helps to know the sun's efficiency. However, where billing is done based on peak hours it will be very useful to adapt the following equations as shown below.

$$I_o = I_{sc}\left(1+0.1033\cos\left(\frac{360+n}{365}\right)\right)\cos\theta_z \tag{15}$$

Where:
n = number of days
I_{sc} = Solar constant
θ_z = Zenith angle

This hourly radiation whose units are in watt/m²sec can be integrated and summed up to give daily solar radiation on horizontal surfaces as:

$$H_o = \frac{24X3600}{\pi} X I_{sc}\left[1+0.033\cos\frac{(360+n)}{365}\right] \tag{16}$$
$$((\cos\phi\cos\delta\sin\omega_s)+(2\pi\omega_s)\sin\phi\sin\delta)$$

Where:
ω_s = Sunset hour angle and its units is in mega Joules (MJ)

Therefore, the instantaneous energy from the sun will be given by:

$$I_o = \frac{12\times3600}{\pi} X I_{sc}\left[1+0.033\cos\frac{(360+n)}{365}\right]((\cos\phi\cos\delta(\sin\omega_2-\sin\omega_1)$$
$$+\left(\frac{2\pi}{360}(\omega_2-\omega_1)\sin\phi\sin\delta\right) \tag{17}$$

This is not a function of radiation.

In order to effectively maximize the solar potential as evident from the Gaussian distribution, it is necessary to use the concept of view factor implored by using inclined surfaces.

The view factor of any location is given by:

$$\frac{(1\pm\cos\beta)}{2} \tag{18}$$

β = the angle between two surfaces

The maximum possible value of the view factor is one (1), because of this effect there are three (3) multiplication factors
Beam radiation = R_b
Diffuse radiation = R_d
Reflected radiation = R_r

So, the total incident radiation on the solar panel will be represented as:

$$I_T = I_B R_b + I_D R_d + \rho_g R_r (I_B + I_D) \tag{19}$$

Where:
I_B = Multiplication factor due to R_b
I_D = Multiplication factor due to R_d
$I_B + I_D$ = Multiplication factor due to I_T
ρ_g = Ground reflectance

However, the effect of beam radiation will be defined by:

$$R_b = \frac{(\cos\delta\cos(\phi-\beta)\cos\omega)+(\sin\delta\sin(\phi-\beta))}{(\cos\delta\cos\phi\cos\omega)+(\sin\delta\sin\phi)} \tag{20}$$

Hence;

$$R_d = \frac{1+\cos\beta}{2}$$

$$R_r = \frac{1-\cos\beta}{2}$$

Parameter formulation

From the above derivations and equations, we can estimate for each month the global solar radiation on horizontal or tilted surface, depending on the latitude of our location and determine respectively the following few parameters.

H_g = Monthly average of daily beam radiation on a tilted surface
H_{total} = Monthly average of daily total radiation on a tilted surface
K_t = Clearness index

These can be manually determined as shown or through appropriate use of any relevant software.

Solar PV electrical characteristics

The most important parts of a PV system are the solar cells, which form the basic building block of the unit, collecting the incident sunlight, the module which brings together large number of cells into a monolithic unit, and in some situations, the inverter used to convert the direct current (DC) electricity generated into alternating current (AC) suitable for everyday use.

PV technology

The design of solar power systems based on PV cells largely depends on the electrical characteristics of the cells. The current- voltage relationships of the cells, under various levels of radiation and at various cell temperatures, are based on the manufacturer's specifications.

PV cells and modules

PV cells are generally made either from crystalline silicon, sliced from ingots or castings or from grown ribbons, or thin films, deposited in thin layers on a low-cost substrate such as glass. Most cell production (about 80% in 2009) has so far involved the former, whilst future plans have a strong focus on the latter. Thin-film technology, based on silicon and other cell materials like cadmium telluride and copper indium diselenide, is expected to gain a larger share of the PV market in future. This

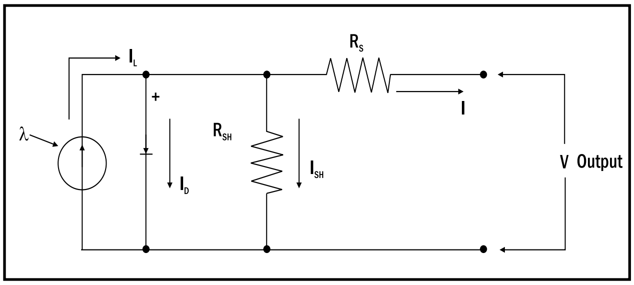

Figure 14 Equivalent electrical circuit of PV module showing the diode and ground leakage currents

technology offers several advantages, such as very low material, consumption, lower weight, and a smooth appearance.

$$V_{oc} = V + IR_{sh} \quad (21)$$

The diode current is given by the classical diode current expression

$$I_d = I_D\left[\frac{QV_{oc}}{AKT} - 1\right] \quad (22)$$

Where:
I_D = The saturation current of the diode
Q = Electron charge = 1.6×10^{-19} Coulombs
A = Curve fitting constant
T = Temperature on absolute scale °K
K = Boltzmann constant = 1.38×10^{-23} Joule/°K

Therefore, the load current is given by the following expression

$$I = I_L - I_D\left[\frac{QV_{oc}}{eAKT} - 1\right] - \frac{V_{oc}}{R_{sh}} \quad (23)$$

The last term, the ground leakage current, in practical cells is small as compared to I_L and I_D, and can be ignored. Therefore, the diode-saturation current can be determined experimentally by applying voltage V_{oc} in the dark and measuring the current moving into the cell. This current is often called the dark current or the reverse diode saturation current.

Open circuit voltage and short circuit current

The two most important parameters, widely used for describing the electrical performance of the cell, are the open-circuit voltage(V_{oc}) and the short circuit current (I_{sc}). The short circuit current is measured by shorting the output terminals and measuring the terminal current under full illumination. Ignoring the small diode and the ground leakage currents under zero-terminal voltage, the short-circuit current under this condition is the photocurrent I_L. The maximum photovoltage is produced under the open-circuit voltage.

Manufacturer's module specifications and I-V characteristics

The electrical characteristic of the PV cell is generally represented by the current versus voltage (I–V) curve. The short circuit current measures with the output terminals shorted (zero voltage). The open-circuit voltage measures with the output terminals open (zero current). In both the cases, the cell works like a constant current source, generating voltage to match with the load resistance. Also, the current drops rapidly with a small rise in voltage. In this region, the cell works like a constant voltage source with an internal resistance. If the voltage is externally applied in the reverse direction, say during a system fault transient, the current remains flat and the power is absorbed by the cell. However, beyond a certain negative voltage, the junction breaks down as in a diode and the current rises to a high value. In the dark, the current is zero for voltage up to the breakdown voltage, which is the same as that under the illuminated condition. The power output of the panel is the product of the voltage and the current outputs. Notice that the curve has a knee point.

Figure 15 Shows the effect that temperature has on the power production capabilities of a module. As module operating temperature increases, module voltage drops while current essentially holds steady. The PV module operating voltage is reduced on an average for crystalline modules by approximately 0.5% for every degree Celsius above STC (that is 25°). Thus, a 100 Wp crystalline module, under STC, now operating at a more realistic 55 °C with no change in solar irradiance will lose about 15% of its power rating and provide about 85 W of useful power. In general, while sizing terrestrial PV systems, one should expect a 15%–20% drop in module power from STC. This needs to be remembered when calculating daily actual energy production.

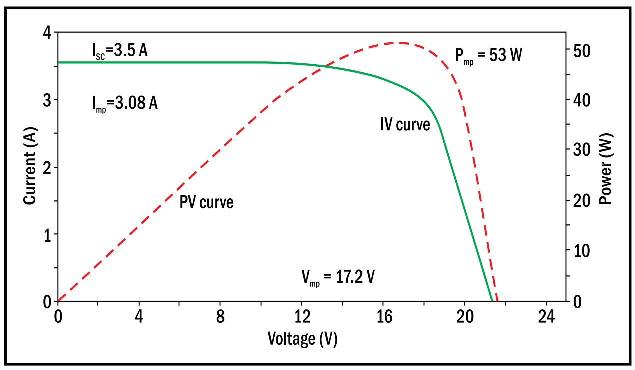

Figure 15 Effect of temperature on power production capabilities of a module

Table 1 Manufacturer's specifications for a Siemens Solar SM 55 1997 Module. Standard test conditions (STCs) 1,000 W/m², 25 °C

S.No.	Operating point	Model BP VLX-53
1	Pmp	53 Wp (peak Watts)
2	Vmp 17.2 V	Imp 3.03 A
3	Voc	21.0 V
4	Isc	3.3A

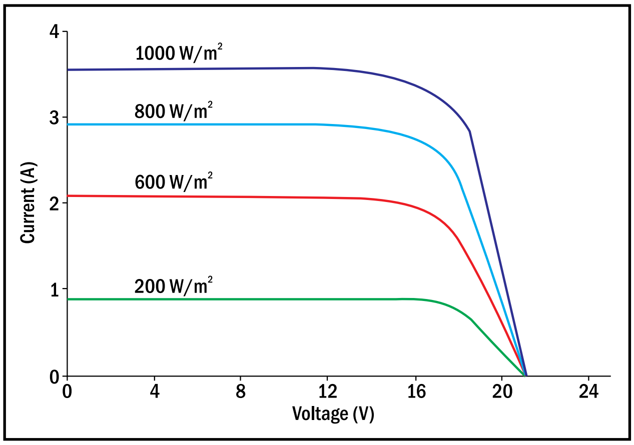

Figure 16 PV module current diminishes with decreasing solar irradiance

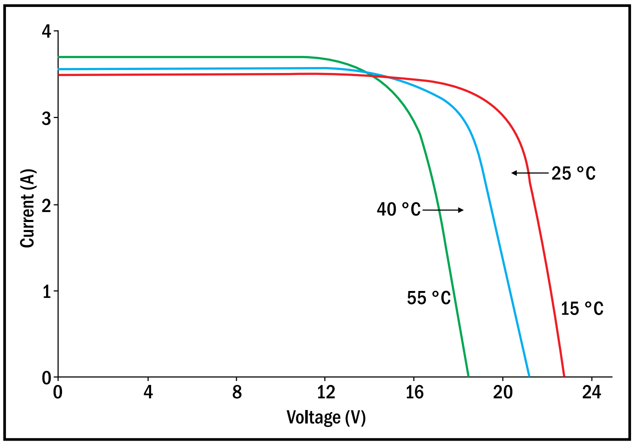

Figure 17 PV module voltage drops with temperature, also with power

After this, the cells are mounted in modules. Multiple modules are used in arrays. Individual modules may have cells connected in series and parallel combinations, so as to obtain the desired current and voltage. For modules connected in series, the voltages are additive, and when in parallel, the currents are additive.

Design characteristics: TERI University, Vasant Kunj, New Delhi

Having determined orientation of the sun through previous experiments and using the above module characteristics, the area of the module can be calculated as follows.

(1) The total area covered by TERI University = 8163.60 m^2
(2) The total built up area = 7962 m^2
(3) The total carpet area = 6707.16 m^2

$$\text{Area of the module} = \frac{53}{0.1237 \times 1000} = 0.43\text{m}^2 \qquad (24)$$

So, the number of modules required will be =

$$\frac{8160}{0.4284} = 19048\text{modules} \qquad (25)$$

Total DC power generated will be 1 009 110 kW DC with capacity power of 17.9%.
Annual energy output = 1 578 407 kWh
System performance factor = 0.70

