evapo-transporative (ET) loss of water from the soil, viz.

$$E_A = \frac{Ard}{\eta_d \eta_p} \times (2.72 \times 10^{-3})\,\text{kWhr/day} \qquad (1)$$

where A is the net area in square metre of cultivable land in the village, r is the rate of ET loss in m/day, d is the average depth of water in meter under the ground, η_p is the pumping efficiency and η_d is the distribution efficiency of pumped water.

If the pump is assumed to operate continuously for H_A hr, the power of the pump P_A given by

$$P_A = E_A / H_A \qquad (2)$$

The electrical energy requirements (E1) for village industries is given by

$$E_I = \sum_{j=l}^{n} \sum_{k=l}^{m} P_{ljk} H_k \qquad (3)$$

where j = 1, n is the number of industries, k = 1, m is the number of time segments of the day, P_{ljk} is the power requirement of the jth industry over the daytime segment H_K.

Thus the daytime energy and power requirements are respectively

$$E_D = E_A + E_I$$
$$P_D = P_A + P_{ljk} \qquad (4)$$

2.2 Night time load

The domestic (E_d) and community (E_c) energy requirements of a village can be expressed as

$$E_I = \sum_{i=l}^{p} N_{di} P_{di} H_{di} \qquad (5)$$

$$E_I = \sum_{i=l}^{q} N_{ci} P_{ci} H_{ci} \qquad (6)$$

where Ndi arid Nci are the ith categories of domestic houses and community centres. P_{di} and P_{ci} are the corresponding power requirements over the time segments H_{di} and H_{ci} respectively.

The energy need for the streetlighting is simply given by

$$E_S = N_S P_S H_S \qquad (7)$$

where N_s, P_s and H_s are the number of light posts, the power requirement and duration of lights respectively.

The total night time energy requirements is thus

$$E_N = E_d + E_c + E_s \qquad (8)$$

3. ENERGY BALANCE CONSIDERATIONS

In order to select the right size solar cell panels and storage battery for meeting the day and night time loads, we define an energy balance condition where the total energy available from the solar array (E_{SA}) is sufficient to recharge the battery (E_B) and the energy required by the system electrical load including system losses (E_L), i.e., in absence of any back up power supply,

$$E_{SA} = E_B + E_L \qquad (9)$$

Assuming that the night time load is solely provided by the storage battery with an overall efficiency factor K_I [4].

$$E_B = E_N / K_I$$

$$K_I = \eta_D F_u \eta_R \eta_L \eta_B \qquad (10)$$

η_D being the solar array diode efficiency, F_u the solar array utilisation factor, η_R the regulator efficiency. η_L the line loss factor and η_B the battery W-hr efficiency.

Similarly, assuming that most of the daytime load is directly fed by the solar array except when $P_D > P_{SA}$, the solar array power output,

$$E_L = \frac{E_D}{K_2}\alpha + \frac{(l-\alpha)E_D}{K_I} \qquad (11)$$

where α is the fraction of daytime when $P_D < P_{SA}$, and $K_2 = K_1/\eta_B$ is the overall efficiency factor by which the solar array directly drives the load.

The solar array size is expressed in terms of its peak power output P_{SAMP} at AMI insolation, which is obtained from

$$E_{SA} = P_{SAMP} \sum_{i=l}^{Z} [\int(t)\Delta t]i \qquad (12)$$

where $f(t) = P_{SA}(t) / P_{SAMP}$ over the ith segment $(\Delta t)i$ during daytime and Z is the number of time segments in the day.

The capacity in A-hr C_B of the storage battery at the rated load is determined by the daily night load and a part of the daytime load for which sufficient storage is to be provided as protection against cloudy weather etc. thus leading to

$$C_B = \frac{(x\bar{P}_N + y\bar{P}_D)}{\eta_L V_D (C\;/100)} \qquad (13)$$

where

$$x P_N = x_l P_d + x_2 P_c + x_3 P_s$$

and

$$y P_D = y_l P_A + Y_2 P_I \qquad (14)$$

x_1, x_2, x_3, y_1 and y_2 are the periods for which storage are to be provided for the different loads, V_D is the average voltage of discharge of the batteries and C_D is the maximum permissible depth of discharge in percentage.

4. BALANCE OF SYSTEM COMPONENTS

As mentioned in Section I, apart from the solar cell panels the PEPS comprises of a number of balance of systems components such as (a) array module mounting frames, frame supports and foundations; (b) electrical control circuits, load management and power conditioning equipment, wiring interconnections, etc.; (c) storage batteries, racks and venting equipments, etc. Further costs are also incurred for the installation and checkout, module test and inspection, system sizing and designs, packaging, maintenance, etc. The sum of all these costs, lumped as BOS costs, need to be taken into account for the design of PEPS. Recently, NASA Lewis Research Centre has analysed the BOS costs for sixteen different PEPS installations including two village energy centres at Schuchuli. U.S.A. and Upper Volta. Africa. The analysis indicates a correlation between the BOS cost/peak W (R) with the size (S) in a peak watts of the installation as

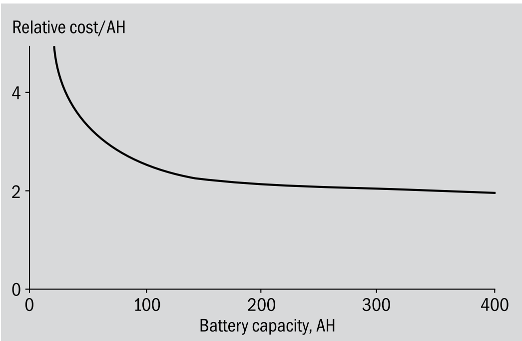
$$R = 296 \times (S)^{-0.412} \quad (15)$$

An important factor contributing to the highly non-linear behaviour of BOS cost/peak W with the PEPS size is the nature of variation of the storage battery cost/ Ahr with the capacity in Ahr of the battery as shown in Figure.1.

In the BOS elements considered above all the electrical loads and equipment have been assumed to be d.c. Otherwise, the BOS cost would increase appreciably due to the cost of inverter/converter units.

5. TYPICAL EXAMPLES OF A VILLAGE ENERGY CENTRE

Let us consider a typical village in West Bengal, India as an example. The village contains about 100 households of which 60 units are electrifiable. The area of the cultivable land is about 70 hectares. There are two small scale industries and 1 km of road that may be used



Fiture 1 Variation of stationary cost/Ahr with A-hr capacity

For street lighting within the village. There are three community centres. There is no scarcity of potable water for which there is no need for electrical energy for pumping. Table 1 shows the description of the different categories of load and the corresponding electrical energies computed on the basis of eqns (1)–(8). The pumping system efficiency has been assumed to be 70 per cent as is readily obtained with large motor-pump systems in the range of 30kW or so. For the sake of simplicity, all households have been assumed to be of similar nature and all the community centres identical.

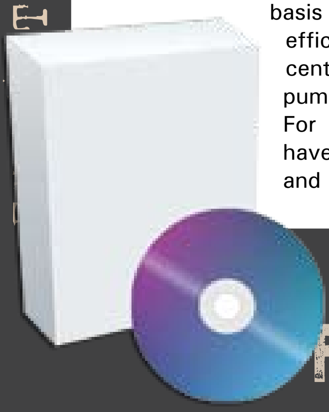


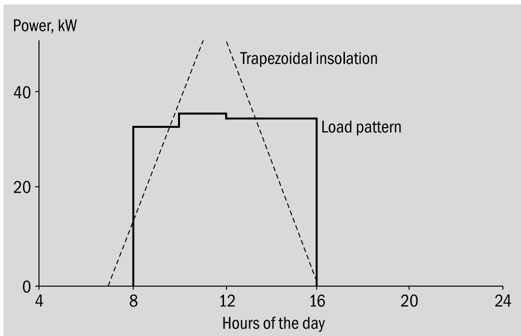
Table 1 Electrical energy needs of a village

Detains of the category	Time segment (hr)	Energy (kWhr/day)	Power (kW)
Agricultural A = 70 gectaresm r = 3 mm/day d = 20 m, n_d = 0.7, n_p = 0.7	0.800–16.00	233	29.125
Industrial (two units)	08.00–10.00	8	4
	10.00–12.00	16	8
	12.00–14.00	12	6
	14.00–16.00	12	6
Total day time load (E_D)		281	
Domestic (60 households each consuming 25 W F. lamp)	19.00–22.00	4.5	1.5
Community (3 centres each consuming 60 W)	19.00–22.00	0.54	0.18
Street lighting	19.00–23.00	2.6	0.65
Total night time load (E_N)		7.64	

Table 2(a) shows the various efficiency factors assumed for computation. The line loss factor has been ignored for both roof-top and village energy centre approaches as these can be made negligible through proper choice of voltage level and distribution grid wires.

5.1 Solar panel and BOS estimate

Figure 2 shows the daytime load pattern after correction for different loss factors and an idealised trapezoidal insolation pattern for a typical day. The insolation pattern can be



Fiture 2 Trapezoidal insolation (--) and load pattern (--) of a village photovoltaic electric power systems

Table 2a Efficiency factors

η_D	Fu	η_R	η_L	η_B	K_1	K_2
0.95	0.8	0.85	1.0	0.8	0.517	0.646

constructed from the annual average of hourly mean insolations received at the place under consideration. From the figure, it is seen that idealised day duration is 9 hr and the fraction of time (α) for which the insolation exceeds the daytime load is α = 3.75/9 = 0.42.

Combining eqns (4), (8), (10) and (11) one thus obtains the total energy (ESA) required from the solar cell array.

Table 2b Solar arrays and BOS costs

α	E_L (kWhr)	E_B (kWhr)	E_{SA} (kWhr)	f(t/Δt	P_{SAMP} (kW)	BOS$ Peak W	Total BOS $	Others $	Solar panel cost $	Grand total $
0.42	497.9	14.8	512.7	5	10.5	2.55	261,576	7000	51,250	319,826

Table 2c Storage battery parameters

X_1 (days)	X_2 (days)	X_3 (days)	Y_1 (days)	Y_2 (days)	C_D/100	V_D (V)	C_B (Ahr)
3	3	3	0	1	0.8	220	402.95

The size of the solar cell array is then fixed from eqn (12) and Fig. 2. The trapeziodal pattern of Fig. 2 leads to 3 segments of Δt with f(t) =1/2 during 7–11 a.m. in the morning and also 12 a.m.–16 a.m. in the evening and f(t) = 1 during 11-12 a.m. at noon, thus yielding a value for

$$\sum_{i=l}^{3} f(t)\Delta t = 5$$

Table 2(b) shows the size of solar cell array and the associated BOS costs for the typical village energy centre under consideration. The capacity of the storage battery is computed on the basis of the assumed parameters shown in Table 2(c) and eqns (13) and (14).

