Q. You had an illustrious tenure in MNRE (Ministry of New and Renewable Energy). In what ways would you like to remember such a long and valued association with the Ministry?

A. I have spent nearly 30 years in the renewable energy field, beginning with my association with the programme in DST (Department of Science and Technology). I was amongst the first group of officers, who formed the DNES (Department of Non-Conventional Energy Sources) in 1982. In the initial years, each one of us had to handle several programmes; I had to work on programmes as diverse as photovoltaics, hydrogen energy, battery powered vehicles and MHD (Magnetohydrodynamics) power generation. However, after a few years gap, I was able to concentrate fully on solar programmes, which continued till the end of my tenure.

Amongst the major initiatives that I was involved with are the NASPED (National Solar Photovoltaic Energy Development) programme which commercialized crystalline silicon technology in the country, the amorphous silicon programme which brought forward thin-film technology, Aditya Solar Shops, interest subsidy schemes for solar water heaters, installation of the world's largest solar steam cooking systems, and the village electrification programme. During this period photovoltaic test facilities were also established and the BIS (Bureau of Indian Standards) for solar thermal and PV (photovoltaic) products began to be enforced.

Internationally, the most memorable experience was being a member of the UN Committee on New and Renewable Energy and chairing its session at the UN Headquarters in New York for two weeks in 1996. To see all this through, I had the support of dedicated colleagues to whom I am thankful.

> *"Amongst the major initiatives that I was involved with are the NASPED programme which commercialized crystalline silicon technology in the country, the amorphous silicon programme which brought forward thin-film technology, Aditya Solar Shops, interest subsidy schemes for solar water heaters, installation of the world's largest solar steam cooking systems, and the village electrification programme."*

Q. Andhra Pradesh, your home state, was perhaps the first state in the country to experiment with the use of solar street lighting systems. Have such systems become any better in terms of actual field performance since the last few decades or so?

A. The first street lights were actually installed in the Bastar district in what is now Chhattisgarh. At a time when a country-wide programme was taken up through the REC (Rural Electrification Cooperation Limited) in the late eighties, Andhra Pradesh took the initiative to install a large number of street lights in the unelectrified villages. The Paderu Block in the state had the highest concentration of solar street lights at one point. Unfortunately the state electricity board did not make adequate arrangements for their maintenance, and thus a number of systems failed. Subsequently however, technical improvements were incorporated in these systems and we also tightened the implementation of the programme. Today the solar lights are far more reliable. Newer designs have also been installed in Ernakulam, Kerela; Manipur, and Kolkata.

Q. India's solar energy programme came to be regarded as one of

the largest field demonstration programmes in the world. Yet China, which started off much later than India, has stolen an easy march on us. What according to you have been the key distinguishing attributes between the two programmes?

A. Until about six years ago, India was amongst the top five countries in the world in both photovoltaic production and use. China was far behind us. However, the Chinese programme grew rapidly so as to overtake us and several other countries as well. I think the decision making and implementation processes in China are much faster than in India. Also, China has been able to attract much more investment than India in the field of solar manufacturing.

"I think the decision making and implementation processes in China are much faster than in India... China has been able to attract much more investment than India in solar manufacturing, as in other fields."

Q. Do you really feel that solar programme in India is poised for a big leap forward with a formal go ahead for the National Solar Mission? If so, what key changes are we going to find between now and then on a countrywide canvass?

A. Yes, I think the National Solar Mission has opened significantly larger opportunities for utilizing solar energy in the country. The mind set of key authorities such as the Planning Commission, the Ministry of Finance and the Ministry of Power seems to have changed for good. The industry also has grown significantly and several states are now supportive of solar initiatives. There is also recognition of the role of off-grid applications.Thus, we can surely look forward to being amongst the top few countries again by 2020.

Q. In your view, what will be the impact of the Direct Tax Code on India's renewable energy sector as a whole, if implemented in the near future?

A. The main impact of the code could be on the accelerated depreciation benefit that is now available for investments in commercial scale renewable energy projects. The impact could be minimized if, favourable feed-in tariffs and other support measures are put in place. I expect other benefits pertaining to indirect taxes such as excise duty exemptions and customs duty concessions to continue.

Q. When do you think solar energy technologies will finally change hands with the polluting technologies of the day for meeting various end-use applications?

A. We cannot replace the fossil fuels totally in the foreseeable future. Some devices such as solar water heaters, drying systems, cookers, and lanterns are already economically viable and can save significant amount of diesel, kerosene, LPG (liquefied petroleum gas) and coal in the coming decade. However, for power generation, the so-called grid-parity has to be achieved. This is a main goal of the National Solar Mission, which is now slated to last until 2022.

Q. Kindly apprise the readers about your ongoing responsibilities and vision for the solar energy development in your present place of work—Osmania University.

A. I am now working, in an honorary capacity, with the Centre for Energy Technology, Osmania University, Hyderabad. I have guided a few Master's

"Solar water heaters, drying systems, cookers, and lanterns are already economically viable and can save significant amount of diesel, kerosene, LPG, and coal in the coming decade."

degree students in their projects and also directed the installation of some solar facilities at the Centre. At times, we provide advice to entrepreneurs and non- governmental organization about the solar projects. However, this is really a small centre. As an individual expert, I advise government agencies and companies on solar policies and business development aspects.

Q. Finally, would you like to put across any special message for the readers of *The Solar Quarterly* magazine with an eye on capacity building initiative for example?

A. There are a lot of new entrants, engineers and managers, in the solar field. Many of them are not aware of the work already done in the country on technology, policy, and programme implementation aspects.

I feel enlightened readers should share their experiences and knowledge through *The Solar Quarterly* magazine so that we can avoid reinventing the wheel. The magazine should also feature articles on the manufacturing processes and economics, because in this country people are increasingly getting engaged with these key aspects.

Taking renewable to the masses

In India, the state nodal agencies are playing a very important role in promoting renewable energy and implementing various schemes pertaining to energy conservation and renewable energy. In Chhattisgarh, CREDA is doing extensive work in the field of renewable energy focusing on rural areas and stand alone devices. *Shailendra Shukla, Director, CREDA*, in an interview with *Dr Suneel Deambi and Arani Sinha*, talks about the various initiatives undertaken by CREDA and the future of renewable energy in the state of Chhattisgarh and other parts of the country.

Q. Could you kindly tell us about the performance status of the first PV (photovoltaic) power plant installed at Lamni (under your jurisdiction)?

A. First SPV power plant of 6 KWp was installed at village Lamni in the Bilaspur district, Chhattisgarh, in 1992. It is still functional and provides electricity to 108 households, forest rest house, a tribal hostel, one *dhaba* (road side hotel), and two grocery shops. Initially, it was a DC distribution network which has now been converted into an AC distribution network. Since the village is very compact, underground armoured cable of about 4 kms long for power distribution is being used. Tubular plate batteries connected with the system, for storage, are being maintained properly. Interestingly, we had to replace batteries once after 12 years. A VEC (village energy committee), headed by one of the beneficiaries, is maintaining the system with the support of one a local operator and a cluster technician. It is certainly one of the best examples of remote village electrification through SPV systems in the country.

Q. Solar PV water pumping programme is believed to be one of the most need-based programmes for adoption in a developing country like India. So far, what has been your experience with such systems in your state?

A. We have installed SPV water pumping system not only for providing potable water for the human beings but for the wild life also. There are

11 forest sanctuaries and three national parks in Chhattisgarh. Normally during summer season animals like tiger, panther, and bison come out from the dense forest area in search of water. CREDA (Chhattisgarh State Renewable Development Agency) has constructed more than 25 bore wells, within the sanctuary area and installed SPV water pumping sets. They pump the water and store it in the nearby reservoirs. Thus, it ensures a regular supply of drinking water for use within the sanctuary area.

We have installed more than 135 solar water pumps in forest villages and have developed *'Nal Jal Yojna'*, through which villagers get 24 hours potable water from the taps installed in the village. We have a unique experience of setting up normal 0.75 hp AC submersible pumps in SPV powered villages, where villagers are getting clean potable water from the deep wells. It is reported that villagers of such villages are now free from the waterborne diseases. Prior to these SPV installations, villagers used stored water of the reservoirs or from hand pumps using shallow water.

Also, I would like to mention that a solar water pump installed at village Daldali in the Kabirdham district, Chhattisgarh, in the year 1989, is still fully functional.

Q. Solar thermal energy applications can work wonders in terms of possible energy savings, if implemented on a massive scale. Could you kindly tell us about the initiatives undertaken by you in your state and with what results?

A. Ours is the only state in the country where state subsidies is given on the use of solar thermal devices. We started this programme in 2002, when there were hardly any solar water heating systems in the state. Now the accumulated capacity of solar water heating system installed in the state is more than 8 lac litres per day. There is hardly any hotel in the state without a solar water heating system. We have installed solar water heating system at various community cooking centres. This particular programme is growing

"We have installed more than 135 solar water pumps in villages and have developed 'Nal Jal Yojna', through which villagers get 24 hours potable water from the taps installed in the village."

three-fold every year. Use of electric geysers by any government department is now completely banned. Even government organizations cannot incur any expenditure on repairing of the electrical geysers. The installed electric geysers once it fails will be replaced by solar water heating system only. State Housing Board has made use of solar water heating system mandatory in all the houses above MIG (middle income group) category. All the colonies/ housing complexes constructed on more than two hectare land will have to make a provision for incorporating the solar water heating systems.

We are using solar air dryers for drying different forest produces.

Q. The just approved Jawaharlal Nehru National Solar Mission is expected to open up new vistas of solar energy technology utilization. Could you please share with us its possible positive influences in your state?

A. There is a very high percentage of waste land available in the state. The uncultivated land can be used for generation of power through solar power plants. The transmission network in Chhattisgarh is very strong and reliable. The uniqueness of solar power generation is its decentralization. Power can be generated at any part of the state as per the local requirement, thus avoiding heavy expenditure and loss in 440/132 KV transmission lines. Recently introduced solar mission can help us to develop small capacity solar power plants at hundreds of remote locations within the state according to its requirement.

Q. CREDA has been undertaking RE (renewable energy) programmes across the state for a variety of end-

use applications. Of these, which programme holds a special significance for you and why so?

A. Chhattisgarh has more than 2000 rice mills in the state. There was no proper use of rice husk at the time of inception of the state. Now there are 19 biomass based power plants using rice husk with an aggregated capacity of 190 MW. 11 such plants are still in the pipeline and likely to be commissioned by the end of 2010. Now the farmers of the state have started getting an additional Rs 1.5–2 per kg on the sale of the rice husk. Similarly not a single small hydro power project existed in the states earlier. Now 51 different sites have been allocated to the private investors for setting up small hydel power plants, with a total capacity of 680 MW.