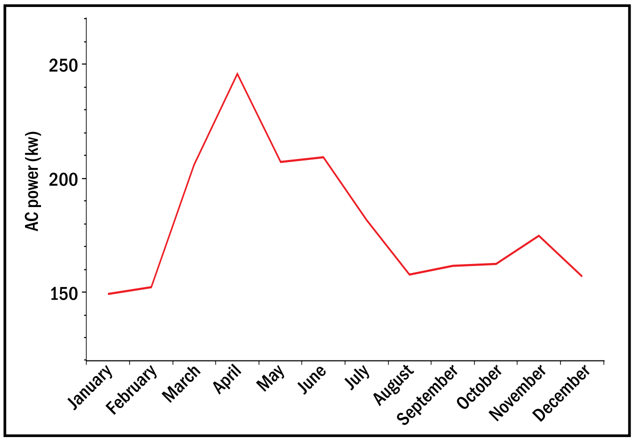

Figure 18 Monthly AC power generated

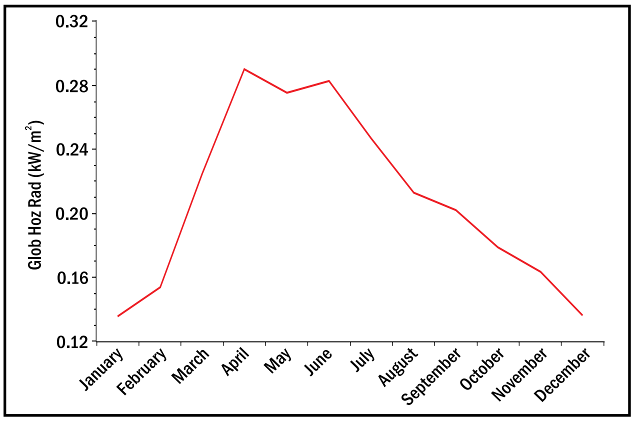

Figure 19 Monthly global horizontal radiation

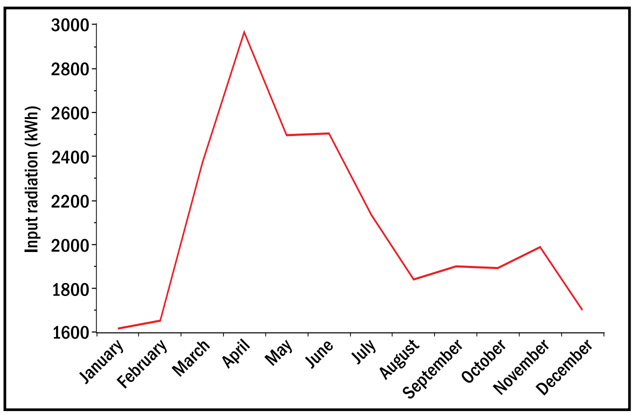

Figure 20 Monthly input radiation

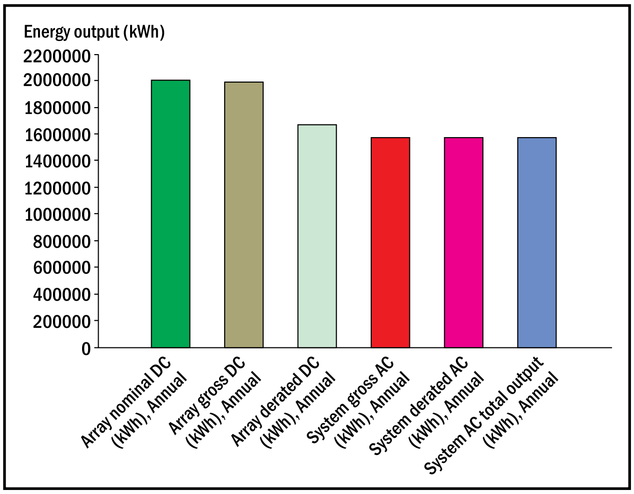

Figure 21 Annual energy flow

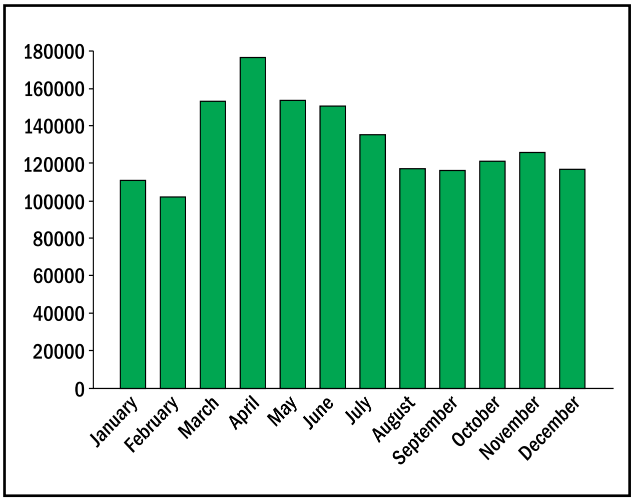

Figure 22 Monthly output of AC power

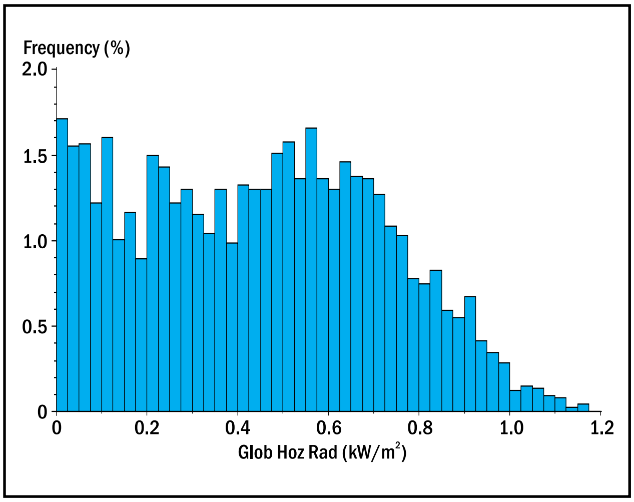

Figure 23 Probability distribution function of global horizontal radiation

Economic considerations of the Indian PV scenario

The Ministry of New and Renewable Energy (MNRE) has already formulated guidelines for generation-based incentive (GBI) related to large-scale PV power generation. Its financial arm—the Indian Renewable Energy Development Agency (IREDA)—is currently assisting the ministry in fund handling, monitoring, and other associated activities. In this regard, the financial terms shown below are the benefits accruable to prospective project developers with 30% subsidy for special applications and up to 90% subsidy for special category areas in remote and difficult locations.

- Quantum of assistance: Up to 70% of project cost
- Rate of interest: 11.25% to 12.75% p.a.
- Repayment period: Up to 13 years

The decision to use a solar PV system over conventional technologies depends on the economics, energy security, and environmental benefits expected. Solar PV systems have a relatively high initial capital cost, however, they often require little maintenance over other solar energy systems, for example, the solar thermal power generation systems. Due to these characteristics, the long-term life cycle costs of a solar PV energy system should be understood to determine whether such a PV system is economically viable.

The following are the economic optimum factors for reducing cost development.

- Limit liability to define capacity and observe cost trends.
- Identify and eliminate risks upfront, including land and off take arrangements, physical and commercial.
- Maximize competition and transparency and do not set artificial constraints.

Profitability of any energy resource project depends on per MW cost and the capacity factor. Capacity factor shows the maximum capacity utilized by the system out of its available capacity. It is the annual energy output divided by the theoretical maximum output.

The capacity has been calculated to enhance the performance as indicated. The long-term expectation was also calculated from the trend line equations. It can also be done using forecasting techniques, which we will not be discussing here. However, the capacity would be used to work out the system availability, correlated with the Mean Time To Repair (MTTR) values to obtain lifetime of this PV system.

The operational data provided in the design of TERI University PV roof top system included capacity and availability factors.

The capacity factor presented in the data includes the availability factor and the system gross capacity after considering availability.

The definitions of capacity and availability as they are used are as follows.

$$\text{Gross CAPACITY} = \frac{\text{Actual Generation by the PV system in a given time period}}{\text{Period} \times \text{rated output of PV system}} \quad (26)$$

$$\text{Availability} = \frac{\text{Total hrs in a period for which the PV system is available for Generation}}{\text{Total hrs in the same period}} \quad (27)$$

$$\text{Net CAPACITY} = \text{Gross CAPACITY} \times \text{Availability} \quad (28)$$

$$\text{Gross CAPACITY} = \frac{\text{Net capacity}}{\text{Availability}} \quad (29)$$

$$\text{Per MW cost} = \frac{\text{Total Project Coast}}{\text{Total capacity}}\ \text{MW} \quad (30)$$

In arriving at the annual output values as given in Table 3, I have used the attractive subsidies as provided by the IREDA in conjunction with the MNRE in computing the figures with the others values.

Analysis period	= 31 years
Inflation rate	= 2.50%
Real discount rate	= 6.00%
Insurance	= 0.50%
Internal rate of return	= 15%
Loan rate	= 6%
Loan term	= 20 years

Simple payback

A simple payback calculation can provide a preliminary judgment of economic feasibility. The easiest calculation is the cost of the system divided by cost displaced per year.

Simple Payback

$$= \frac{\text{Initial cost of Installation (rupee)}}{\text{Energy produced annually}\left(\frac{\text{kWh}}{\text{year}}\right) \text{X}_{\text{kWh of energy displaced}}^{\text{Cost in Rupee}}} \quad (31)$$

Cost of energy

The cost of energy (COE) is primarily driven by the installed cost and the annual energy production. For the TERI PV systems, that cost was determined primarily by the cost of the modules, which is Rs 115/Wp. After losses, each Watt produces 2–6 Wh/day, depending on the available solar resource; this translates to about Rs 10.56–16.8/kWh.

The levelized value over the life of the PV system assumed in the case of TERI University was 31 years with a utility factor of an extra year.

Cost of Energy

$$= \frac{\text{Installation Cost} \times \text{Fixed Charge rate per year} \times \text{Anual Operation and maintenance}}{\text{Energy produced annually}\left(\frac{\text{kWh}}{\text{year}}\right)} \quad (32)$$

The COE is one measure of economic feasibility, and when it is compared to the price of energy from other sources (primarily the utility company) or to the price for which that energy can be sold, it gives an indication of feasibility.

If the COE is within 30% above these prices, further analysis is justified. The annual energy production for a PV system can be estimated as follows.

$$\text{AKWH} = \text{EF} \times \text{AKWH} = \text{EF} \times \text{Wp} \times \overline{\text{ADSI}} \times 365 \quad (33)$$

Where

EF = system efficiency factor—typically about 50% off grid and 75% for a grid tied system

Wp = array rating (peak kilowatts)

$\overline{\text{ADSI}}$ = average daily solar insolation (sun-hours) (kWh/m^2/day)

Present value and levelized costs

Depending upon the interest rates for borrowing, saving, and inflation, the value of money increases or decreases with time. Many people assume energy costs in the future will increase faster than inflation. The same mechanism of determining future value of a given amount of money can be used to move money backwards in time. If each cost and benefit over the lifetime of the system were brought back to the present and then summed up, the present worth could be determined. The discount rate determines how money increases or decreases with time. Therefore, the proper discount rate for any life cycle cost calculation must be chosen with care. Sometimes the cost of capital (interest paid to the bank or, alternately, lost opportunity cost) is appropriate. Possibly, the rate of return on a given investment perceived as desirable by an individual may be used as the discount rate. Adoption of unrealistically high discount rates can lead to unrealistic life cycle costs (LCC). If the total money is uniformly spread over the lifetime of a system, this operation is called levelizing.

Present value (PV) is the adjusted cost, at present, of future expenses using the real discount rate. The present value of a single payment made in the future is as follows.

$$\text{Present value} = \text{Future Value} \times (1 + \text{Real Discount Rate}) - \text{N} \quad (34)$$

Where

N is the number of years between now and the year of the payment

For a given discount rate and number of years, the present value factor for a future payment, given by

$$\text{Future Value payment} = (1 + \text{Real Discount Rate}) - \text{N} \quad (35)$$

The present value of a fixed annual payment is

$$\text{Present value} = \text{Value amount paid annually} \times \frac{\left(1 - \frac{1}{(1+\text{Real Discount rate})n}\right)}{\text{Real Discount Rate}} \quad (36)$$

Where
n is the time period, in years, in which the annual payment is incurred

For a given interest rate and time period, the present value factor for annual payments, given by Equation 34

Real discount rate = Interest rate – inflation rate (37)

The interest rate is the rate at which capital increases if it is invested. The inflation rate is the rate at which price increases. Once the real discount rate and the associated time period are known, the present value of each expense in the future can be found as well as the LCC of the option under consideration.

Considering the efficiency of a PV module at 12.37% (STC), Table 3 has been calculated for each of the items indicated as follows using the equations outlined previously for an analysis period of 31 years. The LCOE was calculated from the following relationship in equation 28. The calculation for the LCOE is the net present value of total life cycle costs of the project divided by the quantity of energy produced over the useful life of the system.

$$\text{LCOE} = \frac{\text{Total Life Cycle Cost}}{\text{Total Life Energy Production}} \tag{38}$$

The LCOE equation can be for solar power generation as shown in Equation 39 below.

Table 2 Calculated annual data and values

Sl.no	Annual data	Total output figures
1	Total radiation (kW/m^2)	80 674.00
2	Incident radiation, shaded (kW/m^2)	1588.33
3	Incident total (kWh)	18 286 151.98
4	Array nominal DC (kWh)	2 262 654.44
5	Array gross DC (kWh)	1 988 002.45
6	System gross AC (kWh)	1 578 407.14
7	System AC total output (kWh)	1 578 407.14
8	System performance factor	0.70
9	Capacity factor (%)	17.86
10	Annual energy (kWh)	1 578 407.14
11	Analysis period (years)	31
12	LCOE(nom)	141.71
13	Internal rate of return	32.83

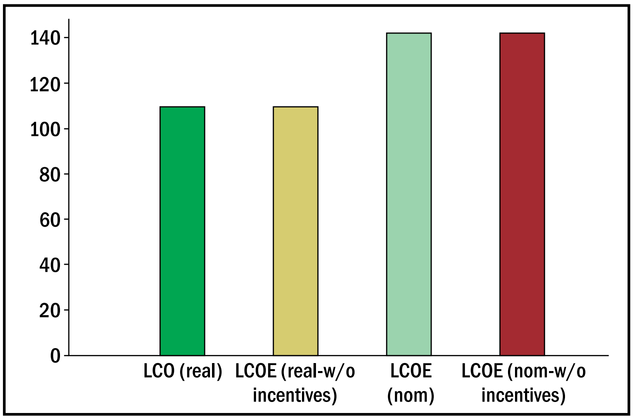

Figure 24 LCOE

Economic factors to be considered

1 Load (power) and energy, calculated annually
2 Cost of energy from competing energy sources to meet the demand
3 Initial installed cost is
 - purchase price;
 - shipping costs;
 - installation costs (foundation, utility inter-tie, labour, etc.); and
 - cost of land (if needed).
4 Production of energy
 a. Type and size of system
 - System warranty
 - Company (reputation, past history, years in business, future prospects)
 b. Solar resource
 - Variations within a year and from year to year
 c. Reliability and availability
5 Selling price of energy produced and/or unit worth of energy and anticipated changes in energy cost (escalation) of competing sources.
6 Operation and maintenance costs
 - General operation, ease of service
 - Emergency services and repairs
 - Insurance
 - Infrastructure
7 Time value of money (interest rate, fixed or variable)
8 Inflation (estimated for future years and how conventional energy source costs will increase)
9 Legal fees (negotiation of contracts, titles, easements, permits)
10 Depreciation if, system is a business expense
11 Any national or state incentives

$$\frac{\text{Initial Investment} = \sum_{n=1}^{N}\frac{\text{Depreciation}^n}{(1-\text{Discount Rate})^n}\times(\text{Tax Rate})+\sum_{n=1}^{N}\frac{\text{Annual Costs}^n}{(1+\text{Discount Rate})^n}\times(1-\text{Tax Rate})-\frac{\text{Residual Value}}{(1+\text{Discount Rate})^n}}{\sum_{n=1}^{N}\frac{\frac{\text{Initial kWh}}{\text{kW}_p}\times(1-\text{System Degradation Rate})^n}{(1+\text{Discount Rate})^n}} \tag{39}$$

Annual energy generation

The mean global solar radiation exposure over New Delhi at the TERI University has been used to calculate the estimated annual energy generation. The mean global solar radiation exposure varies from an approximate value of 3.29 kWh/m² /day in the month of January to 7.05 kWh/m² /day in the month of April, as shown in Table 3.