If VD is selected to be 220 V to comply with the existing electrical loads in India, CB turns out to be about 400 Ahr.

In the absence of any reliable data valid for Indian conditions, the corresponding BOS cost/W is computed from the regression equation (15) and is shown in Table 2(b). Further costs should be added to this for individual service connections to houses which may be taken as $50 per household, and about $4000lkm of overhead line installations. The total thus amounts to $268,576. The cost of solar cell panels are assumed to be $500 per peak kW.

6. ROOF-TOP APPROACH

Because of the highly modular nature of both solar cells and storage cells, specific loads can be provided separately by individual roof-top PEPS, dispensing with the necessity of distribution networks. Table 2 shows the BOS costs for these individual roof-top PEPS for meeting the same energy needs of the village as indicated in Table I. The total agricultural plot is divided into 35 holdings each of 2 hectare area. The pumping system efficiency has been taken as 50 per cent, the best reported so far in this small range of power [5]. All the street lights, households, community centres and industries are separately powered PEPS. The values of α and Σf (t)Δt have been assumed same as before.

The BOS cost/peak W for individual households, street lights and community centres appears to be very high according to the regression equation (15). This is because of the d.c. to a.c. or d.c. to d.c. inverter/converters that must be included in these installation for feeding the ftourescent lamps from 12 V batteries and also the high labour cost, high battery cost etc.

Table 3 BOS cost for roof top PEPS of a village

Details	Energy (kWhr/day) (E_D or E_N)	Array power (kW) (P_{SA})	BOS $/peak W	Number	Total BOS cost $	Solar Panel cost $
Agriculturel A = 2 hectares r = 3 mm/day d = 20 m ηd = 0.7, ηp = 0.5	9.32	3.30	10.47	35	1209285	57750
Industrial	24	8.5	6.86	2	116708	8500
Domestic	0.075	0.029	73.90	60	128627	870
Community	0.180	0.069	51.7	3	10706	104
Streetlighting	0.075	0.029	73.9	26	55720	377
Total					**1521046**	**67601**
Grand total					**1588647**	

7. CONCLUSIONS

A methodology has been developed for computing the total electrical energy needs of a village and the corresponding photo voltaic electric power systems which include the solar cell panels, storage batteries and the other balance of system components. A comparison is made between the economics of village energy centre model and the highly decentralized, roof-top model of PEPS for meeting the energy needs of the village on the basis of the balance of systems regression equation developed by NASA Lewis Research Centre in absence of any suitable Indian data. The village energy centre approach appears to be about five times more cost-effective than the roof-top approach. Further, a number of other benefits like better maintenance, superior load management and greater security are also associated with the village energy centre approach. However, a detailed experimentation is necessary for obtaining a more reliable and realistic data suitable for Indian conditions, an experiment which is now under active consideration.

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Making headways in renewable energy-based technologies

Designing and development of renewable energy-based technologies as well as manufacturing of solar energy devices is gaining lot of importance. *Amit Kumar, Director, Energy Environment Technology Development Division, TERI* managed the design, construction, and commissioning of one of the largest solar ponds at Bhuj, Rajasthan, and Asia's first solar powered cold storage in 1980s. In an interview with *Arani Sinha*, he talks about the present and future renewable energy-based technologies and specifically the National Solar Mission

Q. The National Solar Mission witnessed a fair amount of veiled and unveiled criticism till it was approved at the highest government level. Do you feel there was some rationale to it or is it that solar as usual was being touted as a technology with a big promise but low realization at least on the power generation front?

A. The major emphasis on solar energy in NAPCC (National Action Plan on Climate Change) has a very strong basis and that pertains to very good solar radiation levels, almost throughout the country.

The average intensity of solar radiation in India is 200 MW/km^2. With a geographical area of 3.287 million km^2, this amounts to 657.4 million MW. However, taking into account various other uses of land, about 0.413 million km^2 can, in theory, be used for solar energy installations. It has been estimated that even if 10% of this area is used, the available solar energy would be eight million MW, which is equivalent to 5909 mtoe (million tons of oil equivalent) per year.

As regard the issue whether solar technologies can deliver, the fact remains that even now these are being used extensively for applications ranging from water heating to rural electrification. Even for power generation, one has to realize that take-off of any technology does not happen in the vacuum but it requires appropriate policy and regulatory mechanisms. Besides the pricing of the conventional power – with which these alternatives have to compete – also has a major bearing on the propagation. Otherwise, as far as solar technologies are concerned, including concentrating solar power, they are technologically mature ones.

Q. There is just a very minuscule solar PV (photovoltaic) installed power capacity of 2 MW and ironically almost nil capacity for solar thermal power in practical terms. Then is this not a very tall order to expect solar power capacity realization of 20 GW within the next 10 years or so?

A. As I explained earlier, so far there was no programme in the country for MW-scale solar power generation. With finalization of various programmes under the National Solar Mission, a major impetus would be provided to the solar power. I am sure that five years down the line, there would not be any room for such scepticism.

But on the other hand, why do we only talk about 2 MW of solar power. Let us also talk about 1.1 million solar home systems and solar lanterns that are illuminating so many homes in those far-flung areas where the wait for the extension of the grid (with actual electricity flowing through them!) would have remained a dream for ages. Indeed, TERI's Lighting a Billion Lives campaign is all about using so called 'small' device like solar lantern to create tremendous positive impact on not only socio-economic conditions in the villages, but more importantly, on the lives of the rural populace per se.

And to the question that the goal of 20 GW by 2020 is very ambitious, it is high time that we set an ambitious goal and work in concerted fashion to realize that. Given our leadership role in many other spheres, we should take lead in this area as well.

Q. You have been actively associated with the development of various solar thermal technologies for a long time. How do you look at solar PV technology receiving precedence over the cheaper solar thermal mode in this mission statement?

A. This is a misconception. The National Solar Mission focuses on a bouquet of technologies, including solar thermal technologies. In fact, the target of 12 000 MW of grid electricity has a major component of electricity generated through concentrating solar thermal technologies. In addition, there are specific goals and roadmaps for solar thermal technologies for domestic, commercial, and industrial applications. And at the end of the day, we all are talking about accelerating the utilization of solar energy in the country where routes are immaterial.

> *"There are specific goals and roadmaps for solar thermal technologies for domestic, commercial, and industrial applications. And at the end of the day, we all are talking about accelerating the utilization of solar energy in the country..."*

Q. It is a fairly common knowledge that majority of both existing and new high rise buildings in the urban marketplace continue to depend on diesel power generating units for standby power requirements. So when do we really see solar PV making its way in such environs more so when it is now priced so closely with the diesel generation costs?

A. I am quite optimistic on this front, and I feel that a combination of increased public awareness about such technological options and the decreasing prices of solar PV would help bringing about this change. In this context, sensitization of architects would be very crucial because they only advice the clients. Also, perhaps, what is required is to position building-integrated solar PV as a premium product that could be shown off as a 'statement' of being green.

Q. The super-critical thermal power stations being installed in the country now are experiencing conveniences like technology imports and cheap finances from multi-lateral funding agencies. Would solar power realization under the ambit of national solar mission hinge around arrangements of a similar nature?

A. National Solar Mission is not about one single solar technology, rather a mix of indigenous technologies and ones that are not available in the country right now. So as such National Solar Mission is not dependent on the imports only. In fact, as has happened in many other advanced technologies, for instance large-scale wind, in due course of time indigenization increases substantially. And the fact that the very premise of National Solar Mission is to bring in grid parity, would necessitate the rapid localization.

Q. Heightened climate change concerns have often been advanced as the driving force for emergence of national solar mission. What according to you is the true connection between solar technology use and

carbon emissions in the backdrop of very limited capacities being installed in our country for example?

A. It would be wrong to look at the climate change mitigation potential in terms of the current capacities only. If the goals as enumerated in National Solar Mission get converted in to reality, the scope of reduction of GHG (greenhouse gas) emission is quite substantial.

Indeed, for India to fulfil its commitment, 'India's per capita greenhouse gas emissions will at no point exceed that of developed countries even as it pursues its development objectives' would necessitate multifold increase in deployment of solar energy.

Q. Solar energy technology has hardly been seen as an area with a sizable potential for job offerings. Do you feel major initiative like the National Solar Mission will open floodgates of opportunities for a curious lot of youngsters equipped with varied science and engineering skills. If so, could you please spell out the role that organizations like TERI can play in making it happen?

"Future solar vision for India is about solar energy becoming one of the defining parameters of India's energy independence equation..."

A. The National Solar Mission estimates for the trained personnel are to the tune of 100 000 jobs by 2020 in specialized areas like engineering, management, and research. Incidentally, TERI University has already started M.Tech. (Renewable Energy Engineering and Management) programme from this academic year. Likewise TERI too is focusing on capacity building at different levels—from the grass roots to the decision makers in various sectors.

Q. Kindly share your future solar vision for India with the readers of, 'The Solar Quarterly' from selective few realistic considerations

A. In very simple terms, my future solar vision for India is about solar energy becoming one of the defining parameters of India's energy independence equation.

Analysing India's solar PV programme

Dr J Gururaja is a proponent of the development of solar energy programme and its wholesome promotion. He served as a faculty member at the Indian Institute of Science, Bangalore, in the Department of Mechanical Engineering from 1960–76 and thereafter till 1994, he was with the Government of India, first as Director of New Energy Sources Division, Department of Science and Technology, and subsequently as Adviser in the Ministry of Non Conventional Energy Sources. His vision and administrative acumen saw the then DNES (Department of Non-Conventional Energy Sources) march from strength to strength. Dr Gururaja has enjoyed long lasting associations with several professional bodies and societies, including SESI (Solar Energy Society of India). Presently, *Dr J Gururaja is the Executive Director of the Renewable Energy Advocacy Forum*. In an interview with *Arani Sinha*, he talks about the various dimensions of India's solar photovoltaic programme and the future of solar technology in India.

Q. You have been one of the prime movers of the Indian SPV (solar photovoltaic) programme since its very early days. How do you look at its various dimensions?

A. We have come a long way in PV technology development in India from its early days, and today it is gratifying to note that we now have a wide-ranging PV programme that addresses technology development and applications with active participation of various organizations and production establishments.