Q. State nodal agencies like CREDA are widely regarded as the real agents of RE market stimulation/transformation. Could you please tell us about what all you still lack in terms of infrastructural needs and so on, so as to manage RE programmes still better?

A. There is shortage of power in almost all part of the country. People of the country purchase expensive cars, LCD and plazma TVs, fridge, computers and lot many electrical and electronic gadgets without any subsidy. All these gadgets are worthless without electricity. Even after having reliable solar technology, it is not as popular as it ought to be. The manufacturers of the solar systems do not have a proper marketing strategy. There is no solar showroom like Sony, Panasonic, and LG in the market. If, somebody wants to purchase and use solar systems for his/her house or institute, he/she still does not know from where he/she should buy it. Solar systems are not very expensive given their long term use. Almost all the solar manufacturing companies are still dependent on the government agencies like, CREDA, PEDA (Punjab Energy Development Agency), MEDA (Maharashtra Energy Development Agency), and so on for their regular sale. Government of India has been providing subsidy on the solar systems for the last 25 years. Solar items cannot become popular without an aggressive marketing by the companies themselves. A millionaire living in Raipur sometime faces electrical load shedding for hours together but does not use an alternative arrangement like SPV systems due to lack of proper information. Likewise, solar service centres are required to develop the much needed confidence amongst the prospective users of various solar devices. We are still lacking such facilities in the state.

“Now there are 19 biomass based power plants using rice husk with an aggregated capacity of 190 MW. 11 such plants are still in the pipeline and likely to be commissioned by the end of 2010.”

Q. Solar PV lighting systems, apart from meeting the crucial domestic lighting needs are also proving useful for small entrepreneurs in terms of their extended hours of working. Would you like to share with us a few such interesting case studies pertaining to your region?

A. Normally in the villages surrounded by forest, the main livelihood of the villager is collection of forest produce and its sale after some value addition. Villagers collect the forest produce during the day time and start the value addition activities in the evening. Now after having solar domestic lighting systems, they have sufficient time for such value addition activities. For example, they collect *tendu patta*, wrap it into bundles and then make *beedies* in the night.

In some villages, the whole family is involved in collecting *mahul patta* and makes *dona* and *pattal* by stitching the leaves together. Similarly, villagers get ample time during the night hours for segregation and cleaning of tamarind and other forest produce. These are all income generating activities and with the installation of the solar domestic lighting systems, these small entrepreneurs get longer working hours, which helps in their income generation process.

Q. PV systems are now meeting an increasing number of end-use applications. What are your views regarding the replacement of small capacity diesel generators with PV rooftop systems for the commercial purpose in the urban areas?

A. CREDA is the only agency in the entire country, which has installed more than one thousand small size solar generators replacing normal inverters and DG sets. Most of the commercial institutions and offices run during the day time. A solar system with hardly four hours storage can provide electricity for all basic loads throughout the office hours. It works online during sunny hours and requirement of evening hours can easily be met out through a battery storage system.

Commercial institutions like the computer centres, phone booths, medical shops, and cloth markets can easily be run on solar systems without any interruption.

Q. The solar energy programme outreach in the country across various sectors is expected to increase manifold within the next five years or so. Please elaborate on what capacity building initiatives are on anvil at CREDA to match that kind of change?

A. Almost all the major solar companies are actively participating in marketing activities in the state. Most of the companies have their zonal office at Raipur and they have dealers and service network all over the state. There are seven regional and 16 district offices of CREDA in the state to look after various renewable energy activities. CREDA has developed a network of operators, technicians, and service engineers throughout the state. It conducts training programmes to train the mechanics in repairing and maintaining the solar devices. We have separate set of policies to develop solar technology.

> *A solar system with hardly four hours storage can provide electricity for all basic loads throughout the office hours.*

Q. Do you wish to share any special thought (s) with the readers of, *The Solar Quarterly* magazine that could further increase their interest in the field of renewable energy?

A. My dream is to convert all the energy consuming buildings into generation generating buildings. Total investment to meet out the energy requirement of any building is expected to be not more than 2% of the cost of premises. We maintain cars worth Rs10–20 lakhs to have conveyance security, and install dish TV on the rooftop to have entertainment security. We purchase lot of luxurious items which has no pay back value, but I fail to understand why we do not want energy security, even if, we can afford to spend Rs 2–3 lakhs on solar systems? There are no movable parts in solar systems and hence there is no question of wear and tear. There is no question of servicing, overhauling, and changing oil. A solar system once installed works for 25 years without any monthly bill. Thus, it is only the mindset that needs to change in order to become self sustained in the energy front.

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DECENTRALIZED V GRID ELECTRICITY FOR RURAL INDIA

The economic factors

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Abstract—*The provision of rural energy in India has been regarded as synonymous with rural electrification. Low load factors, long distribution lines with low load densities and the associated high transmission and distribution losses in most rural areas of India, however, make many of the rural electrification programmes economically unattractive. Decentralized energy technologies based on local resource availability can be a viable alternative to rural electrification through the extension of the grid. In this paper, the cost of grid electricity to the end-user is quantified and compared with the cost of electricity from decentralized energy systems to obtain the specific distances from the grid, the level of demand and the load factor conditions under which using decentralized energy systems for rural India makes economic sense.*

Keywords: Rural electrification; India; Decentralized technologies

Provision of energy for rural areas has been considered a priority in India. However, rural energy provision has been regarded as synonymous with rural electrification, implemented through the extension of low-voltage distribution lines from the regional grid.[1] Low load factors in most rural areas which contribute significantly to seasonal and diurnal peak demands, long distribution lines with low load densities and the associated high transmission and distribution losses make many of the rural electrification programmes economically unattractive. In many cases such programmes lead to misallocation of scarce funds especially when one con siders that the Seventh Five Year Plan (1985-90) (hereafter referred to as the Seventh Plan) envisages the electrification of about 118 000 villages and the provision of electricity to 2.39 million pumpsets in rural India. Furthermore, even the under-estimated official projections estimate that the peak load deficit will escalate from 8 345 MW in the Seventh Plan to over 11 293 MW in the last years of the Eighth Five Year Plan (1990-95). Thus, it becomes imperative to re-examine the implicit policy of rural electrification through the extension of the regional grid and to identify cost-effective options for the power requirement of the rural sector. Experience in India over the past decade has shown that decentralized energy technologies based on local resource availability can be a viable alternative to rural electrification through the extension of the grid. This paper attempts to identify the specific conditions under which different decentralized energy technologies become cost-effective. The analysis is based on a comparison of the cost of delivered grid electricity to rural areas with the cost of delivering an equivalent amount of electricity using a decentralized technology.

The investment required for extending a grid depends on the distance of the village/area from the existing grid and the estimated demand. The cost of delivered electricity, however, is also dependent on the load factor, the transmission and distribution losses and the cost of power generation. Therefore, the cost of grid electricity is quantified below in terms of these parameters and then compared with the cost of electricity from decentralized systems to obtain

- the specific distances from the grid;
- the level of demand; and
- the load factor conditions

under which decentralized systems are cost-effective.

Table 1 Progress of rural electrification in India

Year	Installed capacity (MW)	Villages electrified Number	Villages electrified As a percentage
1950–51	1840	3061	0.5
1968–69	12960	73739	12.8
1980–81	30210	272625	47.3
1984–85	42590	370332	64.3
January 1987	48590	401647	69.9

RURAL ELECTRIFICATION IN INDIA

Remarkable progress has been made under the rural electrification programme in India since the commencement of the Five Year Plans in 1950-51 (see Table 1). Assuming that the Seventh Plan targets of electrifying 118 000 villages are met, only about 90 000 villages, mostly small and remote, would remain unelectrified by 1990.

About 55% of the Seventh Plan rural electrification target is to be met by the Rural Electrification Corporation (REC). Until 1986 REC had financed the electrification of 190 210 villages at the cost of about 175 000 per village (in December 1988, 1 US$ = 17.60 Rs). The total installed distribution transformer capacity was then estimated at 12 649 MVA.[3] Ramesh et al have made a detailed study of the rural electrification programme financed by the REC in four States covering four out of the five regions into which the country is divided for power sector planning.[4] Using their data for the RECfinanced schemes completed up to March 1986, both the average load factor and the load factors for specific energy end-use sectors for the rural areas in the four States have been computed and are shown in Table 2. The average load factor varies from a low of 0.059 for Karnataka in south India to a high of 0.16 for Haryana, which produces about 5% of the total foodgrain in India though it accounts for less than 4.4% of the net sown area of the country.

In India the electrification of a village is regarded as a part of the larger exercise of electrifying an area. The projects approved under a rural electrification scheme, therefore, generally deal with a cluster of villages rather than a single village. However, with about 70% of rural India already electrified, many of the remaining villages are dispersed and remote. Thus, even though projects may be implemented on a 'scheme-wise' basis, in many cases they will amount to electrifying a single village. For densely populated areas, with villages situated close to one another, the contribution of the distribution network to the total cost is strikingly different from that of an isolated village (as will be shown later). It should be kept in mind, therefore, that the past cost of rural electrification and its contribution to the end-user cost of electricity in rural India will be very different from expected future cost. In the next section an attempt is made to estimate this cost in terms of the distance from the existing grid, the peak demand of the area and the load factor.

COST OF ELECTRICITY FOR RURAL AREAS

The thermal-hydro electric mix of installed capacity in India has been increasingly in favour of thermal power generation. From the 50:50 ratio of thermalhydro electric capacity in the early 1960s a ratio of 70:30 is expected by 1990. Thus, the cost of thermal power generation is the most logical benchmark for comparison of the cost of electricity. In the present analysis, the cost of the cheapest thermal power is estimated to show that even with the cheapest grid electricity, decentralized energy systems are viable under certain conditions.

