilated PV with heat recovery PVT concentrator	PV facades are often unglazed so temperature levels that can be reached are limited. The application for heating (for example, preheated ventilation air) is limited to climates that have a substantial irradiation during the heating season. Concentration has a potential of reducing the cost, through replacement of expensive PV area by cheap mirror area. Market share for PV concentrator has been marginal so far due to several reasons.	PVT systems are highly suitable for building integration. Using air systems for ventilating, heating and cooling of buildings generally needs large pipe installations and big volumes. Large concentrator ratios require tracking which makes building integration impossible and strongly increases the maintenance costs; not all climates suitable for high ratio concentration.	Heat transfer from PV to the airflow is generally not very good as the losses to the ambient are large. Thermal efficiencies are generally in the range of 10%–20% for a well designed system. Small cell area needs use of more efficient and expensive PV material specially designed for PVT performance.	Suitable for use in assembly rooms, and so on and production areas. This option is beginning to gain momentum lately.

Research, Austria; Fraunhofer Institute for Solar Energy Systems, Germany; Institut fuer Solarenergieforschung GmbH, Germany; and University of Patras, Greece were involved in PVT R&D activities and developing the PV/T road map. There are just about 8–10 manufacturers of PVT collectors worldwide with India drawing a blank.

Practical examples of PVT devices: glazed PVT liquid module, glazed PVT liquid system RES (www.beaufortcourt.com), unglazed PVT air roof

Table 3 gives a quick insight into few development initiatives.

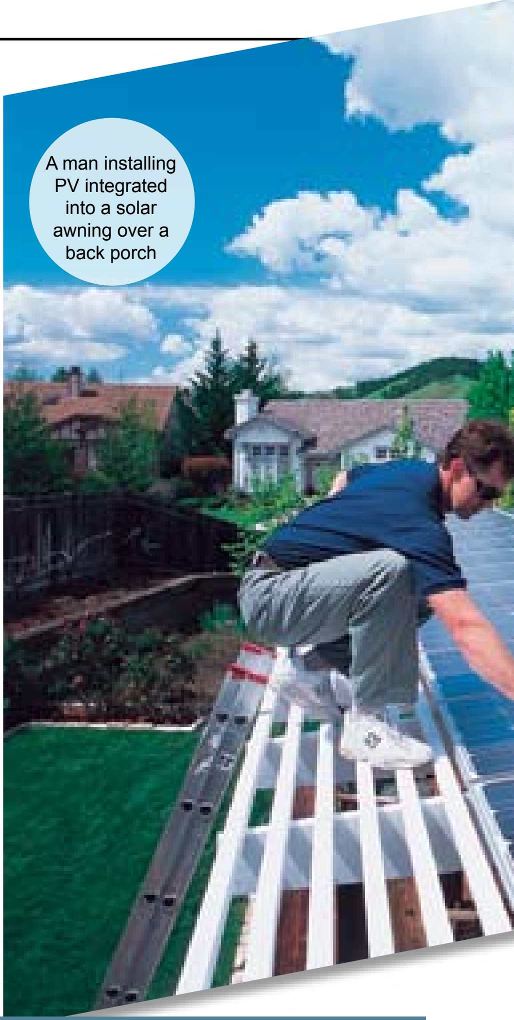
There are quite a few design variants of PVT collectors available in the market today. Table 4 lists selective few types along with their power generation capability and accompanying areas of use.

Niche markets for PVT collectors

Various types of market opportunities exist for these collectors. For example, in case of glazed PVT liquid collectors, the key market is viewed as the domestic water-heating segment. The niche markets for such a product may also exist in the hospitals and remotely located holiday homes, and so on. As against this, the main market for the unglazed PVT liquid collectors is generally seen in the combination of this collector with a heat pump. The intended use is that of space heating applications. The heat pump is capable of providing cooling facilities. Likewise, in case of glazed PVT air collectors, unglazed PVT air collectors, and ventilated PV facades, a sizeable market may exist for space heating in winter. Again, futuristic use may involve its combination with pre-heating air to achieve the much-needed solar cooling during the summer. However, to meet the desired temperature levels, additional support element such as booster collectors may well be needed. Significant use of such a system may be for houses with low energy demand but equipped with a central heat recovery ventilation unit. The concentrating type PVT collector is mainly geared to meet the high-temperature applications.

Paying back via PVT

It is expected that the application of PVT can lead to reductions in BOS and installation costs, as compared to the individual systems. Initial estimates indicate a cost reduction of roughly 10% for a PVT module as compared to a combination of the separate modules. Economic assessment as well as the simulated energy results show that the payback period of the PVT system is almost half of the payback period of the conventional PV system. It is mainly because the total useful energy generated in a PVT system is much higher



A man installing PV integrated into a solar awning over a back porch

Table 3 Some development initiatives

Type of collector	Early developers	Period of development	Key problems observed (in)	Key commercial producers	Specific remarks
PVT liquid collectors	Solarwatt Zenit ICEC Powerlight Sollektor SDA, Sunearth and Unisolar Batec and Racell	1996–2003	Electrical insulation/ delamination	PVT Wins Millennium Electric	It has a definite potential to churn out huge numbers while addressing the needs of both lighting and water heating.
PVT air collectors	Cythelia			Conserval Engineering Grammer Solar Aidt Miljo	Just a few PVT air collectors developed.
Ventilated PV with heat recovery	Atalantis Energy Cenergia Secco Systems	1991–2005		Secco Sistemi	Use of these systems for pre-heating of ventilation air.
PVT concentrators	Sunwatt Vattenfall Utveckling	1981–1989		Heliodynamics Menova Engineering Inc. Arontis Solar Solutions	Cooling is required to avoid too high temperatures; 300 m^2 demonstration project in Austria producing electricity and hot water.

as compared to conventional system. Thus, the LCS (life cycle saving) in case of a PVT system is quite high.

PVT: entering the Olympic arena

The use of solar energy technologies for lighting and water heating in the sports arena of international dimensions is not entirely new. However, what is certainly new is that the most recently held Olympic games at Beijing boasted of a relatively different technology combination. It used a cutting edge solar technology believed to one of the world's first solar wall PVT hybrid system. This system was placed on the roof of one of the central buildings, which functioned as a service centre for athletes during the Olympic games.

The technology thus incorporated resulted in simultaneous production of electricity and heat energy from the same surface area. Available estimates point to generation of 200%–300% additional energy than a traditional PV system. The resultant gains are visible in the form of reduced payback period as well as a sizeable displacement of CO_2. The solar wall panels take out the heat from the back of modules and direct it to the facility's traditional heating systems.

The Indian scenario

Solar energy flows freely in this part of globe and every possible effort is being made to deploy it on an enhanced scale of visibility to meet various end-use applications. However, system combination like a PVT system is yet to emerge on the market scene.

The path forward

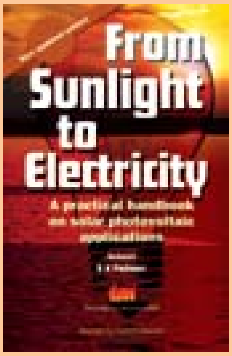
Solar energy technologies are sooner or later going to take every one by a sheer surprise. Sizeable numbers can come through only by opening up new commercial vistas of applications alongside an increased market deployment of traditional uses. PVT collector use is one such novel application with a ready ability to fulfill multiple energy needs. It can also ensure a maximum possible use of the available roof space. Thus, it is somewhat analogous to a situation of rolling out multiple services like photocopying, faxing, scanning, and printing from a single machine.

Table 4 Some PVT collectors available in the market

Type of collector	Make	Area (m^2)	Electric power (W)	Thermal power (W)	Remarks
Liquid PVT	PVT Wins	1.28–6.4	150–735	765–3840	—
	Millennium Electric	2.8	300	2000	Provides added use of air heating
Air PVT	Aidt Miljo Grammer Solar	0.39–3.06 2.0–12.55			Used for automatic ventilation of summer cottages with PV on part of the absorber.
	Conserval Engineering	1.75	190	710	It is a solar wall perforated absorber with PV on top.
Ventilated PV (with heat recovery)	Secco Sistemi				Besides power, the ventilated PV supplies hot air. It can then be used for room heating or to assist a solar cooling system in summer.
Concentrator PVT	Arontis Solar Solutions	5.0	500	2250	Single-axis tracking, modular PVT concentrating collector for building as well as ground installations; designed especially for hotel rooftops and recreation centres and so on.
	Heliodynamics	24	1000	10000	Designed for mounting on flat and sloping roofs or pole mounted over the parking areas.

From Sunlight to Electricity

A Practical Handbook on Solar Photovoltaic Applications (Revised Edition)



From Sunlight to Electricity: A Practical Handbook on Solar Photovoltaic Applications is a compilation of information that gives the readers an overall understanding of the photovoltaic sector in India. The book serves the interest of all the stakeholders in the PV sector, including policy-makers, government officials, non-governmental organizations, and academic and research organizations.

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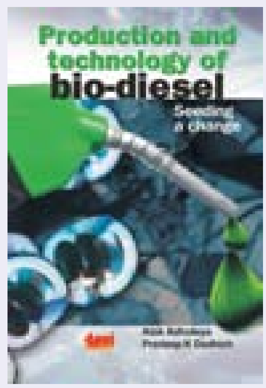
Production and Technology of Bio-diesel: seeding a change



The book covers the entire value chain involved in the production of bio-diesel, right from the nursery stage for the saplings to the production of transesterified oil (bio-diesel) for use in diesel-powered engines. The reader will get, in one volume, valuable information pertaining to the production of bio-diesel, a process that requires inputs from various disciplines—environment, biotechnology, chemical engineering, finance, economics, and automotive engineering.

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Solar Power

walking the distant talk

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The global economy is presently showing a downward slide leaving its footprints of change in several areas. However, one area that seems unscathed is that of mobile telephony. In fact, it is blurring an otherwise escalating difference between haves and have-nots. Why not, after all a man is a social animal and is ever keen to confide into the other? A not-so-recent UN report clues of about 50% global population not having made any telephonic call so far. The moot question is if, mobile phones will touch their lives too in the time ahead? It has taken about 21 years to get mobile phones into the hands of three billion people around the world, but equipping the next 1.5 billion may happen sooner than later. Incidentally, these people inhabit the world's poorest and remotest corners thus bringing to fore the massive opportunities and challenges too.

Take for instance the thorny issue of justifying the expense of raising the installation towers in areas with very poor affordability. Leave alone the vexed issue of meeting the cost of running and servicing the accompanying equipment. Happily enough, India now has the fastest growing mobile subscriber base in the world and is now ranked second only after China. To take this initiative further, telecom operators in both these countries are working on an ambitious plan to reach out to the rural areas. The plain intention is to put in place a viable, sustainable, and efficient telecom infrastructure prior to rolling out mobile services to them. However, it is easier said than done for a variety of reasons.

Tracing the Indian connection

As of now, mobile connections form India's most powerful movement, which is impacting the lives of both the ordinary and powerful alike? Available market estimates point to a whopping addition of about 10 million customers to the country's mobile network month after month. The total number of telephone connections in the country has gone up from a modest 15 million in 1997 to more than 350 million today. Lately, there is a heightened emphasis on rolling out the mobile infrastructure to the rural market by a few reputed operators.

This has essentially been fuelled by a rapidly burgeoning mobile telephony market. It is truly a charming sight to watch a vegetable vendor, a labourer or even a house maid keeping contact with their nears and dears on their mobile phones. All seems rosy, then what is the real issue at hand? Well, urban markets are beginning to saturate in mobile use and remote rural areas are getting in the line of sight of mobile service providers. However, a lot is waiting to happen to combat the challenges staring in the face. Further, it is not just the voice that places over between the two humans. Few more value-added services like mobile banking, mobile payments, and mobile money transfer are going to become a rage soon. This may transform the way we go about our daily chores.

The share of private telecom players has increased to more than 66% and the contribution of mobile telephony has gone up to 80%. The




MICT (Ministry of Information and Communications Technology) has set up an ambitious target of about 500 million telephones by end of 2010.

Challenges (rural) staring in the face

India lives in villages, most of which are remote. These in no way are craving less for a phone connection. Just think of a farmer who is keen to market his produce in a local market, but is not too sure about the market being open. A simple click on a mobile phone may well change all that and empower him better in also knowing the daily rates in a *mandi*. However, a big issue is of creating a rugged telecom infrastructure in the rural areas. Presently, the electricity network covers most parts of the country, but it may take another 10–20 years to electrify the remaining villages. That is not the sole issue, as telecom equipment cannot be left at the mercy of frequently occurring blackouts even in the electrified villages. In short, the rural areas pose a unique set of issues and challenges vis-à-vis the specific consideration of mobile telephony as under.

- High infrastructure cost
- High power consumption
- High running cost
- Too difficult to deploy (more so in areas with no electricity, poor roads)
- Low traffic density
- Low subscriber revenues
- Non-availability of skilled manpower

Is mobile the answer to rural telephony?

A mobile phone offers the following types of advantages, which makes it an ideal contender for the rural sector.

- Completely independent of the power supply (for most of the time)
- Unaffected by the blackouts

However, it needs to be recharged every once in a while. Thus, availability of power becomes a prime concern in this case. The supply of power is also a potential problem to the base stations, as these will not run without electricity.

Consuming more to talk

Typical base stations today are about the size of a large refrigerator. These need about 1000 W (watts) of power. Most of that energy is simply wasted as heat, which prompts the use of cooling equipment consuming yet another 1000 W. In addition, the backup batteries draw another 500 W or so. Expensive diesel-powered generators are now being used in the rural areas of the developing countries. In India alone, an estimated 1.8 billion litres of diesel are used each year to fuel the mobile-phone networks. This option is turning out to be more expensive as the price of diesel increases. Roughly, fuel can account for as much as 66% of the base station operating costs.

The added expense is for trucking diesel over usually poor roads to quite remote and inhospitable locations.

Table 1 Comparative analysis of possible power options for planning remote cells sites

Power option	Pluses	Minuses	Remarks
Mains power	Either already available or may be made available via grid extension	Costly new grid connection; time consuming affair	Battery back-up unit needed for locations experiencing frequent power cuts
Generators	Most common choice of use for either delayed or intermittent electric supplies	Need to be refuelled Need to be transported to the site and stocked Both fuel and generator prone to theft Increasing cost of diesel	Biofuel generators: beginning to emerge as a good choice but issues of refueling cost still exist
Solar technology	Well proven and reliable even in the most inhospitable terrains; need minimal system maintenance	Initial capital cost of a PV system is still a roadblock in the path of large-scale use of solar power	Solar power is inherently advantaged to meet power requirements as low as 1 W, which is at least not the case with generators
Wind technology	Well established and proven	Not amenable to use at every location Economical; however not preferred for very low power capacities	Peak wind speeds a true determinant of the structure size; additional use for mounting the antennas or even mini or micro base stations
Biofuels	Increasing use of bio-diesel; good resource generation avenue for locals	Production and utilization aspects yet to mature fully	Large scale use may not be a matter of convenience for various reasons
Fuel cells	Gradually evolving as potential source of power; cleaner and more efficient too	High cost of the system application at present	May turn out to be an effective power substitute to conventional engine driven generators ultimately
Hydro (up to 5 Kw)	Presence of steep flowing streams or rivers to produce energy; maximum possible use of local skills including that for routine maintenance	Limited to few geographical regions within an easy accessibility	Perhaps would be the cheapest source of power but with its own share of problems

To remedy this type of situation, the GSM Association, an industry group, has successfully tested wind- and solar-powered base stations in Namibia, and so on made by Motorola. It has also run the base stations from Ericsson on the used restaurant cooking oil in India. However, the big change in this direction of fuel switching is yet to happen, as keeping an eye on pilferage of diesel is multiplying the problems further.

Weighing the power options

The mobile operators are weighing all possible options of using a safe and convenient source of power. Today, just a tiny fraction of base stations are run on alternative energy like solar power thus leaving the majority of 1.6 billion people (living off the electricity grid) and another billion living in areas with inconsistent grid supply. There are a few possible power options at hand for planning remote cell sites. Table 1 provides a brief comparative analysis of such options with their accompanying advantages and disadvantages:

Solar power: emerging on the scene

Sun is shining fairly bright on the global horizon. In fact, the solar power segment is enjoying a fast upswing. The cell/module production is expected to grow from 3900 MW in 2007 to more than 7000 MW in 2008. Further, it is likely to increase to about 52 000 MW or 52 GW by 2012—a record of sorts for a technology which began not so long ago. Likewise, the revenue of the solar sector may move up from about $27 billion in 2007 to an astounding $274 billion by 2012. The die is now firmly cast in favour of attaining the economies of scale together with realizing lower costs in the actual production setups. The year-round availability of silicon wafers hitherto a vexed issue for the entire solar industry is soon going to be relegated to the past with more and more production capacities coming on stream. It may also lead to realization of lower costs. Coupled to these specific initiatives is an unfailing desire of the PV industry to serve new and challenging markets. These very well include the fast emerging and often talked about application of rural mobile telephony apart from lighting. Both these applications together may bring cheer on the faces of millions of deprived people. Solar power is by far firmly entrenched across the length and breadth of India too and is poised for a big leap forward.

Selective rural telecommunication: traditionally solar

The use of solar power for telecommunications is not entirely new. In fact, it is considered as one of the largest PV applications worldwide. The following few reasons make solar a happening source of power for such a critical use.

- Dependable and robust solar power solution for telecom networks
- Proven system engineering to provide reliable, low-maintenance, cost-effective power typically for power loads from 1-W single wireless terminal to 4-kW hybrid systems for backbone repeater stations
- Applications can be as varied as rural payphones and single subscriber telephones to multi-access radio, digital and analogue microwave repeaters, domestic satellite, radio, telemetry systems, and fibre optic repeaters

Solar mobile stations: on the way

The mobile base stations may well be bonded on a large scale with solar panels and backed up by diesel generators in some cases. Market estimates point to a massive deployment of more than 300 000 such solar-powered stations by 2013. Solar manufacturers are also bound to gain in the process not to talk of mobile operators. However, it may be naïve to rule out the existence of equally promising if, not more sources like the fuel cells for a similar purpose subsequently. While talking here about the other sources, submarine batteries for example have also been used by Ericsson, a well-known telecom operator. These batteries can be charged and recharged for much longer durations and diesel is being used just for charging. In the process, the consumption of diesel has come down by an estimated 40% or so.

Dera village, Mohorola BTS

Ericsson also installed some 40 base stations that run on bio-diesel, essentially recycled cooking oil. Further, Ericsson and Alcatel-Lucent have separately installed about 400 solar-powered base stations in African countries including Senegal and Uganda though with varying degrees of success. In India, Alcatel-Lucent's solar base station requires about 750 W to run, while Ericsson's solar base station requires about 600 W. Only about 200 of Ericsson's 1.3 million installed base stations around the globe use solar power while a far larger number uses just diesel or alternative fuels.

Towering initiative

A few telecom companies are designing a new approach to constructing the towers. These towers mostly made of steel were confronted with a problem of large-scale theft earlier on. That is not the case anymore as new tower tube is now made of concrete cylinders. It leads to better protection of the batteries and other equipment minus the need for any expensive cooling. Presently, more than 30 startup companies are trying to take the field challenges headlong by focusing mainly on the following few aspects.

- Reducing power consumption
- Introducing alternative sources of energy, primarily the solar power
- Make system operation site friendly

Base stations: cost less from more

Present day GSM stations, incidentally the most widely used, cost anywhere from $40 000 to $100 000. The most energy-efficient models in current operation need almost 600 watts to run, while others may need several thousand watts. All that is perhaps set for a big change, as a startup company (VNL) is upbeat about running a similar show at just 100 watts or so. It may well turn out to be a $3500 affair as is being projected in some circles. Is it not truly a mesmerizing optimism waiting to be unveiled? This is also expected to directly reduce the carbon footprints so well needed in the present times. It may thus multiply the gains via accrual of carbon credits for the whole lot of telecom operators ultimately.


Village site development, VNL

Sun communicating early in India

The SPV programme in the country took off on a massive scale of demonstration, which subsequently opened new vistas for using solar power for a few commercial applications too. These mainly included uses like power source for telemetry on offshore oil platforms, low-power TV transmitters, microwave repeaters, and so on. A major expansion of the telecommunication network took place in the early 1990s. Indigenously developed SPV systems came handy for the purpose of lending small amounts of power in rural radiotelephones. This resulted in a massive deployment of such systems numbering more than 220 000, which reinforced the rural telephone network. PV telecom application contributed to as much as 22 MW out of a total installation capacity of about 110 MW for rest of the end-use applications like lighting and water pumping. Incidentally, the period in-between then and now saw a quite subdued demand for solar power due to one reason or the other. There are market reports of more PV systems making their way into the country's traditional telecommunication domain soon. So, use of solar power for the upcoming mobile telephony may result in far greater visibility of solar systems—a change perhaps waiting to happen.

Case studies: solar mobile telephony

The mobile telephony scenario projected in the preceding sections may well open floodgates of opportunities for quite a few PV companies in India. Lately, PV has found favour in providing uninterrupted and unmanned power to the mobile signal repeater towers. One such company to gain in the process is the Delhi-based Advanced Electronic Systems or simply AES. Mr Gulshan Kapur who runs AES sounded deeply optimistic on the use of solar power for mobile telephony during my discussions with him. Seemingly, he is a reasonably pleased man today having erected more than 200 solar-powered systems for this specific application alone. However, it has not been a smooth sailing for him like many others in the PV business to convince the mobile operators about what all solar power was capable of doing. The uphill task of the past has now gradually paved way for such systems being in demand from the operators themselves. In turn, the solar companies are much too happy to offer their well-designed and reliable solar power systems. Table 2 depicts the key features of AEC-designed solar-powered operated mobile telephony sites at two village sites namely Dera and Budhla. This information may be more or less representative of similar sites elsewhere in the country.