Table 3 Daily solar radiation on a horizontal surface

Month	Daily solar radiation on a horizontal Surface	
	kW/m²	kWh/m²/d
January	0.13 524	3.29 084
February	0.15 328	3.729 813 333
March	0.22 446	5.46 186
April	0.28 995	7.05 545
May	0.27 525	6.69 775
June	0.28 271	6.879 276 667
July	0.24 686	6.006 926 667
August	0.21 238	5.167 913 333
September	0.2016	4.9 056
October	0.17 833	4.339 363 333
November	0.16 338	3.97 558
December	0.13 577	3.303 736 667
	0.2 082 675	5.0 678 425

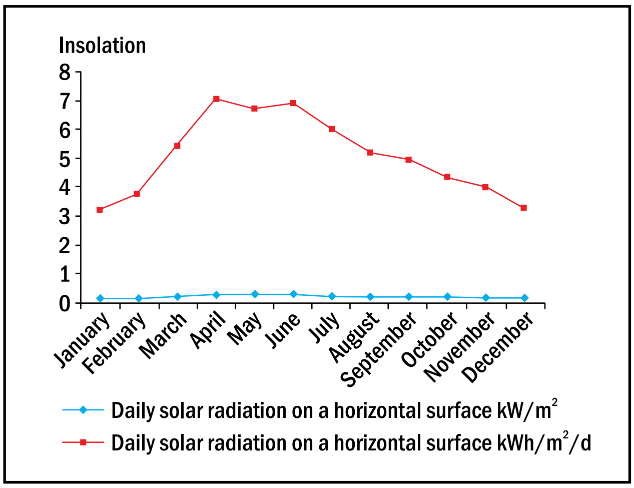

Figure 25 Daily solar radiation on a horizontal surface

The energy available from this PV system would vary from a minimum of 101 986 kWh during the month of February to a maximum of 176 775.3 kWh during the month of April.

The month-wise energy generation during the year is given in Table 4.

Table 4 Month-wise energy generation

Month	AC power output (kWh)
January	110976.0655
February	101985.7785
March	153089.2119
April	176775.2872
May	153823.5111
June	150396.8922
July	135085.9497
August	117062.3484
September	116044.5365
October	120818.1853
November	125754.6325
December	116594.7415
Total	1578407.14

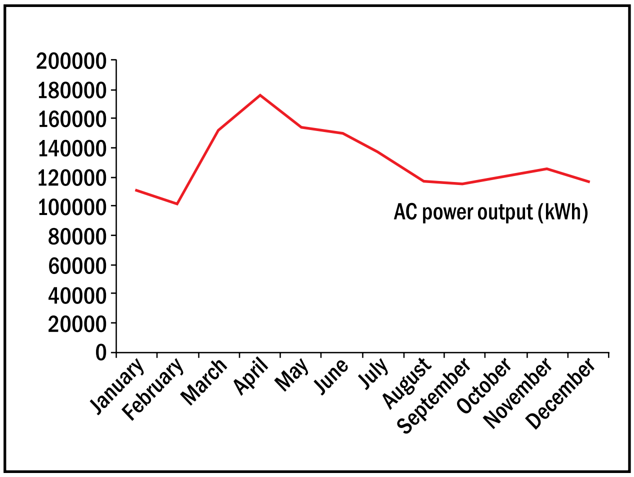

Figure 26 The month-wise energy generation during the year

However, the system has been designed to augment the annual power requirement of TERI University by 204 692 kW/day as against an observed value of 577.25 kW/day (as was systematically calculated during the month of March 2010). Therefore, this value can be optimized to any capacity within the review period of 31 years by adopting sizable high performance modules of higher power capacity with an appropriate inverter interface to match as the case may be for green and energy-efficient research institution.

The total annual power generated is 1 578 407.14kWh, therefore, according to our design procedures, the Gaussian probability distribution predicted a 68% effective capacity utilization. Hence, the estimated annual energy production to be fed into the grid will be 1.07 MWh with annual capacity utilization factor of 17.8%.

REVIEWING THE TEST STANDARDS FOR THERMOSYPHON TYPE SOLAR DOMESTIC HOT WATER SYSTEMS

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Courtesy: NOAA

Background

Fossil energy resources are limited and will not last forever. Oil and natural gas are the world's primary fuel sources, used for both transportation and thermal energy requirements. Together, they meet about 60% of the total energy consumption. It is assumed that by 2012, their combined energy peak consumption will be at a whopping 6679 Mtoe. However, by 2050, they will be producing a combined energy of just 1386 Mtoe, thus, a sharp reduction of 80%. This massive shortfall presents an enormous challenge in terms of the demand fulfilment via other sources of energy. It is a challenge that can alter the shape of our civilization over the next three to four decades. To add to this, the continuous use of fossil fuel is having an adverse effect on the Earth's climate and causing great damage to our environment. These issues and concerns have forced us to shift our focus to renewable source of energy. Solar energy, mainly due to its inexhaustible nature, seems to be the most promising renewable energy source.

The advent of solar water heating systems

Various initiatives have been undertaken to utilize solar energy. This has resulted in many successful applications with water heating being one of them. It can be grouped in two distinct categories—domestic and industrial requirements. In the domestic sector, hot water is used for cooking, bathing, washing, cleaning, and so on. For this sector, the quantity of hot water needed in India is about 300 l/day at 40 °C for a high income urban household of 4–5 persons, and about 100–250 l/day (at the same temperature level) for the other income groups.

Rural households generally use non-commercial fuels like firewood or cow dung for heating water, whereas, urban households use kerosene, coal, LPG, and electricity for heating water.

Why use solar energy for water heating?

It is highly impractical to use a high-grade energy source like electricity for such low temperature applications. It can be easily and efficiently substituted by solar energy. At present, a wide range of solar hot water heating systems are locally available, which can be classified on the basis of their attributes. However, the commonly used classification is as follows.

a) Thermosyphon type
b) Forced flow type

Performance testing of solar water heaters

In India, solar domestic hot water systems based on natural circulation without any auxiliary heating are more popular. In these systems, the working fluid circulates from collector to storage by buoyancy forces. In order to rate the systems, testing their performance is of utmost importance. A number of investigators have conducted extensive studies on different aspects of Solar Domestic Hot Water Systems (SDHWS), and based on their research work, two main comparison methods stand out. The first method involves direct simulation, while the second method deals with actual testing of the complete systems. The direct simulation methods are based on detailed mathematical models and a number of softwares, such as TRNSYS, WATSUN, T*SOL, SOLCOST, GetSolar and so on, have been developed for this purpose. In this approach, the characteristic parameters of various components are the key inputs. Any error in evaluating these parameters due to insufficient knowledge will propagate and lead to significant error in the prediction of the system performance. However, the key advantage of this approach is that if, these key parameters can be correctly determined, then the performance of the system can be predicted for any set of end-use conditions.

Classification of relevant standards

Testing a complete system, under specific test procedure, will determine the characteristic parameters of that system. A number of standards (Australian Standard [AS] 2813–1985, 1985; AS 2984–1987; American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 95–1987; British Standards (BS) 5918–1989, 1989; Chinese National Standards (CNS) B 7277: No.12558–1989, 1989; Canadian Standards Association (CSA) F379.1 M 1985; Indian Standards (IS) 13129 [Part 1 and Part 2]-1991, 1991; International Organization for Standardization (ISO) 9459 [Parts 1–3 and 5]; and Japanese Industrial Standards (JIS) A 4111-1997) have been developed for testing the system. Based on their applicability, the standards can be categorized, for both outdoor and indoor test methods.

Table 1 Classification of standards

	Outdoor	Indoor
Thermosyphon type	JIS A 4111:1997 CNS B 7277: No.12558:1989 ISO 9459 (Part 2): 1995 AS 2984–1987 IS 13129 (Part 2): 1991	JIS A 4111–1997 AS 2813–1985 ISO 9459 (Part 1): 1993
Forced flow type	ISO 9459 (Part 2): 1995 ISO 9459 (Part 3): 1997 AS 2984–1987 IS 13129 (Part 2): 1991 BS 5918: 1989	AS 2813–1985 ISO 9459 (Part 1): 1993 ASHRAE 95: 1987 CSA F379.1 M1985 IS 13129 (Part 1): 1991

The BS-5918:1989 standard suggests that it can also be used for the thermosyphon system, but it does not recommend any experimental procedure. It recommends only a code of practice or design nomogram. Thus, it is not fit for an experimental evaluation.

Although, in indoor testing, the environment can be easily controlled with the help of either the solar irradiance simulator or the thermal simulator, yet the realistic sky conditions can never be achieved. Moreover, the set up for indoor testing is expensive and thus, an outdoor testing is generally preferred.

Amongst the standards for outdoor testing, for TSDHWS, as shown in Table 1, AS 2984–1987, IS 13129 (Part 2), and ISO 9459 (Part 3) are applicable to systems with auxiliary heating. CNS B 7277, JIS A 4111, and ISO 9459 (Part 2) qualify for the testing TSDHWS without auxiliary heating.

Characteristic parameters

The basic expressions and characteristic parameter for these standards are given in Table 2.

In the CNS standard, the slope of the line between η and X' gives the overall heat loss coefficient (U_s) of the system during the heat collection period and the intercept gives the efficiency (η_0) under the zero loss condition. Although the supporting research also recommended a system cooling test during non-sunshine hours, the standard does not include that in its present form.

According to ISO 9459 (Part 2) (1995), the system is characterized by daily output (Q) and is defined as the following.

$$Q = \sum_{i=1} Q_i = \sum_i (\Delta V_i)(\rho C_p)(\bar{T}_{draw} - T_{mains})$$

Qi is the energy contained in one-tenth of the volume of tank water having average water temperature of $\bar{T}_{draw}$, a_1, a_2, and a_3 are correlation coefficients, which will be determined by the test results and least square curve fitting.

The experimental results of Q are plotted against H_T and the system characteristic, predicted by the regression equation of Q for various values (10K, 0K, 10K, and 20K) of ($\bar{T}_a - T_{mains}$), is shown in these plots. These graphical representations are known as the input-output diagram. Similarly, test results for the maximum temperature rise; ($T_{dmax} - T_{mains}$) are correlated with H_T and ($\bar{T}_a - T_{mains}$) as shown in Table 1. The plots of experimental points and predictions are generated and presented graphically. These are known as temperature increase diagram. The standard also prescribes a cooling test during night time and defines loss coefficient (U_{ns}) of the tank, which is given by the following relation.

$$U_{ns} = \frac{\rho V C_p}{t} \ln\left[\frac{T_{ss} - \bar{T}_a}{T_{se} - \bar{T}_a}\right]$$

Table 2 Characteristic parameters of standards for TSDHWS

Standard	Basic expression	Characteristic parameter
CNS B 7277	$\eta = \eta_0 - U_s X, \text{were } X' = (T_{si} - \bar{T}a)/H_T$ $\text{and } \eta = \frac{(\rho V C_p)(T_{sf} - T_{si})}{A_c H_T}$	η_0 and U_S
JIS A 4111	$S = \frac{20930(\rho V C_p)(T_{sf} - T_{si})}{A_c H_T}, \text{ and } (KA) = \frac{(\rho V C_p)(T_{ss} - T_{se})}{\Delta t\{(T_{ss} + T_{se})/2 - \bar{T}i\}}$	S and (KA)
ISO 9459 (Part 2)	$Q = a_1 H_T + a_2(\bar{T}_a - T_{mains}) + a_3$ $(T_{dmax} - T_{mains}) = b_1 H_T + b_2(\bar{T}_a - T_{mains}) + b_3$ $U_{ns} = \frac{\rho V C_p}{\Delta t} \ln\left[\frac{T_{ss} - \bar{T}_i}{T_{se} - T_i}\right]$	Monthly and annual solar energy output

This standard stipulates the calculation procedure from the results obtained so for determining the monthly and annual solar energy output from the system for the required climatic conditions and load demand.

In JIS, the system is characterized by total heat content 'S' and storage effective loss coefficient 'KA'. 'S' specifies the amount of heat collected during the specified test period and 'KA' specifies the heat loss during the non-sunshine hours.