India started out early in the game, and we were one of the frontline countries in PV technology development, and manufacturer of cells, modules, and systems. If we look at the current global scene, while our overall program is, no doubt, quite impressive, in terms of production capacity and large scale deployment, we seem to have fallen behind many other countries. For example, China had limited capability both in technology and manufacture in 1980s and 1990s but today, China has established huge PV production capacity with vertically integrated production plants from polysilicon to cells, modules, and systems and exports far in excess of what we have in India. China is poised to capture bulk of the worldwide export markets for PV. One of their production establishments has a capacity to produce 1GW (gigawatt) per year. In addition, 3–4 PV production plants in China have capacities in the range of 300–500 MW (megawatt) per year, besides numerous other smaller companies. We do not have such production facilities in India and our largest one is Tata BP Solar India Limited with an installed capacity of about 150 MW per year of cells and modules and a number of smaller players. We still do not have polysilicon production in the country. We are continuing to import practically all the silicon material needed by our PV industry. China exports a considerable quantity of silicon ingots and wafers to other countries and yet it produced 2 GW of PV cells and modules in 2008, whereas India has about 0.2–0.3 GW total installed production capacity per year, but the actual production seems to be considerably less than this. Germany and Spain have become major players in terms of large scale deployment, especially grid connected systems. In United States, both the federal and state governments have introduced policies and incentives in support of growing markets and wider scale applications of solar systems. Viewed in this context, the PV scene in India is beset with many gaps. The program needs to be strengthened considerably. The same applies to solar thermal power generation also. This notwithstanding, there is optimism in the sense that the National Solar Mission has set out ambitious goals for the country which, if effectively implemented, can reposition India again as a frontline country in PV and solar thermal power generation technologies.

> *"China exports a considerable quantity of silicon ingots and wafers to other countries...yet it produced 2 GW of PV cells and modules in 2008, whereas India has about 0.2–0.3 GW total installed production capacity per year, but the actual production seems to be considerably less than this."*

Q. Having a sound policy framework in place is regarded as one of the cornerstones for pushing forth any technology amongst the diverse sectors of our economy. Are there any major changes in it that you would like to advocate for reaping even better gains from the national solar energy programme?

A. Sound policy framework for PV is crucial for making rapid progress in India. The policy regime in India has to shift away from a subsidy-oriented one, to one that is progressively market oriented. A beginning seems to have been made to bring about such a shift as is evident from some of the initiatives that MNRE (Ministry of New and Renewable Energy) is taking or proposes to take in the coming years. The initiatives with regard to feed-in-tariffs, portfolio standards, net metering, and large grid connected PV power plants, building integrated PV, and so on all of which forms part of the National Solar Mission, are steps taken in the right direction. However, unless these are effectively translated into practical steps in a time bound manner, results on the scale envisaged and breakthroughs needed are unlikely to materialize.

Both policy and institutional reforms are needed to spur large scale PV deployment and to encourage massive investments in this area. The provision made in the latest electricity act that stipulates that all electric utilities should generate a part of their electricity from renewable sources must be enforced in all utilities. Mandatory use of PV systems on roof tops along the lines of solar water heating systems which have been made mandatory by some civic bodies could be explored.

It is not merely the formulation of policies that matters. The challenge lies in effective implementation of policies in a timely manner for which appropriate institutional and organizational structures at the central and state levels are vital.

The National Solar Mission envisages the setting up of a Solar Energy Commission and a Solar Energy Authority. Can such bodies provide the necessary institutional muscle for the mission programme? It may be recalled that proposal for a Solar Energy Commission had indeed been pursued as early as late 70s or early 80s by DST (Department of Science and Technology). Subsequently the CASE (Commission of Additional Sources of Energy) with full executive and financial powers was set up in the 80s under the erstwhile DNES (Department of Non – Conventional Energy Sources). CASE continued to function for some years but for some reason it has been wound up. The experience of CASE must not be ignored. What is important however is to ensure that whatever new institutional arrangement is finally put in place, it should become an effective instrument capable of operationalizing policies and plans into practical steps in a time-bound manner.

Q. You always spoke quite passionately (at various national and international fora) about India having the largest demonstration scale PV programme in the world. What immediate steps do we need to take so as to emerge stronger in the global scenario?

A. While India has pursued a wide ranging demonstration program, it is time to go beyond demonstration programmes of already proven systems into programmes that can significantly impact on our problems in the electric power sector. Grid-connected PV, BIPV, and PV pumping are key applications, among others, that have to be pursed more vigorously through a policy push based on attractive incentives and innovative financing.

We have practically no large scale PV or solar thermal power generation projects of the kinds that have been implemented in Europe, and USA. In those countries valuable experience has been gained in the design, manufacture, installation, and operation of large, grid-connected solar thermal, and PV power plants. We need to gain such experience quickly by embarking on grid-connected multi megawatt projects in addition to the decentralized applications, and then we can project our capacity at the global level while meeting our domestic needs. We need to expand our production capacity of both solar thermal and PV rapidly and build world class facilities in these areas. Only then can we emerge stronger on the global scene.

Q. India still does not have a volume production base for the silicon wafers. Are you still optimistic about some large scale manufacturing initiative for the same finally maturing under the SIP (Special Incentive Package) announced by the Ministry of Communications and Information Technology?

A. For almost two decades there has been lot of discussion on the establishment of polysilicon facilities in India but commensurate action has not been forthcoming on this front. There were opportunities earlier to scale up an indigenously developed technology at METKEM or alternatively, establish a green field facility. It is high time that initiatives are taken to establish a polysilicon plant of at least 2000 tonnes per year capacity with provision to scale it up to about 10 000 tonnes per year capacity. It is also necessary to build associated facilities for wafers as well. Such a plant can be pursued as a public–private partnership venture. China has already established in a single location a polysilicon facility for an eventual capacity of 15 000 tonnes per year with an initial capacity of 5000 tonnes per year. Without an indigenous polysilicon facility, India's ambitious goals in PV could be adversely affected by cost and supply factors in the global arena.

"It is high time that initiatives are taken to establish a polysilicon plant of at least 2000 tonnes per year capacity with provision to scale it up to about 10 000 tonnes per year capacity. It is also necessary to build associated facilities for wafers as well..."

Q. Solar PV is always tagged with a constraint of having a high initial capital cost. However, the same is not quite true with the use of solar thermal systems. What according to you needs to be done so as to increase the market penetration of not only the solar water heating systems but other such systems?

A. Both solar thermal power generation and PV currently face barriers in terms of high initial capital cost. But this situation is likely to change as we move along the learning curve and reach cost levels that will render PV cost competitive with conventional power. Life cycle costing approaches need to be adopted to provide a better basis for comparison of solar with other energy forms.

A distinction has to be made between solar thermal power generation and solar water heating systems. Solar water heating systems are relatively low temperature devices and are already cost effective and gaining wider acceptance particularly in urban and semi-urban areas. On the other hand, solar thermal power generation involves high temperature systems that are much more complicated, and are of higher cost. However, in the foreseeable future, further technology development and cost reduction are expected in this area.

While PV is amenable to applications from a small scale to large ones, the same does not hold good for solar thermal power plants. The latter is dependent to a large extent on economies of scale. In the case of PV, economies of scale operate at the level of production of PV cells, modules, and systems. That is why it is important to establish large scale production facilities for PV and build large scale solar thermal power plants.

In order to increase market penetration of other solar systems like the way solar water heating systems are gaining traction, what seems to be needed is to place greater emphasis on market mechanisms including price signals and innovative financing. Several PV systems are already cost-effective in remote locations and for such applications such as telecommunication, railway signalling, data centres, and lighting, among others. In such cases, commercialization efforts should be intensified through incentives and credit facilities.

With regard to PV, increased market penetration will occur if the cost of PV can be brought down by a factor of two or more. For this to happen, two factors are critical—technology improvements and increased volume of production. It seems feasible to achieve in the next five years a cost reduction by a factor of two if process technology can be improved, thinner wafers are employed, and efficiency of solar cells can be increased from current levels of 15%–16% for crystalline silicon to about 18%–19 % at the production level. Simultaneously, volume production should increase by at least one order of magnitude. The two together has the potential to bring down costs that will make PV attractive for many market-driven applications. Similar goals can be worked out for thin-film technologies. It can be argued that based on worldwide developments, PV costs will, in the next 5–10 years, reach levels that will be comparable to grid electricity. Therefore, it is critically important to define technical and cost goals under Indian conditions and link them with incentive structures and market promotion strategies. Such approaches should be embedded in the national solar mission and linked to the goals and targets of the mission.

Q. You worked amongst the top echelons in the UN (United Nations) on the renewable energy front. Do organizations like UN still place a distinct preference for supporting solar programmes in developing countries like India?

A. The UN system as a whole has always been a strong proponent of renewable energy as evidenced by actions such as the holding of the UN conference on new and renewable energy way back in 1981 in Nairobi, and innumerable technical cooperation programmes all over the developing world with the involvement of UN organs and organizations such as UNDP (United Nations development Programme), UNEP (United Nations Environment Programme), UNIDP (United Nations Industrial Development Organization), UNDESA (United Nations Department of Economics and Social Affairs), WHO (World Health Organization), UNCTAD (United Nations Conference on Trade and Development), UNICEF (United Nations Children Fund), WMO (World Meteorological Organization), and the World Bank. The UN programmes are almost always in support of national efforts, and can at best provide modest inputs. Nevertheless international cooperation is vital for supplementing and complementing national efforts.

Q. India is currently brimming with various activities vis-à-vis solar energy utilization-cum-manufacturing initiatives. To what extent you feel such capacity building initiatives help in actual transformation of ideas into practical solutions and businesses?

A. It is true that awareness of the need for and the potential of solar energy have increased significantly in recent times. This has raised the level of expectation about the role that solar energy can or should have in our energy mix. Increased level of activity in solar, spearheaded by MNRE and other establishments in the country is a welcome feature and augers well for the country.

"The capacity of state level agencies will have to be substantially augmented and new institutional arrangements with stronger implementation capability might be required..."

While the objectives and goals of the National Solar Mission are indeed laudable for its vision and ambitious goals, India's capacity to translate the grand vision and lofty goals of the mission into practical steps is, I believe, woefully inadequate at the present juncture, and is unlikely to materialize in the required time frame unless massive efforts are mounted immediately to build capacity—both institutional and human resources. Also, a whole range of technical, managerial, and entrepreneurial capacity will be needed across businesses from production to service delivery. The capacity of state level agencies will have to be substantially augmented and new institutional arrangements with stronger implementation capability might be required. Capacity building should also encompass the enterprise and financing sectors as the tasks involved call for wide-ranging skills including those required in areas such as service delivery, enterprise development, maintenance, risk management, carbon credits, among others.

Q. Do you foresee India having any cutting edge solar technology that could help attain some kind of grid parity within the next five years or so?