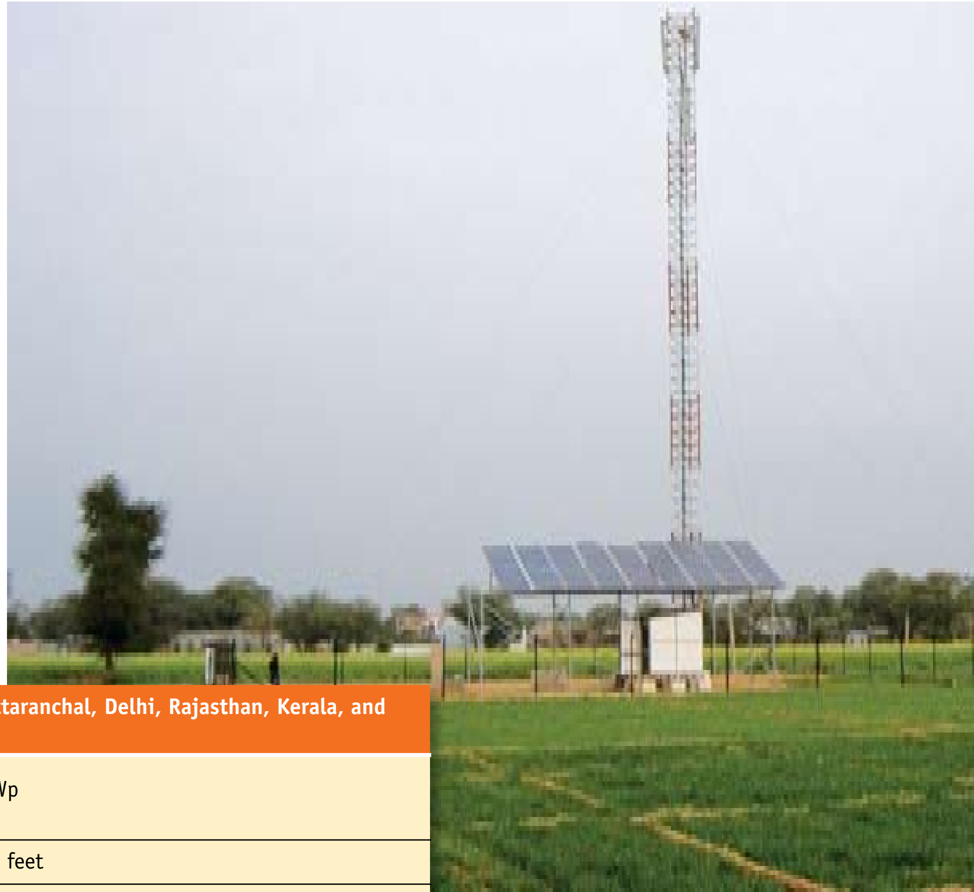

Table 2 Geographical spread of Haryana, Uttaranchal, Delhi, Rajasthan, Kerala, and Uttar Pradesh

Typical solar array capacity used	3000–4000 Wp
Foot print area required	~ 300 square feet
Key determinants of solar capacity	Location, volume of traffic
Expected hours of operation	12–20 hours on solar + battery (on a daily basis)
Reduced downtime of the diesel generators	2–6 hours/day from a near total dependence of about 20 hours/day
Modularity of the solar system	Solar power capacity can be increased in direct proportion to a higher load demand
Key operational features	• Feeds the load at the precise manufacturers defined bus voltage during the day time directly • Extracts the maximum energy from solar and ensures its full use by the load and the battery • Customized battery-centric algorithm takes care of battery charging and ensures full state charging of the battery periodically • The above feature guarantees full cycle life of the battery bank thus preventing its premature collapse
Outdoor performance	• These systems have been running trouble-free for the last two years

Market size: solar mobile telephony

The global market for rural base stations is estimated at $15 billion annually. It is currently growing in the range of

Budhla village site

15% to 20% per year. Incidentally, mobile equipment sales in the emerging markets are soon expected to edge past the developed market volumes. Premier cellular operators like Ericsson, Motorola, Alcatel-Lucent, and Nokia-Siemens Networks are presently building alternative energy-based (wind, solar, and biofuels) stations in the developing countries of the world. India for sure is one of the world's most mobile-demand-centric growth markets. Nearly 700 million people inhabiting the rural areas are waiting in the wings to get a mobile phone connection in India alone. Their dream may well be realized if the operators figure out a cheap way to set up the rural infrastructure.

The availability of grid is generally very poor in the remote areas of India. At present, there are approximately 250 000 cell sites, which are expected to nearly double within the next few years or so. Thus it signals a sizeable market opportunity for the use of solar power by transforming at least 70% of the existing DG-based sites. A big plus for solar power is that one does not have to worry about any rise in fuel prices.

Power that small

The use of solar power to run the rural mobile telephony system is still deemed as a costly proposition. However, it offers several advantages, such as on-site availability, over the diesel-based generators, which also means almost negligible T&D (transmission and distribution) losses. Telecom operators around the world are making all out efforts to bring down the power consumption of a BTS. VNL, an Indian–Swedish telecom company, has recently developed a new product, that is, solar-based GSM station. It is expected to address quite cheaply the ongoing needs and challenges in rolling out the mobile infrastructure into rural areas. This is evidenced by the fact that VNL base stations may need just about 50–120 W of power to operate in direct comparison to use of 3000 W for a typical GSM station. The system includes a rural-optimized MSC (mobile switching centre) and a compact BSC (base station controller).

Expected features of VNL's WorldGSM™ base stations

- Low cost: priced at less than a quarter of traditional GSM base stations and profitable at very low densities and subscriber revenues.
- Easy to transport: an entire WorldGSM™ base station packs into two carts and can be transported over rough terrain in something as simple as a bullock cart.
- Self-deploying and near-zero maintenance: can be assembled and activated by non-engineers.
- Small solar panels: the solar panels used are 2–8 m² and the power required is between 50 and 120 W as compared to the 200 m² solar panel and 3000 W required for traditional GSM base stations.
- Such base stations are inter-operable with equipment from most major equipment manufacturers and are thus compatible with all standard handsets.

Technology rethink at VNL

The conventional type computer chips finding use in the telecom equipment are often energy intensive to run besides being costly. In contrast, VNL took recourse to less energy-consuming chips generally finding use in the consumer electronics. The company has evolved an innovative version of the base station-one for the village centres recording higher voice traffic. The second version is intended for the surrounding field registering low traffic. An added feature is that the towers in the fields can be put in virtual sleep during no call mode to

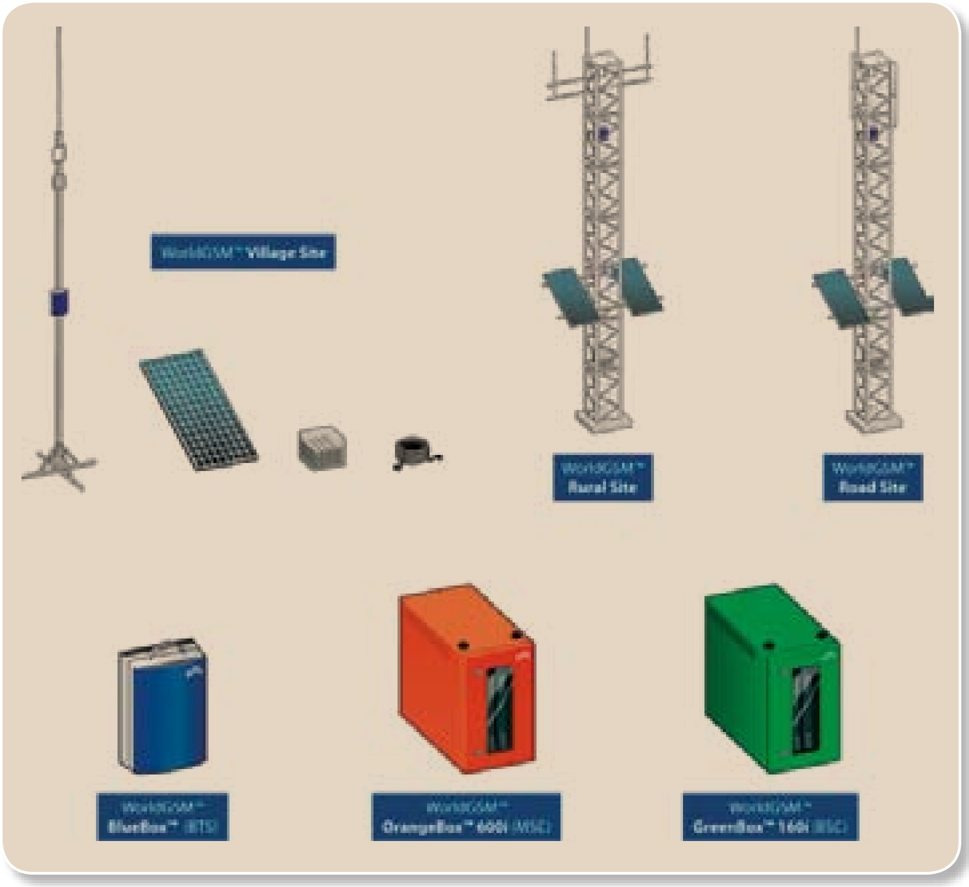

Figure 1 Schematic layout of a WorldGSM™ village site

in the commercial setup(s). One expects a multiplying effect of solar system usage for a variety of end-use applications across the country. Who knows this import dependent commodity, that is, diesel may finally be on its way out not only for this specific application, but wherever it is being used for charging batteries. Indian companies like Airtel are also expected to lap up this big development in a big way.

Conclusion

Solar-powered mobile telephony may set a record of sorts in the time ahead. However, what is equally needed is to care for the regular upkeep of such installations. The rural employment gain too seems to be in a clear line of sight, if, everything materializes in a time bound manner. The long-term alliance between solar system providers and mobile telephony companies is not an ill-founded perception either.

save power. Figure 1 gives a schematic layout of a WorldGSM™ village site.

The big gain in the offing

VNL is currently conducting private field trials with chosen few mobile operators at a few remote sites (photograph below) following a series of mail-based communication(s) from Mr Par Almqvist (Sweden) and Mr Suraj Chaudhary (New Delhi). A sizeable number of remote villages may get wired at little cost and in a quick time interval too. However, it would be quite necessary for the cellular operators to repose an early faith in this path-breaking technology initiative. Solar power may well receive a shot in the arm, if, what VNL aims for is realized

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SOLAR POWER

THE RGGVY CONNECTION

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Introduction

India's dream journey of attaining a developed country status by 2020 hinges around the capability to provide an uninterrupted supply of quality power to all. However, the hard fact is that remotely located villages and hamlets like the Karbi village Hambaing, riverine village Chalakurachar in Assam, the Korku village Kekedia in Khandawa district of Madhya Pradesh, the Santhal village Bhaliaguda in Mayurbhanj district in Orissa, Balihote village in Ramban district of Jammu and Kashmir or the densely populated Maheshpur village in the Sundarban delta have one thing in common. These villages offering all sorts of diversities otherwise plunge into darkness soon after sunset. Women here attend to household chores under the faint and choking light of a kerosene oil lamp. The children are unlucky to study under candlelight. That is not all. These people don't even venture out of their house after sunset fearing a possible attack from animals or snakes. So, everyone eagerly await the onset of an early dawn to begin their activities afresh. These villages' happen to be amongst the 25 000 inaccessible villages in the country yet be electrified. A good thing is that the sun can help light up their lives at night, thanks to solar energy being considered as an option under the NREP (National Rural Electrification Programme) of the Government of India. It is more popularly known as the RGGVY

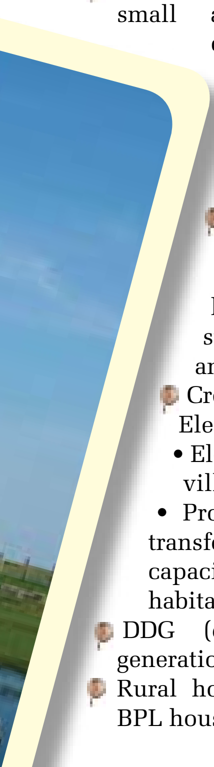
Wind hyprid plant at the Sagar Island, West Bengal

(Rajiv Gandhi Grameen Vidyutikaran Yojana).

Underlying objectives of RGGVY

Our country embarked upon an ambitious electrification goal in April 2005 with the launch of this innovative scheme. The government set a target of complete village electrification by the year 2009 and 100% household coverage by 2012. This entails electrification of 119 570 villages and providing electricity access to 78 million households. The RGGVY addresses mitigation of common ailments of rural electrification in the country often characterized by poor network, lack of maintenance, low load density with high technical and commercial losses, high cost of delivery and importantly, poor quality of power supply. Rural electrification is not the sole aim. The emphasis of RGGVY is also to facilitate the following things.

- Rural development
- Employment generation and poverty alleviation (by providing access to electricity for all rural households, inclusive of BPL households)
- Demand fulfillment of agriculture, small and micro enterprises, cold chains, health care, education, and IT sectors.



The broad scope of RGGVY includes the following.

- REDB (Rural Electricity Distribution Backbone), that is, provision of 33/11 kV (or 66/11 kV) sub-stations of adequate capacity and lines in blocks.
- Creation of VEI (Village Electrification Infrastructure)
  - Electrification of un-electrified villages and habitations
  - Provision of distribution transformers of appropriate capacity in electrified villages/habitation(s).
- DDG (decentralized distributed generation) and supply
- Rural household electrification of BPL households

Distributed generation at Gosaba Island, West Bengal

Programme implementation

RGGVY provides a capital subsidy of up to 90%, disbursed through REC (Rural Electrification Corporation) Ltd, which is a nodal agency for implementation of the scheme. However, electrification of BPL households is financed with 100% capital subsidy. The RGGVY's implementation process includes some notable features such as the following.

- Involvement of the CPSUs (central public sector undertakings) like NTPC, NHPC, PGCIL, and DVC for undertaking the creation of distribution infrastructure and village electrification
- Signing of tripartite (REC, state, and DISCOM) and quadripartite agreements (REC, state, DISCOM, and CPSUs)
- Appointment of franchisees for feeder management and revenue sustainability besides accountability of the executing agencies.
- Inclusion of the DDG programme for electrification of villages and hamlets where grid supply is not feasible.

RGGVY, in its third year of implementation, has achieved an impressive target of providing electricity distribution infrastructure in 52 313 un-electrified villages so far. As of 16 November 2008, electricity connections were provided to 38.24 million BPL households. However, it faces two critical challenges related to the following.

- Supply of electricity through newly created and/or upgraded distribution infrastructure
- Sustaining the franchisees being developed under the scheme and providing them with a mutually rewarding growth opportunity

Key concerns

Given the current and projected demand–supply scenario in the country, there are concerns about sustaining electricity supply to the rural areas. An accompanying challenge is to ensure the planned consumption of 1 kWh per household per day. Incidentally, even a dedicated generation capacity at the centralized level may not ensure the supply to its villages. However, a possible solution lies in the third component of the scheme, that is, DDG (decentralized distributed generation)

A power plant at Sagar Island, West Bengal

and supply. Despite a rich history of promotion of decentralized energy technologies in the country, especially renewable energy, the DDG component has been neglected during the initial phase of the RGGVY. It is owing to the following few reasons mainly.

- Limited experience of the mainstream power sector in using the DDG technologies for rural electrification
- Lack of an efficient network for supply and after-sales service
- Variation in renewable resource availability, and so on

However, one of the critical reasons appears to be a rigid mindset about RE promotion being in the sole domain of the MNRE (Ministry of New and Renewable Energy)/departments. Thus, it has restricted the market for RE-based DDG for rural electrification and also left the problem of 'last mile' connectivity in the RGGVY unaddressed. Last mile in the context of RGGVY refers to those villages where grid extension is currently not cost-effective or feasible.

Distributed generation: advantages galore

DG (distributed generation) is defined as installation and operation of small modular power generating technologies that can be combined with energy management and storage systems. The plain intention is to improve the operation of the electricity delivery systems at or near the end user. However, such systems may or may not be connected to the electricity grid. Following few are the key advantages of a DG system.

- DG units are modular in size and the modularity has two major advantages. First, units are standardized to common designs, site requirements, and operating methods. Second, modular units are available 'off-the-shelf', with little lead-time and at a standard price.
- The DG units are closer to the customers so T&D costs and losses are reduced.
- Most of the remote villages have low population density and so the energy need is in kilowatts, and not in megawatts. This makes the DDG systems best suited for such villages.
- The DG units may meet the actual needs perceived by the community and would match the financial risks the community may be willing to undertake.
- The RE-based DG technologies are generally without any environmental impacts.
- DG system also conforms to democratic principles. Simply put, the running of such systems requires participation of individuals and communities in greater numbers. Thus, RE-based DG is decentralized both in a technical and social sense.

There are many technologies, either based on the prime movers used such as engines, turbines, fuel cells or those based on the fuel source such as renewable and non-renewable, available for DG schemes. However, the solution to electricity access does not lie in selecting the best-suited technological option alone, but also in developing mechanisms for an effective delivery of its services.

Rationale for distributed generation

DG, decentralized or grid connected, could perhaps address many of the challenges, if mainstreamed in the planning and implementation process of RGGVY. The DDG programme under RGGVY is also relevant for India to cover 100% village and household electrification—all this to supply quality power at a more economical rate on cost to serve/avoided cost basis to the remote rural areas. Although renewable energy based DDG poses many challenges, it would still be a good alternative to supplement and complement the scheme in the following manner.

- Augmenting the electricity supply in electrified villages in order to achieve better healthcare, education, and community services.
- Providing dedicated power to livelihood activities such as food processing and rice hulling .
- Meeting universal service obligations by improving the household electrification level in electrified villages where households are scattered.
- Managing the periods of low demand.
- Providing electricity in de-electrified villages.
- Preventing de-electrification of newly electrified villages.

Why solar?

Solar energy can help to fulfill rural India's energy needs, particularly through SPV (solar photovoltaic) technology. PV is based on direct conversion of incident solar radiation into direct current electricity using silicon-based solar cells primarily. It offers the following few key advantages.

- System modularity.
- Zero fuel dependence.
- Availability at most locations.
- Low maintenance.
- Can be installed in any capacity.

India being a tropical country receives 5 trillion MW of solar energy, or about 4 to 7 kWh/m^2/day. It has an average of 250–300 sunny days for most parts of the year depending on site-specific factors. Further, PV is a matured technology with a robust learning curve behind it. Barring the cost issues, it is ready to take off on a massive scale to meet the rural electrification needs and so on in a varying measure. An additional benefit of its use comes through savings in carbon emissions. Further, PV installations can be located within short distances of the load centres to avoid the development of long-distance T&D networks. It can thus lead to lower system losses too. Expectedly, PV plants would also have applications in the future when demand outstrips the capacity of the T&D networks.

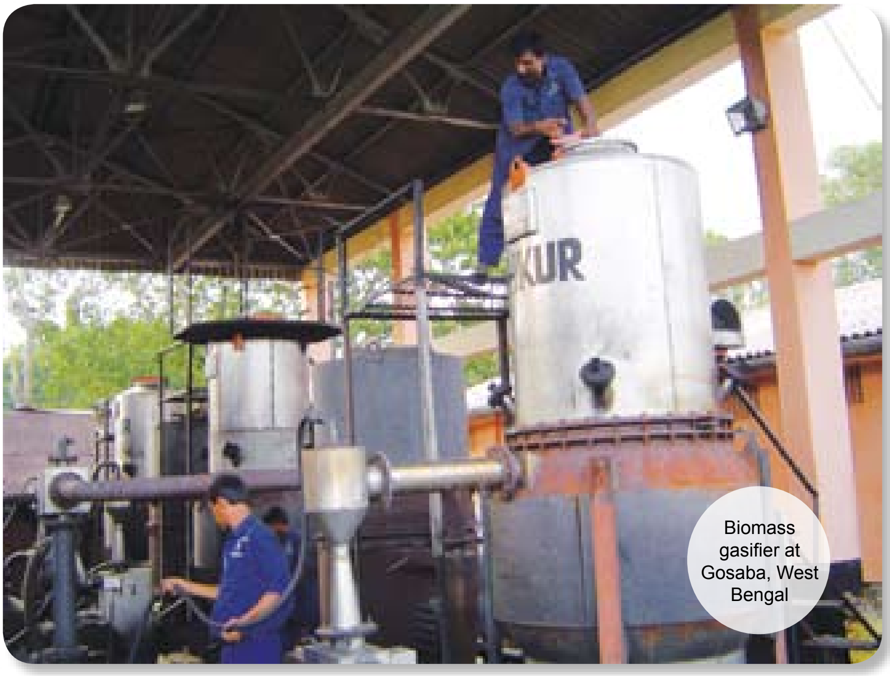
Solar power outreach

Solar power may be supplied through two basic distribution options, that is, village mini grids or isolated systems. The village mini grids, sourcing power from the centralized power plants, should definitely be a preferred choice. This is because it provides grid-quality power to the rural areas on the lines of electrification. The isolated option, that is, solar home systems could be an ideal choice for the very sparsely populated villages. Within these, the cost of laying the distribution infrastructure would be exorbitantly high in addition to facing high-line system losses. Thus, solar power plants with capacities up to 100 kWp can be an ideal choice for providing access to electricity in remote areas. In contrast, the larger capacity (more than 1 MW connected to the grid) can be considered to address capacity shortage issues.

Solar: not a failed field initiative

Globally, about 10 GWp of solar electricity has been installed for all the applications and for all customer types so far. Likewise, in India, 120 MWp of decentralized solar devices (such as off- grid power plants, home systems,

Wind hybrid power plant at Sagar Island, West Bengal


Biomass gasifier at Gosaba, West Bengal

streetlights, lanterns, and water pumps) and 2.12 MWp of grid-connected SPV power have been installed under different programmes of the MNRE. For remote village electrification, the ministry has been promoting the solar technology in the country through the state renewable energy development agencies. The best example of the solar technology for village electrification can be cited from the states of Chhattisgarh, West Bengal, and the Lakshadweep group of islands. A power plant of 6 kWp installed in 1992 in a village called Lamni in Chhattisgarh is still working successfully. The power plant of 10-kWp capacity in Sagar Island installed by WBREDA (West Bengal Renewable Energy Development Agency) in 1996 is continuing to supply electricity to its consumers. These villages have become a benchmark in the country telling the success story of SPV technology. CREDA is now providing electricity supply from SPV power plants to about 30 000 households of 632 villages and hamlets. In contrast, WBREDA has more than 15 functional solar power plants with an aggregate capacity of more than 1 MWp. These supply stable and reliable 400/230 V 3 phase 50 Hz electric power to the households, for domestic, commercial, and community requirements. Drinking water supply and streetlights, for 5–6 hours daily through mini grids are a few successful examples. These mini grids use state-of-the-art inverters and storage systems to ensure long life and reliable field performance.

Involving the user community

From a users' perception, it also has all the features of grid power supply such as sub-station, overhead LT lines, service connections, and tariff structure. These bring it closer to the conventional power supply. For example, in Sundarbans, the mini grids are operated by cooperative societies formed by the local people. These societies are mainly responsible for the following few things.

- Selection of consumers.
- Planning for the distribution networks.
- Tariff setting in consultation with WBREDA.
- Revenue collection from consumers and passing the same to WBREDA.

As per WBREDA, the revenue collected from consumers is sufficient to cover 100% of the operational costs in addition to about 20% of the capital costs of the power plant. As many as eight solar power plants with an aggregate capacity of 750 kWp are providing electricity in the Agatti, Amini, Andrott, Chetlet, Kadamat, Kalpeni, and Kavaratti islands of Lakshadweep group of islands. Similarly, many of the villages in the Ladakh region and north-eastern region of India are getting the benefits of solar lighting either from solar power plants or solar home systems depending on the topography of the village.

More recent estimates

The ISA (Indian Semiconductor Association) and NMCC (National Manufacturing Competitiveness Council) recently carried out a joint study on the Indian SPV industry. The economic estimation is based on a typical village in Rajasthan with about 50 households. In this case, SPV was found to be more attractive as an electrification option for a village at a distance of 12 km or more from the nearest substation. This inference is based on a current cost of SPV panel (that is, Rs 145/Wp; estimated based on primary survey of select SPV firms), and calculating the levelized cost of energy delivery to the village over a 20-year period. However, if, the cost of an SPV panel comes down to Rs 60/Wp, the viability of a solar-based DG increases. In such a case, a village that is even 5.8 km from the nearest sub-station would be served more economically by a stand-alone SPV system. Presently, the unit cost of power generation from a PV system ranges between Rs 12 and Rs 14. Presumably, fresh capacities being planned under the SIPS (Special Incentive Package Scheme) could bring down the cost to anywhere between Rs 4 and Rs 7 per kWh within the next few years or so.