Cost of thermal power generation

Major thermal power projects being implemented in the Seventh Plan and under consideration for the Eighth Plan are based on super-thermal power plant units of 200-500 MW capacity. Many of these projects are to be implemented by the National Thermal Power Corporation (NTPC) which plans to add 27 920 by the year 2000 at a total cost of 300 billion Rs. So far, the government of India has approved NTPC plans to add 11 740 MW at the cost of 106.89 billion Rs by 1993.[5] All the NTPC projects are super-thermal power plants and most of them are situated at or near coal pit-heads. Given the capacity of the

Table 2 Pattern of load distribution and load factors in REC-financed schemes completed up to March 1986

State	Agricultural		LT-industry		Domestic		Street lighting		Average
	Load (kW)	Load factor (%)	Load (kW)	Load factor (%)	Load (kW)	Load factor (%)	Load (kW)	Load factor (%)	Load factor (%)
Gujarat	640292	9.0	62814	13	197917	13.0	3611	33.0	10.2
Haryana	481328	12.7	202816	24.0	61758	15.0	472	25.0	16.0
Karnataka	701601	4.7	53973	12.0	110533	10.0	3947	33.0	5.9
Orissa	89388	5.4	41173	13.0	59825	15.0	580	25.0	10.1

Table 3 Cost of generation from NTPC projects

Project	Average cost (Rs/kW)	Annual capital recovery cost (Rs/kW)	Annual O&M cost (Rs/kW)	PLF	Annual cost coal used (t/kW/year)	Annual cost of delivery coal (Rs/t)	Annual fuel costs (Rs/year)			Cost of generation (Rs/kW)
							Coal	Fuel oil	Total	
Singuarali	6875	853.5	171.9	0.74	4.53	233.6	1057.1	231.6	2314.1	0.358
Korba	5421	673.0	135.5	0.80	4.93	238.2	1174.4	252.3	2235.2	0.317
Ramagundam	8106	1006.3	202.6	0.81	4.99	238.2	1189.0	255.5	2653.3	0.372

Assumptions:

1 Annualized capital cost based on CRF using interest rate of 12% and system lifetime of 30 years

2 Annual operation and maintenance cost assumed at 2.5% of capital cost.

3 Coal price of Rs 229 tonne is used based on weighted average cost of new open-cast mines in India.[15] Coal consumption is assumed at 0.7 kg/kWh.

4 NTPC plants use merry-go-round for transporting coal because of their proximity to coal mines. Cost of transportation is reported at Rs 0.46 per tonne/km.[16]

generating units, the location of the plants at coal pit-heads (which drastically reduces transport costs) and the excellent record of the NTPC, the cost of thermal electricity from these stations is the lowest possible in India. The calculated cost of generation from the three NTPC plants operational in 1986-87 is Rs 0.538/kWh for Singrauli, Rs 0.317/ kWh for Korba and Rs 0.372/kWh for Ramagundam (Table 3). For the purpose of analysis here, the busbar cost of thermal power generation is assumed at Rs 0.35/kWh.

Transmission and distribution losses

Transmission and distribution (T&D) losses in India have gone up steadily from about 13% in 1960-61 to 21.1% in 1985-86. In 1985-86, T&D losses varied between States from a low of 14.5% in the industrialized State of Maharastra, to a high of 45% in the sparsely populated hill State of Manipur in the north-east. An important reason for the high T&D losses is the widespread extension of the low-voltage distribution network to more and more areas resulting in long lines with low load densities. Unfortunately, a breakdown between rural and urban T&D losses is not available. For the State of Karnataka, it was estimated that the rural T&D losses were about 2.4 times the urban losses.[6] If Karnataka is assumed to be typical, then the rural losses corresponding to the national average losses of 21.7% in 1986-87 would be about 35%. Assuming a 5% auxiliary consumption in the power station, for every kWh consumed in rural areas, about 1.67 kWh has to be generated at busbar.

Cost of rural distribution network

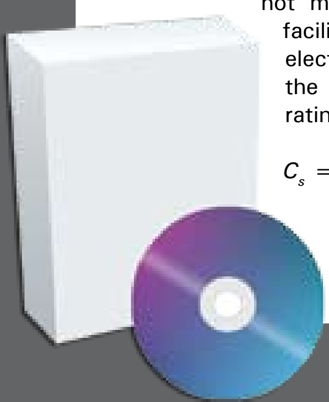
A cost function for the distribution network can be obtained by disaggregating its costs into the cost of 11 kV distribution line, the cost of the 11 kV/440 V transformer substation and the cost of the 440 V distribution line.

The cost of the 11 kV line would obviously depend on the distance of the village from the 33 kV grid. Additional 11 kV lines may be required depending on the location of the load centres within the area. For a relatively densely populated area in the state of Bihar the total cost of the 11 kV line was estimated to be represented by:

$$C_g = 40\,785\ L_g + 856\ P_t \qquad (1)$$

where C_g a is the total cost in Rs, L_g is the distance from the grid (in km) and P_t is the transformer rating or the peak demand in kVA).[7]

The cost of the sub-station housing the 11 kV to 440 V transformer depends on the peak demand of the area which, in turn, determines the transformer rating. The transformer cost shows a considerable scale effect with the cost per kVA going down with the rating. Though transformers are not manufactured in continuous ratings, to facilitate the calculation of the cost of electricity for any given demand level, the substation cost as a function of the rating, is:[8]



$$C_s = 6\,935 + 3\,432(P_t)^{0.4505} \qquad (2)$$

The length of the 440 V line used would depend on the demand of the area to be electrified and the location of the load centres within it. Based on the cost incurred in electrifying 31 villages in the densely state of Bihar, the average cost of the 440 V line as a function of the demand was found to be:

$$C_d = 1350P_t \qquad (3)$$

where C_d is the cost in Rs.[9]

Using Equations (1) to (3), the total cost of the distribution network can be expressed as

$$C_t = 40785\ L_g + 2206\ (P_t)^{0.4505} + 3432(P_t) + 6935 \qquad (4)$$

where C_t is the total cost in Rs L_g is the distance of the area from the 33 kV grid (in km) and P_t (in kVA) is the peak demand of the area considered (or the rating of the transformer required).

Using Equation (4), the capital cost for the distribution network is calculated for different distances (L_g) from the 33 kV grid and the peak demand (P_t) of the area. The capital recovery factor (CRF) is determined for a distribution network life of 20 years and a discount rate of 12% to calculate the

Table 4 Cost of delivered electricity (to an isolated village)

Distance (km)	Peak load (kW)	Cost of electricity for load factors (in Rs/kWh) 0.5	0.1	0.15	0.2	0.25	0.35
5	10	8.0	4.29	3.05	2.43	2.06	1.64
	25	4.01	2.30	1.72	1.44	1.27	1.07
	50	2.67	1.62	1.28	1.10	1.00	0.88
	63	2.39	1.48	1.18	1.03	0.94	0.84
	100	1.98	1.28	1.05	0.93	0.86	0.78
10	10	14.23	7.40	5.13	3.99	3.31	2.53
	25	6.50	3.54	2.55	2.06	1.76	1.43
	50	3.91	2.25	1.69	1.41	1.25	1.06
	63	3.37	1.98	1.51	1.28	1.14	0.98
	100	2.61	1.59	1.26	1.09	0.99	0.87
12	10	16.72	8.65	5.96	4.62	3.81	2.89
	25	7.50	4.04	2.89	2.31	1.96	1.57
	50	4.41	2.50	1.86	1.54	1.35	1.13
	63	3.37	1.98	1.51	1.28	1.14	0.98
	100	2.86	1.72	1.34	1.15	1.04	0.91
15	10	20.46	10.52	7.21	5.55	4.56	3.42
	25	9.00	4.79	3.39	2.68	2.26	1.78
	50	5.16	2.87	2.11	1.72	1.50	1.23
	63	4.36	2.47	1.84	1.53	1.34	1.12
	100	3.23	1.90	1.46	1.24	1.11	0.96
20	10	26.70	13.64	9.29	7.11	5.80	4.31
	25	11.49	6.04	4.22	3.31	2.76	2.14
	50	6.41	3.49	2.52	2.04	1.75	1.41
	63	5.35	2.97	2.17	1.77	1.53	1.26
	100	3.85	2.22	1.67	1.40	1.23	1.05
25	10	32.93	16.75	11.36	8.67	7.05	5.20
	25	13.98	7.28	5.05	3.93	3.26	2.49
	50	7.65	4.12	2.94	2.35	1.99	1.59
	63	6.34	3.46	2.50	2.02	1.73	1.40
	100	4.48	2.53	1.88	1.55	1.36	1.14

Assumptions: Generation cost (in Rs/kWh) – busbar 0.350; including T&D loss (T&D loss fraction 0.4) 0.583

annual cost of the network. The load factor determines the use of the distribution network to deliver the consumed power and thus the annual cost of the distribution network is attributed to the total energy consumed during the year.

Since for every kWh consumed in rural areas 1.67 kWh has to be generated at busbar, and the cost of thermal power generation at busbar is assumed at Rs 0.35/kWh, the cost of generation of utilized power from the grid in rural areas of India is Rs 0.58/kWh. Adding the contribution of the distribution network to this cost would give the cost of delivered power. The cost of delivered electricity for rural areas in India for some selected distances from the 33 kV grid and for varying load factors are shown in Table 4.

It may be worthwhile to point out that although here and elsewhere in the paper reference is made to the 'distance from the 33 kV grid', and argument and conclusions remain valid for electrification projects involving the extension of the existing 11 kV line. In such cases, however, instead of the distance from the 33 kV grid, the distance from the 11 kV line must be substituted when calculating the costs through the cost functions presented in this section.

COST OF DECENTRALIZED ENERGY OPTIONS

Table 5 presents a brief summary of the economics of certain decentralized energy technologies. Kishore and Thukral have extensively reviewed the cost of biomass-based decentralized systems in India.[10] Their costs include the cost of creating fuelwood plantations, briquetting agro-waste, and labour and transport costs, apart from the cost of the energy conversion systems. Their cost for the gasifiefs, pelletizers and briquetting machines are based on the prices of the systems presently manufactured in India. The cost of the solar-pond generated electricity is based on the cost estimates for the 5 000 square metre solar pond project at Kutch Dairy, Bhuj, Gujarat.[11] The cost of the photovoltaic electricity is based on the studies of Ramesh *et al*.[12] Although to date there is little experience in decentralized solar thermal power generation in India, the Department of Non-conventional Energy Sources plans to use dish-stirling systems. The cost estimates for electricity produced by such systems are included, based on the works of Kishore and Thukral.[13] The cost of wind electric generation is based on the works of Sinha and Kandpal.[14] As Table 5 indicates, the cost of wind electric power is given in terms of the capacity utilization factor of the turbine which, in turn, depends on the wind-speed distribution of the area being considered.

COMPARISON OF COSTS AND ITS IMPLICATIONS

As pointed out earlier, the rural electrification programmes in India arc implemented through schemes involving a cluster of villages. However, with the progress of electrification, the difference (in terms of investment) between an 'electrification scheme' and 'electrifying a village' may become insignificant. The comparison is, therefore, present both for a single, isolated village and a cluster of villages or 'scheme'.