A. For India to achieve technology breakthroughs that will bring solar into the realm of grid parity, huge investments in R&D (research and development) is vitally needed. Unfortunately, India has not invested sufficiently in R&D for achieving technological breakthroughs or for pursuing cutting-edge technologies. It is high time that a well-orchestrated and well-funded R&D programme is taken up with the involvement of academia, research establishments, and industry. International cooperation and joint research programmes will be needed. Our PV industry will also have to increase its investment in R&D. Nano based PV is an area of high promise and breakthrough potential. Some of the thin-film technologies also hold considerable promise to achieve cost breakthroughs. A US company called First Solar which has built a production capacity of more than 500 MW per year is reported to have achieved a cost of $1 per peak watt with their thin-film technology. This is the kind of cutting-edge technology that is needed to get to the stage of moving closer to grid parity. India should not fall behind in such developments.

"For India to achieve technology breakthroughs...huge investments in R&D is vitally needed... Unfortunately, India has not invested sufficiently in R&D for achieving technological breakthroughs..."

It is quite conceivable that solar technology will be able to achieve grid parity in the foreseeable future if massive national and worldwide efforts are put forth in a concerted manner to intensify research on new materials, device structures, fabrication methods, and scale up strategies. This calls for a multi-stakeholder approach in which governments, industry, research community, financing bodies, user agencies, and civil society will have get involved with missionary zeal and genuine enthusiasm dictated by compulsions we face for meeting our energy requirements for development on the one hand, and safeguarding of the environment on the other, particularly the threat of climate change.

Q. What special message would you like to extend to the readers of, 'The Solar Quarterly' magazine?

A. The message to the readers is simply this: solar energy is bound to be an important component of energy mix at the national and global level as the world confronts the twin challenges of development and climate change. One should continue to be optimistic about the future of solar energy in all its forms and play a constructive role in spreading awareness of its prospects, and get engaged in becoming a practitioner by using solar devices in homes and workplaces.

CENTRAL LANTERN CHARGING-CUM-JUNCTION BOX

Parimita Mohanty, Fellow, TERI and **Dr Nivedita Dasgupta**, Research Associate, TERI

In a centralized solar lantern charging station number of lanterns are charged simultaneously through a central lantern charging-cum-junction box, from one or more number of solar modules, which are centrally located. The central lantern charging-cum-junction box is considered as one of the most critical components of the entire charging station as it controls and protects the charging of different solar lantern, which is connected simultaneously. Generally the solar PV panel of high wattage used in centralized charging station offers higher efficiency as compared to smaller low-power panels used in stand-alone systems for charging single lanterns. The junction box facilitates the use of such efficient and relatively economic solar panels while simultaneously offering the versatility of connecting a gamut of loads with wide range of ratings.

Similar central lantern charging-cum-junction box are designed and developed by TERI (The Energy and Resources Institute) under its LaBL (Lighting a Billion Lives) campaign. Under LaBL campaign, such junction boxes are disseminated and used widely in various places across the country. The response on the performance of utilization of such product is found to be very satisfactory.

6V junction box feeding LED lanterns

It basically contains the electronic interface circuitry that is required between the solar PV module and the lanterns. Each solar PV module is connected to a lantern charging-cum-junction box having the same number of ports as the number of lanterns that the solar PV module is capable of charging. For example, it contains 10 ports where 10 lanterns can be connected simultaneously. This junction box is fed by a large SPV panel, which is meant to charge the 10 lanterns simultaneously. The loads are connected to the ports with proper connectors.

A typical central lantern charging-cum-junction box—designed and developed by TERI

The central lantern charging-cum-junction box houses the necessary protections such as short-circuit and reverse-polarity protections for foolproof charging of the lanterns. For proper distribution of current and for the protection of the lanterns, the central lantern charging-cum-junction box contains current limiting circuits for each individual port.

Similar to the charging of lantern batteries, junction boxes can be designed optimally for a wide range of loads by adjusting the current-limiting circuitry. Therefore, customized junction boxes can be designed for various as well as multiple applications. The loads can range from low-wattage utilities such as mobile phones, to higher-wattage utilities such as high capacity buffer batteries to a wide range of DC/AC devices. Depending upon DC or AC loads, small inverters are included in the junction box ports.

As mentioned above, a typical junction box can be further modified and customized for catering to specific requirements. Junction boxes with 12V rating can generally be used for universal loads such as small DC motors, CFL lanterns, universally available 12V batteries, and so on. At times, loads needing an input of 6V are required to be driven by junction boxes. Examples of such loads are mobile phones, smaller LED lanterns, 6V batteries, and so on. In such cases, the 12V junction box can be used by simply adding a 12V–6V DC–DC converter. Thus, a 12V junction box can also be versatile enough to drive 6V loads. On the other hand, customized junction boxes with 6V rating can also be devised that are dedicated to drive 6V lanterns and other such loads.

In addition to the above, there is a great demand of having an alternative means of charging mobile phones in areas without access to the grid. For such cases, the central charging station can also have specially designed junction boxes that have appropriate circuitry such as proper voltage converters and regulators for charging mobile phone battery. This also includes current limiting circuitry for DC ports for mobile charging. Further, inverters can also be incorporated in case AC ports are to be provided for charging mobile phones through their respective adaptors.

Many such customizations can be done for designing versatile electronic junction boxes for an array of PV applications. Thus, the junction box basically works as an effective interface between the solar PV panel and loads in solar PV based systems and plants.

2nd Enviro Tech-Energy Tech, 2009

11th –14th December 2009 • Pragati Maidan, New Delhi

The 'Envirotech'09' and 'Energytehc'09', 2nd in the series, will be organized concurrently at Pragati Maidan, New Delhi during 11–14 December 2009 by India ITPO (Trade Promotion Organization) — a Government of India Organization under Ministry of Commerce & Industry. These events are being organized essentially to address the issues such as climate change, water supply and waste water, air pollution, waste management and hazardous waste, and land use issues such as deforestation, desertification, and urban sprawl, energy efficient technologies and systems, renewable energy like solar wind, hydro electricity, bio fuels, nuclear energy, atomic energy, oil, petroleum and gas, and so on.

These twin events will provide an ideal platform for not only business transactions, but also for creating awareness on these two important issues.

Business seminars, buyer-seller meets, and one-to-one meetings will also be organized to facilitate business contacts and negotiations.

The following were the highlights of the first edition.

Theme Pavilions

1) On 'Climate Change' by TERI (The Energy Resources Institute
2) On 'Energy Efficiency' by BEE (Bureau of Energy Efficiency)

B2B Meetings

Environment Information Centre

Seminars on

1) Water Pollution Management
2) Energy Efficiency
3) Role of Nuclear Energy
4) Work Shop on Environment Training

Screening of Documentary Films on Environment & Energy

Concurrent Event

Annual Eco Meet, Govt. of Delhi

Exhibitors

NEDO (New Energy Development Organization), Japan, Suzlon Infrastructures Ltd., CPCB, Nuclear Power corporation of India and group participation by Ministry of New & Renewable Energy Government of India as well as Department of Environment, Government of NCT Delhi

Visitors

The dignitaries during the first fair included Shri Kapil Sibbal, Honourable Minister for Science and Technology, Government of India, Mrs Sheela Dixit, Honourable Chief Minister of Delhi, Noble Laureate Shri R K Pachauri, Director General, TERI, besides Secretaries and Government officials from concerned Ministries, promoters of various NGOs and over thousand registered business visitors.

Further, keeping in view the relevance of the subject and the need to create awareness about these two burning issues, a very attractive package is being offered by ITPO for exhibitors. The participation charges have been kept very nominal. A booth of 9 sqm under shell scheme, which includes wall panels, fascia, floor covering, three spot lights, one power point, one table, two chairs and one waste paper basket, is priced only at Rs. 40,500/- plus service tax as applicable.

ITPO has taken many initiatives to attract a large number of business visitors. These include websites of both the events, hyper linking of the web site with many other sites including ITPO's business portal and other leading business portals. Advertisements through specialized publications, leading news papers, e-mail blasts, circulars/news letters of supporting NGOs and organizations. The target visitors will include business visitors from India and abroad, representatives of different pollution control boards, officials from Govt. agencies, representatives of national and international media, representatives of trade and industry of the relevant field, NGOs, and so on.

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ECOTECT

ENABLING AN OPTIMIZED BUILDING DESIGN

Sudipta Singh, Research Associate, TERI

Introduction

There is a wealth of information available on the green buildings and accompanying evaluation tools.

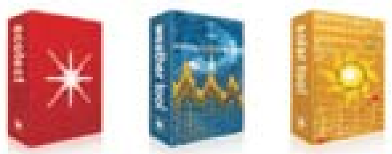
Making a right choice of the tools is quite difficult for budding architects and building service engineers. It is quite imperative to take a stock of all possible design options during the early stages of designing a sustainable building. The next obvious step is to evaluate the environmental performance of such options. As such, the building professionals require tools that can guide in optimizing their building designs with default data and intelligence.

ECOTECT is one such building design and environmental analysis tool. It covers a whole range of simulation and analysis function required to understand how a building will perform with respect to solar and daylight conditions. TERI (The Energy and Resources Institute) is using this tool, for more than a decade, to enable green building designs across the country. This article is based on our prolonged research experience on this software. With ECOTECT, architects and engineers can reliably and conveniently measure the fundamental criteria that will affect the building performance in the conceptual and detailed phases of design. Normally, architects and designers are quite accustomed to 3D and it would not be problematic to apply all the tools necessary for evolving an energy-efficient and sustainable building design.

Key applications

ECOTECT has a wide range of usage for building performance analysis such as shadows and reflections, shading design, solar analysis, lighting design, right-to-light, acoustic analysis, thermal analysis, ventilation, and air flow, building regulations, resource management, visualization and import/export, and so on. Autodesk® ECOTECT™ is a comprehensive conceptual building performance analysis software which covers a wide range of support tools, user interface for simulation and analysis to truly understand the ways in which building design will operate and perform.

- ECOTECT–Radiance
- Solar tool
- Weather tool



Each tool has a certain set of applications to optimize the building design in order to improve the energy efficiency. (Figure 1)

ECOTECT–Radiance

The new version of ECOTECT has a comprehensive wizard that guides the users for exporting and rendering ECOTECT models in Radiance interface for daylighting analysis. It also allows the generation and extraction of both grid-point and surface values from Radiance and visualizes them in the ECOTECT OpenGL page. As part of ECOTECT, a free updated version of Radiance Image Viewer (for rendered image with contour lines) has been developed.

Solar tool

With its interactive user interface, the solar tool makes the process of accurately sizing and positioning overhangs, shading devices, and louvres easy. This tool helps architects, planners, and building services engineers who need to consider the extent of solar penetration into buildings, overshadowing or the most appropriate means of shading a window.