The solar hybrid alternatives

The viability can be further increased if the solar project can be developed in a hybrid mode with other distributed generation technologies. These may include biomass gasifier, wind aero generators, micro/pico hydro or even conventional diesel engines depending on the resource availability at a particular location. The combination will also help in an optimal use of the other available renewable energy resources. Solar, because of its high cost, can be used to cater to the lighting or base load in

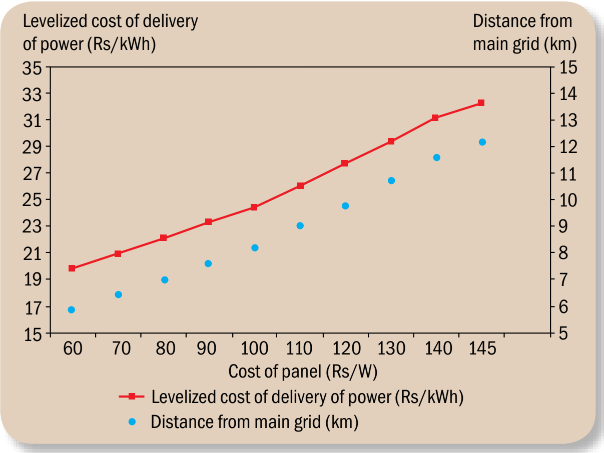


Figure 1 Variation of distance where PV becomes viable with decreasing panel cost
Source Study on Solar Photovotaic Industry: Global and Indian Scenerio. Indian Semiconductor Association - National Manufacturing Competition Council. 2008

the area. While as the other distributed generation technologies can be used for peak load such as local micro enterprise or irrigation pump sets for a particular duration. In one of the pilot projects in Sundarbans, Laxmijanardanpur village in Patharpratima block consisting of about 750 households is being electrified using a combination of biomass gasifier–SPV hybrid system along with a properly sized battery bank. It is envisioned to supply electricity from the hybrid system through a local mini-grid for about 12 hours for various applications including streetlights. About 200 households located on the periphery of the village and thus outside the reach of the LT network, will be given solar home lighting systems to meet their basic lighting requirement.

The capital cost of solar technology projects can be further reduced through use of upcoming lamp technology such as LEDs instead of the CFLs at present. Thus, capital cost can be brought down by 25%–30% because of reduced panel and storage capacities. Solar projects being clean technology projects also have an added benefit of obtaining carbon finance through bundling or programmatic CDM to increase its viability.

Accruing gains via solar-based DG

Even as a pre-electrification option, solar-based DG would be a viable option on account of the following.

- In a time span of five years (say) till grid comes to the village, a 10-kWp solar project would have generated about 75 000 kWh of electricity, (about 15 000 kWh per annum) or would have saved 75 000 kWh of electricity, which can be used by the utility for some other applications.
- If units thus saved are used by the industry which currently depends on diesel genset, it would amount to savings of about 25 000 litres of diesel fuel.
- At the end of five years, if the grid reaches the village the plant can be (a) synchronized with the grid and for feeding electricity to the grid and also provide tail end voltage support to the grid; (b) used as a DSM option to run some dedicated loads; or (c) can be shifted to an alternate site where grid is not available.
- In a time span of five years, the solar power plant would have facilitated creation (or growth) of loads that would enhance the viability of grid extension in the future.
- In a time span of five years, the cost to the society and to the nation of not having an opportunity for socio-economic development would justify the investment on the solar project today.
- Being modular in nature, the capacity can be enhanced for any additional load that may develop within the five-year time-frame without actually losing money for dismantling any old equipment or on a distribution network.

The way forward

RGGVY works on a cost recovery approach for which true cost to serve needs to be correctly estimated. The implementation strategy for SPV projects should be based on the cost to serve/avoided cost basis. If investment decisions are made on the basis of cost to serve figures, grid extension may not be found viable in many of the remote villages in India. Bundling of other service delivery and establishing linkages with other developmental and entrepreneurial programmes can further enhance the revenue sustainability of such projects.

Project developers from both the private sector and NGOs can be involved for putting up DDG projects. Instead of a direct capital subsidy, annualized subsidy/incentive could be provided to the project developers based on actual generation from the projects. The project may be given to the lowest bidder and also ensure the subsidy for a minimum number of years. This will require concurrent monitoring and actual tracking of annual generation in such remote areas. Advanced inverter technology and remote monitoring using GSM platform can be utilized at a nominal incremental project cost. The project developers can take an overall responsibility of implementing and operating DG projects and the existing franchisee role can be extended to the DG project. This way, a franchisee gets benefitted by adding more energy services to its portfolio besides undertaking routine O&M.

The opportunities have to be seen not only from the point of view of rural electrification but in the larger context of sustainable development of the country. India may thus attain the much-needed energy security in the process.

Storage batteries in a PV power plant

ECONOMICS OF SOLAR ENERGY TECHNOLOGIES

a life cycle cost analysis of solar cooking and solar water heating systems within NCT of Delhi

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Background

Energy is one of the most critical components and thereby a prime agent in the generation of wealth. It is also a significant factor in the economy for ensuring sustainable development. The production and consumption of energy is quite often linked to other major issues including poverty alleviation, environmental degradation, energy security, and pricing. The extraction, conversion, and utilization of fossil fuels, especially during the last century, have led to serious environmental degradation. Being a tropical country, India is blessed with good sunshine over most parts. Accordingly, the number of clear sunny days in a year is also quite high ranging between 250 and 300. The country receives solar energy equivalent to more than 5000 trillion kWh/year, which is far more than the total annual energy consumption of the country. The daily average global radiation is about 5 kWh/m^2 in northeastern and hilly areas to about 7 kWh/m^2 in western regions and cold dessert areas with the sunshine hours ranging from 2300 to 3200 per year. The annual solar radiation varies from 1600 to 2200 kWh/m^2 over the country.

Solar energy utilization

The abundantly available solar energy can be put to wide ranging uses. Typical examples of solar thermal energy applications are cooking, water and space heating, drying of agro-produce and food, water distillation, industrial process heating systems, and fast emerging power generation. Out of these, solar-assisted water heating and cooking constitute most widespread applications. In this study, the economic viability of solar cookers (box-type) and solar water heaters has been studied for the NCT (National Capital Territory) of Delhi using an

LAC (levelized annual cost) approach. LAC generally includes the annual O&M (operation and maintenance) cost for a technology in addition to annualized capital costs (that is, capital cost converted into a series of uniform payments).

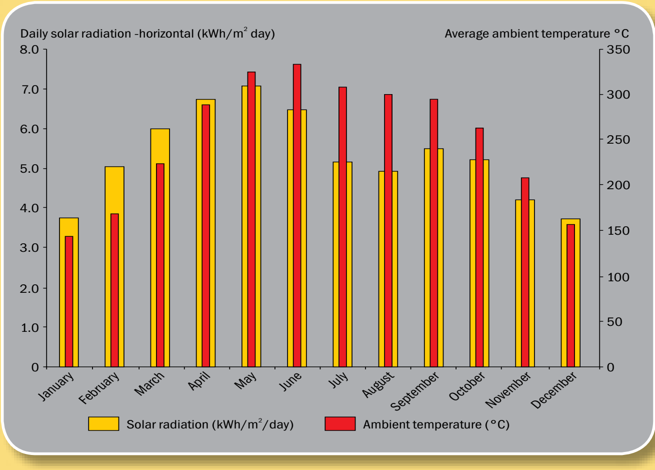


Figure 1 Solar radiation over New Delhi

Case specifics

The geographical area of NCT is approximately 33 578 km² (square kilometres). Within it, the monthly average daily radiation on horizontal surface varies from 3.75 kWh/m²/d (in January) to 7.08 kWh/m²/d (in May). The annual average solar radiation over the region is 1939 kWh/m², which is equivalent to an annual solar energy availability of about 65 million GWh. Assuming 10% utilization of the area with 10% efficiency of solar energy system, 650 000 million units of electricity can be generated. This is equivalent to an installed electric power capacity of 93,000 MW with 80% PLF. The current power and energy demand of the Delhi NCT is about 3722 MW and 21602 MU respectively.

Methodology for calculating LAC

The levelized annual cost (LAC) in Rs/kWh can be defined as;

$$LAC = \frac{\text{Annual costs incurred (Rs/year)}}{\text{Annual useful energy produced (kWh/year)}} \quad (1)$$

The annualized costs can be estimated as;

$$\text{Annual costs} = I(C) \times CRF + OMRC + FC \quad (2)$$

where I(C) represents the capital investment which is a function of the capacity C of the system, CRF the capital recovery factor, OMRC the operation, maintenance and repair cost and FC the annual fuel cost.

The CRF (capital recovery factor) is obtained as

$$CRF = \frac{r}{[1-(1+r)^{-OL}} \quad (3)$$

where r represents the marginal return rate and OL the operating life in years. The annual fuel cost (FC) is given as

$$FC = UC \times W \quad (4)$$

where UC and W represent unit cost of fuel and annual fuel consumption respectively. The annual useful energy production is estimated as following

$$UE = \eta \times W \times CV \quad (5)$$

where η is the efficiency of the device, and CV the calorific value. Hence

$$LAC = \frac{I(C) \times CRF + OMRC + UC \times W}{UE} \quad (6)$$

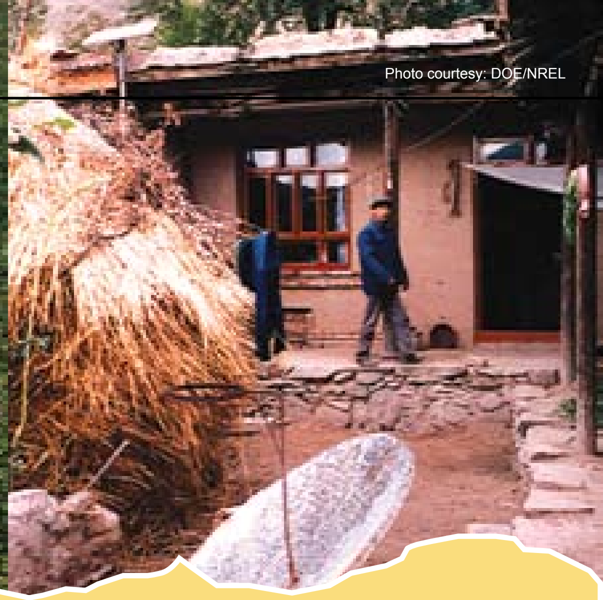
or

$$LAC = \frac{I(C) \times CRF}{UE} + \frac{OMRC}{UE} + \frac{UC}{\eta \times CV} \quad (7)$$

The last term of this equation is the energy cost, and is generally independent of the size of the device and intensity of use. The LAC method will now be applied to cooking and water heating in the following sections.

Photo courtesy: DOE/NREL

Photo courtesy: DOE/NREL



Cooking

We have identified three cooking options namely LPG, electricity and solar cooker. The initial cost of electrical heater (plate type) and LPG system is taken as Rs 300 and Rs 2400 respectively.. The cost of box type solar cooker is also taken as Rs 2400. The useful life of these options has been taken as 5, 20 and 10 years respectively. Table 1 shows the values of CRF and LAC based on these figures taking into account the standard values of associated parameters in above methodology.

Table 2 LAC values and corresponding values for electricity operated water geyser

	LAC (without subsidy)			LAC (with subsidy)			
System	25%	50%	100%	25%	50%	100%	Remarks
Solar water heating	1.43	2.86	5.71	1.07	2.14	4.28	Solar water heaters are cheaper in comparison to electric geysers both for 50% and 100% usage
Electric water geyser	4.73	5.02	5.59				Very little change from 25% to 100% usage in view of electricity cost dominance on LAC

Table 1 Values of CRF and LAC

Fuel option	CRF	LAC (Rs)	Remarks
LPG	0.134	4.45	Obviously LAC for electricity is almost twice in comparison to other two options
Electricity	0.277	8.13	
Solar cooker	0.177	4.52	

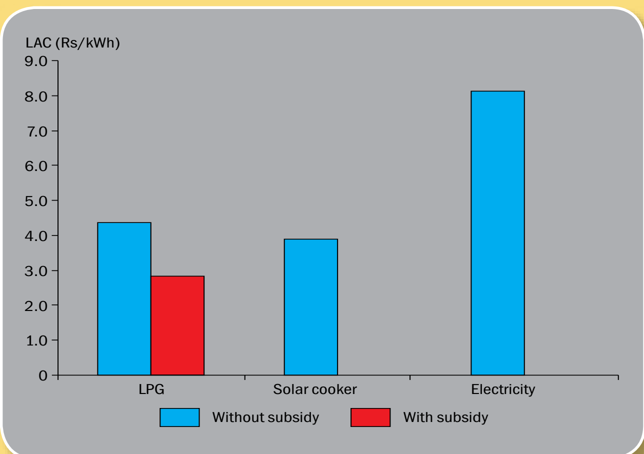


Figure 2 LAC of cooking using LPG, electricity, and solar energy

Impact of Subsidy

As per the existing government policy, LPG use is subsidized in India. The quantum of total allowable subsidy is Rs 178 per cylinder. It thus translates into LPG specific LAC of Rs 2.90 per kWh. As against this, there is no subsidy on use of box type solar cooker. Figure 2 shows various costs on this front. It can be seen that solar cooking cost is comparable with that on LPG cooking. This leads to an important recommendation of expanding the use of solar cookers in NCT with a twin objective of reducing the LPG consumption and providing some relief to the customers. Provision of any subsidy on solar cookers (either to the manufacturer or user) will reduce the LAC further. Pertinent to mention here that near total absence of solar cookers within NCT needs to be replaced by some fresh manufacturing cum marketing efforts.

Water Heating

Solar water heating systems find wide application in large establishments such as hostels, hotels, hospitals, industries (textile, paper, food processing, and so on). These are also used though in a limited way in households and swimming pools. As per the climatic zones classification, entire NCT region comes under the composite climatic condition. It effectively means just a seasonal requirement for water heating. The present study estimates LAC in respect of electricity and solar water heating systems as under.

A domestic water heating system of of 100 litres/day capacity has been taken as a base-case for economic analysis. Its initial cost has been taken as Rs 20 000 with 2% O&M cost and having 15 years of useful life. The CRF has been obtained as 0.117. It is well known that the hot water use pattern in different climatic conditions is not similar. Therefore the LAC has been obtained under 25%, 50%, and 100% use of the solar water heater over the year. Accordingly, LAC has been obtained as 1.43, 2.86, and 5.71 under 25%, 50%, and 100% utilization conditions respectively. The Govt. of India provides 25% subsidy for commercialization of solar water heaters in the country. Table 2 shows the LAC values (with subsidy) and the corresponding values for electricity operated water geysers.

Expanded use of solar water heaters is expected to result in lower electricity bills and peak load in Delhi too. The estimated peak load due to water heating is approximately 3000 MW in Delhi NCT. However, the use of solar water heaters is abysmally low in Delhi. Predominant reasons for the low market penetration of these heaters could be the following:

- lack of design specific innovations
- poor marketing efforts
- subdued awareness (amongst potential customer segments)

This is despite the fact that Delhi government is offering a rebate of Rs 6000 per domestic water heaters for instance. So, major effort needs to be launched to promote solar water heating systems in Delhi NCT.

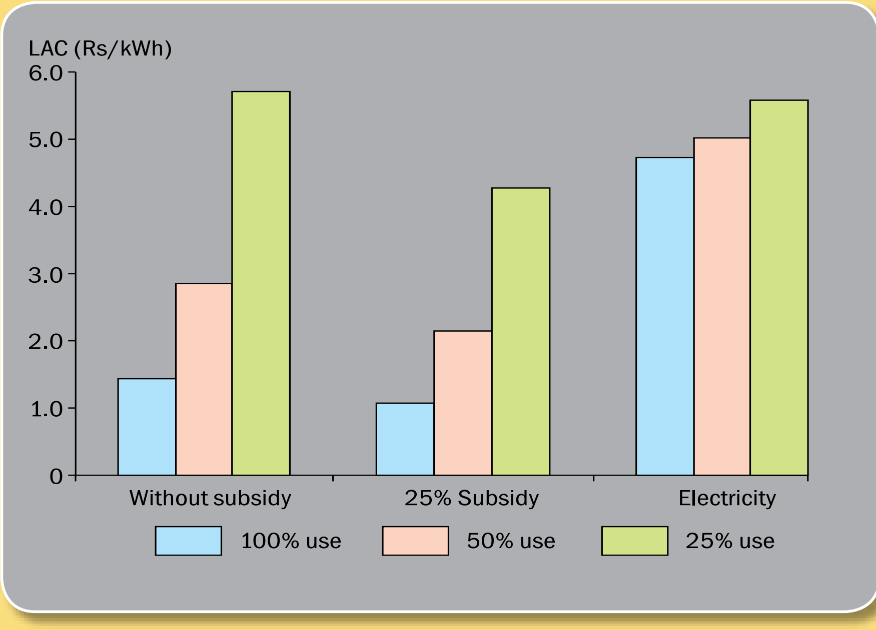


Figure 3 LAC of water heating using electricity and solar energy (with and without subsidy)

Conclusion

Life cycle costing methods (as above) show that both solar cooking and solar water heating are economically viable as compared to conventional methods. Thus path breaking initiatives are needed to fully popularize the use of these solar assisted applications amongst the potential customer segments. In turn, it will result in sizeable environmental and economic benefits.

Thriving on a Wide Solar Lighting Initiative

Dr Ranganayakulu, President, Thrive
<rangathrive@yahoo.com>

Introduction

Worldwide, more than two billion people have no access to electricity. In countries like Afghanistan and Cambodia, only 6% and 20% of the population, respectively, is connected to the grid. The universal distribution of electricity is not economically feasible over the plains and mountains of Africa, Asia, and South America due to various geographical reasons. In India, 95% of the households in Bihar, 80% in Orissa, 53% in Chhattisgarh, and 47% in Uttaranchal use kerosene for lighting. These communities have to make do with antiquated sources of light like candles or kerosene lamps. For example, a household probably spends at least $4 a month for kerosene at $1.25 per litre for lighting. It is usually of low quality, unreliable, and a health hazard too. The supply of kerosene is often seasonally limited, imposing even more hardships on households. Simple tasks of life like studying, cooking or sewing or profitable home-based employment such as weaving cannot be performed efficiently with kerosene lamps. Kersosene-based cooking is 80% as against lighting efficiency of just 5%–7%. Table 1 shows the distribution of households by source of lighting.

Thriving initiative from THRIVE

THRIVE (www.thrive.in) is an NGO founded by a group of professionals under the Indian Societies Act in 2001 to work for the benefit of rural and tribal communities. The key work areas include home lighting, ICT, education, and health using advanced and innovative technologies. Thrive has a strong belief in action-based rural research projects vis-à-vis ICT, water-conservation, energy conservation, ecology development, rural connectivity, and livelihood training.

The LED connection

Hamlets and villages that are without electricity or suffer long power cuts, can get benefits

Table 1 Distribution of households by source of lighting

Source of lighting	Total	%	Rural	%	Urban	%
Total	13 982 590	100.0	12 660 007	100.00	1 322 583	100.0
Electricity	14 33 477	10.3	649 503	5.1	783 974	59.3
Kerosene	12 488 085	89.3	11 960 569	94.5	527 516	39.9
Solar energy	40 700	0.3	35 228	0.3	5 472	0.4
Other oil	7 648	0.1	5 799	0.0	1 849	0.1
Any other	6 973	0.0	5 244	0.0	1 729	0.1

Source Census of India 2002

Table 2 Distribution of households by source of lighting

Source of lighting	Total	%	Rural	%	Urban	%
Total	4 862 590	100.00	3 802 412	100.00	1 060 178	100.0
Electricity	1 181 628	24.3	379 987	10.0	801 641	75.6
Kerosene	3 660 073	75.3	348 058	89.6	252 015	23.8
Solar energy	10 333	0.2	7 965	0.2	2 368	0.2
Other oil	4 961	0.1	3 199	0.1	1 762	0.2
Any other	2 695	0.1	1 685	0.0	1 010	0.1

Source Census of India 2001

after sunset under a brighter, healthier, clean, and much more affordable light. It helps children to study, village tradesmen to work for more hours, and women to do more productive work.

THRIVE has worked over the last five years to develop its uniquely designed LED home light. This also takes care of the procedures for the installation and maintenance for the benefit of poor people across Asia and Africa. THRIVE has excellent technical and financial specialists, as well as a strong network of social entrepreneurs, NGO leaders, and senior energy experts. They are committed to witness a social transformation through reliable home lights to millions of the needy. The product is of high quality and has already won the World Bank and United Nations award for technology innovation in May 2006. This has fuelled a huge demand for the LED lighting systems. THRIVE has been organizing this kind of lighting arrangement in Orissa, Andhra Pradesh, Maharashtra, Cambodia, Afghanistan, Kenya, and others.

Product specifications

The lighting unit uses a 6-volt, 4.5-ampere maintenance-free battery housed inside. It is charged either from the grid or by a small 2.5-watt solar panel. The light uses state-of-the-art LEDs operated by a micro-processor-based proprietary circuit for 60 hours plus. It effectively means almost a month-long operation of 2–3 hours per day. The lumen output ranges between 80 and 220 lumens based on the model and capable of illuminating a 10 × 12 square feet/metre room very effectively.

CFL vs LED initiative

Governments in various countries have tried solar-based CFL lanterns, of varying cost, but often subsidized at 100%. The MNRE has so far disseminated a total of 697 419 solar lanterns alone during the last 24 years but succeeded in meeting the lighting requirements of only 0.34% of the needy. The solar, CFL-based lanterns seem to have the potential of helping millions. However, it has just been able to supply a few hours (3–4) of light every day with a single solar charge.

Rationale for LED lighting

THRIVE's LED-based light solves all the above problems in a genuine manner by offering the following features. It works for a long duration – almost a month – with one charge. Further, it is a very reliable LED assembly and is delivered in partnership with local NGOs through the village entrepreneur. He provides quality service at a nominal price. THRIVE works on the premise that the light has to work 12 hours a day 365 days a year and has built a product and service line to meet this objective. Sufficient supply of spare lights and replacement parts is always ensured by the village entrepreneur. The THRIVE light and the business model it developed won the World Bank DM 2006 award and is being implemented in Koraput district of Orissa.

Direct social gain

Just think of the following numbers, which are proof enough of a possible huge impact from LEDs.

Targeted users	**Needy rural people**
Number of lights for distribution	10 crore (100 million)
Expected gain in productivity per light	Rs 10 per day
Financial gain (likely to accrue)	Rs 365 million
Level of investment needed	Rs 40 000 million
Expected savings on use of kerosene subsidy	Rs 250 000–Rs 300 000 million

- Number of increased study hours available for children.
- Number and type of activities adults are able to carry out using the light.
- Percentage of improvement in family incomes through additional work hours and savings over the use of other lighting methods.
- Percentage reduction in kerosene pollution.
- Improved health of the family through reduced pollution.