The test procedure specified in various standards also differs significantly from one another. A summary of conditions, sampling rate, and test duration specified by the various standards are presented in Table 3.

Standard test durations

The CNS standard prescribes a test for an entire day. Data for a minimum period of 10 days with certain specific solar conditions is required to conduct this test. ISO 9459 (Part 2) test includes the following durations.

i) One day test for at least six days
ii) Short test
iii) Overnight heat loss test
iv) Mid-day draw off test

Table 3 Comparison of experimental procedure of different test standards for TSDHWS

Standard	Sampling rate	Test duration (Number of hours)	Experiments (Measurements)	Condition
CNS B 7277	5 min	10 days (one hour after day break to one hour before night fall)	Daily performance test (Solar radiation and temperature)	• HT > 7 MJ/m^2-day • X= 0.5–2.0 • Wind speed < 4 m/s
JIS A 4111	Hourly	1 day (8)	Thermal performance test a) Heat collecting performance (solar radiation and temperature) b) Heat insulating performance test (temperature and time)	• H_T > 16.75 MJ/m^2-day • $\bar{T}_a$ > 15 °C • Initial tank temperature should be within ±5°C of the ambient temperature • Initial storage tank water temperature shall be 35 °C (±2 °C) higher than the initial (at the start of the heat insulating performance test) ambient temperature • Duration of test should be 3 hrs
ISO 9459 (Part 2)	Hourly average (except 15 sec for temperature of water during draw off)	6 one day tests (12)	• One day test (Solar radiation, temperature) • Short test (temperature and time) • Overnight heat loss test (temperature) • Mid-day draw off test (optional)	• HT = 8-28MJ/m^2-day • $(\bar{T}_a – T_{mains})$ = 5–20 K • During draw off, T_{mains} value shall be same as the one used during preconditioning; T_{mains} shall not fluctuate and drift by more than ± 0.25 K and 0.2 K, respectively • Storage temperature shall be greater than 60 °C • Duration of test > 12 h

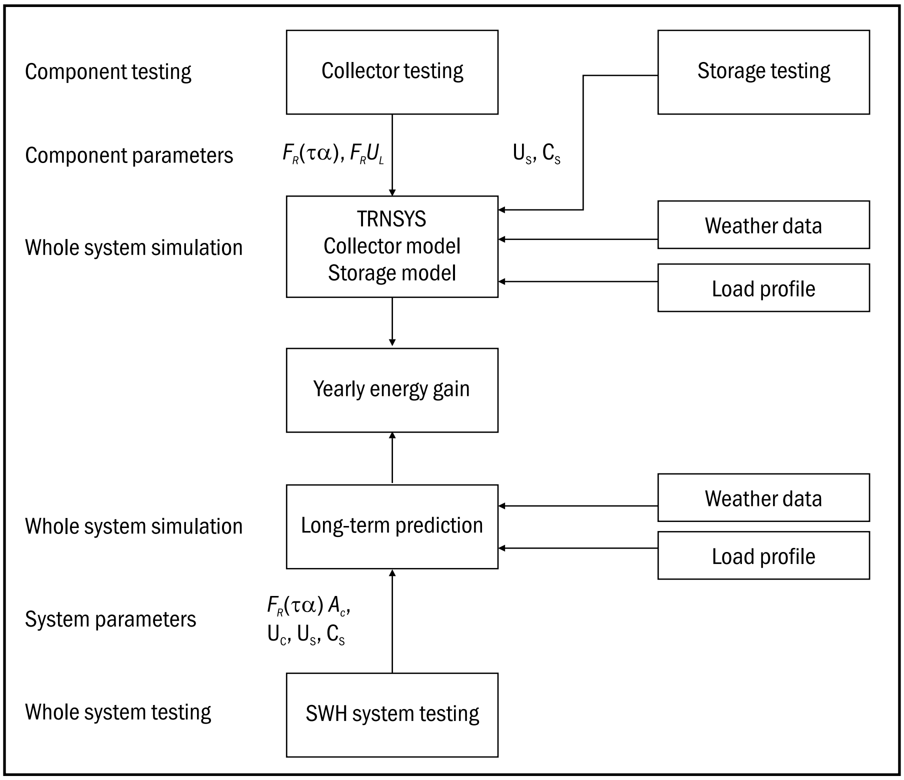

Figure 1 Structure of the test method of SDHWS by means of component test and whole system testing and simulation

The mid-day draw off test is conducted only if the mid-day hot water consumption is accounted for. The JIS prescribes two types of tests i) thermal performance test and ii) the system quality test. The first test consists of two sub tests—heat collecting and heat insulating performance.

A simple approach that integrates both the experimental and simulation techniques for testing and evaluating SDHWS with the help of component testing and whole system testing and simulation are schematically represented in Figure 1.

In this method, the key parameter is the solar fraction gain 'F_{solar}' which is obtained by the following relation

$$F_{solar} = P_{net} / P_d \tag{2.5}$$

where P_{net} = average system gain

P_d = average power required to heat the water

Obtaining the perfect standards

It is quite clear that testing can serve a number of purposes, apart from the long-term thermal performance of the system or giving relative performance for specific test conditions. For testing standards of TSDHWS, CNS ISO 9459 (Part 2), and JIS can be used but they do not individually cover the full day thermal performance test. The minimum daily insolation that is needed for JIS and ISO 9459(Part 2) are very difficult to achieve on any number of test days. Further, CNS and ISO 9459 (Part 2) standards specify 12 hours as testing period. Also, CNS standard does not take into consideration the night loss of the system. JIS specifies that the ambient temperature must be higher than 15 °C. Hence, the standard cannot be adopted in places where the ambient temperature is less than this value. In short, every existing standard test procedure has one drawback or the other. On the other hand, the review of various experimental works reveal that, so far, no attempt has been made to compare different systems, based on their energy output, by bringing them on a common platform. It is necessary to compare the different systems because systems available in the market are different, not only in their collector technology but also with respect to their collector area and storage volume. Importantly, energy output is of great interest for a user as it directly reflects the economic benefits expected out of a particular system. Hence, a method of comparing different systems should be such that it eliminates the limitations mentioned in this article, which are associated with the test standards.

Courtesy: NOAA

SAILING WITH THE SUN

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Background

The Sun has long been identified as a source of energy and life on the Earth. From time immemorial, mankind has tried tapping the energy of the Sun and the winds. With the advent of modern technology, human beings have managed to use solar power and wind turbines to generate electricity. Off late, innovations have reached newer heights, for example, solar powered airplanes. The newest concept to have gained ground is solar sails.

Knowing a solar sail

Simply put, a solar sail is a spacecraft propelled by the sunlight. While a conventional rocket is propelled by the thrust produced by its internal engine, solar sail is pushed forward by the light drawn from the Sun. This is possible because light is made up of packets of energy known as photons, which act as atomic particles, but with more energy. When a beam of light is pointed at a bright mirror-like surface, its photons reflect right back, just like a ball bouncing off a wall. In the process, the photons transmit their momentum to the surface twice—once by the initial impact, and again on reflection. Ever so slightly, propelled by a steady stream of reflecting photons, the bright surface is pushed forward.

Design features of a solar sail

Depending on its design, a solar sail is made up of a reflective surface or several such surfaces. When the bright sails face the Sun directly, they receive a steady barrage of photons that reflects off the shiny surfaces and propels the spacecraft to move forward, away from the Sun. By changing the angle of the sail relative to the Sun, it is possible to affect the direction in which the sail is propelled. This is akin to a sailboat, which changes the angle of its sails to change its course. It is even possible to direct the spacecraft towards the Sun, rather than away from it, by using the photon's pressure on the sails to slow down the spacecraft's speed and, thus, bring its orbit closer to the Sun.

Size of a solar sail

For sunlight to provide sufficient pressure to propel a spacecraft forward, a solar sail must capture as much sunlight as possible. This means that the surface of the sail must be big, in fact very big. Cosmos 1 is a small solar sail intended only for a short mission. Nevertheless, once it spreads its sails, even this small spacecraft is as tall as a 10-storey building and as high as the rocket that will launch it. Its eight triangular blades are 15 m (49 feet) in length, and have a total surface area of 600 m^2 (6500 sq feet). This is about one and a half times the size of a basketball court.

Exploring beyond the known frontiers

For a proper exploration mission, the requirements are far greater. To pu it in perspective, when a team from the National Aeronautics and Space Administration (NASA), headed by Louis Friedman, in the 1970s, suggested using a solar sail spacecraft for a rendezvous with the Halley's Comet, they proposed a sail with a surface area of 600 000 m^2 (6.5 million sq feet). This square is roughly equivalent to 800 m (half-mile) by 800 m—the size of 10 square blocks in New York City! Parachutes would have a very low mass, but theoretical studies show that they will collapse due to the force applied by the shrouds. Radiation pressure is not similar to aerodynamic pressure.

Till very recently, the highest thrust-to-mass designs known to us were theoretical designs developed by Dr Kim Eric Drexler, an American engineer. He designed a sail using reflective panels of a thin aluminium film (30–100 nanometers thick) supported by a purely tensile structure. It rotated and needed to be continuously under slight thrust. He made and handled samples of the film in the laboratory, but the material is too delicate to survive folding, launch, and deployment. Hence, the design relied on space-based production of the film panels, joining them to a deployable tension structure. Sails in this class would offer area per unit mass and, hence, will have accelerations up to fifty times higher than the designs based on deployable plastic film.

Operational characteristics

The highest-thrust to mass design for ground-assembled deployable structures are square sails with the masts and guy lines on the dark side of the sail. Usually there are four masts that spread at four corners of the sail, and a mast in the centre to hold the guy-wires. One of the major advantages is that there are no hot spots in the rigging from wrinkling or bagging, and the sail protects the structure from the Sun. Therefore, this form can move quite close to the Sun, up to a position where maximum thrust is present. Control would probably use small sails on the ends of the spars. However, even with such a gigantic surface, a solar sail spacecraft will accelerate very slowly as compared to a conventional rocket. Under optimal conditions, a solar sail on an interplanetary mission would gain a speed of just 1 mm/sec for every second that it is pushed by the available solar radiation. The Mars Exploration Rovers, by comparison, accelerated by as much as 59 m (192 feet)/sec during their launch by the conventional Delta II rockets. This acceleration is 59 000 times greater than that of a solar sail!

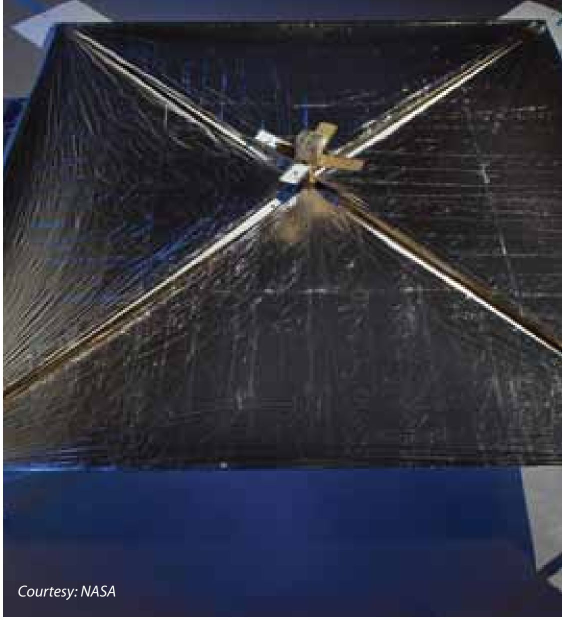
Advantages beyond comparison

The advantage of a solar sail is that it accelerates constantly. A rocket only burns for a few minutes, before releasing its payload and letting it cruise at a constant speed for the rest of the way. A solar sail, in contrast, keeps on accelerating, and can ultimately reach a speed much higher than that of a rocket-launched craft. At an acceleration rate of 1 mm/sec (20 times higher than the expected acceleration for Cosmos 1), a solar sail would increase its speed by approximately 310 km/hr (195 mph) after one day, moving 7500 km (4700 miles) in the process. At the end of 12 days, it will have increased its speed to about 3700 km/hr (2300 mph).

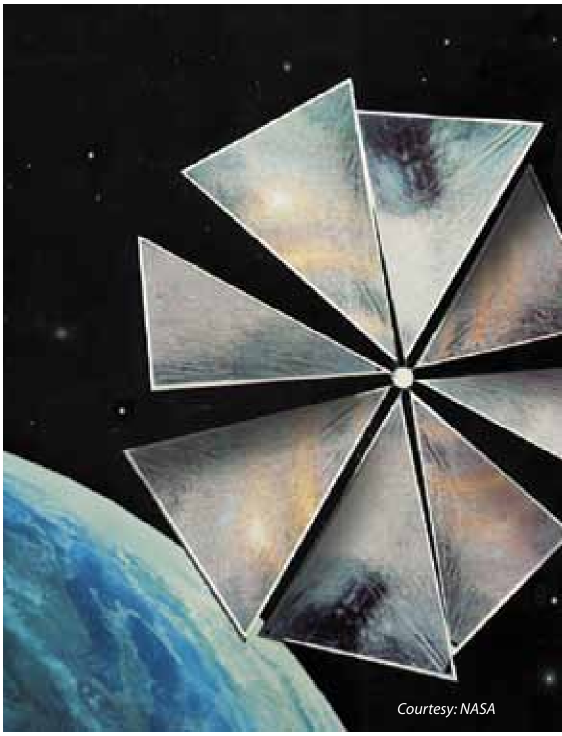
The star dilemma

It can be argued that these speeds and distances may be substantial for interplanetary travel. However, they are insignificant when compared to the requirements of a journey to the stars. Given time, however, with small but constant acceleration, a solar sail spacecraft can reach any desired speed. Assume a situation when the acceleration diminishes due to an increasing distance from the Sun. Some scientists propose that for the spacecraft to propel forward, powerful laser beams should be pointed at it. Although such a strategy is not practical given the current technology and resources, solar sailing is nevertheless the only known technology that could someday be used for interstellar travel.