Weather tool

The weather tool is a visualization and analysis program for an hourly

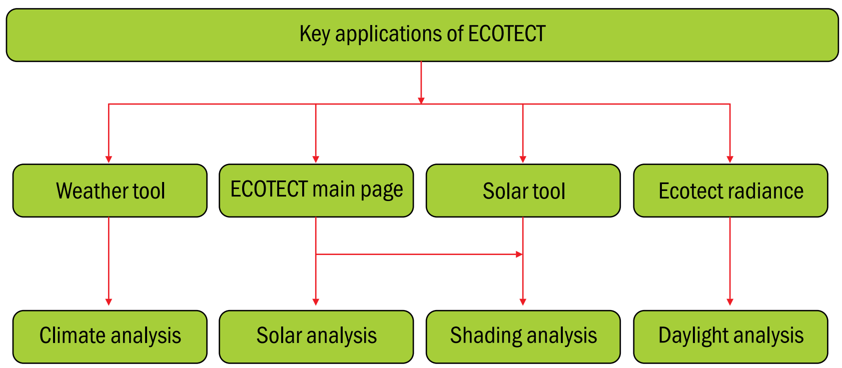


Figure 1 Key application of ECOTECT

climate data. It recognizes a wide range of international weather file formats as well as the customized Indian weather data in .wea format. It also provides a wide range of display options, including both 2D and 3D graphs as well as wind roses and sun-path diagrams.

Building design optimization

The basic objective is to apply solar passive measures, including daylighting, in order to reduce the demand on conventional energy for space conditioning and lighting systems in buildings. In order to optimize the proposed building design and minimize energy consumption while ensuring thermal and visual comfort within specified limits, the following analysis has to been done with the help of ECOTECT.

- Climate analysis
- Solar analysis
- Shading design
- Daylight analysis

Climatic analysis (weather tool)

Objective To study the bio-climatic weather data (temperature, relative humidity, and solar radiation), appropriate design strategies (active + passive), and optimum orientation of proposed building as per the geographical location.

Inputs required Location Data – weather file (.wea file)

Methodology

Step 1 Bio-climatic analysis (temperature, relative humidity, solar radiation, and so on)
- Monthly data
- Weekly data
- Hourly data

Step 2 Optimum orientation analysis (prevailing wind and best orientation)
- Solar position
- Wind analysis

Step 3 Appropriate design strategies (active and passive)
- Psychometric chart analysis

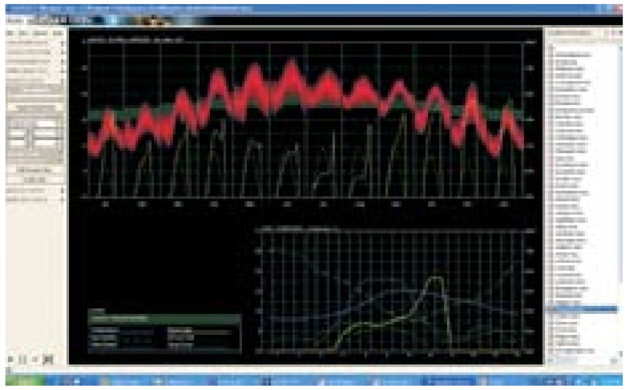


Figure 2
Hourly weather data analysis

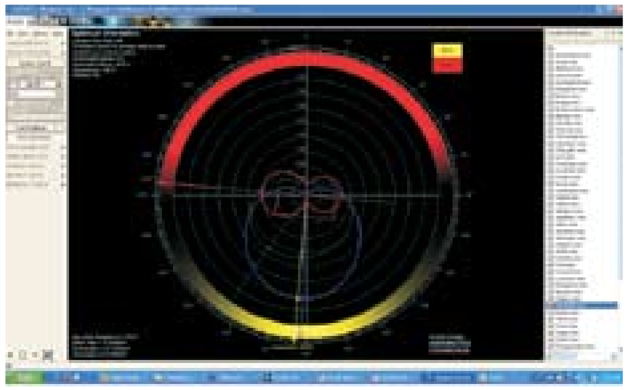


Figure 3
Optimum orientation analysis

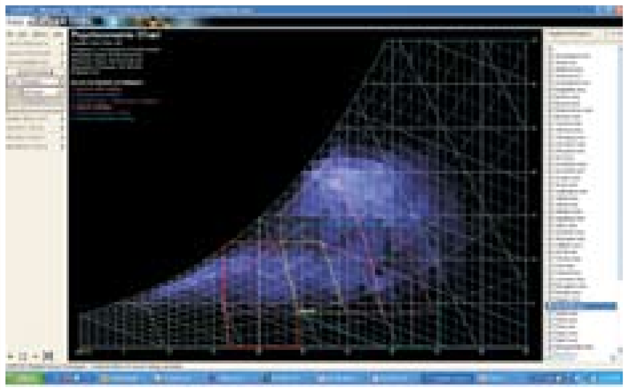


Figure 4
Appropriate design strategies analysis

Solar analysis (ECOTECT)

ECOTECT main page has all the drafting and editing tools to develop the 3D model for a proposed building, which will be the base for solar design. It has an ability to calculate and visualize incident solar radiation on the windows and surfaces of your building. This type of analysis is specifically made to identify the critical facades as well as the critical solar angles over the façade of the building so that an appropriate solar design can be achieved.

Objective
To find out the critical façade of the building with its respective critical shadow angles.

Inputs required
1. Site plan giving north line
2. Detail building floor plan
3. All side elevations and sections

Methodology
Step1 ECOTECT 3D modelling
a. Load the weather file and draft the 3D-Model

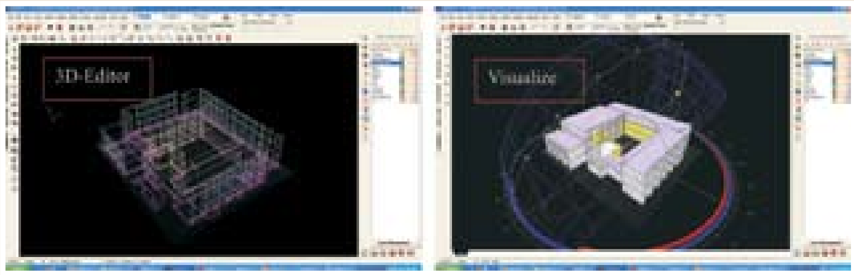


Figure 5 ECOTECT 3-D modelling in 3-D editor and visualize

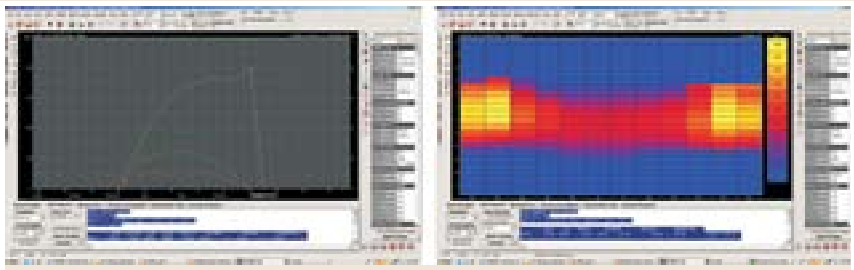


Figure 6 Solar exposure analysis

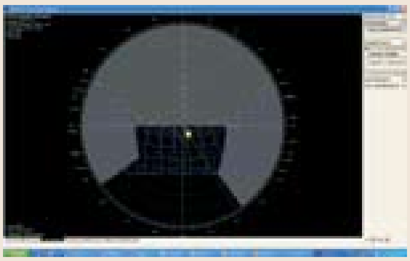


Figure 7 Sun-path analysis

Step 2 Solar analysis (critical facade of building)

b. Solar access analysis
c. Solar exposure analysis

Step 3 Sun-path analysis

d. Critical Shadow angle calculation (HSA-horizontal shadow angle and VSA-vertical shadow angle)

Shading design (ECOTECT and solar tool)

The design of shading device can be made easier with the help of ECOTECT analysis. It has a wide range of computer-based methods to accurately shape shades for very specific purposes. The Shading Design Wizard (shading and shadows) guides through the process of designing shading devices so as to meet complex shading requirements. Otherwise shading design can also be done manually with a little understanding of the mechanics of solar position and the sun-path diagram.

There are various methods of designing appropriate shading device in ECOTECT

e. Shading and shadows (shading design wizard)
f. Manual drafting of shading device (Sun-path diagram)
g. Solar tool (Multiple options of shading)

Daylight analysis (RADIANCE)

In order to save the lighting energy consumption in the green building, certain daylight standards have been prescribed by National Building Code (NBC-2005) and SP-41 (Bureau of Indian Standards). Thus, after finalization of facade orientation, fenestration sizes and shading design, it is important to check the avail-able daylight level inside the building. Once the Ecotect-model is prepared with all its climate data, specific date and time, and material specification, it is ready to export the model to RADIANCE for a more complex and physically accurate daylight simulation.

ECOTECT can export models directly to RADIANCE and can even invoke calculations and display results from within its own interface. In addition to simply generating rendered images, ECOTECT can use RADIANCE to analyse the daylight factors over an analysis grid and then import the raw radiances back into the grid, as shown in Figure 9.

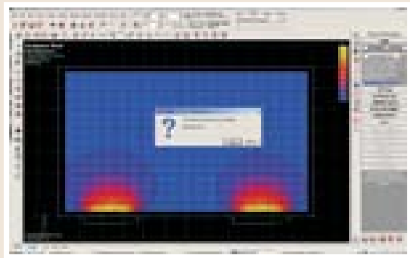


Figure 9 RADIANCE simulation result on analysis grid

The final statement

The basic objective behind this analysis is to finalize the following components of building on the basis of availability of standard daylight level.

- Size of fenestration (width and height)
- Glazing property (VLT- visible light transmittance)
- Shading design (type and depth of shading device)
- Internal reflectance

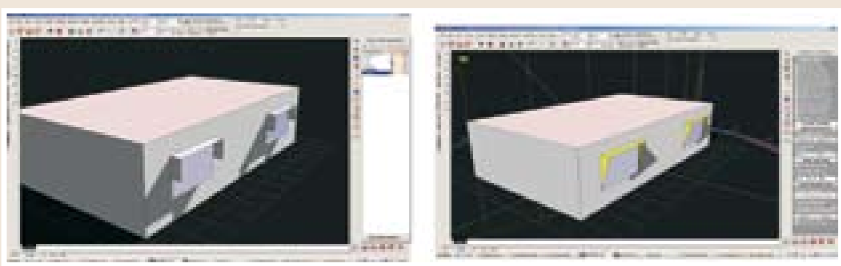


Figure 8 Shading design in ECOTECT

ADVERTISING IN

THE SOLAR QUARTERLY

Circulation information

Solar Industries, Ministries, Government sectors, PSUs, Corporates, Agencies, Institutions,Universities, Educational Organizations, Research professionals, International agencies.