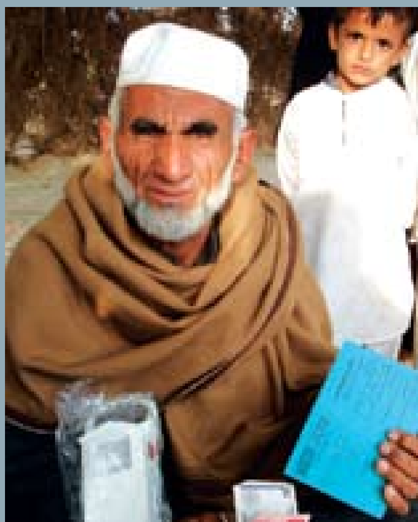
Till now, THRIVE lights have benefitted nearly 1.6 lakh people and most of them are poor or tribals. The approach is to undertake simple studies, observations, and hear from focus group discussions. The images above are drawn from practical applications of our light as put to use by the community.

- Friend's Interest (Mozambique)
- Solar Enthusiast (Sierra Leone)
- Member of Parliament's Political Ambition (Kisan Mahasabha)
- Millennium Village Projects (Columbia University)

Solar initiative with a difference

Village energy kiosk as the key to sustainable home lighting in villages

Solar lanterns have generally been supplied in the last 10 years by government and its agencies to end users without any sustainable supply chain management system like training, maintenance, warranty, back up, and MIS. This results in users themselves (many users are illiterate, women, and some times old) spending their full day to charge. However, they



It is important to mention here that this subsidy keeps growing with the rising prices of petroleum products.

Measurable parameters

THRIVE has been actively involved in a result-oriented activity to measure the following indicators.

- Number of households provided lighting.
- Number of youth trained as entrepreneurs.
- Percentage increase in the entrepreneur's income.

Replicability

THRIVE today has a wide geographical outreach catalysed mainly due to various support organizations/groups around the world. These include the following.

- UN (in Afghanistan)
- UNIDO (in Kenya): for consulting
- Jindal Steel (in Jharkhand): under their Corporate Social Responsibility scheme
- Competitve Awards (in Africa [Kenya]): for lighting
- Donors Interest (Rwanda)

fail to undertake even the minor repair and proper care. Thus, the users miss the facility of light especially during the times of unfavourable weather thus finally losing faith in these devices. THRIVE proposes alternative energy kiosks in each village where a user can walk in and get the light charged for a token fee and thus enjoy continued service. THRIVE has won the lighting Africa award of the World Bank and IFC.

THRIVING on programmes

THRIVE, through successful implementation of lighting project (after the development market place award in 2006), convinced the World Bank group about this particular technology, method of implementation, and its future. This has (along with all other work) now led to a large lighting Africa project by the World Bank group. THRIVE worked with Unama in Afghanistan and successfully implemented a pilot project in 4000 homes. If donors spend few million dollars on light along with the billions on highways and marble parliaments, every Afghan can have light.

- THRIVE at present is working in Kenya with UNIDO for the large-scale deployment of energy kiosks through micro hydro.
- THRIVE is now an active member of lighting Africa and it has won the award for developing lighting entrepreneurs in east Africa.
- THRIVE has been working with various NGOs in India, GRAM VIKAS, ANKURAN in Orissa, Kisan Mahasabha in Jharkhand, Malghat mitra, Vigyan ashram in Maharashtra, SEWA in Gujarat, and CCN in Visakhapatnam to name a few.
- THRIVE is now working with the Government of Andhra Pradesh (social forestry department) on a rural poverty alleviation project in a small way but is making efforts to reach the larger government initiative.
- THRIVE has been working with Jindal group in lighting up the villages near their operations in Jharkhand and has got enquiries from other mining companies in Orissa and Chhattisgarh.
- THRIVE has worked with a simple slum-based organization in Hyderabad.
- THRIVE is now focusing on micro finance agencies like SKS and Basix which have a large base and also envisage a major customer requirement.

THRIVE feels this segment and the kind of financing approaches can give the scale that is required for this kind of work.

The social entrepreneur

THRIVE is quite optimistic about ridding people of their age-old darkness

KEY LESSONS LEARNT

Some of the lessons THRIVE learnt in six years of LED light implementation are given below.

- **Poor people need the best quality light to last for at least three years (they are not rich enough to pay for cheap things)**
- **This light is not for emergency purpose, but almost like your companion for 12 hours of the night**
- **The user needs to pay for the light (only then does he feel like owning and caring the light) we must remember he is already paying a lot for the kerosene light.**
- **There should be a supply chain for the maintenance of the light right upto the village level (even if, you make the best light on the earth, still it might fail)**
- **It is much easier or cheaper and better to pay 10 cents for charging from a village level entrepreneur) rather than losing about $2 of productive day for an effort to charge (and protecting your assets in an open sky with solar panel and light)**
- **With a single charge, the light needs to work at least for a week (not just 3 or 4 hours) so that it runs in rainy/cloudy days. This way they need not fall back on kerosene use.**
- **One light is just not enough for the family. It needs one more for kids to study and other uses.**

by offering them a simple and cleaner solar-based LED technology. It may for sure help in achieving the following few major social objectives.

- Increase the poor people's income in remote villages.
- Raise their self esteem and confidence.
- Generate employment opportunities for about one million youth, who will be trained in the system maintenance aspects, and so on .

THRIVE can act as a big agent of change by being simple implementers, voice makers, and demonstrators. It, along with technical friends, floated a commercial arm THRIVE ENERGY TECHNOLOGIES PVT. LTD in February 2007.

LEDs: a great lighting promise

Companies like OSRAM have already unveiled a 200 lumens per watt white LED. It means that THRIVE's best light will be three times brighter. This kind of LED light product is able to give a large amount of luminance and lasts about a month with one charge. It becomes a simple business proposition for the hundreds and thousands of small and big organizations that will take this light to every nook and corner of the world.

THRIVE Project in Kenya

The significant objective of this project is technology transfer and development of local entrepreneurs in LED-based home lighting. The intention is to create micro, small, and medium energy service enterprises to manufacture, sell, and service LED lamps. This project aims at developing about 10 entrepreneurs who will manufacture LED lights in Kenya and help install them in as many as 25 000 homes with the help of small local businesses within specified periods of time.

Carbon credits

THRIVE has been approved by the GEF (Global Environment Facility) for its unique LED light programme.

In India the kerosene subsidy is approximately Rs 75 a month for three litres (Rs 900 a year) for each family. With just one year's kerosene subsidy equivalent THRIVE can supply a long lasting LED home light to each family and includes charging the batteries for a year. THRIVE LED Home lights consume about 0.6 watts and are nearly equal in luminance to a 25-watt incandescent light bulb or a 11-watt CFL lamp, saving about 90% of energy.

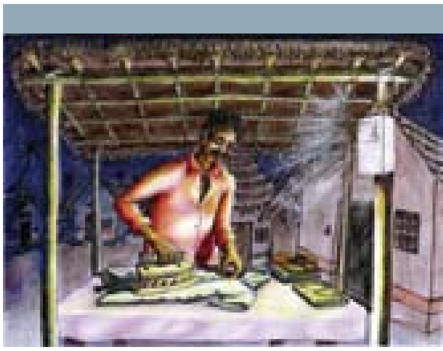
Compared to a kerosene lamp, using an LED light saves one tonne of carbon emissions over 3–4 years, which equates to $30 of gold standard carbon credits. Therefore, 10 million LED lights would save 10 million tonnes of carbon emissions, which would equate to $300 million.

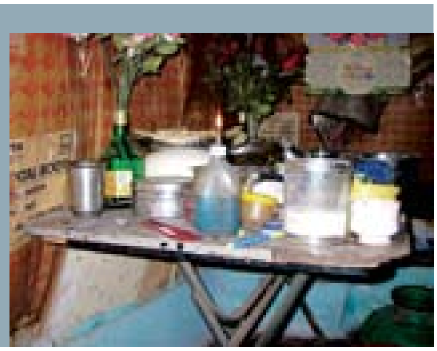
Urban slum lighting

People continue to migrate from small villages and towns to urban and semi-urban areas in search of livelihood. Many of them succeed in getting so, but manage to live in slum like structures. Greater Hyderabad alone has around 300 000 hutments that need a light like this. Surely, THRIVE can bring cheer to their otherwise dark lives.

FACTS ABOUT THRIVE

- **THRIVE, India is an action research organization based in a rural area of India. THRIVE has six years field experience in LED-based lighting.**
- **THRIVE has developed village energy kiosk concept, which is employment linked and maintains the supply chain of the LED lighting.**
- **THRIVE uses state-of-the-art micro controllers in its lights to conserve power, increase efficiency, and last long**
- **THRIVE believes in expanding the knowledge of LED lighting to NGOs, institutions, and entrepreneurs**
- **THRIVE through innovative develop niche products to help disadvantaged sections like, fishermen, weavers, fruit gatherers, dairy farmers, and street vendors**
- **THRIVE worked and networked a team of technicians working in plastic moldings, battery manufacturing, electronics, village entrepreneurs and others to bring about the best lighting products possible.**
- **THRIVE till now has benefited nearly 150 000 community with 42 000 lights.**





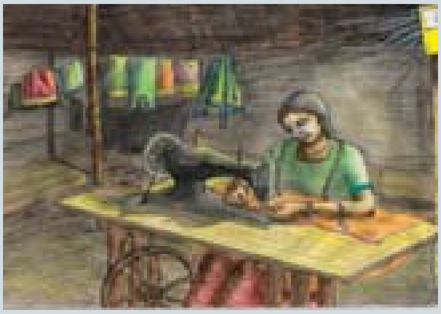
THRIVE LED Home Lights
User FAQs

How is THRIVE light charged?
The light can be charged either through solar energy, using a solar panel or through electric energy using a power connection.

How many modes of lighting does the THRIVE light have?
It has three modes of lighting: bed light mode, reading light mode and bright light mode.

How often does the THRIVE light need to be recharged?
A fully charged light is sold to you; it needs to be recharged only after 500 hours in bed light mode, 70 hours in reading light mode and 30 hours in bright light mode.

Can the THRIVE light be used with the charger connected to it?
The electric charger or the solar pin needs to be disconnected from the light before using it.



How many hours does it take to fully charge the THRIVE light using electricity?
It takes 5 hours to fully charge the light.

How long does it take to fully charge the THRIVE light using the solar panel?
The solar panel needs 10 hours of exposure to sun light, while being connected to the light, to be fully charged.

Is the THRIVE light affected in any way if continuously left charging to either an electric charger or a solar panel?
The light is not harmed in any way if continuously left charging to either an electric charger or a solar panel

Where should the solar panel be fixed?
The solar panel should be fixed at a place where it is best exposed to maximum sun light.

Where should the THRIVE light that uses the solar panel for charging be placed?
The light can be always connected to the solar panel by means of an extended wire and placed at any place within the house.

Should the THRIVE light that uses the solar panel for charging be always connected to the solar panel?
It is advisable to always have the light connected to the solar panel during the day and unplug it for use during night.

How does one know that the battery is low?
The red light indicator comes on when the battery is low and the light shuts down.

Is there any way the user can still use the light after the red light indicator comes on for the first time?
The light can glow in the reading light mode for a further 20 minutes, after the first time the red light indicator comes on and the light shuts down; the light can glow in the bed light mode for a further 10 hours, after the first time the red light indicator comes on and the light shuts down

How often does the battery need to be replaced?
The battery will last for 3 years before needing replacement

What are the specifications of the THRIVE light battery?
It is a very commonly available 6 Volts 4.5 Amps lead acid battery.

How can one replace the battery?
The battery can be replaced by sliding open the plate located at the bottom of the light, removing the old battery and replacing a new one.

Can the old battery be exchanged?
The old battery can be exchanged for a new one at no cost if deposited with THRIVE

Is there a specific voltage specification with which the THRIVE light can work?
The light can work on voltages specific to the USA and India. It can also work on very low voltage that exists in village power systems.

What would be the monthly expenditure that one would incur by using one THRIVE light in a household?
If the light is used for 4-5 hours a day, the electric power cost (metered) is around 30 paisa a month for charging the light.

Can a water spill over the THRIVE light damage the light?
An accidental water spill cannot damage the light, but if the light is immersed in water for a prolonged period, it can damage the circuit; the circuit can be repaired at our customer care centre for less than Rs100.

SOLAR PV INDUSTRY making waves globally*

Report by the **India Semiconductor Association**

The RE (renewable energy) sector around the world, including India, is developing rapidly. Solar is one of the major growth segments globally catching almost 30% of the total RE investments. The Indian solar industry, which is gradually evolving, holds huge potential. But the pace at which it is growing does not compare with global standards. One of the main reasons for this is the lack of adequate investments in SPV (solar photovoltaic) manufacturing and R&D in India. There is an urgent need to facilitate and enhance investment in SPV manufacturing in India. This would enable the domestic SPV industry to provide cost-effective and sustainable solutions within the domestic market and compete with the rest of the world. The present study has been carried out with the intent to provide the requisite background for investment in this sector.

The study provides a broad overview of the SPV market globally and in India. It provides the current status and future trends in SPV manufacturing, technology, R&D, market dynamics, commercial and financial aspects, and government policies and market drivers in leading countries in this area, namely, Germany, Japan, and the USA. The study also identifies key market segments where SPV can be implemented and evaluates the market viability and the size of these market segments. Based on these analyses, a set of recommendations has been put forth to enhance the growth and competitiveness of the Indian SPV industry.

Solar PV industry: the global scenario

The SPV industry is the fastest growing area in the energy sector and is expected to grow four-folds by 2011. In 2007, of the $71 billion invested in new renewable energy capacity globally, 30% was in SPV alone. The main factors holding back an even faster rate of growth for this energy source is the high cost of energy production and lack of adequate supply of basic feedstock particularly polysilicon. The shortage has caused polysilicon prices to go up from an average of $20/kg in 2001 to over $50/kg in 2006 for long-term contracted supplies and prices for on-spot supplies is much higher.

On the other hand, the shortage has pushed for higher efficiency in production and the introduction of new SPV technologies, that is, thin-film technology. In 2007, there was an increase in the volume of polysilicon available globally by 30%. However,

* This has been reproduced from a report by the ISA supported by National Manufacturing Competitiveness Council

access to adequate polysilicon supply remained the main bottleneck for growth of the SPV industry. The global silicon feedstock capacity servicing the SPV as well as the semiconductor industry was up from 38 000 TPA (tonnes per annum) in 2006 to 52 000 tonnes in 2007. Currently, polysilicon manufacturing is dominated by seven major players in the US, Japan, and Germany. However, after seeing the huge demand for SPV, a large number of new players have entered or are set to foray into this space. There are reports of a few major silicon-manufacturing initiatives coming up both in the public (BHEL–BEL and private sectors).

Photo courtesy: DOE/NREL

The global wafer manufacturing capacity grew at 60% in 2006 (over 2005) and 73% during 2007 (over 2006). The market for silicon wafers has been dominated by multi-crystalline with a share of almost 54% in 2007. One of the key shifts occurring in wafer manufacturing is the emergence of China and Taiwan as major players in the near future. Presently, more than 50% of the installed capacity for wafer manufacture is based in these two countries. Global PV cell production grew by 55% during 2007 (over 2006), with both mono- and multi-crystalline losing ground to thin films, though gradually. The five largest SPV cell-producing countries were Japan, China, Germany, Taiwan, and the US. Recently, China has emerged as a major player in cell production, displacing Japan as the second-largest producer of SPV cells in 2007.

Concurrently, thin-film technology has evolved with a substantial increase in capacity since 2005 (at almost 80% in 2006 and more than 100% in 2007) due to polysilicon shortage. In the thin films market, significant expansion is expected in future and some of the main players lining up are First Solar (cadmium telluride) and Sharp. Both hope to have a thin-film capacity of 1 GW by 2012. In recent times, the geographical focus of SPV manufacturing has shifted towards developing countries, especially China, India, Malaysia, and Taiwan. It is expected that by 2011/12, a sizeable chunk of the manufacturing base will be developed by leading manufacturers in these countries. Both India and China will remain the main strategic destinations.

Presently, in India there are about 90 companies into SPV, which comprise of 9 manufacturers of solar cells and 19 manufacturers of PV modules. Rest of the 60 companies are engaged in the assembly, supply and installation of SPV systems.   too. During fiscal year 2007, nearly 45 MW of solar cells and 80 MW of SPV modules were produced in the country, of which over 60 MW of SPV products were exported. In 2007, the Government of India announced the Semiconductor Policy that offers a capital subsidy of 20% for manufacturing plants in SEZs (special economic zones) and 25% for manufacturing plants outside SEZs. The subsidy is on the condition that the NPV (Net Present Value) of the investment is at least Rs 1000 crore.

At present, crystalline silicon technology dominates the market. It had an overall share of close to 90% of the 2007 production, followed by 10%

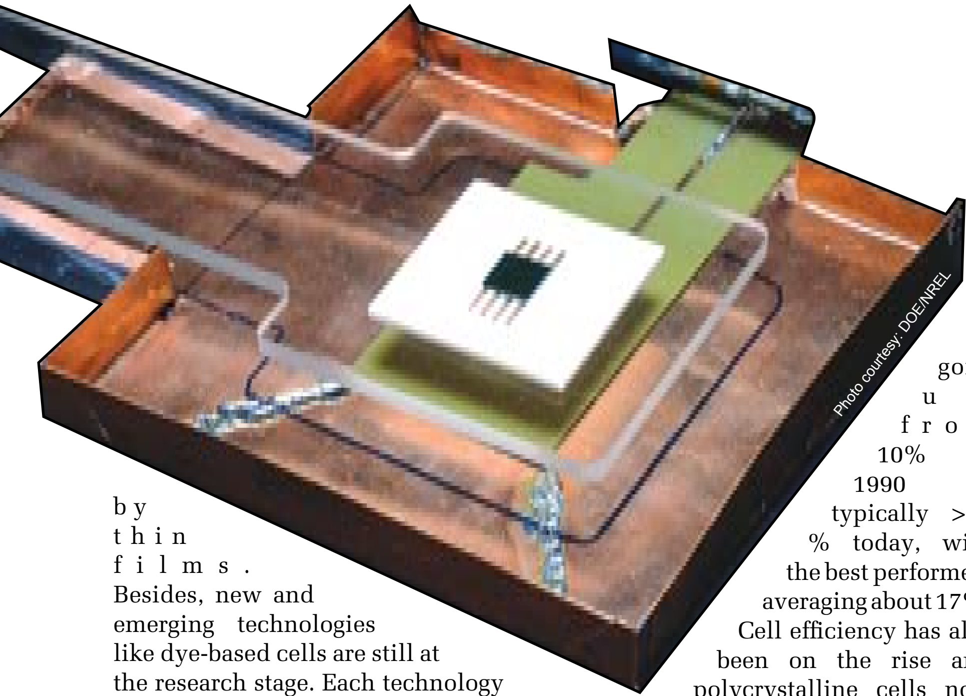


Photo courtesy: DOE/NREL

by thin films. Besides, new and emerging technologies like dye-based cells are still at the research stage. Each technology has its pros and cons on cost and efficiency.

Technology

Crystalline silicon (c-Si) solar cells have a larger surface area and relatively higher conversion efficiency. However, c-Si cells require high inputs during manufacturing (that is, energy and labour). These are heavily dependent on the availability of pure solar grade silicon, incidentally with a limited supply base till now. However, this scenario is soon going to change with large-scale production facilities for silicon wafers expected to come on stream between 2009/10.

In contrast, thin-film technology has an advantage over c-Si technology in terms of better cost economics for electricity generation. Much lower material (silicon) usage and lower energy requirements contribute to reduced generation cost. However, the land area requirement for this technology is higher than in c-Si technology.

The main areas where cost reduction is expected are in the development of new, lower cost, and less energy-intensive techniques for polysilicon production and a reduction in material usage. According to available market research, crystalline silicon modules (c-Si) may touch \$1.3–1.7/Wp in EU by 2012. Module efficiency of c-Si has gone up from 10% in 1990 to typically >13 % today, with the best performers averaging about 17%. Cell efficiency has also been on the rise and polycrystalline cells now have an efficiency of 18% and mono-crystalline almost 23%. Also, with increasing standardization of manufacturing equipment and improving efficiencies of modules, it is expected that there will be a further reduction in production costs in the medium term.

Market segments for solar

Power deficits continue to plague the Indian power sector and impede the country's economic progress. Today, the country experiences an average energy (electricity) shortage of 9.6% and a peak shortage of about 13.8%. To meet the growing demand and shortages, the generation capacity needs to be doubled in 10 years from the current level of approximately 146 752.81 MW. In addition, the

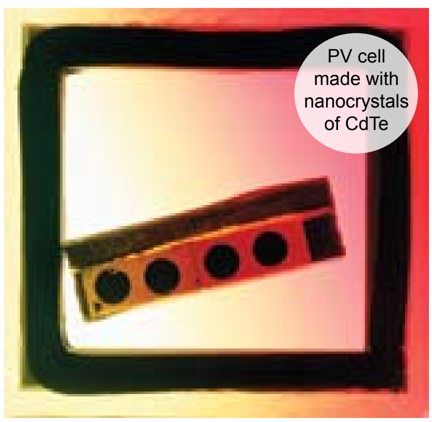


Photo courtesy: DOE/NREL

Government of India in 2007 mandated that electricity utilities purchase power from renewable sources. The target for electricity generation through this route is fixed at 10% by 2010 and 20% by 2020.

Based on the market size and its attractiveness, four market segments appear to have the maximum potential in the coming years. These are as follows.

- Rural electrification: DDG (Decentralized Distributed Generation)
- Grid-interactive SPV power plants
- Backup power for telecom (Base Transceiver Stations or BTs)
- Rooftop SPV systems

Rural India is home to more than 70% of India's population and energy is crucial for raising the standard of living there besides encouraging employment generation. The Government of India has kept a target of providing electricity for all by 2012 with a minimum consumption of 1 kWh per day per household. But even grid-connected villages today experience large power outages. Under the 'Power for All' programme, the Government of India has targeted electrification of all villages by 2012 in which 18 000 remote villages would be electrified using non-conventional power sources.

In order to provide an impetus to grid-interactive solar power generation, the MNRE (Ministry of New and Renewable Energy) has decided to support grid-interactive solar power generation projects. To begin with, this support in the form of a subsidy is limited to only 50-MW capacity. However, after the recent announcement of the GBI (generation-based incentives), MNRE has received Expressions of Interest for setting up of more than 1000 MW of PV-grid-interactive power generation projects. MNRE is now targeting a capacity of 500 MW through solar by the end of the Eleventh Five-year Plan, that is, 2012.

The analysis highlighted that the life-cycle cost of SPV is lower for all scenarios (requirements for 4, 6, 8, and 12 hours) of power backup, if diesel price is assumed to be Rs 55 per litre. It is higher for all scenarios when the diesel price is assumed to be Rs 35 and Rs 40 per litre. SPV becomes a viable option for telecom (based on today's prices) if the retail price of diesel touches or exceeds Rs 45.9 per litre. The telecom sector has the potential to provide a large and viable market for SPV in the future with retail prices of diesel likely to move up and prices of SPV panels likely to come down. If solar becomes a viable solution in this sector, it has the potential to cater to a market in excess of 1000 MW in the next 7–8 years (that is, till 2015). That is not all, as it will also avoid the need of transporting diesel to the difficult locations besides stopping its pilferage as well.