Sources: <http://planetary.org/radio/show/00000366/>, <www.wikipedia.com>



Courtesy: NASA



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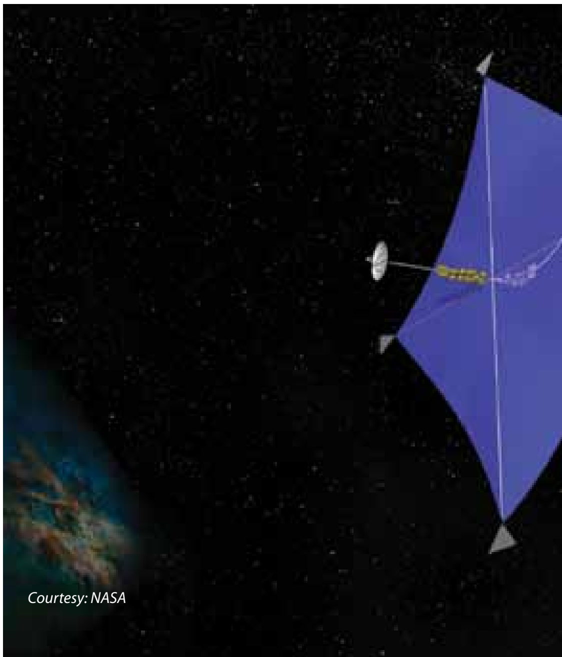

Courtesy: NASA

WHY SOLAR?

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Sun at work

Every form of life on Earth needs the Sun's energy, directly or indirectly. It means that we all are also somehow connected to each other through this unlimited source of energy——the Sun. The Sun is revered in the form of a god in Indian mythology. Conventional forms of energy, such as coal, oil, and gas, also originated due to small inputs of energy from the all powerful Sun. The economic structure of the world has been built with dependence on these forms of energy. However, increasingly, there is arealization that climate change is an effect of the disproportionate utilization of conventional forms of energy and far lesser use of renewable sources of energy. Even those these renewable sources of energy like wind energy, biomass, and hydro, but the Sun is the main source. Solar energy is an ideal combination of heat and light. Of late, the threat of climate change has compelled everybody to take recourse to renewable energy-based projects. For this reason, we now frequently come across various solar energy projects, not only in our country but worldwide. The outcome is visible in the form of all round awareness generation about the key merits of solar energy utilization. There are a number of questions in the minds of common people, for instance, what size of a solar system will be ideal to cater to a complete household or factory? However, customized solutions are still not easily available from those who produce the solar equipment.

Courtesy: CREDA

The emergence of solar power plants

Today, there are a large number of solar companies engaged in the production of cells, modules, and, systems in India. They are producing a wide range of products such as solar lanterns, home lighting system, street lighting system, water pumping system, and multi-purpose battery charging system. There is also the community-based power plant, referred to as a village power pack. It is an independent power generating unit and mainly comprises of solar photovoltaic (PV) modules, module mounting structure (MMS), power conditioning unit (PCU), battery bank (if required), cables, junction boxes, control panels, and so on. However, major solar companies, such as Tata BP, Suntechnics, Reliance, Central Electronics Limited (CEL), Bharat Electronics Limited (BEL), Rajasthan Electronics and Instruments Limited (REIL), Photon, and Moser Baer, are not manufacturing

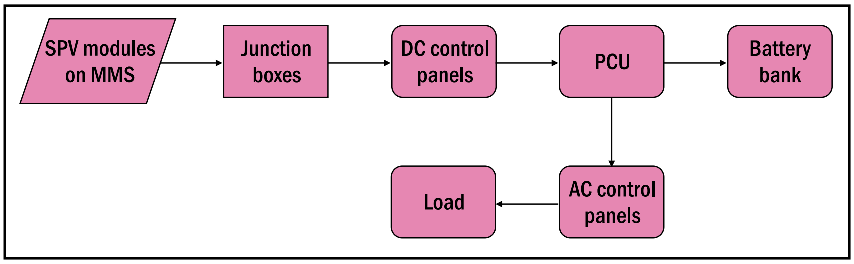


Figure 1 Schematic representation of a typical solar PV power plant

balance of system (BOS) like battery, PCU, control panels, and so on.

Continued dependence

There are a large number of system integrators who usually supply the BOS components like the charge controllers, support structures, and control panels to the big companies for a variety of reasons. Thus, there is a dependence of sorts, howsoever small it may be, which also points to non-availability of various BOS configurations with companies that produce solar modules. Ideally, a solar company should be like a pan shop, which is a one-stop-shop with all varieties of pan (betel) available. There should be a one stop solar shop for all types of solar demands. For example, one customer may demand that he requires a solar system to deliver power to operate the dedicated load for six hours during daytime, whereas another customer may want the solar system to deliver the same amount of power, but during the non-sunshine hours. There may be yet another customer, who may desire to operate double the load, but only for two hours during the daytime, and so on.

In totality, solar companies should try to keep ready stocks of BOS of various capacities like PCU of different capacities, battery bank of different capacities, control panels of various ranges. However, it may be easier said than done keeping in view several end-use considerations as well as the real market demand. There may not be many takers amongst the solar companies for this type of consideration. Till now, there used to be a sound margin of a lead time for the manufacturers of BOS to supply their products to solar companies, in keeping with the customer demand. Thus, we can say that in most cases, BOS components are tailor made as per site specific requirements, which are less variable.

Normally, PCU and battery manufacturers have their own market operations apart from serving the needs of the solar market. So, it is for the solar companies to search for the best suited PCU and battery bank in sync with the technical and financial aspects. Usually, there are no service networks of PCU and battery manufacturers in the areas, where solar systems are being installed. Many a time, it creates customer dissatisfaction. So when the demand increases service networks of BOS may get enhanced by sheer default. The primary responsibility of assuring the supply of best quality equipment should be the concern of the respective state nodal agencies of the Ministry of New and Renewable Energy (MNRE). This should be done till the efficient channel partners are developed as per the provisions envisaged in the guidelines of the Jawaharlal Nehru National Solar Mission (JNNSM).

The CREDA model

In the Chhattisgarh, Chhattisgarh State Renewable Energy Development Agency (CREDA) has come up with various technical specifications for solar photovoltaic power plants (SPVPP) to suit the financial limitations as well as the demand for power. For example, CREDA has recommended that the crystalline silicon modules of a minimum 125Wp capacity (with minimum of 24V) duly approved by MNRE, should be used. The basic aim behind using a higher wattage module is to reduce the shadow-free space required for the installation of the SPVPP. This also reduces the number of joints of cables on the direct current (DC) side of the system, thereby reducing the power loss. Also, the price comes down marginally. Second, the module mounting structure should be of steel, with a hot dipped galvanized (minimum 80 microns) type. The panel frame structure should be capable of withstanding a wind load of 150 km/hour, after grouting and installation. The array support structure should be sturdy and designed to enable SPV modules to render the maximum output. The hardware used

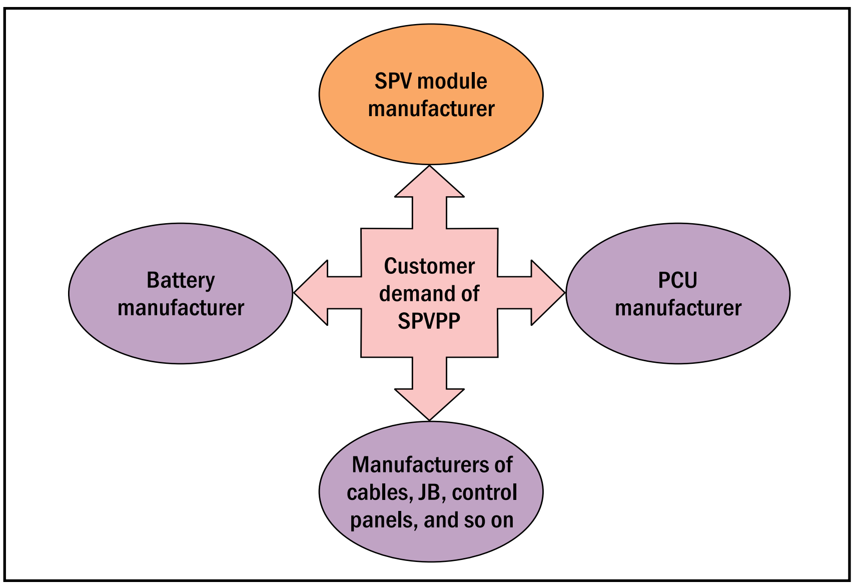


Figure 2 Solar companies turn solar solution provider

Table 1 Minimum suggested sizes of cables

Module to module /AJBs	4 mm^2 (single core)
AJBs to MJBs	10 / 16 mm^2 (two core), with respect to current ratings of designing
MJB to DCDB	minimum 25 mm^2 (single core) or per design and rating
DCDB to PCU	minimum 25 mm^2 (single core) or per design and rating
Battery to BPP	minimum 25 mm^2 (single core) or per design and rating
BPP to DCDB	minimum 25 mm^2 (single core) or per design and rating
DCDB to PCU	minimum 25 mm^2 (single core) or per design and rating
PCU to ACDB	as per design and rating

for the installation of SPV modules and array support structure should be made of stainless steel. Junction boxes should be made up of FRP/PP/ABS with dust, water, and vermin proof (with IP 65). There should also be a proper locking arrangement. It is suggested that cables should be of copper as per IS and should be of 650 V/1.1 KV grade as per the requirement. All connections should be properly made through suitable lug/terminal, crimped with proper cable glands. The size of cables/wires should be designed considering the line loses, maximum load on line, keeping voltage drops within permissible limits, and other related factors. For a normal system design configuration, the Table 1 shows the minimum suggested sizes of cables.

The size and rating of the cables may vary depending on the design and capacity of SPVPP, control panels, battery bank (if applicable), power conditioning unit (inverter-cum-charge controller), earthing kits and lighting arrestors, and measuring and data recording equipments, which the manufacturer has to supply for any SPVPP within Chhattisgarh. It should be compatible and at par with the requirement of the project, on a case to case basis. Norms for installing SPVPPs are also pre-defined by CREDA.

Inspecting with a long-term purpose

SPV modules, module mounting structures, junction boxes, control panels, cables, power conditioning unit, battery bank, and so on are factory tested prior to delivery at site. This is in the interest of the manufacturer, CREDA, and importantly, the end-use customer. It would be better for the customer to seek a pre-despatch inspection of the power plant material. This shall avoid any confusion and unknown faults, which may otherwise occur during the commissioning of SPVPP. Pre-despatch inspection is in favour of the manufacturer also, as the testing facility normally available at the manufacturers premises will generally be much better equipped and manageable than what exists at the installation site. Accordingly, CREDA recommends to all the customers of SPVPPs to follow the same norms with the twin objectives of furthering the technology as well as deriving the true value of a system. Before and during installation of the SPVPPs at the site, CREDA has put in place a working mechanism, as per which the complete specifications, together with the quality of each and every component, are duly verified during an inspection by a team constituting of CREDA employees, manufacturers/suppliers, and the authorized representatives of the end-user. The observations related to the inspection are then duly recorded in the joint commissioning documents specified for the purpose. Proper training and awareness creation activities for the users of SPVPP are also part of the project activity.

Dispelling the myth

There is a myth that solar systems do not require any kind of maintenance. This is not true; rather every solar system installed requires some routine maintenance. It is quite true that there are no moving parts associated with a SPVPP but the current and the voltage are always actively involved in its regular operation. These need to be monitored and taken care of for obtaining the

maximum possible output from any solar PV system.

Installations galore

CREDA has so far electrified about 1400 remote villages/hamlets and more than 850 tribal hostels, in addition to putting up more than 500 solar systems at tourist locations, educational institutes, religious places, police stations, primary health centres, forest rest houses, offices, residences, shops, factories, and other community specific locations. The capacity of SPVPPs at these locations varies from 150 Wp to 100 KWp. To keep these solar systems functioning properly, a cohesive plan of action is needed right from the stage of project conceptualization to the stage of commissioning, to be followed up as routine operation and maintenance for its lifetime.

Accordingly, CREDA has devised its own norms with regard to designing, supply, installation, commissioning, operation, and maintenance of solar systems. It has its own operation and maintenance strategy under which the installed solar systems are in operation since 2003, throughout Chhattisgarh. The decentralized solar power plants offer some major advantages over the centralized solar power plants as they directly are of concern to the consumers.

Courtesy: CREDA

Key advantages of decentralized power generation

The best way to cater to the power (electricity) needs of a society is through installation of decentralized SPVPP. It simply means generating power at the point of utilization itself, without losing power in the transmission network. The following are the few virtues of the decentralized solar power generation systems.