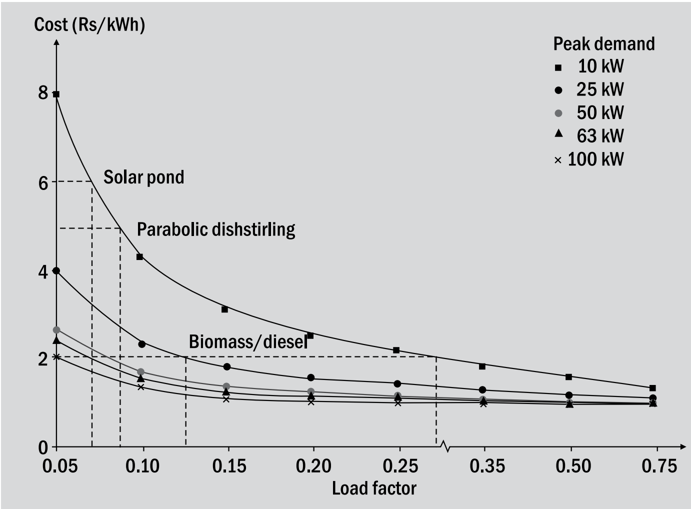
Table 5 Summary of economics of some decentralized technologies

Technology	Source	Annual cost (Rs)	Annual net generation (kWh/kW)	Cost of electricity (Rs/kWh)
Diesel	Ref 10	5566	4192	1.33
Biomass	Ref 10			
dendrothermal		5698	3942	1.45
agro-waste				
briquetted		5566	3066	1.82
pelletized		5566	3679	1.51
gasifier				
wood		4425	2957	1.50
briquetted		4431	2497	1.77
Solar				
pond	Ref 10	6835	1005	6.80
photovoltaic	Ref 4	22775	1140	19.98
dish stirling	Ref 10	9189	1838	5.00
Wind				
small turbines CUF	Ref 14	15510		
5			438	35.41
8			701	22.13
10			876	17.71

Isolated village

In order to determine the viability of a decentralized energy technology by comparing the cost of electricity, the distance from the 33 kV grid and the peak demand of electricity must be known. These allow the estimation of the cost of delivered electricity (using Equation (3)) for different load factors of the distribution network. As an example, this exercise is carried out for three distances: 5, 15 and 25 km from the 33 kV grid. For the discussions presented in this paper, it is assumed that the load factors calculated earlier for the four States are representative of the sload-factor range in rural areas of India.

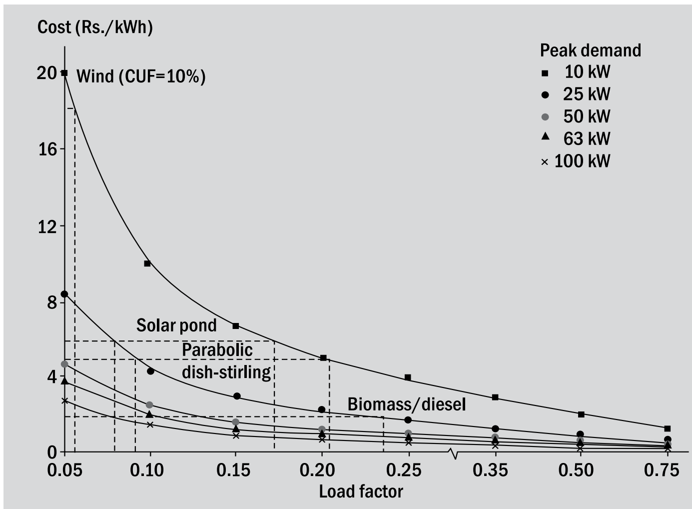
Village at 5 km from the 33 kV grid. For the distance of 5 km and a peak demand of 10 kW, diesel generated power is cheaper than electricity for load factors less than 0.6 (Figure 1) and biomass-based technologies become viable for load factors of less than 0.3. Since the average load factor in four representative States was found to be in the range of 0.06--0.16, these technologies are cheaper than grid supplied electricity for most rural areas in India. This would be especially true for irrigation-water pumping where the load factor is below 0.10 for three of the four States. Of course, with an acute shortage of biomass in India, systems based on biomass are ruled out in most areas - except for regions generating non-fodder agricultural wastes and wood wastes resulting from activities such as timber processing. Such systems may be viable in the north-eastern, hilly regions of India where many villages are yet to be electrified. For peak demands exceeding 25 kW and for a low-load factor, only diesel remains competitive compared to electricity.



Fiture 1
Cost of electricity (5 km from the grid)

allow a small, stand-alone wind turbine to generate about 875 kWh of electricity per kW of installed capacity per year, wind-generated electricity would be cheaper than grid electricity for load factors up to 0.10. For a wind turbine generating only about 700 kWh per kW of installed capacity per year, wind-generated electricity costs less than grid electricity for load factors up to 0.08. For the same demand of 10 kW, photovoltaic systems become viable for load factors below 0.10. At a peak demand of 25 kW, only solar thermal and biomass systems can compete with grid electricity, with solar thermal systems requiring the load factor to be below 0.15. When the peak demand is 100 kW, diesel and biomass systems are the only viable alternatives to grid electricity.

Village at 15 km from the 33 kV grid. For a village situated 15 km from the grid and with a peak demand of 10 kW, diesel- and biomass-based technologies become cost-effective for nearly all load factors (Figure 2). Solar thermal systems (dish stirling and solar ponds) become competitive for load factors below 0.2 - a condition, as stated earlier, satisfied by most areas in rural India. Solar thermal systems remain viable even for 20 kW peak demand under the condition that the load factor is below 0.09. For the peak demand of 10 kW, small, standalone wind turbines are economically attractive for low load factors of around 0.05 provided local wind characteristics allow the turbine to generate about 700 kWh per kW of rated capacity per year. For example, in the coastal State of Orissa, which has favourable wind characteristics, stand-alone wind generators will be economically competitive with grid electricity for rural applications as the average load factor for rural Orissa is below 0.06. Both solar thermal and stand-alone wind electric systems appear to be attractive options for the north-western region of India (approximately corresponding to the desert regions of Rajasthan and the State of Gujarat) with good wind conditions and with the highest solar radiation intensity in India. Only diesel and biomass systems are competitive if the peak demand of the village is 100 kW and if the load factor is below 0.08.

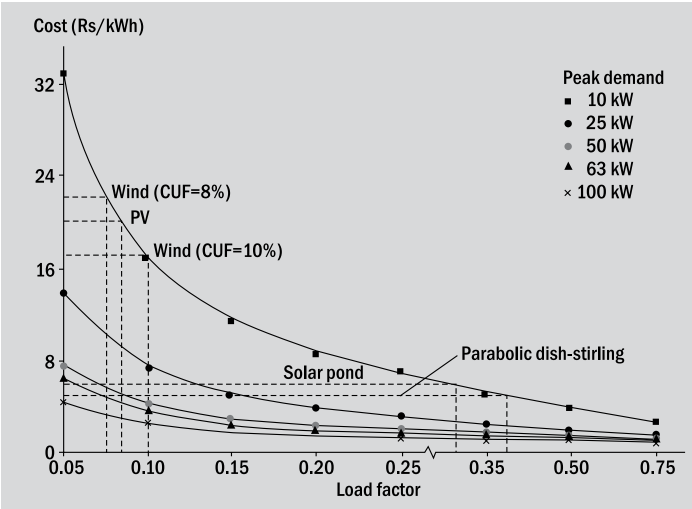


Fiture 2
Cost of electricity (15 km from the grid)

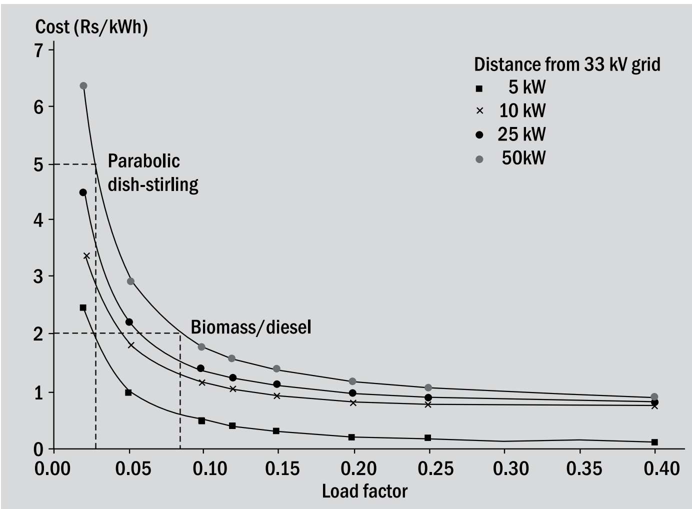
Village at 25 km from the 33 kV grid. If the grid is 25 km from the village then all decentralized technologies are viable for existing load-factor conditions for a peak demand of 10 kW (Figure 3). Diesel- and biomass-based technologies are cost-effective for all load factors while solar thermal systems require load factors below 0.35. If wind conditions

Cluster of villages

Figure 4 shows the variation of the cost of grid-supplied electricity for a cluster of villages. We have assumed the cluster to contain three large villages with a peak demand of 100 kW each; seven moderate-sized villages with a peak demand of 63 kW each; and 20 small villages with a peak demand of 25 kW each. Thus the total peak demand of this hypothetical, but typical, cluster is 1 214 kW. The variation of the cost shown is for different load factors. Four different curves corresponding to the distances of 5, 15, 25 and 50 km from the grid are plotted. For this typical cluster of villages, standalone wind generators and photovoltaic electricity cannot compete with grid electricity. As can be seen from Figure 4, the decentralized energy technology option is viable only when the load factor is below 0.10 - irrespective of the distance from the grid. There is a limited potential for solar thermal devices when the load factor is below 0.03 and the distance from the grid is about 50 km. Biomass- and diesel-



Fiture 3 Cost of electricity (25 km from the grid)



Fiture 4 Cost of electricity for a cluster of villages

based systems are competitive to a marginally greater extent with the cost of electricity from these sources being lower for load factors ranging from 0.025 to 0.10 depending on the distance from the grid.

The total cost of grid electricity is now in the range that the cost of generation at busbar becomes a significant parameter for deciding the cost effectiveness of decentralized energy technologies, especially for diesel- and biomass-based systems which have marginally higher costs.

Conclusions

The cost of electricity supplied to the end-user from the regional grid and different decentralized energy technologies in rural India has been estimated. An attempt has been made to incorporate the site-specific nature of this cost by empirically establishing a generalized cost function for the distribution network.

The contribution of the distribution network to the cost of electric power generation has been computed for different conditions. The cost of grid-supplied electricity was then compared with the cost of supplying electricity through decentralized energy technologies.