General information

Quarterly ▪ All Colour ▪ Mat Paper
Number of pages 96 ▪ Readership of 25 000

Technical specification

Final size of magazine (finished size):	20.5 cm × 26.5 cm
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Expert Speak

Answers to questions on solar energy

Dr V V N Kishore
Professor
TERI University

Solar energy is a promising source of future energy supplies because not only is it clean, but also remarkably abundant. Not only is the potential of solar power enormous, we also already have the technologies to take advantage of it. We can design our homes to take the maximum benefit of solar energy. Solar water heaters can reduce our electricity bills and solar electricity can power our homes, and even our cars. Solar energy technologies are sooner or later going to take every one by a sheer surprise. Sizeable numbers can come through only by opening up new commercial vistas of applications alongside an increased market deployment of traditional uses. PVT collector use is one such novel application with a ready ability to fulfil multiple energy needs. It can also ensure a maximum possible use of the available roof space. All we have to do is start using it on a wider scale. However, there are many questions in the minds of a consumer who wants to use solar energy in his day-to-day life. This section attempts to answer some such questions, however basic they may be. Dr V V N Kishore, Professor, TERI University fields questions on solar thermal and PV (photovoltaics).

Q1. What is solar constant? Is it related with the age of any star?
Neha Joshi, Delhi

Ans: The solar constant is defined as the energy received from the sun per unit time on a unit area of surface perpendicular to the direction of propagation of the radiation at the mean sun-earth distance. The earth's orbit is elliptical, and the distance between the sun and earth varies by 1.7%. The mean sun-earth distance is 1.495 x 1011m. There were several measurements of the solar constant, but the value of 1367 W/m2, adopted by World Radiation Centre is commonly used.

Q2. Which type of solar collectors and solar water heaters are recommended for the locations where ambient temperature goes below zero degrees centigrade?
Jyotsna Singh, Jaipur

Ans: At sub-zero temperatures, water freezes and the collector tubes can be broken due to the reduced density (which means increased volume for the same mass). Hence water cannot be used in solar collectors in very cold climates. In such cases an anti-freeze fluid, such as propylene glycol is used as a heat transfer fluid in the collector loop, in conjunction with an external heat exchanger.

Q3. What are the factors which affect the solar panels' productivity?
Abhimanyu Ghosh, Kolkata

Ans: This question is not clear. If you are referring to solar thermal collectors, the thermal efficiency of the collector depends on the quantity $(\Delta T)/G$, where (ΔT) is the temperature difference between the fluid and ambient, and G is the incident radiation. Therefore, the productivity depends on the temperatures as well as incident radiation, which keep changing. Other parameters such as the collector loss coefficient, transmittance of the glazing system, and so on will also dictate the collector performance.

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

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European Solar Engineering School

ESES (European Solar Engineering School) provides a unique education in solar engineering at Högskolan Dalarna. The one year Masters programme is based on research work at the SERC (Solar Energy Research Centre). The programme provides proficiency in all main solar engineering subjects and allows the students after graduating to work as experts in the solar industry and in academic research.

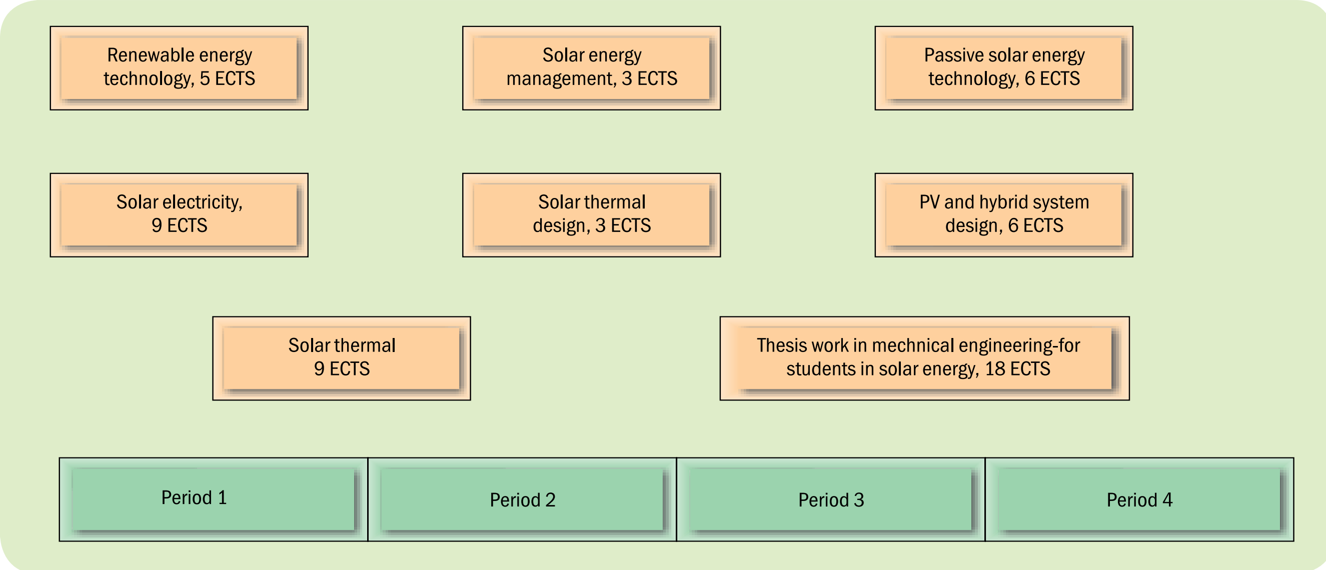
Programme

The ESES Master program is now running its ninth year. After the first few years with less then 10 students, they are now between 20 and 25 students studying the program every year. More than 100 students have studied at ESES—a large community!

The programme is a 1-year continuation course within Solar Energy Engineering. All courses are taught in English. After passing all courses, including passing the thesis work, the student will be awarded the Degree of Master of Science (one year) with a Major in Mechanical Engineering. The programme comprises in total 60 ECTS credits. The intake for the programme is only once a year. The programme starts at the end of August with the start of the autumn semester.

Prerequisites

BSc (Bachelor in Science) from a recognized university, the equivalent of a Swedish 'kandidatexamen', with a major in mechanical or energy engineering, physics, chemistry or similar. Documented good command of both oral and written English is required: English level B from a Swedish senior secondary school or equivalent. E.G. TOEFL (not required for applicants from the Nordic and most



European countries or universities with English as the main language).

Courses

Renewable Energy Technology Course Description

Learning Objectives

After passing the course the student shall be able to

- Show deeper knowledge about different forms of energy and transferring from one energy form to another
- Show knowledge and understanding about different methods for use of renewable energy and the technology in practice
- Show ability to asses, analyse, and integrate knowledge about different forms of renewable energy and their suitability in environments with different conditions
- Show oral and written ability to clearly describe and discuss acquired conclusions
- Show ability to independently identify and formulate questions at issue
- Show insight about the possibilities and limitations of science

Course content

The course content includes: energy technology, renewable energy in a sustainable future, the physics and science behind climate change, and why renewable energy is necessary for the future. Students will understand different types of renewable energy technology, how they work, their advantages, disadvantages, and limitations. The types of renewable energy and technology studied include: wind energy, solar (thermal and photovoltaic), hydro-electric, bio-energy, tidal power, wave energy, geothermal energy, ocean thermal, fuel cells, heat pump systems, and high voltage DC energy transport. The availability and integration of these energy types and technologies are also studied to understand how renewables can work as a compliment to and replacement for conventional technologies.

Software used

RETScreen (www.retscreen.net) is a freeware program for clean energy project analysis. It has been developed and supported by CanMet Energy Technology Centre in Canada. It is built up using Excel and a number of macros. Its main aim is to allow someone to analyse whether a given project can be economically viable or not. A number of different technologies can be analysed with the software. There is an extensive database for both climates and products, which makes the tool useful—which is reflected by the fact that there are over 160 000 users in 222 countries.

Solar Electricity Course Description

Learning Objectives

- Understand the properties of solar radiation before and after being transmitted through the atmosphere and what limitations there are in the radiation measurements
- Be able to find solar radiation data in international databases
- Calculate and judge the effect of the orientation of the receiving surface in terms of gained energy
- Understand the dualistic wave-particle character of light and the consequences for photovoltaics
- Explain the mechanism of current and voltage generation in illuminated semiconductors
- Describe how solar cells are connected into a module, what the losses are and how these can be minimized
- Independently design stand-alone as well as grid-connected solar electricity systems and choose components for optimal system performance
- Choose and evaluate computer system simulation programs for photovoltaics
- Describe different methods for solar thermal generation of electricity with help of solar concentrators

Course content

In this course the basics of solar engineering are studied: the basic properties of solar radiation and its measurements, and the effect of orientation and slope of receiving surfaces, optical properties of materials are reviewed and discussed, the physics of photovoltaic devices and how they can be modelled mathematically, how these devices are manufactured, how the devices are tested, and how they need to be connected and packaged to provide practical power producing modules. Electrical energy storage and control is also studied as well as understanding of the various forms of solar thermal electricity generation.

Software used

PVSYST is used to help design a stand-alone or a grid-connected PV system. Input data include: the energy demand of different loads, location with insolation data, direction of the PV modules and more. Output data include: a suggestion of design and information of input power, used power, lost power, and system cost. In the program Preliminary Design gives rough size estimation for the system. In Project Design a more detailed design is possible and the user can choose between various PV panels, batteries, and regulators; giving more control tot he user over the system design. In this course PVSYST is used to design a theoretical stand alone system. PVSYST is also used to evaluate output of a theoretical grid connected system.

Solar Thermal Course Description

Learning Objectives

This course is split into the four modules each with the following learning objectives:

Optics and Materials for Solar Thermal - 1.5 HEC (Taught by Dr. Ewa Wäckelgård)

- Calculate optical properties based on measurement data from a spectrophotometer.
- Understand which materials are best suited for use in a solar collector as well as explain what surface treatments can be used to enhance thermal performance.

Solar Thermal Collectors - 2.5 HEC (Taught by Dr Chris Bales)

- Understand the physical processes that control the output of a solar thermal collector and use mathematical models to calculate its thermal output.
- Design a new or improve an existing collector
- Use computer programs for comparing solar collectors.
- Describe the existing status of testing of solar thermal components in Europe.

Solar Thermal Components, Storage and Loads - 2.0 HEC (Taught by Dr Chris Bales)

- Describe different thermal loads and be able to estimate them.
- Understand the function of the most important components necessary in a solar thermal system.
- Explain how different heat storage techniques work and in which situations they are suitable to use.
- Describe the basic function and design of different system types including thermosiphon and integrated collector store systems.