- Maintenance of decentralized solar power is the responsibility of the end-user (customer), thereby reducing the responsibility of governmental infrastructure so far as operation and maintenance is concerned
- Reduction of peak power load
- Employment generation by default
- Direct sharing of financial implications with the government for installation of power generating units
- Reduction in conventional fuel consumption
- Energy security at the user's end

Example of decentralized Solar Power Plant at the roof top in California city at the HQ of Google

The objective

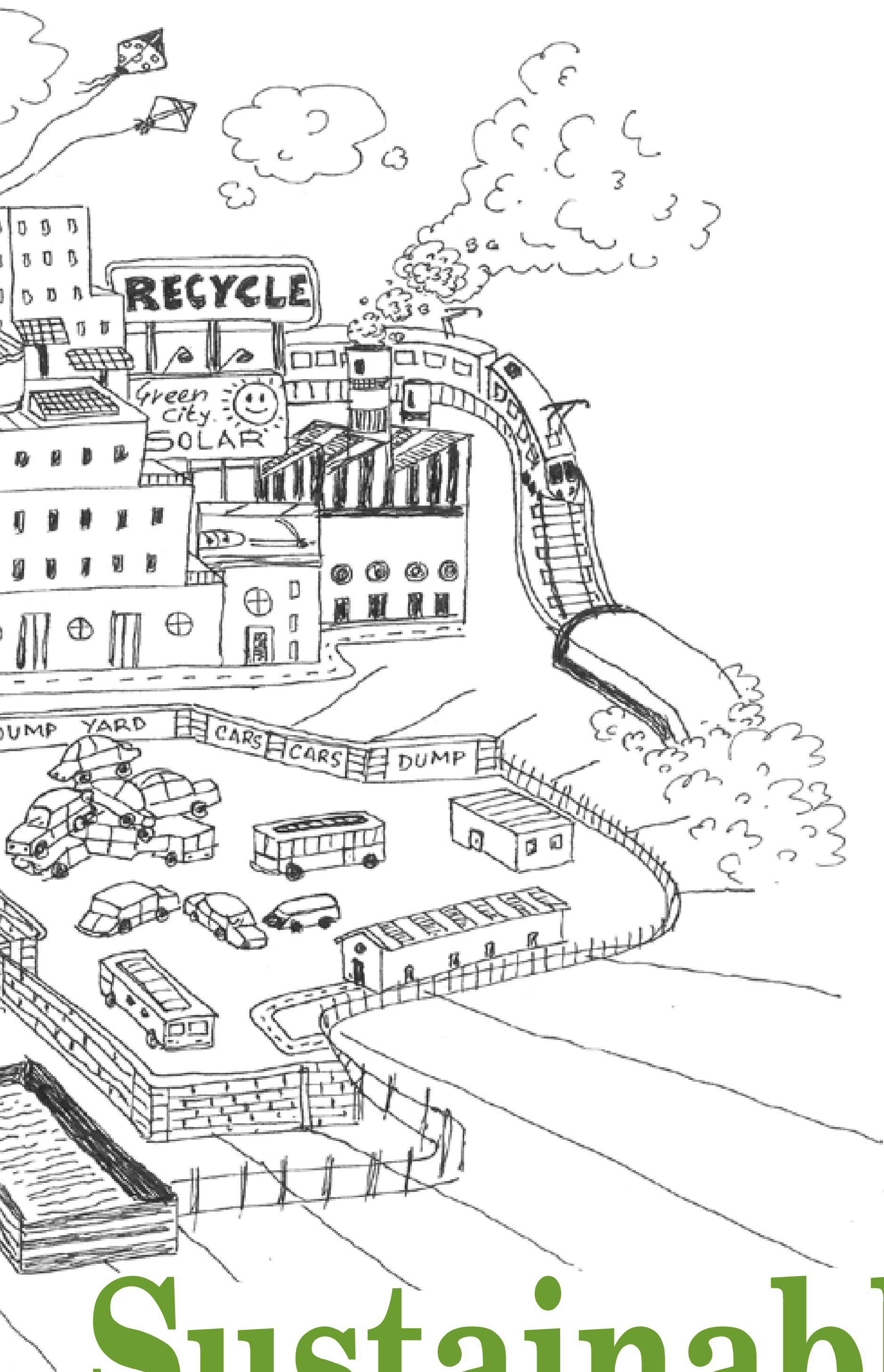
Under JNNSM, all the items to be used in SPVPPs have been defined with a set of certain minimum specifications. If the installation of SPVPPs is done perfectly, then one can assure that the installed SPVPP shall operate smoothly for its lifetime (about 25 years), along with a routinely scheduled maintenance. CREDA has fixed norms for pre-dispatch inspection of almost all the items related to SPVPP. In India, under the flagship of the recently initiated JNNSM, now it is possible to cater to the needs of the society through centralized as well as decentralized solar power plants. Though it is a government's initiative, which has made India an important player in the field of solar energy internationally,

Decentralized solar power plant on the rooftop in California

however, even the citizens of India should understand their role. JNNSM is the mission for the people, by the people, and of the people. The need is to understand the vision and target of the mission. We are almost on the verge of making a quantum leap on the technology front, which may perhaps make the solar systems truly affordable and customer-friendly. Besides, it may be an easy affair to either retrofit or customize a solar system.

Thus, in future, we may find solar shops in every locality of towns and cities, just like mobile telephony shops. The Government of India, along with the state nodal agencies, is trying hard to stimulate the people to come forward and take advantage of becoming the proud owners of their own solar power plant. Every house, shop, and commercial or non-commercial establishment can become independent so far as their electricity requirement is concerned through installation of solar power plants. Energy security may well be attained with the achievement of energy independence for every citizen. Solar companies, channel partners, Renewable Energy Service Providing Companies (RESCOs), system integrators, financial institutions, and financial integrators have to play a big role now. JNNSM has stipulated an ambitious target of solar power generation of 20 000 MW by 2022, but a strong will and inclination of every section of the society can help India achieve the set target well before 2022. We will surely move towards a positive change system, as the solar movement picks up pace, slowly but steadily.

Illustration by Priyabrata Roy Chowdhury



Sustainable community planning

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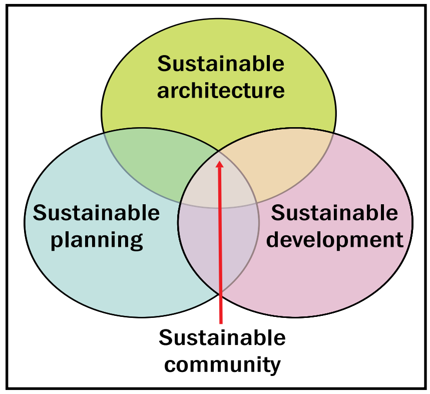
Sustainability has no single or universally accepted definition. It varies with various political ideologies and programmes followed by different research groups, their values and philosophies. For a simple understanding of this article, let us follow the definition of sustainable community available on the worldwide web, that is, the community planned, built or modified to promote sustainable living or sustainable lifestyle.



Sustainable living does not encompass just solar homes or energy-efficient buildings; it is fundamentally expressed as meeting present ecological, societal, and economic needs without compromising the interest of the future generations. Therefore, sustainable living can be described as living within the innate carrying capacities of the proposed land results in three key factors, that is, sustainable architecture, sustainable planning, and sustainable development.

Integrated approach for sustainable community planning

Sustainable architecture includes solar passive and energy-efficient buildings, renewable energy integration, and overall sustainable housing development. Similarly sustainable planning includes site selection and appropriate linkages, land use and transportation planning, physical infrastructure or resource optimization. Sustainable development includes natural resource management, environmental and social quality upgradation and overall economic benefit for the proposed community.

All these essential design and planning components adds together to create a sustainable community at any proposed land. The overall control and development of this sustainable community is the responsibility of architects, engineers, land use planners, transport planners, environmental planner, urban planner, private developer, builders, and the tenants or end users. Therefore, sustainable community planning is a result of an integrated approach and is not possible without the interest or influence of any single agency. The sustainable community development needs to follow a systematic approach of planning components as described in this article.

Site selection and appropriate linkages

The selected site for proposed community development must conform to the development plan or master plan of the city and should comply with the regional and local planning regulations and policies of government. One should plan compact development for optimal use of the land resources. It is recommended that the proposed site should be located on brown field site (environmentally degraded) or in-fill site (previously developed site) rather than exploiting virgin land.

The site should be developed within or adjacent to the existing city transit system so as to reduce the urban sprawl. It should have appropriate linkages with bus terminal, railway station, airport, and other means of mass transit available in the city.

Natural resource optimization

Once the appropriate site is selected, the first step is to identify all the existing natural resources available within the proposed site boundary to calculate the maximum carrying capacity of the proposed land. The carrying capacity study results in the maximum population the land can sustain/support. The proposed development in the site, such as population density, housing, infrastructure is based on this carrying capacity of the natural resources of the land. The detail mapping of each individual natural resource such as the land elevation, slope, natural drainage/watershed, soil, vegetation, wildlife/fauna also results in the land suitability map, that is, the map defines the boundary of the suitable area for various proposed development/activity, such as residential, commercial, transport, public and semi-public area. This map also highlights the eco-sensitive area within the proposed site boundary or the area where development is not possible. This land suitability map guides the entire land use, transport, and environmental planning of the site.

Land use and transport planning

The land use planner determines the crucial variables of land use distribution, such as the land use mix and residential densities. To establish sustainable land use planning, the developer should not follow the approved development plan if it exhibits any interference with the land suitability map. For sustainable land use planning, the environmentally sensitive areas should be considered as the ecological area and preserved or protected. The remaining area should be distributed for other required land uses such as residential, commercial, public and semi-public, recreational, and transport.

The transportation sector also has an important role to play, both in terms of offering desirable dwelling characteristics and the circulation plan. Housing and transportation facilities consume large quantities of energy during its production and use. The co-operation of housing developers, land use planners, and transport planners will be crucial to ensure the following as development options.

- Decrease the amount of space within development for vehicles and maximize space for pedestrians
- Pavements to be widened and roads to be narrowed a bit.
- The setting of maximum rather than minimum parking standards

Traffic free pedestrian environment within the community

- Car-free development where appropriate (for example, in central locations where good quality public transport is available and access to employment, shops, and other facilities is possible by walking or cycling)
- Establishment of home zones—residential developments within which strict controls are placed on vehicles (for example, a very low speed limit such as 10 mph). This creates a residential environment within which public space is more user-friendly, in general, and child-friendly, in particular.

Physical resource and infrastructure optimization

In sustainable community planning, it is recommended to take maximum advantage of the physical infrastructure existing on site (such as water supply, power supply, solid waste management system, drainage, and sewage management system) rather than to explore new resources. It is important to optimize the demand at end-use than that of optimizing the supply of resources.

Water management

Water use can be optimized at various sources to reduce the net demand of municipal water supply for the proposed community by the following three methods.

- Reduce water use during construction by adopting various water saving strategies and technologies in the construction process for the optimum use of potable water.
- Reduce water use in buildings by adopting water conserving sanitary fittings or water-efficient fixtures at individual household levels such as spray taps, low-flow fixtures and toilets, dual plumbing systems, and so on.
- Reduce water use in landscaping by utilization of water-efficient irrigation systems and reuse the treated wastewater for landscape irrigation as far as possible.

Solid waste management

Solid waste generation should be controlled at various stages for a sustainable solid waste management system in the proposed community. The following are the ways by which waste can be managed.

- Prevention of waste during the construction stages of the proposed development can save considerable amount of non-renewable waste, such as sustainable construction practices and waste minimization strategies. It could be incorporated in the contract document.
- Pre-fabrication in housing construction can minimize waste generation on site, and ideally, pre-fabrication should optimize the use of locally available resources so as to reduce the transportation cost.
- Re-using and re-cycling plays a vital role in minimizing resource use and waste.

Solar passive/energy-efficient buildings and sustainable housing

Solar radiation and other climatic factors, such as temperature, humidity, wind and rainfall, are the governing parameters for sustainable community design. Architects need to evaluate the above key parameters to establish design guidelines for the housing layout and individual building design. The overall objective of the design scheme is to provide maximum thermal and visual comfort to the building and community users', in terms of indoor and outdoor spaces. The following design components are considered in case of sustainable group housing/mass housing design, such as orientation of the plot, building height, typology (compact-introvert or open-extrovert), distance between the buildings, self shading and external-shading devices, buffer spaces or thermal zoning inside and outside buildings, opening/window size and orientation, type of glazing used in the buildings (energy-efficient properties), provision of adequate daylight, and so on.

To reduce the energy/electricity demand at individual household levels, the following principles can be adopted by the housing provider or developers.

- Energy audit and retrofitting of existing housing stock
- Energy Conservation Building Code

Alignment of the proposed site with the existing development

(ECBC) compliant building envelope (wall, roof, glass) for AC buildings
- Efficient artificial lighting fixtures
- Energy-efficient heating and cooling systems (Bureau of Energy Efficiency star rated)
- Integration of control systems (Heating, ventilation and air-conditioning and Lighting) in large buildings (with >500 m^2 built up area)

Integration of renewable energy (RE) technologies in the newly developed communities and even in the existing housing stocks results in following benefits.

- Minimizes the load on city electricity supply
- Results in a low running cost to the community
- Minimizes air pollution

However, integration of RE within a building envelope can only be beneficial if the overall energy consumption in the housing sector can be reduced by taking proper energy conservation measures. It is always cost-effective to conserve energy rather than produce it in the housing environment. Solar power seems to be the easiest RE resource to use in urban areas. This is evident from the growing popularity of building integrated photovoltaics (BIPV) and solar water heating systems.