It was found that for small and isolated villages with low load factors, decentralized energy technologies make economic sense. The specific load-factor conditions as well as the distance from the grid at which some of these decentralized technologies become economically viable were identified without having to resort to debatable accounting and pricing assumptions of grid electricity.

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11 Ibid.

12 Ramesh et al, op cit, Ref 4.

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CURRENT RESEARCH AND DEVELOPMENT

Single dimensionless variable for solar chimney power plant modelling

Koonsrisuk Atit and Chitsomboon Tawit. 2009
Solar energy **83**(12): 2136–2143

ABSTRACT
The solar chimney power plant is a relatively new technology for generating electricity from solar energy. In this paper, dimensional analysis is used together with engineering intuition to combine eight primitive variables into only one dimensionless variable that establishes a dynamic similarity between a prototype and its scaled models. Three physical configurations of the plant were numerically tested for similarity: fully geometrically similar, partially geometrically similar, and dissimilar types. The values of the proposed dimensionless variable for all these cases were found to be nominally equal to unity. The value for the physical plant, actually built and tested previously, was also evaluated and found to be about the same as that of the numerical simulations, suggesting the validity of the proposition. The physical meaning of this dimensionless (similarity) variable is also interpreted; and the connection between the Richardson number and this new variable was found out. It was also found that, for a fixed solar heat flux, different-sized models that are fully or partially geometrically similar share an equal excess temperature across the roof outlet.

Keywords: Solar chimney, Solar tower, Solar power plant, Similarity variable, Dimensionless constant, Natural convection ■

Realistic generation cost of solar photovoltaic electricity

Singh Parm Pal and Singh Sukhmeet.2010
Renewable Energy **35**(3): 563–569

ABSTRACT
SPV (solar photovoltaic) power plants have long working life with zero fuel cost and negligible maintenance cost but require huge initial investment. The generation cost of the solar electricity is mainly the cost of financing the initial investment. Therefore, the generation cost of solar electricity in different years depends on the method of returning the loan. Currently levelized cost based on equated payment loan is being used. The static levelized generation cost of solar electricity is compared with the current value of variable generation cost of grid electricity. This improper cost comparison is inhibiting the growth of SPV electricity by creating wrong perception that solar electricity is very expensive. In this paper, a new method of loan repayment has been developed resulting in the generation cost of SPV electricity that increases with time like that of grid electricity. A generalized capital recovery factor has been developed for graduated payment loan in which capital and interest payment in each installment are calculated by treating each loan installment as an independent loan for the relevant years. Generalized results have been calculated, which can be used to determine the cost of SPV electricity for a given system at different places. Results show that for SPV system with specific initial investment of 5.00 \$/kWh/year, loan period of 30 years and loan interest rate of 4%, the levelized generation cost of SPV electricity with equated payment loan turns out to be 28.92 ¢/kWh, while the corresponding generation cost with graduated payment loan with escalation in annual installment of 8% varies from 9.51 ¢/kWh in the base year to 88.63 ¢/kWh in the 30th year. So, in this case, the realistic current generation cost of SPV electricity is 9.51 ¢/kWh and not 28.92 ¢/kWh. Further, with graduated payment loan, extension in loan period results in sharp decline in the cost of SPV electricity in base year. Hence, a policy change is required regarding the loan repayment method. It is proposed that to arrive at realistic cost of SPV electricity long-term graduated payment loans may be given for installing SPV power plants such that the escalation in annual loan installments is equal to the estimated inflation in the price of grid electricity with loan period close to working life of the SPV system.

Keywords: Solar photovoltaic economics, solar electricity price, Graduated payment loan, Levelized cost, Variable cos, SPV electricity generation cost ■

Simulation of a photovoltaic/thermal heat pump system having a modified collector/evaporator

Xu Guoying, Deng Shiming, Zhang Xiaosong, Yang Lei, Zhang Yuehong .2009
Solar energy **83**(11): 1967–1976

ABSTRACT
A new PV/T-HP (photovoltaic/thermal heat pump) system having a modified C/E (collector/evaporator) has

been developed and numerically studied. Multi-port flat extruded aluminium tubes were used in the modified C/E, as compared to round copper tubes used in a conventional C/E. Simulation results suggested that a better operating performance can be achieved for a PV/T-HP system having such a modified C/E. In addition, using the meteorological data in both Nanjing and Hong Kong, China, the simulation results showed that this new PV/T-HP system could efficiently generate electricity and thermal energy simultaneously in both cities all-year-round. Furthermore, improved operation by using variable speed compressor has been designed and discussed.

Keywords: Solar energy, PV/T (Photovoltaic/thermal), Heat pump, Optimization, Multi-port flat extruded tubes ■

Flexible polymer photovoltaic modules with incorporated organic bypass diodes to address module shading effects

Steim Roland, Schilinsky Pavel, Choulis Stelios A, Brabec Christoph J. 2009 Solar Energy Materials and *Solar Cells* **93**(11): 1963–1967

ABSTRACT
We present experimental results on large-area low-cost processed flexible OPV (organic photovoltaic) modules incorporating organic bypass diodes to eliminate the negative effects of shading on the module power output. A fully organic-based structure (organic solar module combined with an organic bypass diode) is essential to allow monolithic interconnection of the bypass diode during the solar module production within the same printing steps. The origin of shading losses in OPV modules is analyzed in detail, and guidelines for the design and architecture of flexible OPV modules are derived. Inorganic and organic diodes were tested on their functionality as bypass diodes, and a set of diode specifications to minimize shading losses is summarized. Organic bypass diodes were found to efficiently reduce the adverse shading effects in OPV modules.

Keywords: Polymer photovoltaics, Flexible organic solar cells, Shading, Degradation, Reverse bias, Organic bypass diodes, Large-area flexible organic solar cells ■

An ANP-based approach for the selection of photovoltaic solar power plant investment projects

Aragonés-Beltrán P, Chaparro-González F, Pastor-Ferrando J.P, Rodríguez-Pozo F. 2010
Renewable and Sustainable Energy Reviews 14(1): 249-264

ABSTRACT
In this paper, the ANP (Analytic Network Process) is applied to the selection of PV (photovoltaic) solar power projects. These projects follow a long management and execution process from plant site selection to plant start-up. As a consequence, there are major risks of time delays and even of project stoppage.

In the case study presented in this paper, a top manager of an important Spanish company that operates in the power market has to decide on the best PV project (from four alternative projects) to invest based on risk minimization. The manager identified 50 project execution delay and/or stoppage risks.

The influences between the elements of the network (groups of risks and alternatives) were identified and analyzed using the ANP multicriteria decision analysis method. Two different ANP models were used: one hierarchy model (that considers AHP as a particular case of ANP) and one network-based model. The results obtained in each model were compared and analyzed. The main conclusion is that unlike the other models used in the study, the single network model can manage all the information of the real-world problem and thus, it is the decision analysis model recommended by the authors. The strengths and weaknesses of ANP as a multicriteria decision analysis tool are also described in the paper.

Keywords: Multicriteria decision analysis, Analytic Network Process, Photovoltaic solar power projects ■

Distributed photovoltaic generation and energy storage systems: a review

Toledo Olga Moraes, Filho Delly Oliveira, and Diniz Antônia Sônia Alves Cardoso. 2010
Renewable and Sustainable Energy Reviews 14(1): 506-511

ABSTRACT
Currently, in the field of operation and planning of electrical power systems, a new challenge is growing which includes with the increase in the level of distributed generation from new energy sources, especially renewable sources. The question of load redistribution for better energetic usage is of vital importance since these new renewable energy sources are often intermittent. Thus, new systems must be proposed which ally energy storage with renewable energy generators for re-establishment of grid reliability. This work presents a review of energy storage and redistribution associated with PV energy, proposing a distributed micro-generation complex connected to the electrical power grid using energy storage systems, with an emphasis placed on the use of NaS batteries. These systems aim to improve the load factor, considering supply side management, and the offer backup energy.

Keywords: Distributed generation, Photovoltaic systems, Energy storage systems, Load management ■

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TECHNICALCORNER

Solar power generation around the clock

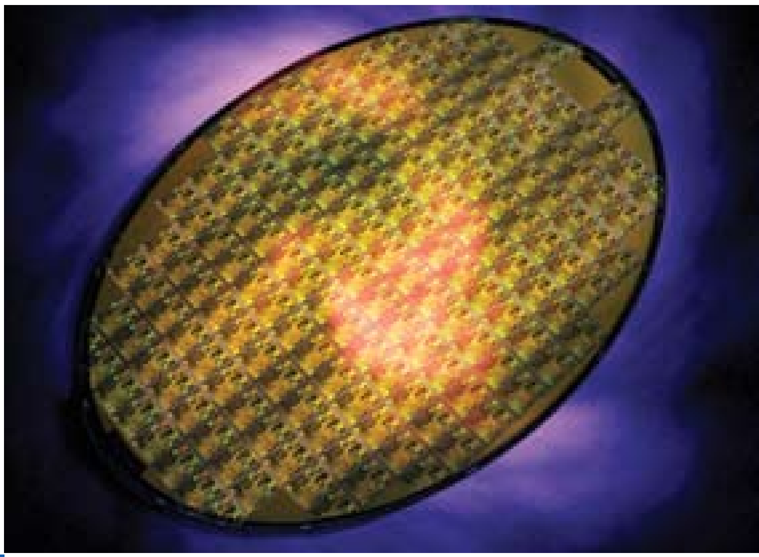
A California based company, Solar Reserve, is developing a solar power system that can store seven hours' worth of solar energy by focusing mirrors onto the millions of gallons of molten salt, thus allowing the plant to provide electricity for 24 hours a day. The company has applied to regulators in California for permission to build a 150-megawatt Rice Solar Energy Project near the town of Rice in San Bernadino County, California. The solar energy is stored using a massive circular array of up to 17 500 mirrors (heliostats), each measuring 24 by 28 feet and attached to a 12-foot pedestal. The heliostat field encircles a concrete solar power tower 538 feet high, with a 100-foot high receiver on top, which holds 4.4 million gallons of molten salt. When the heliostats focus the sunlight onto the receiver, the salt is heated to over 1 000 ºF.

As and when needed, the heat is released by passing the molten salt through a steam generator that drives a turbine to produce electricity. The cooled salt is then recirculated to the receiver for re-heating. The project brings the dream of a solar system that generates electricity in the dark to a reality, and thus avoids the need to use fossil fuel plants for backup electricity generation.