Solar Thermal for Hot Climates - 3.0 HEC (Taught by visiting Professor from the Indian Institute of Technology, Dr. Tara Kandpal)

- Understand and appreciate the need for and challenges involved in solar energy for cooking, cooling, distillation and drying applications in tropical areas of the world.
- Explain the functioning of different existing designs of solar cookers, distillation systems, cooling systems and dryers and size the same, as well as analyse the effect of different design and operational parameters.

Course content

The following topics will be studied in this course: the physics of solar thermal systems, especially collectors, properties of suitable materials for collectors, and different types of heat storage. Students will develop models that describe the radiation-heat

conversion mathematically. Different types of collectors are compared. The most important technologies in hot climates are extensively studied such as: solar cooking, desalination, water purification, solar thermosiphon heating systems, and crop drying. Solar air conditioning is also given a special place.

Software used

CoDePro is written using the software Engineering Equation Solver (EES). CoDePro is a flat plate collector design program. According to the description that accompanies the software: CoDePro has been developed so that most details of the collector configuration can be specified. The program has been developed with the professional version of EES and beta-tested from its development level by solar engineers. CoDePro calculates the instantaneous efficiency, incident angle modifier coefficient, and stagnation temperatures. Thus, CoDePro determines the theoretical efficiency based on the materials and geometric properties of the collector. The test methodology is based on the standard test methods provided by ASHRAE Standard 93-86 and SRCC Document RM-1. In this course CoDePro is used to find different methods to practically improve the cost performance of a solar collector. CoDePro is also used is conjunction with Microsoft Excel to have students quantify how components that differ in efficiency and cost affect the solar collector's cost per unit energy output.

Solar Energy Management, 3 ECTS

Learning outcomes

After passing the course the student shall be able to

- Derive expressions for various equivalent formulae of engineering economics taking the time value of money into account
- Describe different measures of financial and economic performance and discuss their relative merits and limitations
- Undertake financial evaluation of solar energy systems and compare with other alternatives
- Describe and compare different methods of financing solar energy systems
- Analyse the effect of regulations and legislation on the economics of solar energy systems

Course content

This course includes: different measures of financial and economic performance and their relative merits and limitations specifically for solar energy projects, the time value of money and derivation of relevant formulas including but not limited to, B/C ratios, discount rate, IRR, standard and discount payback period, depreciation, and net present benefit. Also studied are approaches for considering uncertainty, financial incentives, and various financing methods of solar systems. Lastly, regulations, legislation, cultural aspects, maintenance, insurance issues, and subsidy programs are also studied.

Solar Thermal Design, 4 ECTS

Learning outcomes

After passing the course the student shall be able to:

- Use simulation tools to calculate the energy gain of a solar thermal system
- Analyse the function and characteristics of different types of solar thermal systems
- Size a solar heating systems
- Show understanding of the various methods for protecting the system from frost and overheating damage and to be able to choose the most suitable method for a specific application
- Design collector fields

Course content

The function and characteristics of different types of solar thermal systems are studied including: large and small scale, hot water systems, combi-systems, pool systems, collector fields, short term storage, and seasonal storage. Control and operational strategies are studied as well as calculation of heat loads. Simulation programs are used to evaluate a real case study. The case studies come from local housing agencies or other local groups that are interested in installing solar thermal systems. The situation is evaluated, then simulations are run to find the most economic system design and size for the given case study. Lastly a detailed design is created and presented to the housing agency or the local group.

Software used

PolySun is solar thermal design program that is used to model the case study for the written assignment. The aim of the project is to give students experience in all stages of designing a solar heating system. PolySun lets the user select/build a system, select appropriate parts and then run a simulation for each hour of the year. An energy balance summary is then given revealing losses, gains, system temperature as a function of time in different locations in the system and much more. Multiple simulations are used in conjunction with Microsoft Excel to optimize the system from a financial stand point and an energy stand point before a detailed design is drawn up.

PV and Hybrid System Design, 6 ECTS

Learning outcomes

After passing the course the student shall be able to:

- Understand and describe the properties and availability of energy resources for hybrid systems such as solar, wind and water power,
- Understand and describe the energy conversion from these energy sources,
- Show understanding of the main types of hybrid systems for electricity and combined electricity and heat production,
- Show understanding of the functioning of the main components of PV and hybrid systems,
- Independent detailed design and optimization of PV- and hybrid system for different applications,
- Show understanding of the different electrical concepts of standalone PV and hybrid systems,
- Use and evaluate computer simulation programs for the design and economic evaluation of PV and hybrid systems.

Course content

Energy resources for hybrid systems. Components studies. Design and measurements of a standalone PV system. Study of system solutions. Measurements and calculations on a standalone PV/Wind hybrid system. Computer programs for system design, performance and economic evaluation.

Software used

For the design and evaluation of power systems the simulation tool HOMER is used. With HOMER both grid-connected and off-grid systems can be modelled. A variety of energy sources such as PV, wind turbines, hyrdro power, and fuel cells can be combined modelled and cost optimized. HOMER has inbuilt optimization and sensitivity algorithms allowing to evaluate a large number of system types.

The students will use the program HOMER for a case study where they need to model various types of systems in order to find the most technically and economically feasible system.

Passive Solar Energy Technology, 6 ECTS

Learning objectives

After passing the course the student shall be able to

- State different ways to adjust and design buildings so that they can utilize passive solar heating
- Show an understanding of the importance of daylight and be able to describe the daylight requirements for different types of buildings.
- To use heat balance equations for buildings with respect to both internal and external generation of heat, including energy transfer through windows
- Quantitatively and qualitatively describe different types of windows and how they influence both heating and cooling demand
- Display comprehension of IDA and CASAnova computer software that are for heat balance calculations of buildings.
- Show comprehension of natural ventilation and technologies for causing and facilitating natural ventilation in buildings
- Be bale to perform shading calculations with sun path diagrams and display comprehension about the importance of shading calculations with respect to planing buildings and built areas
- Understand how the micro climate around a building and built areas affect the heat balance of the buildings

Course content

The course content includes: passive solar engineering, daylight, building physics, windows, ventilation, simulation and calculation computer software, shading, and micro climates. Cost effectiveness, economic feasibility, social acceptance, and the history of various passive solar design techniques are discussed. The concept of daylight is explored in the class and a practical lab. Energy conservation equations are used to quantify different energy saving techniques and design options related to passive solar design and building thermodynamics. Shading is explored using sun path diagrams and a practical lab to give students experience with various measurement techniques and equipment. The effects of micro climates on design and build physics are discussed.

Software used

IDA is a software tool used to simulate building temperature, indoor air quality, and building energy consumption. It uses models to simulate different zones in a building using~600 time dependent variables which can be plotted.

CASAnova is software developed by Universität Siegen in Germany. It is used to give a estimation of the energy performance of different types of buildings in different climates. The software using inputs of building geometry, Inslation, themral mass, window size and types, ventilation rates, and so on to calculate heat balances as well as the number of hours with over heating.

Thesis

During the spring semester a 18 ECTS thesis project is carried out, working with one of the research groups at the Solar Energy Research Centre SERC or with other researchers or professionals. The student participates actively and under supervision in the research group. Halfway through the work, achieved results and plans for the continued work are presented in written form as well as orally at a seminar. The completed work is presented as a thesis and defended at a seminar.

The content for this profile is taken from ESES's website—http://www.eses.org/. The webpage is made by actual and former ESES students and provides information about the program, the life in Borlänge and serves as a meeting point for current, former, and prospective students. The photographs used are also taken from the website.

ANNOUNCEMENT

The Solar Quarterly Photographic Competition

Topic
Solar Energy and Solar Photovoltaic System

Age group
Group 1: 15 – 20 yrs • Group 2: 20–30 yrs
Group 3: 30 and above

Last Date for submission
30 November 2009

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The best picture will be on the cover of the forthcoming issue of *The Solar Quarterly* magazine

ANNOUNCEMENT

The Solar Quarterly editorial team invites articles and research papers from professionals, researchers, academicians, and others on solar energy and issues related to solar as a form of renewable energy.

Send in your contribution to:
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Darbari Seth Block, IHC Complex
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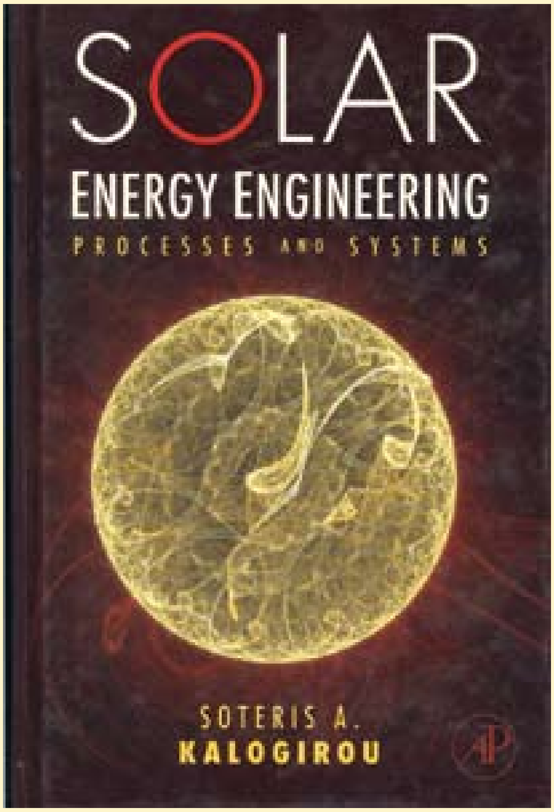
Book review