Benchmarking and policy

Based on the above analysis of market segments, SPV appears to be an attractive alternative source of energy, which till now has a limited market in India. The global SPV market has been growing substantially, especially in developed countries. Led by US and more recently by Germany and Japan, the growth of SPV has been remarkable. A consistent PV strategy based on ambitious and long-term targets, a clearly defined implementation policy programme, and a mix of financial instruments have led to the growth of the SPV market in these countries. Simultaneously, the authorities related to power at the federal, regional, and local levels have been demonstrating a strong commitment in implementing strategies and programme. Instead of the stop-and-go approach, the basic requirement for each PV policy framework is its longevity and stability. That will lead to creating secure conditions for target groups (customers and industry) who would then be willing to invest in PV.

The rooftop programme in Germany was a mega success after the introduction of the EEG (German renewable energy feed-in law) mandating utilities to purchase all available RE-based power. Also, support to PV R&D has created a thrust within manufacturers to systematically reduce production costs and to offer more efficient products. As a result of a favourable policy structure, Germany produces SPV component across the value chain, that is, silicon production (10 000 tonnes, equal to a PV production of approximately 1000 MW), wafer production (about 1300 MW), solar cell production (about 1300–1400 MW), and production of module with capacity of about 1000 MW.

In the previous decade, Japan emerged as the dominant player on the global SPV market, especially the manufacturing companies that have dominated global production. Japan's SPV market development has thrown up a number of important lessons for developing countries on how to develop their indigenous SPV industry. More precisely, Japan's approach is largely focused on the supply side, especially relying on technology interventions. One such area where Japan stands out globally is its expertise in SPV technology. Another area of success is the focus among Japanese policy-makers on balancing both demand and supply. On the demand side, Japan targeted the largest possible consumer group, that is, the residential sector and provided it the incentives (subsidy, net metering, access to easy finance, and so on) to mandate SPV application. On the supply side, the government has been working with the SPV industry to reduce the cost of SPV power.

However, in the previous decade the US solar industry was overshadowed first by Japan and now by Europe (particularly Germany). In the US, the incentive framework for SPV is fairly complex with incentives being available at the federal as well as the state level. However, till now the growth of the SPV industry has been largely due to state-level incentive programmes. Thus, development is taking place only in a few states like California that are proactive in initiating incentives and favourable policies.

Economics of solar photovoltaic manufacturing

SPV adoption globally is in its early phase and is expected to grow significantly over the next few decades. Now is the time for the Indian government to frame and implement more innovative programmes and policies to attract domestic and global investments in this sector. Besides serving the expanding global PV market, this manufacturing ecosystem will ensure that India has a stake in the development of low-cost PV panels for local consumption. This will ensure that the technology achieves grid-parity at the earliest, and thereby reduces dependence on conventional energy sources. The incentive structure currently offered under the SIP (Special Incentive Package) Programme of the Semiconductor Policy is a welcome move. It has resulted in investors showing interest to set up large-scale vertically integrated manufacturing facilities.

CREDA

Expanded lighting via local networking

S K Shukla, Director, CREDA
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Introduction

CREDA (Chhattisgarh State Renewable Development Agency) was established on 25 May 2001. The main aim behind its formation was to promote non-conventional and alternative energy sources. CREDA has been constituted under the Department of Energy, Government of Chhattisgarh for implementation of various schemes pertaining to renewable energy sources and energy conservation, registered under Society Act 1973 on 25 May 2001. The controlling body of CREDA is the governing body with the Energy Minister, Chhattisgarh state, as the chairman. Most of the schemes like the National Programme on Biogas Development, solar thermal, solar photovoltaic, village electrification, and biomass gasifier sponsored by the MNRE, Government of India are implemented by CREDA, being the nodal agency in the state.

CREDA (Chhattisgarh Renewable Energy Development Agency) is a name with a certain difference. This difference is manifested in the manner it handles the post-installation affairs of the solar systems. It also gains added significance for the simple fact that quantitative estimates alone do not matter. To some extent, systems put up in the remote rural areas of the country suffer from the absence of a sustainable O&M (operation and maintenance) structure. CREDA derives satisfaction by having launched a quite ambitious rural electrification programme, which essentially involves lighting up the remotely located villages and hamlets through renewable energy systems. There seems nothing new in this type of arrangement but what follows is a highly successful adaptation of a Golden Model.

There is also enough food for thought if renewable energy systems should be entrusted to the user community/individuals free of any charges. Simply put, it may normally not assign any sense of belonging which also leads to an equitable situation in case of a smooth system operation or otherwise. But that again seems to have no influence on the programme being run by CREDA. The systems are working perfectly fine and meeting the promised end use requirements. It has become possible due to the broad-based support received from the users too. Systems provided by CREDA get about 60% of the central support with the rest chipping in from the state government. Tendering procedure for procuring systems as per the stipulated specifications is adhered to by CREDA with local contractors laying the control structure besides power distribution facility.

The solar programming

CREDA's programme outreach has stretched beyond the normally seen geographical spread of a few clusters at one time. Instead, it has shouldered the responsibility of lighting up about 800 remote villages in Chhattisgarh through SPV systems much in sync with the concept that took shape six years back. The gains to the village

communities are accruing by way of much improved form of light in tandem with being a part of the great TV entertainment revolution. The dreadful and difficult to maintain kerosene oil lantern of yesteryears has given way to a cool white light of good enough illumination.

Beyond denial, the quality of life has gone up and is much too visible now in corners hitherto living in dark desolate conditions—thanks to the immense power of the sun, which CREDA has put to use in a full measure. The underlying objective of this programme is enshrined in an unfailing commitment to keep the systems working by braving all odds. It has developed a unique system known as the 'Golden Model' due to which the movement of solar electrification sustains on its own. The consumer interest is kept paramount in the whole exercise by taking them in the project fold from the very outset. Their counsel is sought even to choose a proper place for housing the control room in addition to laying of distribution lines.

The empowerment of these people does not stop here but extends to an active involvement of an elderly person (from the community) in the Bhoomi Poojan. Such an occasion is also used to announce the name of an eligible person who is later trained sufficiently in the O&M care. He performs the following few roles on a regular basis.

- Minor repair works
- Noting down of energy meter readings (in a log book kept for the purpose)
- Cleaning of the solar modules
- Noting the specific gravity of the battery cells
- Topping up the batteries

Clustered approach

A technician is assigned the task of maintaining systems in a cluster of 10–15 villages. He should however be a resident of one of the cluster villages and is supposed to visit every solar powered village 1–2 times in a month. He is also rolled into attending system-related emergencies on the behest of the system operator. The cluster technician is equipped with spare parts and tools kit and his movement is facilitated by a two-wheeler made available to him. The fault reporting/rectification system moves on from such a technician to the supervisor. Normally, the supervisor is a CREDA employee and is posted at the district level.

Solar installations in various districts of Chhattisgarh

The O&M revenue stream

The beneficiary has to pay the following amount as beneficiary share.

- Rs 100 as connection charges for BPL beneficiary and Rs 200 for others
- Rs 15 per month for each light point

CREDA pays Rs 25 per household per month to the service provider against maintenance of these systems. There are six service providers in the state, which are basically the companies involved in the system installation process itself. Usual practice is to entrust district-specific system maintenance work to one service provider only.

A unique advantage of doing so is that a solar company, say for example TATA BP Solar, gets to care for the systems of a different make say for example those of Suntechnics or BHEL. Thus, it provides the company a definite opportunity to have a close look at how the competitors' systems actually perform.

Localizing the effort

Just look at how much involved the village sarpanch is in the whole process. He only issues a system performance report, following which money is released to a service provider. In turn, the servicing company pays for the monthly salaries of operator and technicians. These field employees stay in regular touch with the CREDA officials mainly via telephone. CREDA makes every possible attempt to enrich their skills by organizing periodical training and refresher courses. Service providers are also committed to maintain the power distribution network, streetlights, and community lights. The regional offices submit the monthly progress reports to CREDA and its O&M cell monitors such reports for making available any support to the service providers. A fully computerized monitoring and feedback system is in place now at CREDA, which aids it in evolving any modifications in its future system designs and so on.

Lighting a Billion Lives Programme INSIDE OUT

Lucas Chancel, Visiting Intern, TERI <chancel.lucas@gmail.com>

Background

About a quarter of humanity is still reeling under darkness due to non-availability of electricity. It is quite a worrisome situation needing an innovative technology solution. Taking a serious cue from it, TERI has embarked on an ambitious plan to propagate the use of solar lighting. This special plan has been aptly named as LaBL (Lighting a Billion Lives). Use of solar lighting is certainly not a new thing, but it has matured over the last quarter or so. The shaky solar lantern of yesteryears is now firmly rooted as a robust and reliable source of lighting in the LaBL programme. It is now equally important to investigate the suitability of existing market delivery mechanisms from a variety of end-use considerations. This article based on an independent report prepared by the author for TERI[1] gives a deep insight into the intricacies of LaBL in totality.

Status of LaBL programme

The LaBL campaign now brings light to 20 villages and provides solar light to more than 5500 villagers.[2] The existing report is based on surveys carried out in LaBL sites of three divergent states, that is, Assam, West Bengal, and Rajasthan. The key strength of this campaign model is its original implementation strategy. However, the model also raises issues, which implementation actors have to address in order to achieve sustainable success of the scheme at local and global levels. The present study takes a serious look at how LaBL works in practice from following three angles mainly.

- Analyses the main issues at stake within the village
- Compares the same with villagers access to solar lanterns elsewhere
- Views it in an international dimension

Participating locally with a purpose

The LaBL model can be described in relatively simple terms. TERI or its state-level implementation partners select local NGOs (non-governmental

[1] Access to Solar Photovoltaics in rural India: Report on the TERI LaBL scheme in Assam and West Bengal, Lucas Chancel (2008).

[2] In December 2008, there were 1150 lanterns installed, providing light to households of 5 people on average.

organizations) . In turn, these identify remote villages as well as the local entrepreneurs. The latter category operates a rental scheme of the solar lanterns for the villagers. The entrepreneur positions solar panels on his house rooftop and organizes a daily inflow of rent. This mechanism is straightforward but is at the same time relatively complex.

Key strengths of the implementation strategy

Smooth project implementation is a key ingredient of any major solar initiative and more so of that intended for the remote rural communities. Key strengths of the LaBL specific implementation scheme are as follows.

- Long-term sustainability
- Decentralized administration
- Dialogical framework

Sustainability in full is ensured by saving money for the future replacement of the batteries[3] out of the daily rental income. Villages can thus become financially autonomous in the long run. The entrepreneur's wages can be seen as incentives for a good management of the charging station. LaBL campaign is also environmentally sustainable because it allows villagers to switch from kerosene-based lighting devices (in more than 90% of the households surveyed) to a green technology, that is, solar. Each lantern permits a 1450 kg of CO_2 mitigation over a period of 12 years.[4]

The campaign also gains from its decentralized administration strategy managed ably by five different types of actors, that is, TERI LaBL team, state-level anchors, local-level anchors (NGOs and self-help groups or youth clubs), local entrepreneurs, and the villagers themselves. All these have some say in the decision-making process.

The weak links

The existing implementation strategy is not devoid of any weaknesses. It is imperative to make a note of the same here as under.

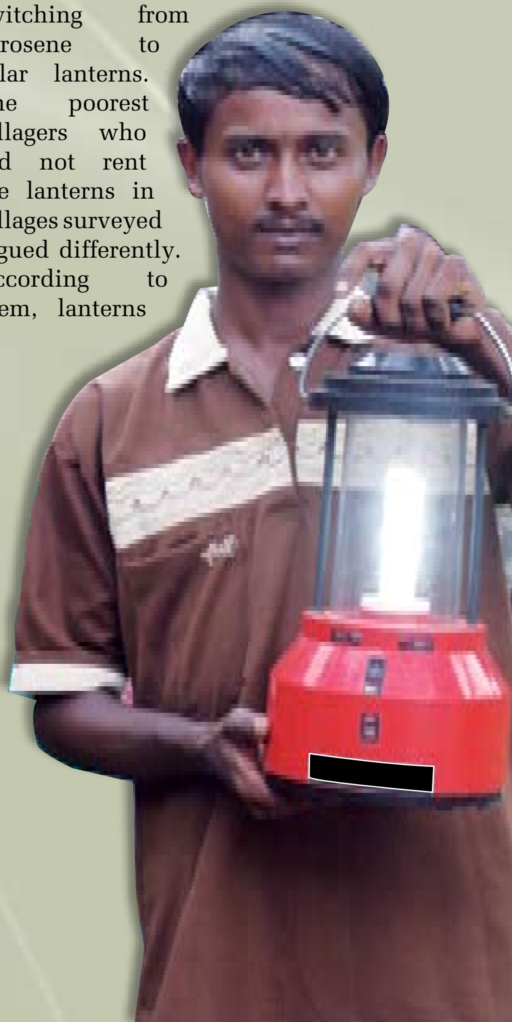
- Sustainability of the operation implies a daily price of rent, which acts as a barrier for the poorest villagers.
- Decentralized strategy also means that each village can set its own price of rent, which has resulted in some over-pricing at some locations.
- Monitoring the operation is rendered more complex because of the decentralized nature of the campaign.
- Question of selection of the actors, who have substantial decision-making power is also at stake in a decentralized framework.
- Dialogical framework of discussion can lead to problems of information amongst the different actors and raises issues of good representation of the groups involved (ensuring that all villagers take part in village discussion on the future price of rent of the lantern is not an easy thing to do).

The rotation mode

Solar lanterns are nothing short of beacon lights, which must benefit all the villagers. It is equally true that there may not be enough lanterns available in the villages. In this type of situation, the daily rent model enables rotation of this device amongst the beneficiaries, so that lanterns reach out to every one. However, the field study points out to a hard fact of some villagers' inability to get lanterns even on rent. The device shortage cannot be the sole factor but a higher rental tag too. The daily rental in the sampled cases was found to be a defacto barrier for many villagers. As such, it may be prudent to keep the rent at the lowest paying capacity of these villagers. However, it is difficult to derive empirically such a paying capacity.

Choosing between kerosene lantern and solar lantern

It is quite logical to assess the financial gains while switching from kerosene to solar lanterns. The poorest villagers who did not rent the lanterns in villages surveyed argued differently. According to them, lanterns



[3] There is no available battery technology on the market that does not need to be replaced. Replacement of LED or CFL batteries is required after a period of time varying from 12 to 24 months.

[4] We assume that a household consumes 4 litres of kerosene per month, which is a reasonable, yet slightly high assumption. We do not take into account here emissions resulting from the production of solar lanterns and panels. This calculation should be incorporated in further studies.

Dr R K Pachauri, Director-General, TERI presenting a lantern to Tarun Gogoi, Chief Minister of Assam

implied a higher expenditure on lighting than kerosene. While as those belonging to the medium or upper income groups found the rental arrangement economically attractive. The villagers in possession of BPL ration cards paid less for kerosene and therefore had fewer incentives to rent the lanterns. The distribution of BPL/ration cards is a problematic issue in many places. However, in the cases surveyed, it corresponded with the poorest villagers. In contrast, those with higher incomes gained from transition to solar lanterns. The high rental made lower income group to spend more. In all, the present study finds a daily price of Rs 2 reasonable enough for an overall operational sustainability as set in a Rajasthan village for example.

The benefit sharing formula

Selection of a right entrepreneur can also be an issue in villages. For example, an entrepreneur's mother was found to be a village sarpanch in one of the surveyed cases. Some villagers themselves also nurse a strong ambition to become entrepreneurs. The existing study makes out a strong case for lower income group people to be chosen as entrepreneurs. It holds a promise for them to get higher daily revenue than what they normally get otherwise.

The advantages galore

There was no clear preference, in the cases studied, between per capita subsidy and the fee-for-service model. Middle- to high-income households tend to prefer per capita subsidy model while lower income households prefer the daily rent (say between Rs 1 and Rs 2). Following few are the key advantages resulting in this manner.

- Villagers benefiting from the operation are extremely satisfied by the lanterns and the scheme.
- Better quality of light and lesser smoke are the main arguments put forward.
- Improved conditions for learning or working are also stressed by many households
- Overall, the lanterns were used for social, educational, economic, cultural, health, and security purposes

Re-orienting the LaBL campaign

It is interesting to note that in border areas (that is, Arunachal Pradesh/Assam) government subsidies on other SPV systems are diverted by the retail shop owners. They sell the devices at a higher price to villagers in the neighbouring states. In such areas, the LaBL campaign can benefit the poorest who can ill afford such PV systems. The LaBL can in fact target the leftovers of government rural electrification schemes. These schemes suffer in many areas from little funding and thus subsidies are not important enough to attract low-income villagers. Lately, the issue of transferring the kerosene subsidy to promote solar lanterns is gaining some ground. However the study shows that this might have consequences in areas, which will not benefit from solar lanterns straight away. Within these areas, real income will shrink if kerosene subsidies are removed[5] without further protection. Finally,

Table 1 Types of use of lanterns

Use of lanterns	Bhatala	Gobindarampur
Social/cultural purposes	• Lights up common rooms/kitchens after dark • Used for small festivals	
Health purposes	Used to prevent effects of oil lamps on health (prevents headache and doesn't weaken sight)	
Studying purposes	Facilitates student's studies at night	
Economic purposes	• Basket making • Leaf cultivators	• Used by betel leaf cultivators (to clean leaves and arrange them together) • Used by shopkeepers (to light up their shops after sunset)
Security purposes	Drives away elephants and snakes	

Source Census of India 2001

[5] Expenditure on kerosene will rise by three times, from Rs 10 per litre at subsidized price to Rs 30 on the open market
[6] TNS-Sofres for voyages-sncf.com

Table 2 Comparison of lanterns and oil lamps

Advantages of lanterns according to villagers (total of 22 households surveyed)	Disadvantages of lanterns according to villagers (total of 22 houses surveyed)
Higher light intensity (better for the eyes) – 16 answers	Does not work in bad weather. However, kerosene for oil lamps can be used anytime (6 answers)
No smoke (14 answers) and thus less headaches (4 answers)	More expensive than kerosene (6 answers)
Less expensive than kerosene (7 answers)	Rapid discharge (2 answers)
Does not blacken clothes and mosquito nets (3 answers)	
No risk of burning (3 answers)	
Better looking (3 answers)	
Students' grades have improved (2 answers)	

dialogue at a national level amongst the different actors of the scheme can be enhanced by an Internet forum for local-level actors to share their experiences, successes, and problems alike.

Working towards reduced carbon footprint

Reaching out to all villagers without any prejudice remains a key objective of this programme. However, the main challenge of such a wide-ranging operation is obviously its' financing. The study shows how LaBL can gain from targeting individual sponsors of one particular sector, that is, those flying from Europe or US to India. A recent poll[6] showed that 65% of French travellers were willing to pay at least 5% of their travel expenditure to offset their CO_2 emissions via travel alone. But in reality, less than 1% of travellers compensate their carbon emissions. The study shows that this is mainly due to poor communication and marketing of current compensation schemes. The LaBL operation brings environmental and developmental concerns together thus leading to high international visibility. Further, it is expecting more people to offset their carbon emissions by financing one lantern by dint of innovative communication strategies or simply better awareness at a global level. Two strategies, one based on CDM (Clean Development Mechanism) registration and the other on voluntary market registration have been considered in the existing study. LaBL could develop a partnership with airline companies on the basis of these two strategies. It seems that the second one, based on voluntary market compensation, is the most efficient for the moment. It can be established at relatively low costs and the strategies developed by TERI seem to go along the right path so far. Tables 1, 2, and 3 summarize the important perspectives as under.

Conclusion

Timely delivery of the solar lanterns is of great essence in making LaBL a huge success. A query, 'When are the lanterns coming? Our children's exams are in March and we need the lanterns by then.' from a village in Rajasthan deserves a special mention here. The author sees a lot of promise in this novel initiative—a sure indicator of its success so far. However, the issues touched above if, properly redressed may lead to achieving the following few key objectives.

- Long-term sustainability
- Impressive penetration of decentralized eco-friendly energy source like solar energy
- Improved quality of life within the marginalized millions.

Table 3 Financial gains and losses due to use of solar lanterns

Prior source of lighting used by the house		Monthly per capita expenditure in rupees on lighting in function of daily cost of rent of the lantern				
		Re 1 *Rs 30 per month*	**Rs 2** *Re 60 per month*	**Rs 3** Rs 90 per month	**Rs 5** Rs 150 per month	**Rs 7** Rs 210 per month
Wax candles (two candles consumed per day)	Rs 2.5 per candle Rs 150 per month	150 – 30 = +120	150 – 60 = +90	150 – 90 = +60	150 – 150 = 0	150 – 210 = –60
	BPL ration card owners Buying three litres at Rs 11 per litre	33 – 30 = +3	33 – 60 = –27	33 – 90 = –57	33 – 150 = –117	33 – 210 = –177
	BPL ration card owners Buying 5 litres 3 litres with ration card and 2 litres extra at Rs 28 in black market	89 – 30 = +59	89 – 60 = +29	89 – 90 = –1	89 – 150 = –61	61 – 210 = –121
Kerosene (oil lamp)	Non ration card owners Buying 4 litres at Rs 28: Rs 112 per month	112 – 30 = +82	112 – 60 = +52	112 – 90 = +22	112 – 150 = –38	112 – 210 = –98

Orange colour denotes configurations where households gain from solar lanterns, and blue colour denotes situations where switching to solar lanterns implies higher expenses on lighting.

Making way for a future powered by solar energy

With the efforts put in by the MNRE coupled with their own efforts, states are now gearing up for a renewable energy revolution. Haryana is one such state where efforts in the area of solar energy have resulted in many benefits to the people.It was also the first state in the country to achieve 100% electrification status. HAREDA (Haryana Renewable Energy Development Agency) has been on the forefront in bringing about this change. *Ms Sumita Mishra, Director, HAREDA* talks about the achievements and future plans in an interview with *Ambika Shankar.*

Q You have been at the helm of affairs in HAREDA for the last few years. Could you please inform the readers about the cumulative achievements of its RE (renewable energy) programme so far against the backdrop of targets set up for the purpose?

When I joined as Director, Renewable Energy Department and HAREDA in March 2005, the department and HAREDA were mainly implementing the MNRE-sponsored programmes, which have limited targets and therefore limited impact. I ensured that the MNRE schemes dovetailed with other developmental schemes of other ministries and departments to increase the number of people covered under the programmes of HAREDA. For example, the solar cooker programme, solar lantern programme, and solar water heating systems programme were dovetailed with the programmes of the SDA (Shivalik Development Agency) and we were able to make an impact in the SDA area through distribution of 2500 additional solar cookers, 2000 additional solar lanterns and installation of 1000-LPD (litres per day) additional capacity solar water heating systems.

During the last three years, HAREDA has distributed 13 300 solar lanterns and 9286 solar home lighting systems. It has also installed 2300 solar street lighting systems and solar power plants of 2.7-kW capacity each in 36 schools to run their computer labs. Haryana is the first state in the country to have implemented a special project for street lighting of villages dominated by SC population in the districts of Ambala, Panchkula, Yamuna Nagar, Rohtak, and Jhajjar with cost sharing from the MNRE and the Ministry of Social Justice and Empowerment, Government of India. Under the project, 1803 solar streetlights have been installed in 234 villages at a total cost of Rs 453 lakhs. A project for installation of 1139 streetlights in 50 minority dominated villages in Mewat district at a cost of Rs 2.57 crore with financial assistance from the MNRE and the Department of Welfare of Schedule Castes and Backward Classes, Haryana, is under implementation. This is also a first-of-its-kind project in the country.