>> Source: http://www.physorg.com

Wonders of Titania Nanotubes

A research team from Northeastern University and the NIST (National Institute of Standards and Technology), United States, has discovered, a residue of a process used to build arrays of titania nanotubes (a residue that was not even noticed before this) plays an important role in improving the performance of the nanotubes in solar cells. These produce



hydrogen gas from water. Their recently published results indicate that by controlling the deposition of potassium on the surface of the nanotubes, engineers can achieve significant energy savings in a promising new alternate energy system. Titania (or titanium dioxide) is a versatile chemical compound best known as a white pigment. It is found in everything from paint to toothpastes and sunscreen lotions. Thirty-five years ago, Akira Fujishima startled the electrochemical world by demonstrating that it also functioned as a photo catalyst, producing hydrogen gas from water, electricity, and sunlight. In recent years, researchers have been exploring different ways to optimize the process and create a commercially viable technology that essentially transforms sunlight into hydrogen, a pollution-free fuel that can be stored and shipped. Increasing the available surface area is one such way to boost a catalyst's performance. Thus, a team at the Northeastern University has been studying techniques to build tightly packed arrays of titania nanotubes, which have a very high surface-to volume ratio. They were also interested in assessing as to how best to incorporate carbon into the nanotubes. Carbon helps titania absorb light in the visible spectrum. Pure titania absorbs in the ultraviolet region, and much of the ultraviolet is filtered by the atmosphere. This brought them to the NIST X-ray spectroscopy beamline at the NSLS (National Synchrotron Light Source). The NIST facility uses X-rays that can be precisely tuned to measure chemical bonds of specific elements. It is about 10 times more sensitive than the commonly available laboratory instruments, thus allowing the researchers to detect elements at extremely low concentrations. While making measurements of the carbon atoms, the team noticed spectroscopic data, indicating that the titania nanotubes had small amounts of potassium ions strongly bound to the surface. It was evidently left by the fabrication process. This was the first time that potassium has ever been observed on titania nanotubes. The result was mildly interesting but became quite pronounced when the research team compared the performance of the potassium-bearing nanotubes to similar arrays deliberately prepared without potassium. The former configuration required only about one-third of the electrical energy to produce the same amount of hydrogen as an equivalent array of potassium-free nanotubes.

>> Source: www.sciencedaily.com

Three-dimensional solar cell

Converting sunlight to electricity might no longer mean large panels of photovoltaic cells atop flat surfaces like roofs. Researchers at the Georgia Institute of Technology have developed a new type of three-dimensional photovoltaic system. The approach could allow PV systems to be hidden from view and located away from traditional locations such as rooftops. Using zinc oxide nanostructures grown on optical fibres and coated with dye-sensitized solar cell materials. Dye-sensitized solar cells use a photochemical system to generate electricity. These are cost-effective, flexible, and mechanically robust, but their tradeoff for lower cost is that their conversion efficiency is lower than that of silicon-based cells. But using nanostructure arrays to increase the surface area available to convert light could help reduce the efficiency related disadvantage. The architects and designers derive new options for incorporating PV into buildings, vehicles, and even the military equipment.

Fabrication of the new Georgia Tech PV system begins with optical fibre of the type used by the telecommunication industry to transport data. First, the researchers remove the cladding layer, and then apply a conductive coating to the surface of the fibre before seeding the surface with zinc oxide. Next, they use solution-based techniques to grow aligned zinc oxide nanowires around the fibre. The nanowires are then coated with the dye-sensitized materials that convert light to electricity. Sunlight entering the optical fibre passes into the nanowires, where it interacts with the dye molecules to produce electrical current. A liquid electrolyte between the nanowires collects the electrical charges. The result is a hybrid nanowire/optical fibre system that can be up to six times as efficient as planar zinc oxide cells with the same surface area. The research team has reached an efficiency of 3.3% and still hopes to reach 7%–8% after surface modification. While much lower than the silicon

solar cells, this efficiency would still be useful for practical energy harvesting. This could potentially lower the cost of their approach can make it attractive for many applications. By providing a larger area for gathering light, the technique would maximize the amount of energy produced from strong sunlight, as well as generate respectable power levels even in weak light. The amount of light entering the optical fibre could be increased by using lenses to focus the incoming light, and the fibre-based solar cell has very high saturation intensity. The research team believes that this new structure will offer architects and product designers an alternative PV format for incorporating into other applications.

>> Source: www.renewableenergyworld.com

Slashing cost: new method reduces waste in efficient solar cells

Engineers at the University of Utah have devised a new method to slice thin wafers of the chemical element germanium for use in the most efficient type of solar power cells. The new method should lower the cost of such cells by reducing the waste and breakage of the brittle semiconductor. The expensive solar cells are now used mainly on spacecrafts, but with the improved wafer-slicing method, the idea is to make germanium-based,

high-efficiency solar cells where now cost is a factor. Brass-coated, steel-wire saws are now used to slice round wafers of germanium from cylindrical single crystal ingots. But the brittle chemical element cracks easily, requiring broken pieces to be recycled, and the width of the saws means a significant amount of germanium is lost during the cutting process. The sawing method was developed for silicon wafers, which are roughly 100 times stronger. The new method for slicing solar cell wafers – known as WEDM (wire electrical discharge machining) – wastes less germanium and produces more wafers by cutting even thinner wafers. The method uses an extremely thin molybdenum wire with an electrical current running through it. Germanium serves as the bottom layer of the most efficient existing type of solar cell. Raw germanium costs about $680 per pound. Germanium is a semiconductor at the bottom of 'multi-junction' solar cells. Above it are layers of galliumindium-arsenide and gallium-indium phosphide. The layers work together to capture different wavelengths of sunlight, and the germanium also serves as the substrate upon which the solar cell is 'grown'. When sunlight hits a solar cell, the energy is converted to a flow of electrons in the cell, namely, electricity. Silicon-based solar cells have efficiency up to 20%.

>> Source: www.sciencedaily.com

Converting sunlight to cheaper energy

Scientists are working to convert sunlight to cheap electricity at the SDSU (South Dakota State University). They are working with new materials that can make cheaper and more efficient electricity. OPVs (organic photovoltaics) are less expensive to produce than the traditional devices used for harvesting solar energy. The new technology OLEDs (organic light emitting diodes) is sometimes referred to as 'molecular electronics' or 'organic electronics'—organic because it relies on carbon-based polymers and molecules as semiconductors rather than inorganic semiconductors such as silicon. The underlying beauty of OPVs and OLEDs is their low cost and flexibility. These devices can be fabricated by inexpensive, solution-based processing techniques similar to painting or printing. The ease of production brings down the cost, while the mechanical flexibility of the materials open up a wide range of applications. OPVs and OLEDs are made up of thin films of semiconducting organic compounds that can absorb photons of solar energy. An organic polymer is used as a substrate on which semi conducting materials are applied as a solution using a technique similar to inkjet printing. The research at SDSU is focused on new materials with variable band gaps. The band gap determines as to how much solar energy the PV device can absorb and convert into electricity. The one heading the research explained that visible sunlight contains only about 50% of the total solar energy. That means the sun is giving off just as much non-visible energy as visible energy. In fact they are working on synthesizing novel polymers with variable band gaps, including high-, medium-, and low-band gap varieties, to absorb the full spectrum of sunlight. By this, one can double the light harvesting or absorption, so SDSU's scientists plan to use the variable band gap

polymers to build multi-junction polymer solar cells or PV. These devices use multiple layers of polymer/fullerene films that are tuned to absorb different spectral regions of solar energy. Ideally, photons that are not absorbed by the first film layer pass through to be absorbed by the following layers. The devices can harvest photons from ultraviolet to visible to infrared in order to efficiently convert the full spectrum of solar energy to electricity. SDSU scientists also work with OLEDs focusing on developing novel materials and devices for full colour displays. But in the future, as OLEDs become less expensive and more efficient, they may be used for residential lighting. The new technology will then make it easy to insert lights into walls or ceilings.

>> Source: 2008. Akshay Urja 2(1): p18

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Renewable Energy Research at the University of Oslo

The University of Oslo is Norway's largest and oldest institution of higher education. It was founded in 1811 when Norway was still under Danish rule. Today the University of Oslo has approx. 30 000 students and 4 600 employees. Four Nobel Prize winners indicate the quality of the research at the University. In this section, we will focus on renewable energy research carried at the University

Faculty of Mathematics and Natural Sciences

- Founded in 1811 as a part of the Faculty of Philosophy.
- Founded as a Faculty in 1861
- Two Nobel laureates are related to the Faculty, Odd Hassel, chemistry (1969) and Ivar Giæver, physics (1973)
- About 4.600 students (Autumn 2006)
- 1.200 man-years
- Yearly budget about 1.200 million Norwegian kroner (About 150 million Euros)
- 9 Departments
- 13 Bachelor's Programmes
- 21 Master's Programmes
- Three Centres of Excellence
- One centre of Research-based Innovation

The Faculty of Mathematics and Natural Sciences is engaged with research in the field of renewable energy. The Faculty of Mathematics and Natural Sciences was established in 1861, and is one of eight faculties at the University of Oslo. It is the largest educational and basic research science faculty in Norway. About 1200 scientists, technical and administrative staff members and almost 5000 students contribute to the pursuit of scientific knowledge and keep the research standard at a high international level.

During the last decades there has been a rapid development within mathematics and natural sciences. These disciplines form the fundament of our understanding of nature and of applied disciplines like information technology, genetics, materials and micro technology. The natural sciences affects our view of the world and the way we think - they form the premises for technological development, and consequently for our material wealth and standard of living.

Being part of this development, today's Faculty of Mathematics and Natural Sciences at the University of Oslo combines a strong research programme, solid instruction and a good relationship with the political and business worlds in its investigations into a wide range of fields. Environmental science, IT, petroleum and astrophysics are areas of particular excellence at the faculty.

Research activities at the faculty span a broad diversity of subjects. Divided into nine departments and three Centres of Excellence, the faculty addresses fundamental problems of theory and practice in mathematics, physics, chemistry, informatics, earth, and life sciences. With a special focus on basic research within these fields, the faculty provides leading-edge scientific competence to its students, its industrial research and development (R&D) partners and to other academic institutions in all parts of the world.

Two Nobel prizes and participation in global research projects like ESA's (European Space Administration) and NASA's 'Solar and Heliospheric Observatory' are testament to the faculty's strength in scientific research.

During the last year, the University through The Centre for Materials Science and Nanotechology, which is a unit at the base level within the organizational structure of the Faculty of Mathematics and Natural Sciences, had built up significant competence on materials important for renewable energy. The University is now active with solar cell research where it, in collaboration with the Norwegian University of Science and Technology, is responsible for the establishment of a graduate school of solar energy technology. Also, through the Department of Geoscience, the University is involved in developing Hydrogen based technologies.