Solar Energy Engineering: processes and systems



Solar Energy Engineering: processes and systems

Soteris A. Kalogirou

Academic Press

ISBN: 978-0-12-374501-9

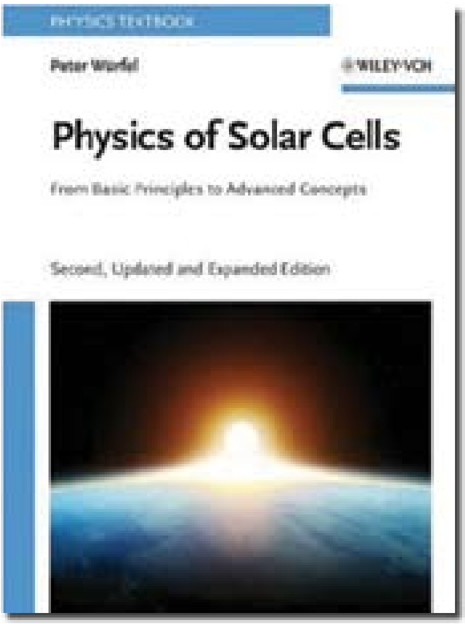
Price: $125.0

With the threat of global warming, climate change, and gradual depletion of fossil fuel, solar power is gaining significance. Solar power, the most abundant renewable energy resource, is crucial for achieving energy security. One of the main prerequisites for the success of solar energy is instructive information on the issue. *Solar Energy Engineering: processes and systems* provides extensive information on all areas of solar energy engineering—from the fundamentals of radiation and system components to calculation methods for determining long-term thermal performance and economic analysis of solar systems. The original idea of this book came after the author had published a number of review papers in the journal *Progress in Energy and Combustion Science*. It provides insight into various technologies for the conservation of solar energy for providing hot water, heating, cooling, drying, desalination, and electricity. It gives a detailed study of environmental consequences of solar energy, solar desalination including indirect systems, and modelling and performance prediction of solar energy systems. In the introductory chapter, the author provides a brief history of solar energy and a review of energy-related environmental problems. The author maintains that is used to heat and cool buildings, heat water for domestic and industrial uses, heat swimming pools, power refrigerators, operate engines and pumps, desalinate water for drinking purposes, generate electricity for chemistry applications, and many more purposes. The objective of this book is to present various types of systems used to harness solar energy, their engineering details, and ways to design them, together with some examples and case studies.' Other than the introduction, the book is divided into eleven sections. It is the material and the way it has been presented that adds value to this book. The material presented in this book is based on more than 25 years of field work and other authentic sources such as journals and biannual conferences. The worked examples and case studies in the book make it an interesting read. Also, the book contains a number of reference tables and schematic diagrams for almost all systems used today. The book has a detailed analysis on solar energy collectors, performance of solar collectors, solar water heating systems, solar space heating and cooling, industrial process heat, chemistry applications, and solar dryers, solar desalination systems, photovoltaic systems, solar thermal power systems, designing and modelling solar energy systems, and solar economic analysis. Moreover, the book is written by one of the most important figures in the field of solar energy. Finally the book includes an economic analysis. The economic analysis in the book provides an account of the life cycle analysis and the time value of money. Then, the life cycle is presented through a series of examples. It also presents the uncertainties in economic analysis.

As a source of basic principles and applications of solar energy systems and processes, this book is an essential read for all undergraduate and post graduate students. It can be used as a reference guide by the practising engineers who want to understand how solar energy systems operate and how to design the systems. The book provides a comprehensive study and a roadmap to the rapidly growing field of solar engineering.

Reviewed by
Arani Sinha, TERI Press

New Book Information



Würfel Peter, 2009
Wiley-VCH
ISBN: 978-3-527-40857-3
Price: $95.00

Physics of Solar Cells: from basic principles to advanced concepts (Second, updated, expanded edition)

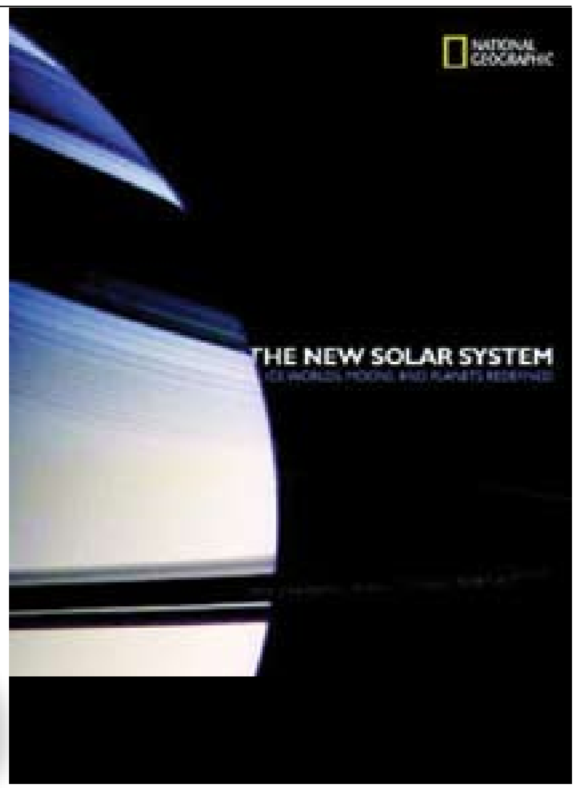
The *Physics of Solar Cell* is revised, updated, and expanded edition which contains detailed information on the mechanism of solar energy conversion. It describes all the features of solar cell function and the physics behind these functions. The book is a useful guide for all students and teachers to understand the development of solar cell and apply the knowledge in their research. The main topics covered in the book are the following.

- Problems of the Energy Economy
- Photons
- Semiconductors
- Conversion of Thermal Radiation into Chemical Energy
- Conversion of Chemical Energy into Electrical Energy
- Basic Structure of Solar Cells
- Limitations on Energy Conversion in Solar Cells
- Concepts for Improving the Efficiency of Solar Cells
- Prospects for the Future

The New Solar System: ice worlds, moons, and planets redefined

It is a basic and fundamental book on the solar system. It provides an overview of our current knowledge of the planets and other objects in our solar system at a level understandable to an educated layman. It covers a wide range of topics from the threats asteroids and comets pose to the earth to the search for life beyond the earth. The book has some very eye catching images and photographs. It has about 160 images, photographs, diagrams, maps exploring earth's planetary neighbourhood. 'From breathtaking full-colour photographs to detailed explanatory diagrams to expert essays, fascinating sidebars, and informative fact boxes, the *New Solar System* is not just an easy-to-use, solidly reliable reference, but also a visually stunning, invitingly browsable volume guaranteed to fire the imagination of even the most casual reader'.

Daniels Patricia, 2009
National Geographic Books
ISBN 978-1-4262-0462-3
US$35



Events calendar

National events

ICORE (International Congress on Renewable Energy) 2009
6–7 October 2009, New Delhi

The Stein Auditorium
Habitat World,
India Habitat Centre
Lodhi Road
New Delhi – 110 003
Web www.icoreindia.org

Solarcon India
9–11 November 2009, Hyderabad

Hyderabad International
Conference Centre,
Novotel and HICC Complex
(Near Hitec City)
Hyderabad – 500 081
Tel. +91 80 4050 9200
E-mail msuresh@semi.org
Web www.solarconindia.org

National Award for Excellence in Energy Management 2009
18–19 November 2009, Hyderabad

Tel. +91 99890 91744/
+91 98499 65810
E-mail sriram.bhaskar@cii.in or
bobby.mathew@cii.in

Third Renewable Energy Finance Forum
20–21 November 2009, Mumbai

Maria Ferreiro
E-mail mferreiro@euromoneyplc.com

Solar Energy Expo
3–6 December 2009, Mumbai

MMRDA Ground,
Bandra-Kurla Complex, Mumbai
Tel. 022-26395589
Fax 022-26395590
Web www.zaksolarenergyexpo.com/

Methane to markets: partnership expo
2–5 March 2010, New Delhi

Tel. +1 (202) 343 9683
E-mail asg@methanetomarkets.org

International

ISES Solar World Congress 2009
11–14 October 2009, Johannesberg, South Africa

Tel. +27 12 807 7171
Fax +27 86 559 4753
E-mail info@swc2009.co.za
Web http://www.swc2009.co.za/

Solar Power International 2009
27–29 October 2009, Anaheim, California, USA

Tel. 1 202 857 0898
Fax 1 202 682 0559
E-mail ebrown@solarelectricpower.org

Solar Energy Expo 2009
29 October–1 November 2009, Dhaka, Bangladesh

Tel. + 91 98403 36657
Fax +91 44282 02728
E-mail manoj@zakgroup.com
Web www.zakgroup.com

Congress on Alternative Energy Applications
2–6 November 2009, Kuwait

Dr Salah Almudh'hi
Web http://www.ec2009kuwait.org/

Trade fair: PV Tech Milan
25–27 November 2009, Milan, Italy

Artenergy Publishing Srl
Davide Grassi
Tel. +390 2 66 30 - 6866
Fax -5510
E-mail logistica.hte@zeroemission.eu
Web www.hitechexpo.eu

Conference: CEE Photovoltaic 2010
27 November 2009, Athens, Greece

East Euro Link Ltd
Danijela Randjelovic
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Fax 6812889
E-mail london@easteurolink.co.uk
Web www.easteurolink.co.uk

Conference: Photovoltaics Beyond Conventional Silicon
2–3 December 2009, San Jose, California, USA

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Web www.idtechex.com/photovoltaicsusa09

Solar Conference 2009 (Can SEIA)
7–8 December 2009, Toronto, Canada

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Industry Registry

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Web www.motech.com.tw

4) E-TON Solar Tech Co., Ltd
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Web e-tonsolar.com

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Suburban Park Dr.. Billerica, MA 01821, USA
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Fax +1/978/663-2868
Web: www.us.schott.com

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Web: www.shinsung.co.kr

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Fax +30/210{9537618
Email: info@schellas.gr
Website: www.schellas.gr

Renewable energy at a glance

S.No.	Source/system	Estimated potential	Achievement as on 31 June 2009
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	10386.00
2	Bio power (agro residues and plantations)	16 881	736.10
3	Bagasse cogeneration	5 000	1 134.73
4	Small hydro power (up to 25 MW)	15 000	2 454.67
5	Energy recovery from waste (MW)	2 700	58.91
6	Solar photovoltaic power	—	2.12
	Sub total (A)	**84 776**	**14772.53**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	170.78
8	Biomass gasifier	—	165.16
9	Energy recovery from waste	—	34.06
	Sub total (B)	**—**	**370.00**
	Total (A+B)	**—**	**15142.53**
II	**Remote village electrification**	—	5 453 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	41.27 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting system	—	70 474 nos
	ii. Home lighting system	—	450 000 nos
	iii. Solar lantern	—	730 000 nos
	iv. Solar power plants	—	8.01 MW_p
	v. Solar photovoltaic pumps		7148 nos
12	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	2.90 million m^2 collector area
	ii. Solar cookers		6.57 lakh
13	Wind pumps		1347 nos
14	Aero generator/hybrid systems		0.89 MW_{eq}
IV	**Awareness programmes**		
16	Energy parks	—	511 nos
17	Aditya Solar Shops	—	284 nos
18	Renewable energy clubs	—	521 nos
19	District Advisory Committees	—	560 nos

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

ISSN 0974 – 5696

ICORE 2009

RENEWABLES : HELPING RURAL DEVELOPMENT

INTERNATIONAL CONGRESS ON RENEWABLE ENERGY

RENEWABLES : HELPING RURAL DEVELOPMENT

6-7 OCTOBER, 2009

INDIA HABITAT CENTRE, LODI ROAD, NEW DELHI, INDIA

Organiser

Solar Energy Society of India

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