Q. The government of Haryana notified a new policy for promotion of RE based power generation in November 2005. Are solar-based technologies making any noticeable impact in this regard—be it attracting investor's interest and so on or actual project implementation for that matter?

■ Haryana declared its Renewable Energy Power Policy in November 2005. Under the policy, electricity duty on generation of power has been exempted; change of land use, internal and external development charges have been exempted; wheeling and banking has been allowed; and industry status has been given to the power projects.

Q. Achieving enhanced energy efficiency across all segments of energy use is not a war cry any more. Do you envisage a major intervention of solar energy technologies as well to attain this key objective?

■ We have always been advocating that Energy Efficiency cannot be achieved in isolation and are of the view that RE is the continuum of energy conservation practices. Various RE technologies, especially solar energy, offers techno-economically viable options for energy management and energy conservation. Solar thermal technologies are the most viable option for low-grade thermal applications. Solar water heating systems of 1 lakh LPD capacity not only contribute to 1-MW peak load shaving but also avoid emission of 1500 tonnes of CO_2 in the atmosphere. Though some commercial/industrial establishments have widely adopted solar thermal technologies for water heating applications, it is unfortunate that many industries and individuals consumers are not readily accepting these technologies. The efforts of HAREDA have resulted in installation of one of the largest solar water heating systems in the country in a textile unit in Gurgaon. We are working on a very ambitious project for increasing the penetration of solar thermal technologies in the textile sector, which uses a lot of hot water in various processes.

Our efforts have resulted in saving of 88 MW of electricity (537 million units) annually thereby avoiding an investment of Rs 352 crore required for the capacity addition. Our initiatives in energy conservation have been recognized by the Government of India also and Haryana was awarded the Best State Award by the Hon'ble Union Power Minister.

> *"We have always been advocating that Energy Efficiency cannot be achieved in isolation and are of the view that RE is the continuum of energy conservation practices."*

Q. The domestic tariff for electricity in the state of Haryana happens to be the highest in India. Why is it that solar water heating systems, for example, are still not being seen on majority of the rooftops there?

■ The Haryana government has taken up a major programme for promoting solar water heating system in the state as a demand side management measure. Haryana is the first state in the country where solar water heating has been made mandatory since July 2005 in industries, hospitals, and nursing homes; government hospitals, hotels, motels, and banquet halls; jail barracks, canteens; and housing complexes set up by group housing societies/housing board, all residential buildings built on a plot of size 500 square yards and above falling within the limits of municipal committees/corporations and HUDA sectors, all government buildings, residential schools, educational colleges, hostels, technical/educational institutes, District Institute of Education and Training, tourism complexes, and universities. To promote solar water heating systems in the domestic sector, the power utilities are giving a rebate in the electricity bills to the users of solar water heating systems in the domestic sectors at the rate of Rs 100 per 100-LPD capacity solar water heating system per month up to 300-LPD capacity. The rebate shall be of Rs 1200 annually for 100-LPD systems, Rs 2400 for 200-LPD systems and Rs 3600 for 300-LPD systems for a period of three years. In addition to this, capital subsidy up to Rs 10 000 is also available on installation of solar water heating systems in the domestic sector. HAREDA has launched an awareness campaign and the results are encouraging. During the last three years, 363 solar water heating systems of 358 700 LPD were installed in the state which is 300% more than the corresponding previous three years period.

So, there is an upward trend in the adoption of solar water heating systems in the state and we expect it to further accelerate with increased awareness and increasing cost of electricity. The reason for less installation in individual houses may be the lack of proper marketing by the manufacturers.

Q. Are their any areas of cooperation possible amongst HAREDA, energy service companies, NGOs, and so on especially with regard to capacity-building efforts in solar energy given its outreach in slightly difficult areas particularly?

■ The energy service company route is an innovative option for bringing in energy efficiency in energy-intensive applications where an ESCO comes into picture to design, install, and finance the energy efficiency measures required to reduce energy bills and the maintenance costs. The ESCO recovers its expenditures from its mutually agreed share from the savings in the electricity bills. HAREDA has facilitated municipal council, Hisar and HUDA, Panchkula for the implementing energy efficiency measures in the streetlighting of their respective area by devising NIT and inviting tender.

New initiatives in photovoltaics

The world is trying to cope with problems of climate change. The solution lies in developing renewable sources of energy. Solar energy is the next big thing and many foreign players are also tapping the Indian market. *Mark Doyle, Global Business Director, DuPont Photovoltaic Solutions* talks about the recently launched DuPont Photovoltaics Solutions and more in an interview with *Ambika Shankar*.

Q. How long has DuPont been in the PV segment? What are its focus areas?

The company is 206 years old. It's quite an old company. It has gone through many transformations and recently in the last 20 years has much become more focused on bio-based initiatives, agriculture, nutrition, and renewable energy. Photovoltaics are big part of that strategy. DuPont has been active in photovoltaics for the last 30 years but has grown to be a significant industry only recently. We will do 300 million dollar sales globally this year. The Indian focus is because of our belief that between the government support for module and cell manufacturing in India and between the quantum of sunlight India has it will be a very significant growth market for the company in the future. This is the reason for our recent announcement.

Q. How advanced do you think is the PV industry in India?

The solar energy industry in India is still emerging when compared with Japan, which has had a very mature solar market for many years now. China is three to five years ahead of India. India is still on an emerging stage. But if you look at the growth ahead, India would become one of the major players within the industry. But it will happen as a result of lot of work and innovation. Here, big companies are investing today. Initially, they would buy technology from outside India. But technology will soon become localized and suppliers like DuPont will localize all technical efforts to support innovations that are really needed to create a kind of global industry in the future.

Q. Are your efforts only linked to the corporate sector or is the government involved? If yes, then to what extent?

We do not have any direct involvement with the government because focus of the government from the subsidy standpoint has been on two areas. One has been on encouraging manufacturers to build facilities and the second has been on renewable portfolio standards. I am not aware if there has been anything to the effect that a portion of your electricity should be generated by renewables. DuPont does not participate directly in the government-related discussions. We are basically following the industry and our customers are Indian companies that are manufacturing solar cell and modules.

Q. What prospects do you think DuPont has in India in the longer term?

India is one of the fastest growing countries for DuPont, even though it is already quite large. If you look at the break down of the company, it is a 30-billion-dollar company with annual sales of two-thirds outside the US today and one-third in the US. The objective in India is to achieve 1 billion sales by 2012.

Q. We have a ministry dedicated to R&D on RE. What more do you think the government can do to give a big boost to initiatives in this area?

The ultimate objective is to enable achieving grid parity and the government can help that to accelerate through incentive programmes. Those incentive programmes can either be portfolio standards where they create demand for solar power by requiring it to be used or there can be different types of subsidies. So one penny spent on electricity will go to solar power installation that would create a demand. Different countries have taken different approaches. Germany has taken the approach of the tariff and that has been successful in terms of creating a very large market even though Germany gets one-fifth of the solar energy as against India on an average. In that sense, solar power is much more expensive in Germany. Through this programme they have created a huge industry, a huge technology industry in terms of local jobs. In the US, the approach is more than portfolio standards. There are different ways to do it. The government can choose to do nothing and it will still happen because solar energy industry is big enough There is clearly a time 5 to 10 years from now when the focus of world would clearly be on developing solar energy and that will happen regardless of whether the government puts in more efforts or not. But the question is whether it is 5 years or 10 years. The government can make it happen in a big way if they desire to do so. You need result and that is the hard part.

Q. Can you tell our readers something about the PV lab in Hyderabad?

It is a very large R&D facility investment that we have announced last year, which is the DuPont knowledge centre. The focus of that lab will be fundamental research and product development. It is a bit of a different process because as a company we have done only fundamental research in the US. Now we are globalizing our fundamental research efforts. This is really a new thing. Within that lab, we have already made announcements of investments for agricultural nutrition area, bio-based materials, and seeds. We basically have three focus areas. The first one is to provide technical support to local customers and a pilot line and small-scale line for cells and modules.

> *"The ultimate objective is to enable achieving grid parity and the government can help that to accelerate through incentive programmes. Those incentive programmes can either be portfolio standards where they create demand for solar power by requiring it to be used or there can be different types of subsidies. So one penny spent on electricity will go to solar power installation that would create a demand."*

Q. So this is for the commercial manufacturers?

Yes, this is for commercial manufacturers such as Moser Baer, and these can come and test their material in our laboratory under better conditions. The second aspect is product development for local market. For example, as the local market develops, there is more demand in India, the modules will change, and they will be suited for the Indian market. The third element is the fundamental R&D. In this R&D, we may not be targeting India marketing, but markets somewhere in Europe and North America or somewhere else. But it will be part of our global R&D efforts on photovoltaics. There are specific areas to be selected to focus on. Though we can't talk publicly about our technical strategy, it would basically be three to five years, long-term R&D efforts.

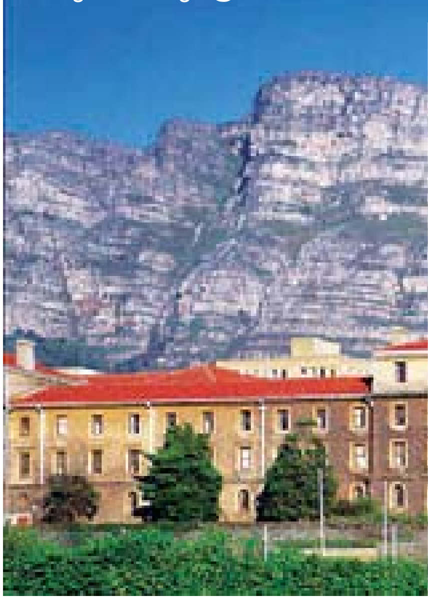
Q Tell us something about DuPont Photovoltaic Solutions, your recent business initiative.

We had a meeting with head of strategic sources, Moser Baer. He has worked with Dupont last year and five different DuPont people visited him. He never knew one from another; he never knew how they are related. The reality is that we have lot of products to serve the photovoltaic industry. But there is no coordination of efforts because we are a big company and they are coming from different ends of the company, from different business units. Here we are forming photovoltaic business unit in India, so that we can coordinate everything DuPont does. So that there is one interface for customers to get assistance and support on any of the DuPont photovoltaics materials offered. It is really a simple thing. If you look at the photovoltaic market here, it is doubling, more than doubling every year and will do for next five years. There are so many things that the Indian customer needs and we want to help them.

Blending with nature

Energy Research Centre, University of Cape Town

Eugene Visagie, University of Capetown
<Eugene.Visagie@uct.ac.za>



Introduction

The UCT (University of Cape Town) is a public university located in Cape Town, South Africa. UCT was founded in 1829 as the South African College, and is the oldest university in Africa, south of the Sahara desert. UCT is the highest-ranking African university in both the World University Rankings and the Academic Ranking of World Universities by the Shanghai Jiao Tong University. UCT is currently ranked 179th and is the only African university to have been listed in the world's top 200.

Energy research at UCT is conducted across engineering disciplines with the ERC (Energy Research Centre) being the leading research unit. The ERC is a multi-disciplinary unit housed in the Faculty of Engineering and the Built Environment. The centre conducts high-quality, targeted, and relevant research and also offers postgraduate opportunities at the Masters and PhD levels. The mission of the centre is to pursue excellence in technology, policy, and sustainable development research; and education and capacity-building programmes, both at the local and international levels.

Partnering with the best

Research in the university has been commissioned by a range of organizations. The international clients include, United Nations Institute for Training and Research, SEI–Boston, UNEP, International Energy Agency, Energy and Stanford University Programme on Sustainable Development, Helio International, Global Network on Energy for Sustainable Development, World Resources Institute, and the International Atomic Energy Agency.

Key research areas

The interdisciplinary mix of the centre's staff enables it to provide balanced insight into energy problems pertinent to Africa. This is reflected in the major research focus areas, which are outlined below, although many projects do, of course, overlap the concerns of these research groups.

Energy efficiency group: spearheading the effort

The energy efficiency group deals with energy efficiency at the demand level. Energy efficiency is an economic resource and can be thought of as an alternative 'fuel'. The effects on single businesses and the national picture are examined. Much of the work continues to be in the industrial sector while work in the building sector is growing. The group is currently carrying out work under the Eskom Demand Side Management programme. It is currently researching the potential for DSM with industrial electrical loads and is also accredited as a monitoring and verification body under this programme.

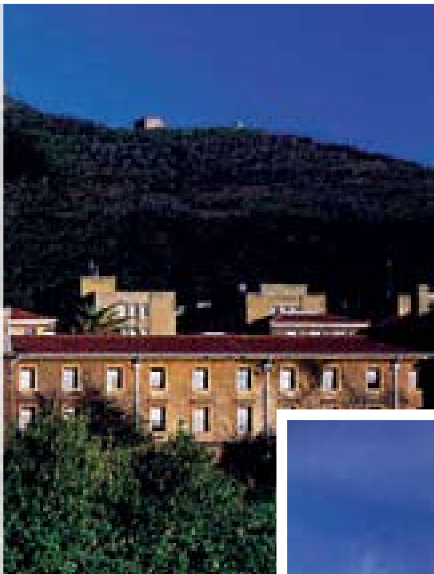
The group does not work in isolation. Many of its activities overlap with other groups, specifically in the areas of modelling and climate change. A good deal of expertise has been built up with regard to the CDM (Clean Development Mechanism) under the Kyoto Protocol. There is a commitment to promoting energy efficiency, and the group offers courses, in addition to components within the Master's programme. There is always a welcome to those interested students who would like to expand the overall body of knowledge, as well as their own, either by participating in research projects, or more directly in industrial projects.

Energy modelling

This group undertakes research using and developing tools to analyse the energy system, its interaction with economy and the environment for various applications besides aiming to provide a clear integrated resource and energy planning service. The group incorporates cost, economic

SOME OF THE TOPICS COVERED

- Solar radiation: basics, geometry, and measurement
- Wind resources: principles, measurement, and results
- Wind energy conversion
- PV materials and modules
- Stand-alone PV system design
- Biogas digesters
- Hydro power
- Biomass, biofuels, and energy
- PV system design for an off-grid household
- Village water pumping project (wind and PV)
- Solar water heater assessment for municipalities
- Passive solar/building design for low-cost housing



interactions, pricing, environmental accounting, and behavioural aspects of energy demand and supply. This includes the identification and quantification of investments, trade, emissions, and other economic effects of single or multi-country energy systems, as well as for single industrial plants or small communities. Also considered are single segments of the energy system, such as least cost expansion planning, or renewable energy strategies for the electricity sector. The key to the approach is being able to trade-off costs and benefits to find optimal solutions. Standard tools applied include least cost energy–environment–economic models such as MARKAL/TIMES and LEAP. New tools are developed for various applications to simulate aspects such as energy user behaviour in low-income areas or multi-criteria decision analysis tools and environmental (externality) costing tools. Simplified input–output models are used for economic analysis such as job creation.

Energy, environment, and climate change

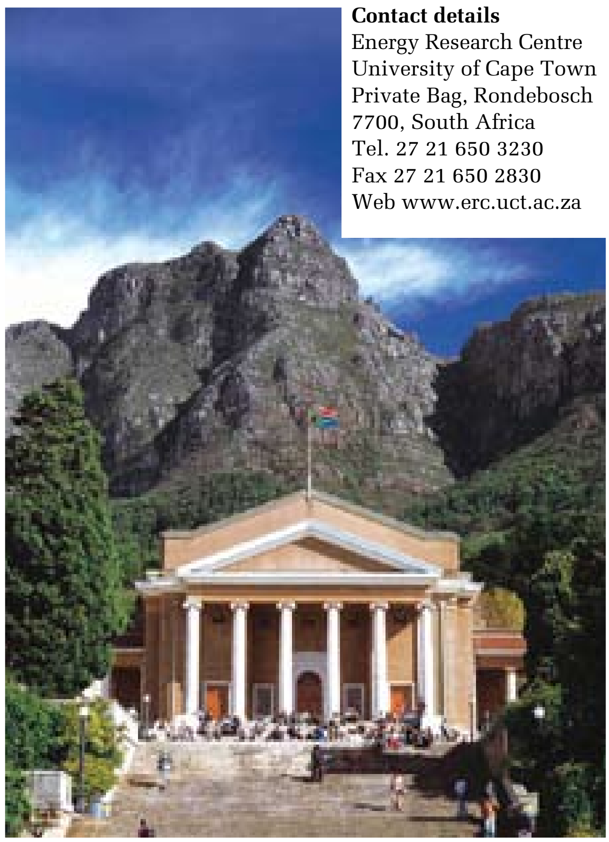
The group researches the intersection between energy, local environment, and global climate change in addition contributing to minimizing impacts of energy use and production, from social, economic, and environmental perspectives. Internationally and in South Africa, energy is the sector contributing most to global climate change and to local air pollution. The group seeks to deepen understanding of these problems, and develop creative policy solutions. Energy solutions for climate change mitigation that are grounded in national circumstances need to be formulated and implemented urgently. Environmentally sensitive planning of energy for sustainable development is a key national priority.

Local environmental issues include indoor air pollution and environmental health, external costs of local pollution, environmental taxes and subsidies for energy, renewable energy, environmental, household energy efficiency, and energy for sustainable development.

Research themes relating to global climate change include mitigation, greenhouse gas inventories, impact of potential future allocation schemes on South Africa, CDM, capacity-building, and adaptation to the impacts of climate change. This includes strategic analysis to evaluate and prioritize mitigation opportunities, methodologies, economic and financial analysis, as well as emission baselines for CDM projects. The group's emphasis lies in demonstrating how these projects can benefit the poor.

Far reaching objectives

Generally, the objective is to undertake independent and objective research of both national and global interest in order to deepen knowledge and understanding of energy and development needs, problems, challenges, and innovative solutions.



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CLEAN WATER WITH SOLAR POWER
Solar Aqua

Mr Srinivas, CEO, Kotak Urja <srinivasksk@gmail.com>

Background

Nearly one-third of the global population is not connected to an electrical grid. More alarmingly, by 2025, about 48% of the total population is expected to have a poor access to safe drinking water supply. Surely, the deprivation of such basic needs as electricity and water in such high numbers calls for a long lasting solution. SPV (solar photovoltaic) technology is already well entrenched in the rural areas especially for meeting a variety of end-use applications like lighting, water pumping, and battery charging. It can play a significant role in offering the facilities of clean water too.

Rationale for PV water purification

SPV technology is quite a feasible solution in areas with high solar radiation. These mainly include India, Middle East, and the North African region. An added benefit is by way of much reduced environmental impact. Solar thermal based water desalination systems have already been put to use for the purpose including the simpler forms of solar stills. However, PV operated units are still few and far between.

Technology at work

Kotak Urja is specially committed to providing the benefits of solar electricity in remote rural areas of the country. It has recently developed a solar-operated water purification system under the brand name, 'Solar Aqua'. It mainly comprises of a solar-power-generating unit in tandem with a multi-stage filtration system. The solar power thus available drives a high power booster pump, which in turn runs water through a thin-film composite membrane. It filters the water to high purity, that is, nanometer levels thereby removing all incoming bacteria, hardness, and fluorides too. An activated carbon filter is in place to improve the taste of water, which makes use of NSF-approved components and storage tank too. The unit works in a five-stage filtration process to ensure highest level of purity of water for drinking. This process of water purification is better known as Reverse Osmosis or simply RO.

Kotak Urja solar water purifier

Technology demonstration experiences

Several pilot units (of other makes like GE) utilizing low-pressure RO systems were deployed for the filtration of brackish water during the tsunami-related relief efforts in Indonesia earlier. A few such demonstration units were also put up in India with a genuine purpose of gaining first-hand experiences of using such systems in special environments. Solar Aqua appears as one more make, which is poised to stand the test of time.

The entrepreneurial opportunity

Solar Aqua offers a good market potential in areas with a huge requirement of safe drinking water. The capital cost, that is, initial investment is about Rs 80 000 for a daily throughput of about 200 litres. The cost is expected to amortize over 300 working days, which yields a per litre cost of Rs 1.33 in addition to an operational expense of Rs 1.50 per litre for a can capacity of 3–5 litres. The big plus would be the availability of safe drinking water as expected of an RO system. It is important to note here that in a solar-powered water purification system of this type the running costs are far lower in comparison to a unit run on conventional power. The need of the hour is to raise the requisite awareness about the availability/use of these solar-powered water-cleansing units far and wide.

EVALUATING RENEWABLE ENERGY PROJECTS

SIMULATION OF SOLAR HOT WATER SYSTEM USING RETSCREEN

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

The RETScreen International clean energy project analysis software can be used worldwide to evaluate the technology optimization, energy production, life cycle cost analysis, and green house gas emission reductions. Thus, a complete project evaluation for various types of energy-efficient and clean/renewable energy technologies is enabled. The simulation task comprises of five easy steps as given in the flow chart.

Solar water heater

An SWH (solar water heater) is an appliance powered by solar energy and uses commercially available and well proven technology. There is a standard test procedure to evaluate thermal performance of an SWH. The thermal performance of a solar water heating system is influenced by a number of factors namely the following.

- incident solar radiation
- the collector type (for example, glazed, unglazed, or evacuated tubes)
- area under consideration
- appliance efficiency
- tracking mechansim (that is, fixed, one-axis, azimuth or two-axis based)
- slope of the azimuth (physical orientation)

In addition, several other factors like the end-use water temperature required, the supply temperature of the water available, and the use of a hot water storage tank have a bearing on the SWH performance. The SWH technology is best suited for domestic, residencial, commercial, and industrial applications.

An SWH is a combination of an array of collectors, an energy transfer system, and a thermal storage system. In active SWH systems, a pump is used to circulate the heat transfer fluid through the solar collectors, while in passive thermosyphon systems the natural circulation of working fluid is used. The amount of water produced from an SWH critically depends upon design and climatic parameters such as solar radiation, ambient temperature, and wind speed. These systems are also characterized as open loop (that is, direct, which circulates potable water through the collector); and closed loop (that is, indirect) which uses an anti-freeze heat transfer fluid loop to transfer heat from the collector to the potable water in the storage tank.

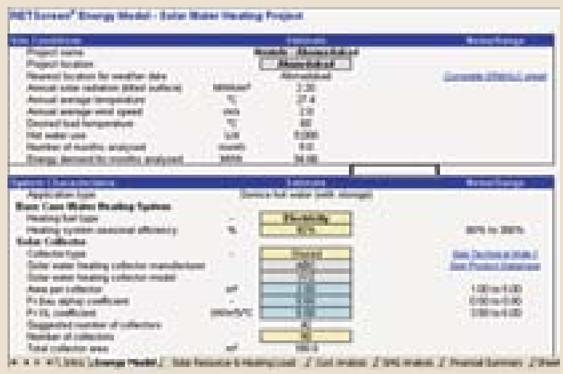

Figure 2 Calculating various parameters on the RETScreen software

Step 1 Development of energy model

The energy model consists of three major sections in which the specific information on location, climate, and technology is required namely site conditions, system characteristics, and annual energy production. The site conditions are defined with the geography (latitude, longitude, and altitude) of the location along with climatic conditions linked with the second step named Solar Radiation and Heating Load.