Sustainable housing also means to have an easy access to employment, schools, shops, places of entertainment, primary health care, and public transport amenities. It would also be at variance in terms of tenures, incomes, and age groups. For a house to be a home, it must be geographically located in an area that enables its inhabitants to use it as a base from which to enter a society at large. It must facilitate social inclusion.

Environmental and social quality upgradation

A sustainable community can provide a stimulating and a relatively stress-free environment that increases our sense of well-being. The following are the three key indicators of healthy community design.

- Interaction of human body with the environment (comfort in terms of temperature, humidity, ventilation, natural light, sound of nature, and so on)
- Toxicity of building materials (chemical in foundation, timber treatment, fittings, PVC in services, interior finishes, paintings, and so on)
- Holistic well-being (air quality, water quality, noise quality, security, basic amenities, community facilities, and so on.)

Specifying appropriate physical responses to human health only partially addresses the issue. Health is a very subtle interaction between mind and body. Mental is as important as physical health and any technology introduced into the development must be closely allied to the user requirements. This means making the users familiar with the control and understanding of the materials, products, and processes used for their community. Thus, the community developers should encourage this qualitative appreciation of the built environment and its interaction with the natural environment.

Economic benefits

The essence of sustainability is a consideration of long-term costs and benefits. Large communities according to sustainability principle may cost more in the short-term, but will have a significant downward effect on overall, long-term costs. For example, incurring extra expenditure on energy efficiency may increase the capital cost (s), but there is concrete evidence that in the long-term the savings in running costs will exceed the initial extra capital costs. There is also supporting evidence that building in accordance with high environmental specifications leads to lower maintenance and management costs. Whole life costing can be used to estimate life-cycle costs and allocate them to different people and agencies (landlord, tenant, developer). Life time planning can increase the flexibility and effectiveness of the sustainable community and result in lowering the long-term costs.

Conclusion

In recent years, the market demand for sustainable community is increasing, therefore, the private developers and housing providers get direct financial benefit from the marketability of the product as green community or green development. But this integrated approach for sustainable community development by various agencies needs an extraordinary planning and investment. Thus, government support is very important for the implementation of sustainable community as a regular practice. Here, the role of policy-makers and local community organizations are significant to think about and to act upon. The local or central government should create policy guidelines and robust systems to evaluate or rate the upcoming communities by taking the help of various technical service providers for the guidance in planning and designing of the sustainable community.

DEMAND SIDE MANAGEMENT VIA SOLAR INVERTERS

Sapan Thapar, IREDA, <sapan@ireda.in>

For the last five years, Indian economy has recorded a sustained growth rate of plus 8%, and has made its impact felt on the global economy front. This has been largely possible due to its resounding progress in the infrastructure segment supported by the burgeoning revolutions both in the telecom and information technology segments. So far so good, but the lack of power supply in a desired measure is turning out to be a weak link in furthering our economic betterment. After all, there is a definite correlation between growth and energy supply. The power situation still continues to be grim in the rural areas. In these areas, over one-third of the population has no access to grid quality power. Even though massive power capacity augmentation plans are underway, envisaged capacity may not be able to meet all the requirements as is evident from the slippages observed during the last few Five-year Plan periods. This is further exacerbated by the fact that due to an increase in the standards of living, the demand for power (especially during the peak hours) in the urban areas is constantly on a rise. Further, distribution utilities, with their ageing infrastructure, are unable to meet this ever-growing demand. Thus, most of the Indian cities and towns are currently facing power outages for about 2–5 hours daily. During the financial year 2009/10, India experienced over 12.7% peak deficit and 10% energy deficit.[1]

Standby options

Buoyed by an increase in the purchasing power, a large number of affluent households, especially in the class I and II cities are using portable generators and inverters for running the bare minimum need-based loads like lights and fans. However, use of generators is turning out to be problematic for a variety of reasons like noise and air pollution, besides the trouble of buying/stocking the inflammable petroleum products like diesel and petrol. These difficulties are now steadily but surely paving the way for an increased market penetration of easy-to-use battery-operated inverters. Some market estimates point to the deployment of more than 10 million inverters in the urban middle class households today.

Paving the way for a solar power inverter

In a typical battery-inverter system, battery is charged from the grid power

[1] http://cea.nic.in/god/gmd/Monthly_Power_Supply_position/Energy_2010_03.pdf

after getting converted to direct current (DC) with the help of a rectifier. In case of any outage/power cut, essential loads (light, fan) are run from the battery power (converted to alternating current [AC] with the help of an inverter). However, the actual cost of power turns out to be many times higher than the utility offered tariff due to the additional cost associated with a battery-inverter system and accompanying conversion efficiency losses. Thus, one of the better alternatives can be solar-based inverters, wherein, a battery is charged through a solar photovoltaic (SPV) module. Solar power is obtained via the direct conversion of freely available incident solar radiation through a solar cell/module. In case of an outage, identified load points can be powered by the battery linked through an inverter. Typically, a 100 W module would be sufficient to meet the bare minimum power requirements of a household facing about 3-hours outage/power-cut.

The DSM linkage

System arrangement of the type indicated above can be effectively considered as a demand side management (DSM) based activity, wherein, power is generated near the load centre (decentralized-mode) through a renewable energy source like the solar. This is expected to increase the availability of power, improve the last-mile voltage levels, and bring down the transmission and distribution (T&D) losses. Further, it being an off-grid approach, the operational mechanism would be simpler to implement, thus obviating the need for metering and protecting the systems, as is required in a grid-interactive SPV system.

Meeting the broader objectives via solar system

Several innovative business models can be rolled out to reduce the financial burden of about Rs 150 00 towards the cost of solar modules and electronics. The use of solar inverters would be associated with reduced power imports, shall be eligible for the Ministry of New and Renewable Energy (MNRE) subsidy, and can benefit from the Clean Development Mechanism (CDM) facility. The utility can promote it under its DSM programme. All these measures may result in reducing the payback to a little over four years. Also, various factors, such as high inverter penetration, large number of suppliers with skilled staff, easy integration, would help in quick rolling of the programme. The initial target can well be 10 million middle-class household base using inverters, who can readily switch over to solar modules if the programme is dovetailed with a sound business model and adequately incentivized. The programme shall result in enormous savings on all fronts—1000 MW of power demand, 165 MU of energy, and 150 million kg CO_2e.

Clean technology at work

Solar inverter converts DC available from the solar panel to a more usable AC. The battery bank acts as a reservoir to ensure continuous supply of power. This type of system would normally comprise of inverter, batteries, solar module, charge controller, mounting structure, cables, and so on.

Prominent features of the solar inverters mainly include the following

- Long-life PV modules with minimal maintenance requirements (like regular cleaning)
- DC feed to batteries, obviating AC-DC conversion
- Solid state system with no moving parts
- Generation period coinciding with the peak power requirements

Battery would get charged by the solar module during day-time, obviating the requirement of a rectifier. A charge controller would be required to prevent battery from getting overcharged and deep discharged. In case of an outage, inverter shall support the identified load points by converting DC to AC.

Power requirements

Given the weather conditions in India, a 100 W solar PV module would generate over 0.5 kWh of electricity per day, assuming insolation levels of 1000 W/m^2 for five hours per day.[2] This shall be sufficient to support two light points (15 W CFL) and two fans (70 W) for three hours each, which shall require 0.5 kWh.

- Total load (W) 2(70+15)=170
- Total hours 3
- Power requirement 510 Wh

[2] http://mnre.gov.in/spv-intro.htm

Space

A 100 W solar module would roughly occupy up to 1 m^2 space (1500 mm X 600 mm), which is normally available on the rooftops of most of the Indian households. In the case of high rise apartments, some innovative techniques like mounting on wall/façade, or BIPV may be adopted. This shows that space requirements of solar PV modules shall not become a discouraging factor for consumers from using them in their households.

A typical off-grid approach and its attributes

This arrangement would be different from the often advocated grid-interactive solar PV systems. Here, the system would not involve any power injection to the grid, instead the system architecture would be much simpler to install and operate, without any metre or instrument.

Reduced dependence on grid

Presently, many of the Indian cities are facing long duration outages. After supporting the designated load profile for a few hours, batteries get discharged and the inverters are unable to re-charge again due to non-availability of grid power. Hence, the hapless consumers depend on costly standby options like the DG sets. This is associated with the use of precious fossil fuel (diesel/ kerosene) and air pollution/greenhouse gas emissions. Solar-based inverters can provide a long-term solution as the battery will be charged with the help of solar module, without any dependence on the conventional power grid.

Integration with existing inverters

Solar PV modules can be used with the existing battery-inverter set-up, with minimal configurational changes. This shall make it attractive for the existing inverter users as they would need to purchase only the solar PV module and some electronic systems.

Benefits to the consumer

The consumers would derive multiple benefits by switching over to solar inverters, or, by integrating solar modules with their existing inverters. The following are some of the advantages.

- Availability of power
- Reduced dependence on grid
- Reduced imports from the grid
- Solution for long duration outages
- Economically beneficial due to lesser conversion steps and power imports

Environment benefits

The use of solar inverters would be associated with the following benefits to the environment.

- Generation near end-use stage
- Minimal T&D losses
- Reduced requirements of grid power
- Reduced GHG—147 kgs CO_2e/ year

Utility benefits

Any utility would accrue multiple benefits as a result of its consumers switching over to solar-based inverters. To meet the peaking demand of its consumers, a utility has to purchase expensive power, vis-a-vis the cost of conventional power purchased under a long-term power purchase agreement (PPA). This additional requirement (peaking power) can be substantially reduced by the novel use of solar modules, which shall lead to flattening of peak load requirements.

Other benefits for the utility will include

- Reduced power surge as batteries shall get charged with the help of the solar power
- Peak load saving as generation would coincide with peak day time
- Reduced T&D loss as generation is near consumption
- Generation from solar inverters can be attributed to meet solar renewable purchase obligation (RPO)
- Improvement in voltage profile of the distribution system

Further, utilization of solar inverters can be categorized as a DSM activity as it involves actions at the end-users front. Forum of Regulators (FOR) has recently come up with model DSM regulations,[3] in which the utilities have been allowed to account for the expenditure incurred on DSM activities while filing their Annual Revenue Requirements (ARR) with the respective regulatory commissions.

These perceived benefits should provide strong reasons for the utility to incentivize the potential developers to install solar inverter systems.

[3]http://www.forumofregulators.gov.in/Data/study/Model%20DSM%20Regulations.pdf

Cost economics

System cost

In comparison to the conventional inverter systems, the cost of solar inverters would be higher, mainly on account of expensive solar PV module and charge controller. Other than these, most of the components in a solar inverter would be almost similar to the ones being used in any conventional inverter system, including battery, cables, and DC-AC converter. In case, where a consumer is already using a conventional inverter-battery system, the same would be required to be suitably configured. Customizing an existing inverter to harness solar power would cost over Rs 15 000[4]–Rs 13 000 on account of a 100 Wp SPV module (at Rs 130/ Wp), and Rs 1000 on account of a 60 W charge controller and Rs 1000 as charges for fitting and cabling.

Payback period

As explained above, Rs 15 000 would be required to customize a conventional inverter-battery system into a solar inverter. In case of a new purchase, similar price differential would be there between a solar-inverter system and any conventional battery-inverter system of similar ratings.

Computing procedure for the payback period

The payback period for this amount has been computed as below.

Reduced grid imports

A 100 W solar PV module would generate 0.5 units of electricity per day. Batteries can be directly charged with the help of solar modules as they generate DC, thus obviating the requirement of AC-DC conversion. Assuming a conversion loss of 10%, 0.5 units would be equivalent to 0.55 units imported from the grid, resulting in an annual monetary savings of about Rs 800 or so. Refer to Annexure I for details on the power generated.

MNRE capital subsidy

As per the latest policy initiatives by MNRE,[5] under the recently announced off-grid solar scheme, capital subsidy of Rs 70/Wp shall be provided. Hence, Rs 7000 would be directly discounted at the time of purchase of a 100 W solar module. Refer to Annexure I for more details on the subsidy calculation.

Incentives from utility

As enunciated above, utilities would derive various benefits from this programme and may provide incentives based on certain criteria. Capital subsidy equivalent to 10% of module cost can be provided on an upfront basis. The expenditure for the same can be attributed towards DSM activities and included in its ARR filing with the regulator. It should be noted that many utilities are already providing benefits to the consumers using solar hot water systems under their DSM programmes.

Power generation from the solar inverters can meet the solar power purchase obligations (RPO) by a utility. Also, utilities procure additional power to meet their peaking requirements from the power exchange, or through power traders at a higher price than normally purchased under long-term PPA. The effective subsidy can be equivalent to the difference between the average pooled power purchase cost for a particular utility and price of power, when procured from market through power traders. The quantum of allowable subsidy works to Rs 660 per annum. Refer to Annexure I for more details on the subsidy calculation.

Generation-based incentive (GBI) from the utility can be provided only up to the pay-back period (three years). The total subsidy support required from the utility shall be Rs 4138 per household.

Incentives under CDM/carbon funds

The projects in a particular utility can be bundled together to get Clean Development Mechanism (CDM) benefits under the programmatic approach/bundling of United Nations Framework Convention on Climate Change (UNFCCC).[6] Under this category, a group of renewable energy projects with size up to 15 MW are permitted to get registered for claiming CDM benefits. Being a DSM activity, the emission reduction calculations will take into account technical grid losses, thereby, increasing the effective certified emission reduction (CER).