Norwegian Research Centre for Solar Cell Technology

Established in 2009, the overall objective of the Norwegian Research Centre for Solar Cell Technology is to give current and future companies in the Norwegian photovoltaic industry access to world leading technological and scientific expertise, thereby enabling this industry to become one of the most important land-based industries in Norway.

The University of Oslo is one of four research partners at the centre, and the Norwegian PV (photovoltaic) industry constitutes the centre's industrial partners. Increased use of solar power requires the development

of solar cells with lower cost or higher efficiency, or preferably both.

The centre will develop fundamental knowledge along the entire solar cell value chain, more specifically within these fields: mono- and muliticrystalline silicon production, solar cell and module technology, new nanostructured materials and new characterization methods.

The University of Oslo focuses on three main research themes:

- Defect engineering and characterization of solar grade silicon
- Solar cells that use thin conducting oxide layers combined with silicon
- Third generation solar cells based on all-oxide materials and nanotechnology

The University hosts a particular strong cross disciplinary team that covers wide areas of expertise in chemistry, materials science and physics. This includes semiconductor physics, thin film technology, nanoparticles synthesis, catalyst, and electronic structure calculations.

Advanced synthesis and characterization tools are available. A dedicated graduate school is currently under establishment as part of the centre and will launch in 2010.

Hosted by the University of Oslo, with NTNU and IFE as important partners, the school will train Ph.D students at a high international level in different areas of solar cell technology, thereby providing qualified candidates to the industry, research institutes, and universities.

Photoelectrolysis - producing oxygen from water using solar technology

Solar energy can be utilized in a number of different ways, for example to split water molecules into geseous hydrogen and oxygen.

This can be done by using a PEC (photoelectrochemical call) and is in fact one of the most promising clean methods of hydrogen production.

When hydrogen is subsequently used as fuel, the exhaust will only consist of water.

Solar thermal

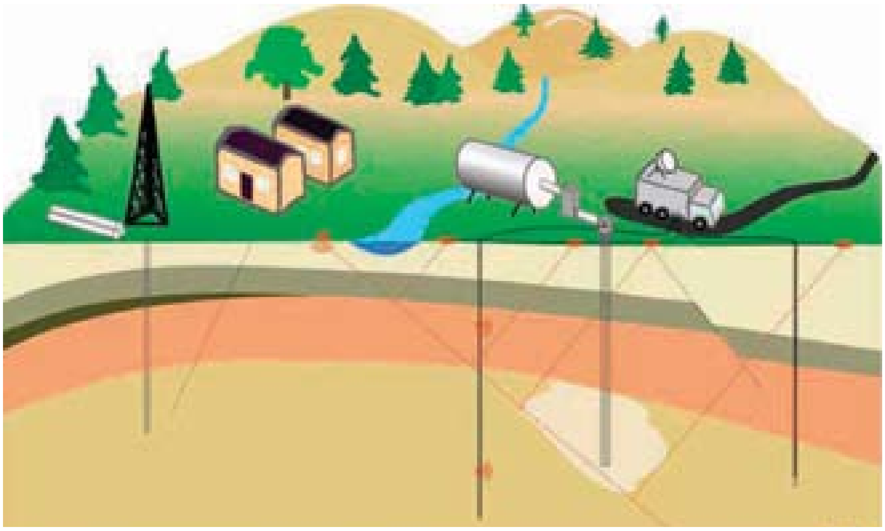
Heat from the sun can also be used in a more direct fashion. Seeing as most of the electric power consumption in buildings goes towards heating and cooling, large amounts of energy can be saved if the conversion to and from electricity, and the consequent energy-loss is avoided.

Most solar thermal collectors are metal-based, but it is worth nothing that the annual production of copper worldwide is insufficient to cover the highly suitable for local solar thermal installation. A key research goal is to develop new ploymer materials that can withstand high temperatures and also, and significantly so, minimize internal stress, thus increasing the lifetime of the solar panels.

Hydrogen technology

The University is carrying out research in the field of fuel cells and co_2 capture, is to gain a sustainable and clean supply of energy. By developing fuel calls that run more efficiently on hydrogen or reformed hydrocarbon fuels, the emission of CO_2 and other pollutants will be reduced. It focuses on fuel cells and electrolysers for hydrogen technologies, based on high temperature proton conducting electrolytes. The research is pursued with the help of several RCN-funded projects and the UiO-coordinated EU project ‘EFFIPRO’.

Gas separation membranes for cost-effective CO_2-free fossil power plants based on mixed ionic electronic conductors, is also a field of high activity. Here, there exists a close collaboration between SINTEF, NTNU and StatoilHydro, and this collaboration is strengthened through the new international Research Centre BIGCCS.



New projects have been initiated on solid state photoelectrochemical production of hydrogen. Finally, many activities are focused on materials stability issues, such as thermodynamics and reactivity of materials.

CO_2 storage

The Department of Geosciences, University of Oslo, has decades of experience in petroleum geology and geophysics, knowledge that translates into a solid foundation for developing the much-needed expertise for successful subsurface storage of CO2. In the search for safe subsurface CO2 storage sites, a number of important questions arise, including: where should CO2 preferably be stored?

Which minerals/rock formations are best suited for storage? How should a CO2 storage site best be monitored? And in case of a leakage to sea or air, how can it be efficiently stopped or minimized?

The CEER (Centre for Environment-friendly Energy Research) -centre SUCCESS (Subsurface CO2 storage – Critical Elements and Superior Strategy) starts up in 2009 with the University of Oslo as a major partner. The main objective of the research centre is to develop a comprehensive industrial methodology for risk assessment and performance analysis for SSC to provide qualified input to regulatory authorities. It is acknowledged that safe storage can only be accomplished through interdisciplinary research combining experimental efforts, advanced theoretical modelling and case studies. The centre will achieve this by joining forces with a total of eight research institutions, as well as trough close collaboration with affiliated industry partners.

Batteries

The University is active in developing all solid state batteries based on thin films/coatings. The ongoing research is funded by the Research Council of Norway, The University of Oslo, and industry. They have developed a novel chemical process for depositing Li-compounds as thin coatings, and have demonstrated technology to deposit solid Li-conducting electrolytes. Furthermore a laboratory test facility for Li-ion batteries is under construction.

In the EU project MAHEATT, coordinated by the University, the research students' are working along with four leading European universities and research institutes, and three high-tech companies to develop yet unknown materials with the capacity to trigger radical advances with respect to energy storage capacity.

If successful, this would open novel markets for Li-ion batteries in heavy duty tools, electrification of the transportation sector, as well as storage of electric energy from solar cells, that is for residential applications. To reach this target, the very materials are the key focus.

At the moment there are 59 PhD candidates and 2 Postdoctoral Fellows involved in research concerning renewable energy at the University of Oslo. In 2008, a total of 130 candidates graduated with a PhD from the Faculty of Mathematics and Natural Sciences.

Other information

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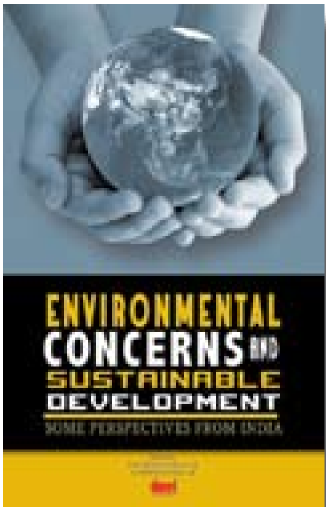

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Environmental concerns and sustainable development: some perspectives from India

Industrialization and development have brought about a radical shift in production and consumption patterns all over the world, including India. However, the impact of these trends on the earth's climate and various natural resources has been quite serious. There is a need to bring about a major transition, whereby this generation, and more importantly, generations yet to come do not suffer from the ill effects of today's development, which is clearly not sustainable. The human race has to bring about a rapid transition to a pattern of growth and development that is genuinely sustainable.

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- Development and displacement in tribal areas
- Sustainable development and liberalization
- Environmental rehabilitation and livelihood impact
- Case of Goa Bachao Abhiyan
- Environmental impact of population, affluence, and technology
- Garbage not in my backyard syndrome in Goa
- Impact of environmental degradation on women
- Development-induced displacement
- Organic produce supply chains
- Genuine people's participation in sustainable forest development
- A review of judicial and legislative initiatives on sustainable development
- Land and water management practices in Warana region
- Sustainability through people's participation in the health sector
- Organic farming and sustainable development

TEDDY(TERI Energy Data Directory & Yearbook, 2009)

An annual publication brought out by TERI since 1986, TEDDY provides an overview of the implications of government policies for the Indian economy. Besides sections on the latest technological developments and the environmental implications of energy use, TEDDY includes India's commercial energy balances for the past four years. The contents of TEDDY are categorized under (1) energy supply (coal and lignite, oil and gas, power, and renewable energy sources and technologies); (2) energy demand (agriculture, industry, transport, and domestic sector); (3) forests and environment; and (4) global environmental issues.

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- Organization of the energy sector
- Indian energy sector: an overview
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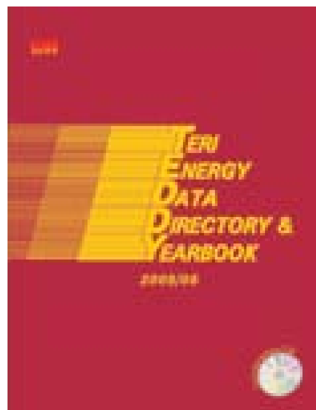

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Expert Speak

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).

1. What is the difference between solar photovoltaic cell and thin film?

A solar PV (photovoltaic) cell is usually made of several semi-conducting materials. These mainly include single crystal silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, copper indium diselenide, gallium arsenide, and so on. These cells are made through an effective combination of the processes ranging from simple substrate cleaning to deposition of active material layers on various substrates. Thin film deposition is basically a growth technique, which helps to deposit very thin layers of active material. It offers a clear advantage of saving the expensive silicon material, and thus helps to keep the cost of cell fabrication lower. Also, these PV technologies offer lower solar to electric conversion efficiencies, and thus need more roof or land area to be mounted in direct comparison to the crystalline silicon based technologies.

2. There are several terms related with solar power like mono- and multicrystalline cells, concentrated PV, Poly Crystalline. Can you please explain these and the difference between them.