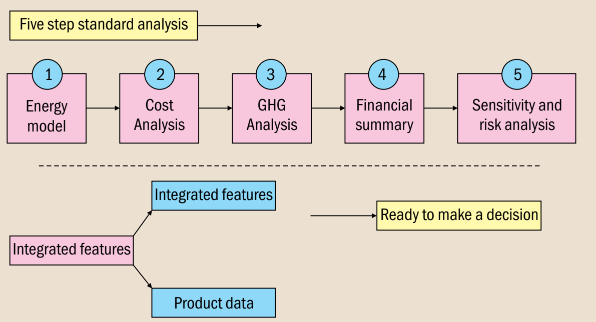

Figure 1 RETScreen software model flow chart

In the sub-section on system characteristics, the standard technical performance parameters of the solar collector (unglazed, flat plate, evacuated tubular, and so on), balance of system, storage, and so on is given. Once the solar collector technology is selected, the user can use the product database. The thermal performance parameters of solar collectors namely coefficient of optical efficiency (FR o) and heat loss factor (FRUL), are essential for estimation of energy generated. In the storage sub-section, the ratio of storage capacity with the required area of solar collectors of a pre-defined capacity is given with the storage capacity. The specifications of heat exchanger (if used) namely the dimensions of connecting pipes; pumping power, piping, and storage tank losses; and losses due to climatic and local weather conditions are defined in the sub-section on balance of system.

The site conditions associated with estimating the annual energy production of an SWH project details such as project name and location, nearest location for weather data, annual solar radiation, average ambient temperature, and so on are provided for the period (months) analysed, and so on. On the basis of all the mentioned parameters, along with the inputs required in the second step, the energy model estimates pumping energy, specific yield, system efficiency, solar fraction, and hence, the renewable energy delivered.

Step 2 Solar resource and system load

The second major step of the simulation model comprises three sub-sections namely site latitude and collector orientation, monthly inputs, and water heating load calculation. If load requirement is seasonal then the solar collectors are installed at a fixed inclination (for summers latitude –15° and for winters latitude + 15°) with south orientation (in Northern Hemisphere). For annual load requirement (industrial and commercial applications), the collectors are fixed on the latitude of the respective location.

Monthly inputs is the major sub-section of this step in which the climatic parameters are defined. The monthly average values of global solar radiation, ambient temperature, prevailing wind speed, and relative humidity at the locations are defined in this step. This sheet gives the monthly average daily values of global solar radiation and ambient air temperature on a horizontal surface of the respective location. The worksheet automatically estimates the solar radiation over inclined or oriented surface. The annual global radiation input obtained from this worksheet is linked with the energy model. The RETScreen has solar radiation database for various locations around the world. In case any location is not in the online database, the site provides a link to the NASA satellite weather database in which, the solar radiation and ambient temperature data can be generated, by providing just the latitude and longitude. This is an outstanding feature of this software.

Step 3 Cost analysis

The cost analysis worksheet is used to help a user estimate costs associated with the SWH project. In addition, the user may refer to the RETScreen online product database for supplier contact information in order to obtain prices or any other information required.

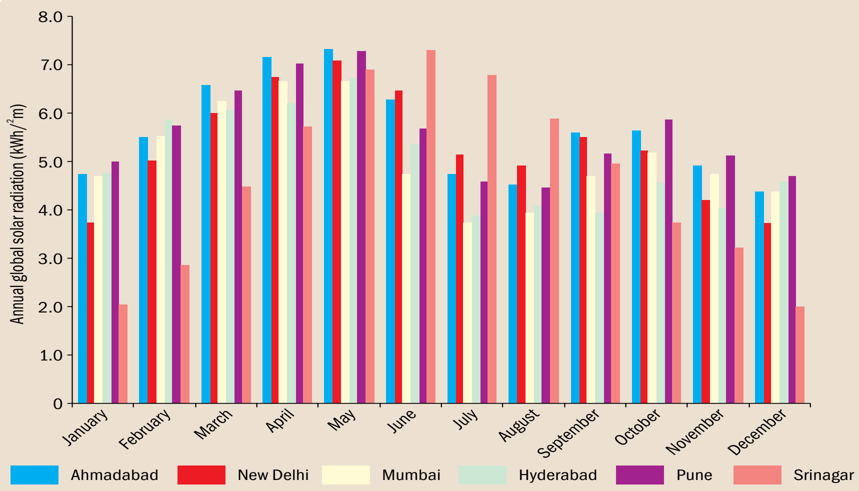

Figure 3 Annual global solar radiation in different cities

The data to be provided in various sections of the worksheet deals mainly with type of analysis, currency, cost references, second currency, rate, foreign amount, initial costs, annual and periodic costs, and so on.

Step 4 GHG analysis

GHG (greenhouse gas) analysis takes into account the estimation of GHG emission reduction (mitigation) potential of the proposed project. The exercise of emission reduction analysis worksheet contains four main sub-sections: background information, base case system (that is, baseline), proposed case system (the project), and GHG emission reduction summary.

The background information section provides project reference information as well as GHG global warming potential factors. The proposed case section provides a description of the emission profile of the proposed project, that is the SWH project. The GHG emission reduction summary section provides a summary of the estimated GHG emission reduction based on the data entered by the user in the preceding sections and from values entered or calculated in the other RETScreen worksheets. Results are calculated as equivalent tonnes of CO_2 avoided annually. One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers.

Step 5 Financial summary

RETscreen provides a comprehensive financial summary for the project evaluated which contains six sub-sections namely the following.

- Annual energy balance
- Financial parameters
- Project costs and savings
- Financial feasibility
- Yearly cash flows
- Cumulative cash flows graph

The annual energy balance and the project costs and savings sections provide a summary of the energy model, cost analysis, and GHG analysis worksheets associated with each project studied. In addition to this summary information, the financial feasibility section provides financial indicators of the project analysed based on the data entered by a user in the financial parameters section. The worksheet is linked with energy model and the cost analysis steps of the evaluating project. The financial summary worksheet, with its financial parameters input items (for example, avoided cost of energy, discount rate, debt ratio, and so on), and its calculated financial feasibility output items (for example, IRR, simple payback, NPV, life time cash flow, and so on), allows the project decision-maker to consider various financial parameters with relative ease. For SWH projects, the payback period is very small and depends on the end-use pattern.

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. Solar energy technologies are sooner or later going to take every one by a sheer surprise. Sizeable numbers can come through only by opening up new commercial vistas of applications alongside an increased market deployment of traditional uses. PVT collector use is one such novel application with a ready ability to fulfill multiple energy needs. It can also ensure a maximum possible use of the available roof space. 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).

Q What is a PV/T System in totality?
Suresh Mathur, Ahmedabad
Ans
a) Concept
Solar energy is a prime mover of life on earth. Lately, it is being used for meeting a variety of end-use applications like water heating, cooking, space heating, lighting, and water pumping. These uses are enabled by two distinctly placed technologies, that is, solar thermal and solar photovoltaics. PV technology in comparison is still walking on a slightly tough turf due to its high initial capital cost. One of the sure ways is to maximize the gains from within the same technology. In a way, such an objective is also a compulsive one as radiation entering the solar module does not convert all of it into electricity.

b) Technology
In practice, most of this radiation is converted into heat and not electricity as otherwise desirable. The trick of the trade lies in making use of such wasted heat via an ideal combination of a solar thermal and PV system. It is more commonly referred to as a PV/T system and also helps to keep the module at a relatively lower temperature. Higher temperature normally results in reduction of power output from a solar cell/module.

c) System

A PV/T system has solar modules and heat extraction units mounted together.

A circulating fluid of lower temperature than that of a PV module is heated by cooling them. The water-cooled PV/T systems comprises of metallic heat exchanger placed at the back surface of a module. This way, water circulating through the pipes is heated. Normally, the water heat extraction is more costly than air heat extraction. In contrast, natural or forced air circulation is a simple and low cost technique to take out heat from the modules. However, it is less effective if, ambient temperature is more than 20 °C. Anyway, a PV/T system can change solar radiation to electricity and heat simultaneously. In addition, it offers higher energy output than the standard solar modules. Thus a PV/T system is essentially a total solar energy system for both electric and thermal energy generation.

d) Application

PV/T seems to be quite a promising technology, which can be applied in a large part of the existing solar thermal market. These days, family apartments in high-rise buildings are an in-thing. So, it makes a definite market sense to try their use in such buildings while considering the limited roof space availability. In general, PV/T systems may be quite suitable for such places, as need both electricity and heat. These mainly include the following few.

- Households
- Hospitals
- Hostels
- Food processing industry
- Beverage industry
- Laundries
- Sports centres

Air type PV/T systems have been essentially used in PV for building applications as against the water type PV/T systems. The last Olympic Games held at Beijing housed a uniquely designed PV/T system, which was thronged by a large number of participants.

e) Cost

The PV/T systems have been an active area of research more so in the European countries. Presently, there are selective few manufacturers of such systems with no indigenous presence in India as such. A system of this type is expected to be cost effective, if, the additional cost of a thermal unit is low.

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

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Surveying the Flat Plate Collectors for their Sunny Promise

Dr Ishan Purohit, Research Associate, TERI <ishanp@teri.res.in>
Smita John Marcus, Research Associate, TERI <smarcus@teri.res.in>

Background

Energy from sun is available almost everywhere except the Polar regions. Solar energy technologies include solar thermal as well as SPV (solar photovoltaic) . The resultant end-uses are utilization of heat and electricity respectively. Solar thermal technologies enable us to use the sun's energy for cooking, water heating, air heating, drying of agro-produce, water purification, and importantly, industrial process heating, and lately, power generation.

India receives more than 5000 trillion kWh (kilowatt-hour) solar energy per year far exceeding its total annual energy consumption. The daily average global radiation is about 5 kWh/m^2 in north-eastern and hilly areas to about 7 kWh/m^2 in western regions and cold desert areas with the sunshine hours ranging between 2300 to 3200 annually. The potential for solar thermal has been estimated at 20 MW/km^2 in India. The annual global solar radiation varies from 1600 to 2200 kWh/m^2 in India, which is comparable with radiations received in the tropical and sub-tropical regions. These numbers are proof enough of growing commercial promise in solar thermal technologies. It is prudent to consider the low-temperature and high-temperature uses like industrial process heating and air-conditioning separately.

Solar thermal collectors

Solar energy collectors are special type of heat exchangers that transform solar radiation to internal energy of the transport medium. These are the building blocks of any solar thermal energy system. A collector is essentially a device, which absorbs the incident solar radiation over it and converts that to heat. It then transfers this heat to a heat-transfer medium like water flowing through the collector. The energy received from solar radiation is thus collected and extracted from the circulating fluid either directly to the hot water, steam or space conditioning equipment, or to a thermal energy storage tank. There are basically two categories of solar collectors.

- Non-focusing or stationary
- Focusing or concentrating

A non-focusing collector has the same area for intercepting and for absorbing incident radiation. A sun tracking concentrating solar collector

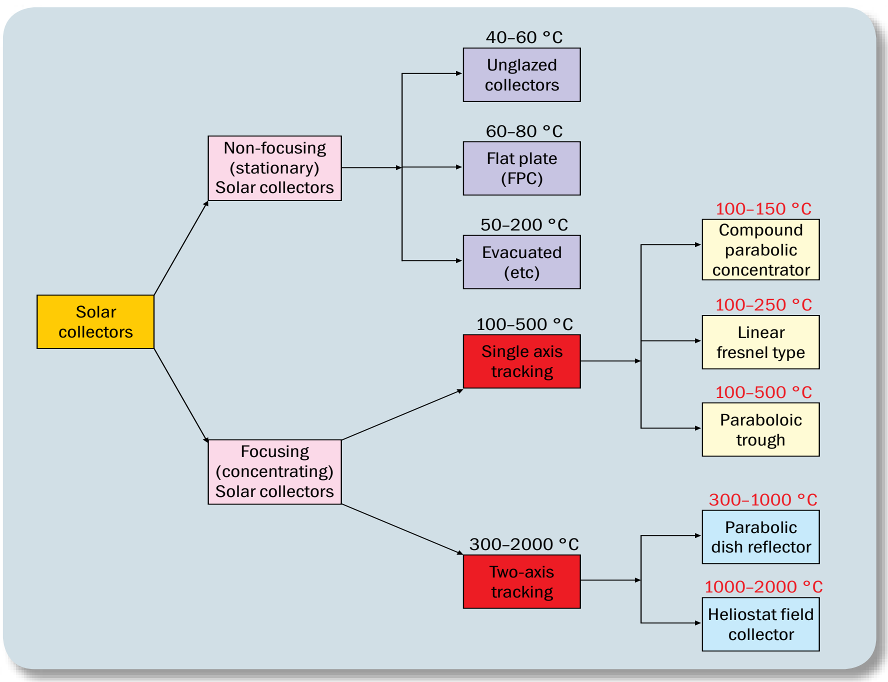


Figure 1 Types of solar collectors

usually has concave reflecting surfaces to intercept and focus the incident direct radiation to a small receiving area. The outcome is a definite increase in the radiation flux. Collectors are usually distinguished by their motion, that is stationary, single-axis tracking and two-axis tracking, and range of their operating temperature.

The most widely used non-tracking/stationary solar collectors include the following.

- Unglazed (plastic made) flat-plate type collectors
- Glazed flat-plate collectors
- Evacuated tubular type collectors, and
- Non-imaging compound parabolic collectors

On the basis of maximum temperature attainability the solar collectors can be further classified into two major categories namely the following.

- Low- and medium-temperature collectors (80 °C–300 °C)
- High-temperature solar energy collectors (>300 °C)

Low- and medium-temperature solar collectors mainly constitute unglazed collectors, flat-plate collectors, air heating collectors, compound parabolic collectors, and evacuated tubular solar collectors.

Flat plate solar collector

An FPC (flat-plate collector) is the most widely marketed solar thermal technology globally. It is best suited for applications that normally require heat at temperatures below 80 °C. A typical FPC consists of an absorber plate, one or more transparent covers, thermal insulation, heat removal system, and outer casing. The absorber plate is generally a sheet of metal of high thermal conductivity such as copper or aluminum coated with black paint or selective coating. A glass cover on the top is used for reducing the convective and radiative heat losses from the absorber to surroundings. The absorber plate rests on a thick bed of glass wool or any other good thermally insulating material to reduce bottom losses.

The heat collected by the absorber plate is extracted by making a working fluid flow through the riser tubes fixed with the absorber plate. The risers are connected to a larger pipe called header at both ends so that heat removal fluid can enter from the lower header and leave from the upper header. The working fluid, usually water or oil, flows through these tubes to carry away the heat of the FPC. An outer casing houses all these components. The FPC can be used to design solar systems for domestic and industrial water heating, space heating, drying, water distillation, and so on.

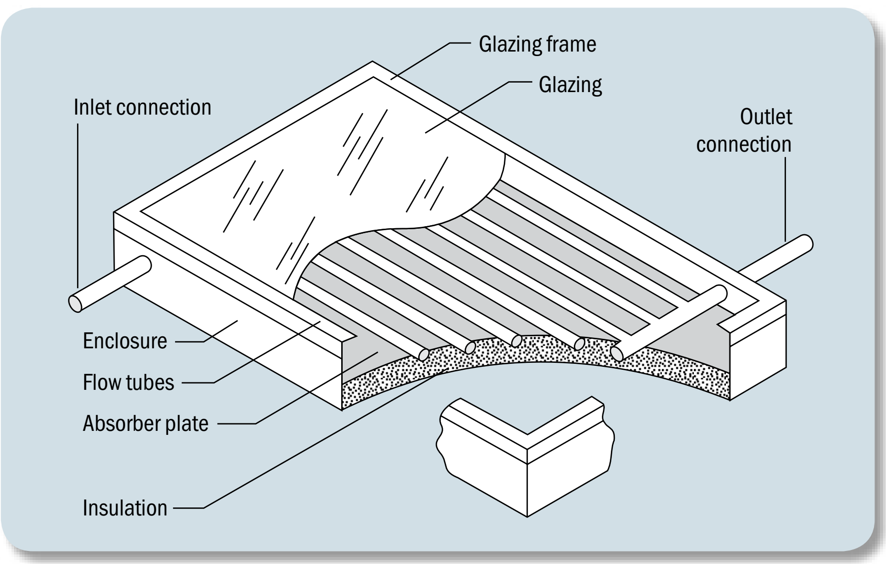


Figure 2 Flat-plate collector

FPC has the advantage of using direct, diffuse, and also the reflected components of solar radiation. Generally, solar collectors are installed at a fixed tilt and orientation, thereby removing any tracking requirements. There is a huge potential of using FPCs to provide low-temperature heat in community, commercial, and industrial establishments. In India, a large number of manufacturers of FPCs are marketing their products locally on an increasing scale.

History of development

The first detailed experimental study for the performance of FPCs was carried out by Hottel and Woertz (1942) based on energy balance measurements on an array of collectors on an experimental solar heating building. Dunkle *et al.* (1975) proposed a method for the evaluation of performance parameters of FPCs. Hill *et al.* (1974, 1976) proposed a standard test method for rating of solar collectors based on thermal performance. This method was later used in developing ASHRAE test procedure ASHRAE (1977). Using the average meteorological data for FPC performance calculations, a steady state, two-dimensional, nodal, heat transfer analysis has been carried out by Siebers *et al.* (1977). Liu and Jordan (1963) proposed a rational procedure for predicting long-term average performance of FPC. This has been simplified by Pereira *et al.* (1979) by developing a procedure for predicting long-term average performance of non-concentrating and concentrating solar collectors. Garg (1974) carried out the effect of dirt on transparent cover of FPCs and concluded that the dirt correction factor for glass plate inclined at an angle of 45 degrees from the horizontal is 0.92. This is lower than 0.99 as given by Hottel and Woertz (1942). Proctor (1984) proposed a generalized test method for evaluating thermal constant for different kind of solar collectors. He also numerically estimated the effect of instrumentation used for measurements of associated parameters during testing

Klein (1975) modified the basic equation of Hottel and Woertz and provided correlation for determination of the top heat loss coefficient of the FPC. It was further improved by Mullick and Samdarshi (1988). They developed an analytical equation for top heat loss factor of an FPC with double-glazing and also a generalized analytical equation for top heat loss factor for a solar collector with a number of glass covers. An improved equation for computing the glass cover temperature of FPCs with single glazing was later developed by Akhtar and Mullick (1999).

A standard collector model compatible with the ISO test standard (ISO 9806-1) has been used with correction terms for beam and diffuse incidence angle modifiers, thermal capacitance, wind speed, and sky temperature. More recently, Nayak *et al.* (2000) carried out detailed studies on experimental and theoretical evaluation of dynamic test procedures for FPCs in Indian conditions and came out with a dynamic test procedure.

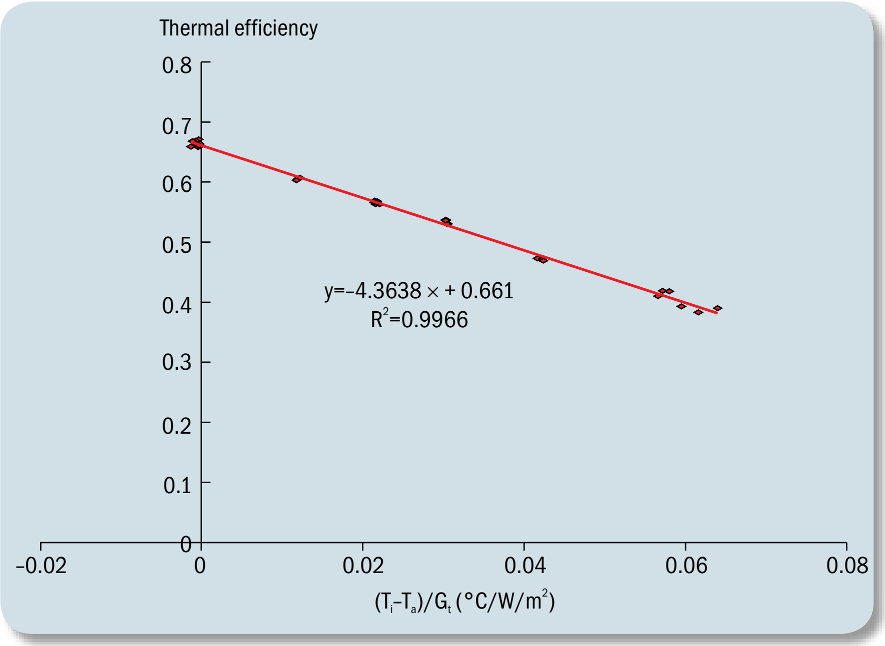


Figure 3 Thermal efficiency curve of FPC

Thermal performance parameters and test standards

It is quite essential to maintain an effective quality control on such market worthy products. So, there is a need to establish test procedures and methodologies for producing performance characteristic parameters. These could provide an equitable basis for comparison of product performances.

The BIS (Bureau of Indian Standards) published Indian Standards (IS 12933) for FPCs in 1990. It was substantially revised in 1992 (BIS 1992) followed up by a further revision in 2002. To study the effect of climatic parameters (and validation of IS12933) on the thermal performance of FPC; IIT Delhi carried out the round robin testing of FPC over India under various climatic conditions in 2001. The FPC was initially tested (under IS 12933) at SEC (Solar Energy Centre) for a period of one year and again tested at all Regional Test Centres of MNRE. However, a negligible scattering has been obtained.

There are two thermal performance parameters associated with the testing of FPC as per IS12923 namely FRUL (thermal efficiency factor) and FRo (thermal heat loss factor). These are basically obtained from outdoor testing. The specified/acceptable range of the performance parameters in the test standard is 4.0 W/m^2 °C and 0.65, respectively.

In India, solar water heating application is already a commercial success with more than 60 manufacturers producing such systems. These are mainly being used in domestic, industrial, and commercial sectors besides hospitals, dairies, hostels, and so on.

Solar water heating

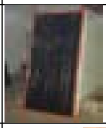
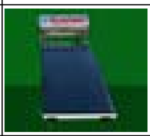
A commercially available solar water heater is a combination of an array of collectors (FPC or ETC), an energy transfer system and a thermal storage system. In active SWH (solar water heating) systems, a pump is used to circulate the heat transfer fluid through the solar collectors. While in passive, that is, thermosyphon systems, the natural circulation of working fluid is used. The amount of hot water produced critically depends upon design and climatic parameters such as solar radiation, ambient temperature, and wind speed. These systems are also characterized as open loop (that is, direct); which circulates potable water through the collector; and closed loop (that is, indirect), which uses an antifreeze heat transfer fluid loop to transfer heat from the collector to the potable water in the storage tank. Some systems also use a load side heat exchanger between the potable water stream and hot water in the tank.

Thermo-syphon SWH systems

This system relies on the natural circulation of water between the collector and the storage tank or heat exchanger. In order to achieve circulation during the day time and limit reverse circulation at night, the storage tank must be above the collector. As water in the collector is heated through the incident solar radiation it rises into the storage tank.