If the programme qualifies under the programmatic approach of UNFCCC, each household using a 100 W SPV module can avail a benefit of about Rs 100 on an annual basis. Refer to Annexure I for more details on CDM benefits calculation.

Payback calculation

To customize its existing battery-inverter systems, a household would be required to invest Rs 6700 on an upfront basis

Table 1 Calculating the payback period

(A) Investments	
▪ Investments	Rs 15 000
▪ MNRE subsidy	Rs 7000
▪ Utility subsidy	Rs 1300
▪ Net investments	Rs 6700
(B) Incentives	
▪ Power generation	Rs 808
▪ CDM benefits	Rs 88
▪ GBI from utility	Rs 660
▪ Total benefits	Rs 1556
(C) Payback period	
▪ Simple payback period(SPP) = 6700/1886 = 4.3 years	

[4] Indicative values for Polycrystalline Silicon PV Modules, courtesy Tata BP Solar
[5] http://mnre.gov.in/adm-approvals/aa-jnnsm-2010-11.pdf
[6] http://cdm.unfccc.int/ProgrammeOfActivities/index.html

after accounting for the capital subsidy. However, during the actual operation of the system, the household shall also be eligible to receive multiple incentives from various agencies, leading to a quick payback period of 4.3 years. Refer to the calculation in Table 1.

Business model at work

With a payback period of little over four years, many middle class households may readily express their preference for a solar system if, the programme is dovetailed with a sound business model. An added advantage is that the inverter manufacturers/ suppliers have a widespread dealer network across the length and breadth of the country. Some of the reputed manufacturers like Luminous, Microtek, and so on, have recently ventured into the field of solar inverters, and can play a crucial role in creating the awareness amongst the potential customer segments.

They can take recourse to ESCO (Energy Supply Company) model, where they would own/ lease, install, and maintain the systems, with the end-user paying on a rental basis. This is akin to the business model adopted by some suppliers of solar water heating systems, wherein, they charge for the energy supplied (quantity of hot water). The suppliers can also claim depreciation benefits for the solar capacity installed.

The upfront capital requirements can be funded under a re-finance facility, similar to what is available for the solar water heating systems. Funds can also be leveraged from the recently launched National Clean Energy Fund. The manufacturers can further tie-up with the state distribution utilities, who can promote it as part of their DSM programme.

Brand ambassadors can be roped in to promote this scheme, being part of the sustainable movement, thereby, raising the overall environmental quotient of the prospective consumers.

Way forward

Individual projects up to 100 kWp per site can be bundled by the channel partners under the existing MNRE solar off-grid scheme. With each household using 100 Wp solar panel, a site may comprise of 1000 households, with a total capacity of 100 kWp. Capacity aggregating up to

15 MW, comprising of 150 such sites/projects (each of 100 kWp size) and 150 000 households, can then be bundled under a programmatic project for the CDM benefits.

The scheme can be quickly rolled out across India, mainly due to the following few favourable factors.

- High penetration of inverters
- Large number of inverter suppliers
- Adequate availability of skilled personnel
- Large manufacturing base of solar PV modules in the country
- Easy integration/configuration with existing battery-inverter systems
- Increased awareness on solar energy with the recently initiated Jawaharlal Nehru National Solar Mission (JNNSM)
- Due to multiple benefits, utilities/discoms having an extensive network would participate willingly

ANNEXURE I

Power generation	
PV module	100 Wp
Average daily insolation	5hrs/day[8]
Daily generation	0.5 kWh
Conversion loss	10%*
Replacement	0.55 kWh
Annual sunny days	300[9]
Annual generation	165 units
Cost of power	Rs 4.9 /unit[10]
Annual savings	Rs 808
MNRE subsidy	
Capital subsidy	Rs 70/Wp[11]
Module capacity	100 Wp
Total subsidy	Rs 7000
Utility Subsidy	
A) Capital subsidy	
Cost of module	Rs 14000
Subsidy@ 10%	Rs 1400
B) Generation-based incentives	
Power market rate	Rs 6/unit[12]
Average PP cost[#]	Rs 2[13]/unit
Differential cost	Rs 4/unit
Annual generation	165 units
Incentives	Rs 660
CDM calculation	
Capacity utilization	19%
Annual generation	165 units
GEF (t CO_2/MWh)	0.82[13]
T&D loss	8%
Price of CER	€10[14]
1 €	Rs 60
Power Saved	179 units
CO_{2e} Reduction	147 kgs
Earnings (Rs)	88

(*) Generating DC, obviating AC-DC conversion

(#) Average pooled power cost for 16 Indian states

The target for this programme can be 10 million middle-class households . If these households[7] switch to solar-based inverters, enormous savings can be achieved—1000 MW in power demand, 165 MU of energy, and over 150 million kg CO_2e of GHG. If pursued vigorously as a DSM measure by the utilities, aptly supported by an innovative business model and catalyzed by incentives, the large scale diffusion of solar PV technology can help urban India meet its peak energy requirements in an environment-friendly manner.

The views presented in this article are strictly those of the author and not of the organization to which he belongs.

[7] http://www.mckinsey.com/mgi/mginews/bigspenders.asp
[8] http://mnre.gov.in/spv-intro.htm
[9] http://mnre.gov.in/spv-intro.htm
[10] http://www.herc.nic.in/orders/pdf/2010/20100913.pdf- Domestic Tariffin Haryana
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[12] http://cercind.gov.in/2010/MMC/MMC_Annual_Report_2009_dated_28.4.pdf
[13] CO_2 Baseline Database for the Indian Power sector, User Guide Version 5.0, November 2009, CEA
[14] http://www.pointcarbon.com

DIREC
A CURTAIN RAISER

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India is blessed with abundant sunlight, wind, water, and biomass resources. Fortunately,, policy-planners, and the civil society at large are steadily but surely promoting these resources as being clean, reliable, useful, and safe.

Thanks to quite a few path breaking initiatives adopted by the Ministry of New and Renewable Energy (MNRE) from time to time, India has one of the largest Renewable Energy (RE) based programmes in the world today. This belief was further reinforced with the decision of MNRE to host the International Renewable Energy Conference during 27–29 October 2010 in the National Capital Region (NCR) of Delhi. This prestigious event will be the fourth in the series, and it is expected to witness a sizable participation of about 7000–9000 delegates, besides other distinguished participants.

According to Deepak Gupta, Secretary, MNRE, "The conference at Delhi (DIREC 2010) is part of a larger initiative taken at the 2002 World Summit on Sustainable Development in Johannesburg acknowledging the significance of renewable energies for sustainable development, especially for combating poverty & environmental and climate protection."

The focal theme

Talking about the theme of this event, Rajneesh Khattar, Vice President of the Exhibitions India Group opined that the focus of the event is expected to be on "key drivers of renewable energy production, applications including global joint research and development efforts, technology transfers, addressing trade and investment barriers, innovative financing and funding, and sustainable business models". Also the event will comprise of the following two key components.

a) the main conference
b) side events and trade show

The event will consist of the following few elements

- Ministerial level plenary sessions
- Interactive ministerial sessions
- Interactive stakeholder sessions
- Joint ministerial and stake-holder sessions

- Break out sessions on cross-cutting issues
- CEO Roundtables
- Official side events
- Business trade show
- Parallel half and full-day workshops

Major attractions

- President of India to address the opening plenary
- Delhi International Action Programme with awards – voluntary pledges to advance renewables deployment
- Ministerial level plenary sessions – stakeholder plenary sessions
- CEO roundtable – interactive panel discussions
- Business trade show
- Official side events
- Parallel events on thematic and cross cutting issues

The aim

DIREC 2010 is the fourth in the series of the International Renewable Energy Conferences. Prior to this, the International Renewable Energy Conferences have been held in Bonn, Germany; Beijing, China; and Washington, the US. The main aim of the DIREC 2010 is to build on the successful outcomes of the last three conferences by focusing on concrete and innovative actions to promote renewables for a variety of end-use applications.

With over 9000 delegates, 250 speakers, and 600 exhibitors from more than 50 countries, the participants will include manufacturers, academicians, decision-takers and policy-makers in various fields of renewable energy. The ministerial level delegations are expected from Austria, Afghanistan, Bangladesh, Bhutan, Finland, Georgia, Germany Iran, Italy, Norway, Qatar, Sri Lanka, Sudan, Sweden, Senegal, Thailand, UAE, Zambia, and other major countries.

DIREC is expected to be the most significant event in renewable energy ever held in India. I would request you all to participate in DIREC 2010 for which you may register at www.direc2010.gov.in

—**A K Tripathi**, *Director, Ministry of New and Renewable Energy*

Side event by TERI

Symposium on promoting rural entrepreneurship for enhancing access to clean lighting options

The Energy and Resources Institute (TERI) is organizing a half-day symposium on 'Promoting Rural Entrepreneurship for Enhancing Access to Clean Lighting Options' on 28 October 2010 at Expo Centre and Mart, Greater Noida, as a parallel event at DIREC 2010. The half-day programme will be supported by REEEP (Renewable Energy and Energy Efficiency Partnership) and Energy for All partnership of ADB (Asian Development Bank).

The symposium will specifically focus on addressing issues towards extending clean lighting globally focusing on strong supply chains, robust technical and quality standards, after-sales service network, and end-user financing to develop viable and sustainable rural market. Participants are expected from various national and international stakeholders like governments, lighting programmes, bilaterals and multilaterals, banks and financial institutions, NGOs/CBOs, and venture capitalists.

For more details on this, please visit: http://labl.teriin.org/index.php

The Delhi International Action Programme will provide governments and other major stakeholders with a roadmap of the global renewable energy progress and information on some specific steps that need to be taken for the large scale advancement of renewable energy. The Delhi International Action Programme is managed by REN21 (Renewable Energy Policy Network for the 21st Century), a key international partner in DIREC 2010. DIREC 2010 is definitely a big opportunity for the various stakeholders as well as the governments to firm up their pledges, visions, and plans for developing the renewable energy sector and eventually moving towards a low-carbon development model.

The event will aim at enabling its participants to acquire a deeper understanding of the following.

- The link from Copenhagen to Cancun via DIREC
- The policy efforts needed to encourage and enable a major renewables scale up
- What is needed to mobilize finance for renewable energy innovation and deployment?
- The benefits of collaboration, synergies, and knowledge-sharing at the international level to scale up renewables

For more details on the event log on to www.direc2010.gov.in

TAKING SOLAR TO THE MASSES

Dipal C Barua, Founder and Chairman of the Bright Green Energy Foundation (BGEF) has devoted more than 35 years of his life, finding sustainable market-based solutions to the social and economic problems of the rural people. He is the Founding Managing Director of Grameen Shakti and the Co-Founder and Former Deputy Managing Director of the Grameen Bank, Bangladesh, which won the Nobel Peace Prize in 2006.

He has played a key role in expanding renewable energy technologies in Bangladesh. He designed and implemented one of most successful models for taking solar PV technology to rural people on a mass scale. His model has been adopted by the World Bank to expand solar technology through Infrastructure Development Company Limited (IDCOL). Over 400 000 Solar Home Systems have been installed in Bangladesh, benefiting more than four million rural people. He won the First Zayed Future Energy Prize 2009 for his innovation and commitment to alternative energy. He has successfully demonstrated that renewable energy technology, especially solar technology is a viable alternative for the rural people, and they can be reached through a market-based model. In an interview with **Arani Sinha**, Dipal C Barua discusses his initiatives, obstacles, successes, and his future plans in taking solar energy to the masses, especially solar technology, is a viable alternative for the rural masses, and they can be reached through a market-based model. In an interview with Arani Sinha, Dipal C Barua discusses initiatives taken, obstacles faced, his successes, and future plans of taking solar energy to the masses.

Q1. You are nourishing a very big dream of empowering 75 million people (that is 50% of the population) of Bangladesh with the help of renewable energy technologies. What makes you believe so strongly in renewable energy? Also, how do you reach out to the rural population who are generally not much aware of renewable energy technologies and issues related to sustainability?

I have tremendous faith in renewable energy, especially for the socio-economic development of the rural people. I have been working with rural people since my student days. Grameen Bank started its journey from my own village, Jobra in Bangladesh. I am one of the co-founders of the Grameen Bank. I have travelled across 20 000 villages on foot during my tenure with Grameen Bank and learnt that lack of access to modern energy is one the main challenges that rural people face, which keeps them trapped in a cycle of poverty and under-development. That is why, I built Grameen Shakti, a not-for-profit renewable energy company, to provide the rural people with an alternative without damaging the environment and increasing the carbon footprint. The success of Grameen Shakti shows that my faith and confidence in the rural people to adopt a new technology and make optimum use of it was not misplaced.

I strongly believe that reaching out to 75 million people with renewable energy technologies is an achievable goal, if we can put in place an appropriate business and technology model. I have set up the Bright Green Energy Foundation (BGEF) to achieve my vision through innovative and practical programmes.

We train our engineers as social engineers who create special rapport with the rural community they serve. Our engineers sit with local leaders, and teachers and hold demonstration meetings in schools, colleges, mosques, and other public places. We also organize special programmes for schools to create awareness among students, who in turn spread the knowledge among the parents and neighbours about renewable energy technologies. We recruit local youth as technicians as they have a better