Figure 4 Solar water heating for hotel industry Installed at Hotel Fisherman's Cove (Taj Group), Chennai

Survey results

Name of the Manu-facturing Company	Sample Photograph	Model	Dimensions		Material of Collector Body	No of Glass covers used	Glass Cover				Absorber Plate				Insulation	
			Gross Area	Aperture Area			Dimension	Transmittance	Material	Extinction coefficient (if available)	5	Material	Thermal Conduc-tivity	Thickness	Material	Thickness (Bottom)
Jay Industries		Standard	2.1 m^2	2 m^2	Aluminum Extruded sections, Aluminum Back Sheet	Single	1000 × 2000 mm	82%	Not Provided	Not Provided	Finsize - 115 × 1900 mm (9 nos./collector)	Copper	Not Provided	0.12 mm or 0.15 mm	Resin Bonded Rockwool slabs.	50 mm
Sunrise Solar Pvt Ltd.		Ultratech	2 m^2	1.98 m^2	Galvanised aluminium	Single	1000 × 2000 × 4 mm	87%	Not Provided	Not Provided	1930 mm	Copper	401 W/m^2 °C	0.19 mm	Rockwool	50 mm
Sunrise Solar Pvt Ltd.		Standard	2 m^2	1.98 m^2	Jindal Anodized Aluminium	Single	1000 × 2000 × 4 mm	87%	Toughened Glass	Not Provided	1930 mm	Copper	401 W/m^2 °C	0.19 mm	Rockwool	50 mm
Tata BP Solar India Ltd.		TataSol	2.21 m^2	2.1 m^2	Aluminium	Single	2040 × 1030 × 4 mm	85%	Toughened Glass	N/A	2000 X 1000 mm	Copper	333 Kcal m hr C	0.12 mm	Rockwool	40 mm
Sun Technics Energy Systems Pvt Ltd.	Not Provided	Sun Technics	2.04 m^2	1.9 m^2	Aluminium Extrusion	Single	2000 × 1000 × 4 mm	82%	Tempered/ Toughened Glass	Not Provided	1926 X 1090	Copper - Coppe; Laser welded	F_RU_L 4.1 W/m^2°C	Not Provided	Rockwool	50 mm
Rashmi Industries		RASHMI	2.10 m^2	2.00 m^2	Aluminium	Single	2000 × 1000 mm	84%	Toughened Glass	N/A	115 mm (width)	Copper	Not Provided	0.12 mm	Rockwool	50 mm
Kotak Urja pvt. Ltd.		Not Provided	2.0 m^2	1.86 m^2	Aluminium Alloy	Single	1990 × 990 × 4 mm	88%	Toughened Glass	Not Provided	110 mm (width)	Copper	Not Provided	0.15 mm	Rockwool	50 mm
Sunlit Solar Energy Pvt Ltd	Not provided	Not Provided	2.09 m^2	1.89 m^2	Aluminium	Single	2000 × 1000 × 4 mm	82%	Toughened Glass	Not Provided	1922 X 1892 X 115 mm	Copper	Not Provided	0.15 mm	Slabwool	50 mm

The cooler water in the tank flows down to the bottom of the collector thus causing circulation throughout the system. This configuration of SWH systems is possible with all kinds of stationary collectors.

Air heating collectors

One of the basic designs of solar air heating system is based on FPCs, which may be integrated with south-facing roof of the industrial house. Depending upon the temperature requirements, absorber could use simple or double-glazing, and air flow over or below the absorber. The solar air heaters could raise the temperature of the air to 65 °C. It essentially comprises of collector box, transparent cover, an absorber, and thermal insulation on the backside. FPC being the building block of all solar thermal systems is more effectively used for desalination of water and active applications in buildings.

Solar collector industry in India

FPC is one of the successfully standardized and commercialized technologies in India. Presently, more than 60 manufacturers are producing ISI-mark solar collectors in the country alongside 35 manufactures marketing ETC (evacuated tubular collectors). In addition, few industries are venturing into production of specialized solar thermal energy devices and systems namely solar air heating systems, so-

		Coating		Header and Riser Tubes		Thermal Performance Parameters			ISI Certification (yes/no)	Certifying Organization/ Test Center	Market introduc-tion of the model (year)	Price for the Flat Plate Collector	Average number of systems	Total number of systems	Main application for which FPC are sold	Additional remarks/ Other provisions in the FPC.
Thickness (sides)	Thermal Conductivity	Material	Absorp-tance	Material	Diameter (both)	F_RU_L (W/m^{2o}C)	$F_R\eta_o$	Tempe-rature coefficient for F_RU_L				*(ex-factory price)*	(or area m^2) sold in a year	(or area m^2) sold	(solar water heating / industrial application / other)	
25 mm	R = 0.96 m^2 °C/W	Nalsun	0.92 – 0.94	Copper	12.7 mm and 11.5 mm	4.68 W/m^2°C	0.671	Not Provided	Yes	Not Provided	1998	Rs. 8,000	1,912 m^2	30,000 m^2	Solar Water Heating	
25 mm	Not Provided	Black Chrome Electro-plating	0.96	Copper	12.7 mm and 25.4 mm	6 W/m^{2o}C	0.65	Not Provided	No	Regional Solar Energy Testing Center, Madurai	2005	Rs. 7,000	3,600 m^2	3,600 m^2	Water heating in domestic application	
25 mm	Not Provided	Selective Coating	0.96	Copper	12.5 mm and 25.4 mm	6 W/m^2 °C	0.65	Not Provided	Yes	Madurai Kamaraj University, Madurai	1999	Rs. 7,500	3,000 m^2	3,000 m^2	Water heating in domestic application	
25 mm	0.029 W/mK	Black Chrome	0.92	Copper	25.4 mm and 12.7 mm	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not Provided	Not provided	Not Provided	
25 mm	K - 0.96m^2 °C/W	Selective Black Chrome	0.92	Copper	25.4 mm and 12.7 mm	4.1 W/m^{2o}C	0.70	Not Provided	Yes	Regional Solar Energy Testing Center, Madurai	2007	Rs. 10,000	6,000 m^2	Not provided	Heating System (Both Domestic / Commercial) / Industrial process heating	
25 mm	Not Provided	Selective Coating	0.95	Copper	25.4 mm and 12.7 mm	5.24 W/m^{2o}C	0.71	Not Provided	Yes	BIS/Regional Solar Energy Testing Center, Madurai	1997	Rs. 8,500	25,000 m^2	Not provided	Water Heating / Industrial application	
25 mm	R = 1.72 m^{2o}C/W (back) R = 0.86m^{2o}C/W (side)	Black Chrome	Not Provided	Copper	25 mm and 10 mm	5 W/m^{2o}C	0.71	Not Provided	Yes	BIS/Madhurai Kamaraj University, Madurai	Not Provided	Rs. 8500	10,000 m^2	1,20,000 m^2	Solar water heating purposes	
25 mm	0.029 w/mk at 100^0 C	Nalsur (selective)	0.96	Copper	25.4 mm and 12.7 mm	5.5 W/m^{2o}C	Not Provided	Not Provided	Yes	Madurai Kamaraj University Madurai	2000	Rs. 9500	1,524 m^2	25,000 m^2	Solar water heating, Industrial application	

lar dryers, large area solar concentrating dishes, and so on. The overall potential of SWH systems in India is estimated to be 140 million m² of collector area. However, just a small area, that is, 1.9 million m² of solar collector area has been installed so far. The rate of growth in last few years has accelerated substantially. Solar thermal installations worldwide had reached 125 million m² of collector area at the end of 2005 representing 14% capacity increase in that year. Majority of the installations are for domestic water heaters, with about 45 million homes having solar thermal installations.

As per a detailed literature review, the required temperatures for processing are up to 400 °C in case of small- and medium-scale industries. For example, in the dairy industry, the thermal energy processes consumes more then 70% of total energy. Production of hot water and pressurized steam are two major thermal energy applications where solar collectors and concentrators may effectively be used. The thermal performance of unglazed and FPCs effectively reduces when operated under high temperatures. For example, FPC may be recommended for hot water in domestic applications, but the same cannot be used to meet industrial applications like pasteurization and sterilization. These need constant supply of hot water at more than 80 °C. Similarly, concentrator systems can be used for pressurised steam needs. However, moderate tempera-

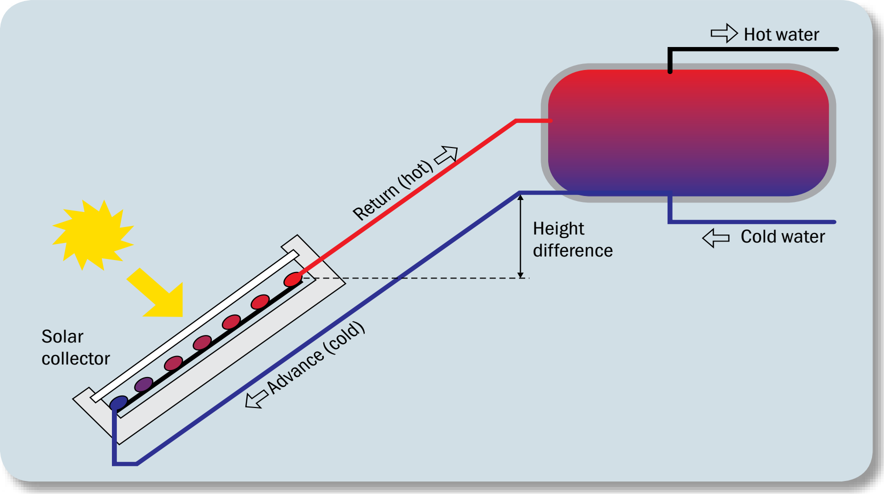


Figure 5 Thermo syphon SWH systems

ture requirements are widespread to meet localized needs in dairy, leather, food processing industries, and so on.

The survey vitals

The present article collates information on FPC manufacturers in India and puts it forward in the form of a comprehensive table. TERI undertook a survey incorporating about 63 BIS approved manufacturers of FPC-based solar water heaters. The survey obtained specific information from these manufacturers about their product range including all key aspects of an FPC. Survey questionnaires were accordingly prepared for onward transmission to above manufacturers. However, only a small number (seven) of responses were received related to eight models of FPCs. A comprehensive information chart (Excel based) on such FPC models was prepared for ready reference of the interested readers.

Presently, six regional testing centres of MNRE exist for testing of FPCs as per IS 12933. The SEC has automatic indoor–outdoor test facility for testing of FPCs. The thermal performance parameters (FRUL and FRo) reported by all seven manufacturers in the survey were found to be similar and within the specified range as per IS12933. The FRUL of all these models ranges between 4.1 W/m^2 °C and 6.0 W/m^2 °C, while the FRo varied between 0.65 and 0.71. The dimensions, quality of glass, insulation material, absorber, and coating were found to be similar for all models and as per the stipulated test standards. The gross area of collector varied between 2 m^2 and 2.09 m^2 as against aperture area variance of 1.86 m^2 and 2.1m^2. All the seven manufacturers used aluminium as the material of the collector body and a single glass cover. The material of the absorption plate was copper while the insulation material used was rockwool.

The average price of FPCs as given by the manufacturers varies between Rs 7000 and Rs 10 000. Further, the collector area marketed by these seven manufacturers since their inception ranges between 3000 m^2 and 120 000 m^2. The most preferred use of such collectors is for water heating both within the domestic and industrial sectors.

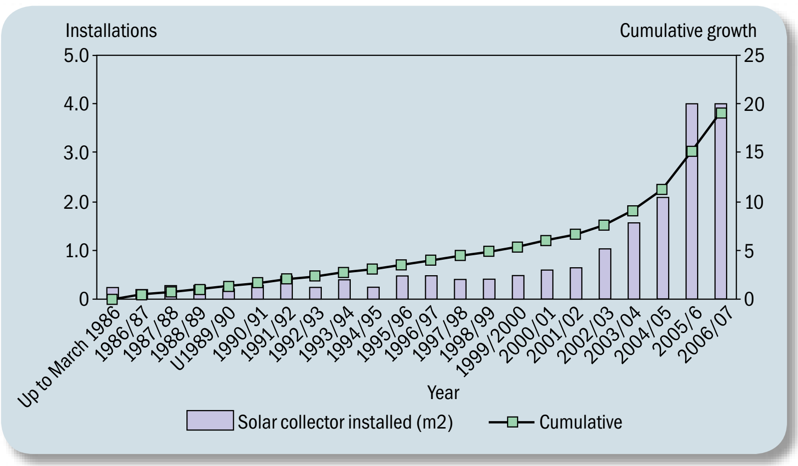


Figure 6 Solar collector area (lakh m^2) installations

Table 1 Low-temperature industrial solar thermal applications

Industry	Process	Temperature (°C)
Dairy	Pressurization Concentrates Boiler feed water	60–80 60–80 60–90
Tinned food	Pasteurization Cooking Bleaching	60–80 60–90 60–90
Meat	Washing, sterilization Cooking	60–90 90–100
Beverages	Washing, sterilization Pasteurization	60–80 60–70
Food and Beverage	Drying Washing Pasteurization Boiling Heat treatment	30–90 40–80 80–110 95–105 40–60
Chemical	Pre-heating water Boiling	60–90 95–105
Flours and by-products	Sterilization	60–80
Timber by-products	Thermo-diffusion beams Drying Pre-heating water	80–100 60–100 60–90
Bricks and blocks	Curing	60–140
Textile	Bleaching, Dyeing Pressing Washing Bleaching	60–90 80–100 40–80 60–100
All sectors	Pre-heating of boiler and feed water Heating of production halls	30–100 30–80

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

Survey Questionnaire

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 are rolling out a survey questionnaire to all PV Cell and Module manufacturers enlisted with us. We anticipate receiving your valued response by 31 January 2009 and the findings would be published in the April 2009 issue of the magazine.

Instructions

1. The survey will take only 10 minutes of your time.
2. The Product Profile in the questionnaire has two parts: Part 1 and Part 2.
3. Companies manufacturing both Cells and Modules are requested to fill both parts.
4. Else, PV Cell manufacturers need to fill Part 1.
5. Part 2 is to be filled out by PV Module Manufacturers. You are requested to kindly specify the capacity of the module being manufactured by your company.
6. Kindly fill the entries against the column assigned.
7. Please answer all the questions.
8. Kindly send us the filled questionnaires by 31 January 2009.

Company profile

Name of the company:
Year of establishment:
Name of MD/COO:
Current annual turnover (rupees) :
Complete address: Corporate office: Factory:
Phone/Fax:
Website:
E-mail:

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Product profile

Part 1: Solar cells

Cell technology used (in production)		☐ Monocrystalline	☐ Polycrystalline	☐ Thin film
Annual production (in MWp)		Monocrystalline	Polycrystalline	Thin film
	Actual (2008/09)			
	Planned (2009/10)			
Existing production capacity (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			
Exports (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			
Imports of wafer (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			

Part 2: Solar module

Range of product: (Please specify the capacity of module manufactured by your company)				
Module technology used (in production)		☐ Monocrystalline	☐ Polycrystalline	☐ Thin Film
Annual production (in MWp)		Monocrystalline	Polycrystalline	Thin film
	Actual (2008/09)			
	Planned (2009/10)			
Existing production Capacity (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			
Exports (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			
Import of cell (in MWp)				
	Actual (2008/09)			
	Planned (2009/10)			

Name of person filling the questionnaire : ________________________________

Signature:________________________

Date:____________________________

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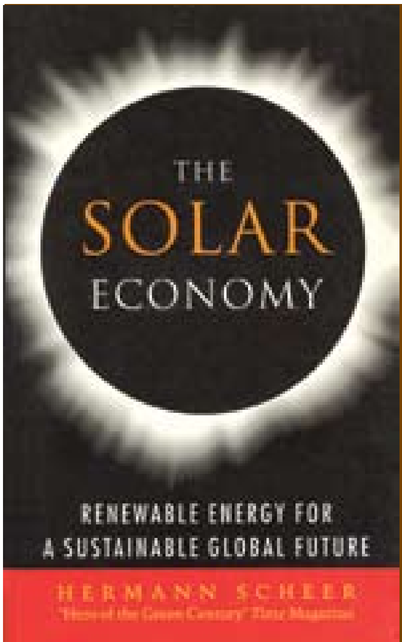
The 'Sun' shines down

"We now find one barrel of oil for every four we consume. The general situation seems so obvious... How can governments be oblivious of the realities of discovery and their implications...given the critical importance of oil to our entire economy…"

— Dr Colin Campbell, ASPO president, in his testimony to the British House of Commons



The Solar Economy: Renewable Energy for a Sustainable Global Future

By Hermann Scheer

Publisher Earthscan, 347 pp.

ISBN1-84407-075-1

Price $25.55

As the world progresses at breakneck speed towards an energy holocaust, Dr Campbell's words seem prophetic. Wars, diplomatic wrangling, international politicking…it is all happening to possess what is left of the world's fossil fuel reserves. The worst nightmare of the average citizen may just come true as oil prices spiral, availability dwindles, and sustainable sources of energy are given the short shrift. The UN-endorsed IPCC (Intergovernmental Panel on Climate Change) has stated that emissions reductions of 60% by 2050 are vital if the global climate is to be stabilized.

But as Hermann Scheer says in his new book The Solar Economy: renewable energy for a sustainable global future, 'Global problems need global – and thus consensual – solutions,' where all governments must recognize that they have a direct responsibility to tackle climate change, and their commitments must be binding. One of the world's best known analysts and advocates of a 'green' future, Scheer lays out the blueprints, showing how the political, economic, and technological challenges can be met using indigenous, renewable, and universally available resources, and the enormous opportunities and benefits that will flow from doing so.

The Solar Economy…is a timely book. It considers the early theories of economists and 'physiocrat's' as canonical and environmentally strong, and begs the question: why were they sidelined and forgotten? The school of thought originating with the French writer Francois Quesnay reiterated that only that much should be taken away from nature, as it was possible to give back. The wider ecological context is thus at the heart of this analysis of economic processes. The physiocrat's thus, formulated the early principles of what we now call 'sustainable development.'

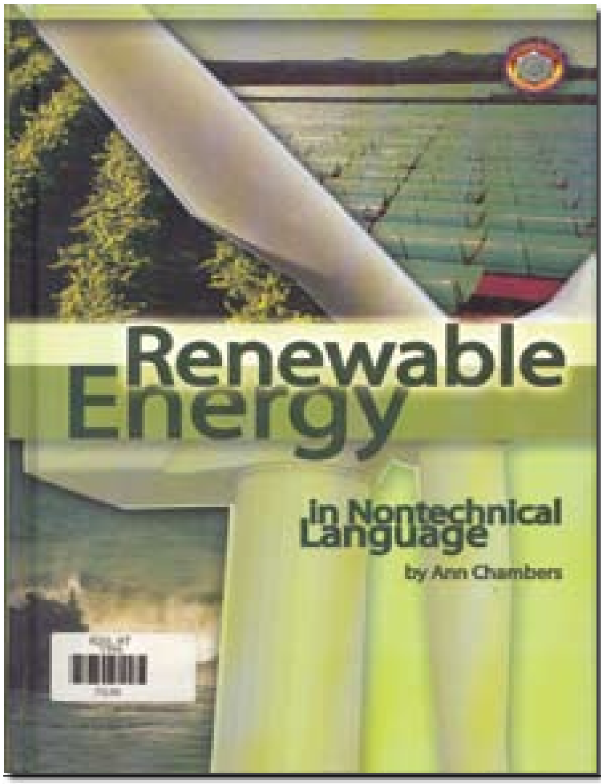
The author marks a break from the past as he states that making the groundbreaking transition to an economy based on solar energy and solar resources will do more to safeguard our common future than any other economic development since the Industrial Revolution. The destructive imperative of the fossil fuel economy needs to be reined in sooner rather than later by adopting the solar economy as an inevitable ally in the march towards economic globalization.

Scheer also argues that an economy based on solar energy and solar resources will make it possible to re-establish the links between development of the economy as a whole and environmental cycles, stable regional business structures, cultures, and democratic institutions—links that are essential if the future security of the human society has to be guaranteed. He also emphasizes the fact that renewable sources of energy have much shorter supply chains and thus, are more economical, contrary to the myth that fossil fuels, with their long supply chains turn out to be a cheaper option.

Concluding that only a solar global economy can satisfy the material needs of all mankind and grant us the freedom to guarantee truly universal and equal human rights. The Solar Economy…confronts the reader with an uncomfortable question: what is prompting the delay in transition before the catastrophe hits us? In the words of the author, 'What is in principle impossible with the ''invisible hand of the market'' alone can be achieved with the visible hand of the sun.

Reviewed by
Roshni Sengupta, TERI

New Book Information



Renewable energy in non-technical language

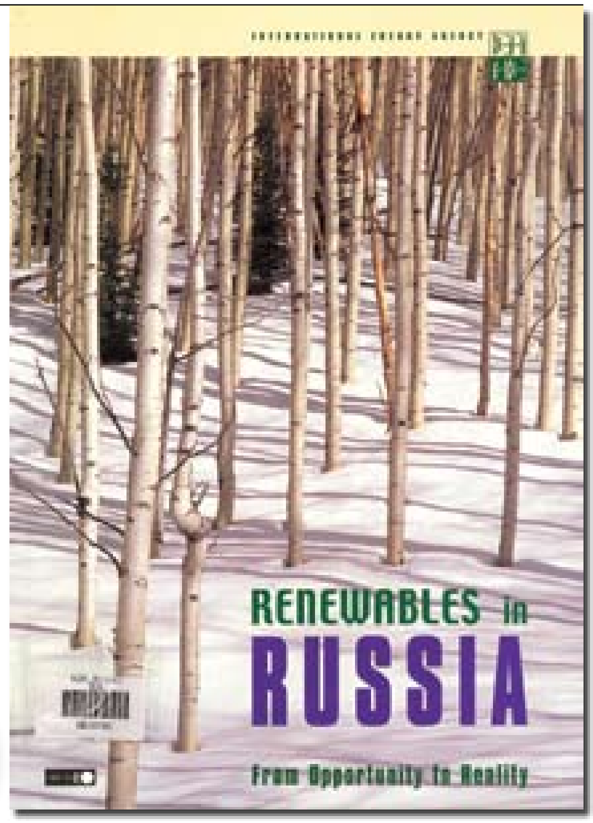
In this book, the author draws from her expertise on energy matters to deliver an unparalleled guide to renewable energy resources. Using a non-technical approach, she introduces sources of renewable energy such as wind, solar, biomass, and hydro supported by several pictures, graphs, and charts showing 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, Oklahoma, USA: PennWell Corporation. 244 pp.
Price: $69
ISBN 978-1-59370-005-08

Renewables in Russia: from opportunity to reality

Russia is rich in renewable energy resources. Russia's renewables can cost-effectively provide energy services where conventional forms are expensive. The existing renewable energy installations can supplement energy from fossil fuels in a cost-effective manner. At the same time, new renewables such as wind and solar energy can serve remote populations and in the right circumstances, provide energy at competitive prices on the grid. This report demonstrates that renewable energy can offer a real means to address some of Russia's energy and economic challenges. It identifies the first steps towards creating a Russian renewables market, and will contribute to a better understanding by both Russian and international industry, of the potential for profitable renewable projects, and the incentive to start undertaking them.

OECD (Organization for Economic Cooperation and Development)/IEA (International Energy Agency). 2003
Paris, France: OECD/IEA. 116 pp.
Price: €100 • ISBN: 92-64-10544-1



Events calendar

National events

LED Expo 2009
9–11 January 2009, Pragati Maidan, New Delhi

Media Exposition and Events
Tel. +91 11 26445191/2
Web www.themediaexpo.com

International Solar Food Processing Conference 2009
14–16 January 2009, Indore

Barli Development Institute for Rural Women
180 Bhamori
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PV Expo Show Management
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PHOTON'S Seventh Solar Silicon Conference
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Solar 2009
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24th European Photovoltaic Solar Energy Conference & Exhibition (EU PVSEC)
21–25 September 2009, Germany

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Organic Photovoltaics 2009
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