Solar cells are made of various semi-conducting materials. The crystallinity of a material shows as to how perfectly ordered the atoms are within a crystal structure. Silicon, as well as other solar cell semiconductor materials, can come in various forms. These mainly include single-crystalline, multicrystalline, and amorphous types. In case of a single-crystal material, the atoms making up the framework of the crystal are repeated in a very regular and orderly manner from layer to layer. That is not the case with a material, which is made of many smaller crystals. Simply put, the orderly arrangement is disrupted while moving from one crystal to another. Amorphous silicon is just a glass like structure, and thus unlike the highly ordered single crystal structure. One more element of difference in the above mentioned cell types is in terms of absorption coefficient of a material. It basically shows as to how far light having a specific wavelength or energy can penetrate the material before being absorbed. A small absorption coefficient means that light is not readily absorbed by the material. Third important element of difference between the above materials is in terms of bandgap. The bandgap of a semiconductor material is the minimum energy needed to move an electron from its bound state within an atom to its free state. So, crystal structure, absorption coefficient, and energy bandgap can be counted as amongst the most important determinants to distinguish one cell material from the other.

Single crystal cell is also known as a mono-crystalline cell. These cells are normally cut from a chunk of silicon that has been grown from a single crystal. In contrast, polycrystalline cell is cut from a multifaceted silicon crystal. Basically polycrystalline and muticrystalline are used as identical terms in the solar cell terminology. The crystalline silicon cells comprizing of single crystal and multi-crystalline is the most efficient cell structures available today. Polycrystalline cells made out of cadmium telluride and copper indium di-selenide are less efficient followed by amorphous silicon. In contrast, concentrator cells surpass these normally used cell types in terms of much higher solar to electric conversion efficiencies. In this case, available sunlight is concentrated far many times onto much smaller cell areas using cheap plastic Fresnel lenses, and so on.

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

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SOLAR PASSIVE DESIGN BY ECOTECT

Case study: an office building for composite climate

SUDIPTA SINGH, Research Associate, TERI <sudiptas@teri.res.in>

The passive connection

In the words of V Olgyay, 'We do not expect to solve the problems of uncomfortable conditions by natural means only. The environmental elements aiding us have their limits. But it is expected that the architects should build the shelter in such a way so as to bring out the best of natural possibilities.'

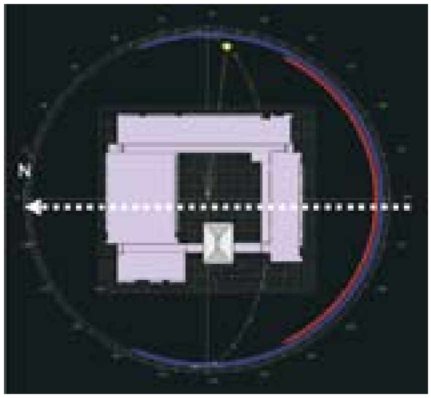
Solar passive design reduces or even eliminates the use of mechanical cooling and heating systems and the use of daytime artificial lighting. Architects and engineers primarily focus on the Sun to minimize heating and cooling needs. The design does not need to be complex, but it does involve knowledge of solar geometry, window technology, local climate, and so on. Passive solar design is not new in India. In fact, our ancient civilizations were using this passive solar design in most of their buildings.

ECOTECT-an optimization tool

In this article, the software reference is to ECOTECT. It is a widely used software tool which enables us to optimize our building design. The immediate objective is to make our building fully climate responsive as well as ensure adequate daylight. Here, we present a case study of such measures in a government building under day time use only. Various recommendations have been made by us to incorporate the solar passive features via ECOTECT software.

Base Case

An administrative building is proposed in the composite climate of Patna (Latitude-25.30 and Longitude-85.20). The proposed building plan is a square plan, which comprises of one double loaded and three single loaded corridors around a central courtyard. This is G+1 building with total BUA of 2325 sq.m (approx.) and only less than 20% of area is air conditioned. The proposed WWR is within 20% and the floor depth of all office areas is within 7 mt.



Proposed building orietation

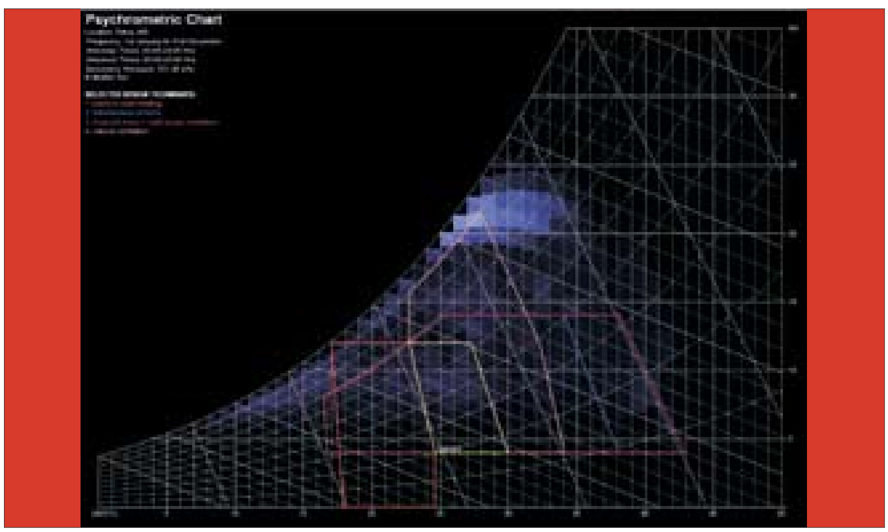
Methodology

In order to optimize the proposed building design and minimize energy consumption while ensuring thermal and visual comfort within specified limits, the following methodology has been adopted for the proposed project.

Step-1: Climate Analysis

The builder is interested specifically in those aspects of climate, which affects human comfort and the use of building. They include averages, changes and extremes of temperature, solar radiation, relative humidity and wind movement of the area. A detailed climate analysis of Patna weather file has been performed to arrive at the following passive design strategies suitable for the project. These include

1. Passive Solar Heating (only for winter)
2. Thermal Mass + Night-Purge-Ventilation
3. Natural Ventilation



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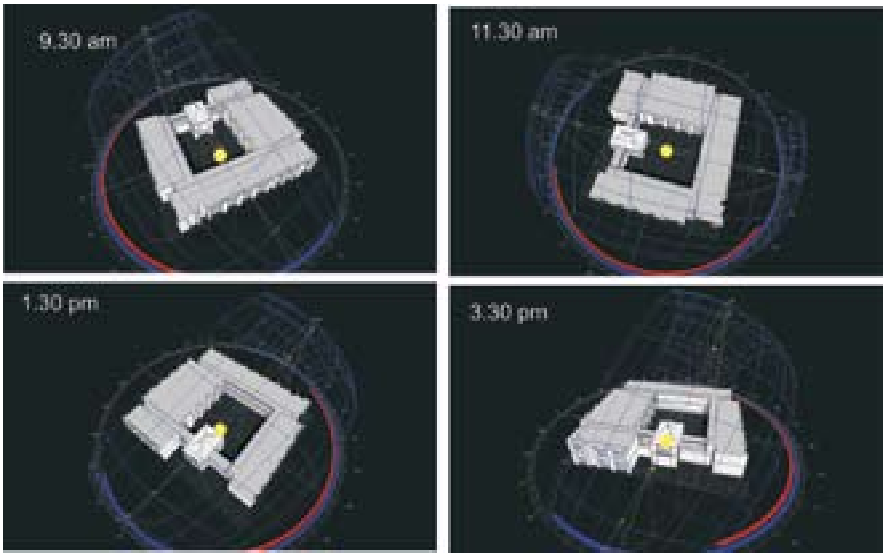


Hourly Solar Exposure Analysis with proposed orientation

Psychometric chart of weather tool analysis showing the suitable passive strategies.

Step-2: Solar Exposure Analysis

As the building block is oriented towards all the directions, so here in this case, it is recommended to provide an ideal orientation (north–south) to the facades with maximum openings. Hence as per the best solar position analysis, it is inferred that the proposed case orientation is good enough and there is no requirement for re-orientation.

The detailed study of the daily and annual solar exposure and solar access analysis indicates that the western façade is getting maximum solar radiation followed by those on the southern and eastern sides. However, as the maximum number of openings has been kept on the southern façade, it is to be most critically followed by east and west in terms of shading priorities.

Step-3: Shading Design

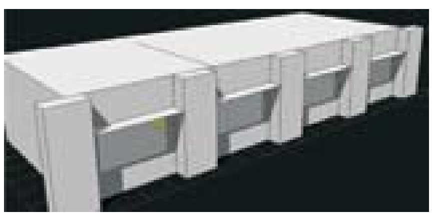
The sun-path analysis has been done on the critical facades (South, East and West) to find out the critical sun angles (Horizontal Shadow Angle and Vertical Shadow Angle) respectively. Hence adequate shading devices have been recommended as per the critical shadow angles. An extremely important feature of ECOTECT is its ability to track the path of incident gains. Thus, it is possible to select one or more objects plus an analysis grid and use the spatial intensity of the radiation as a shading design tool.

For southern façade

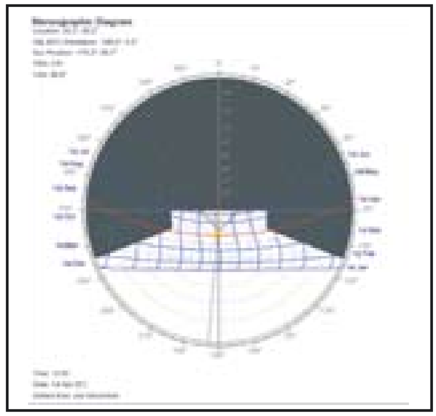
As per the sun path analysis, the critical sun angle is the VSA (vertical shadow angle) of 700 on a vertical plane normal to the elevation. This characterizes a horizontal shading device of 600 mm (min).

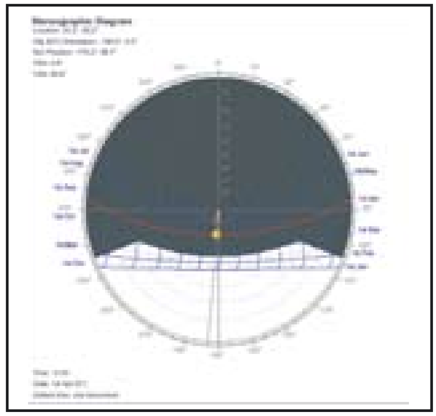
For eastern façade

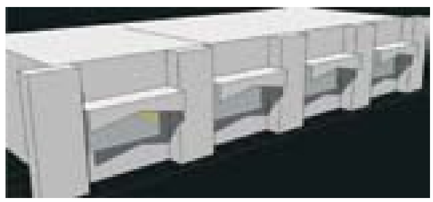
Here the critical sun angle is the VSA of 450 on a vertical plane normal to the elevation. This characterizes

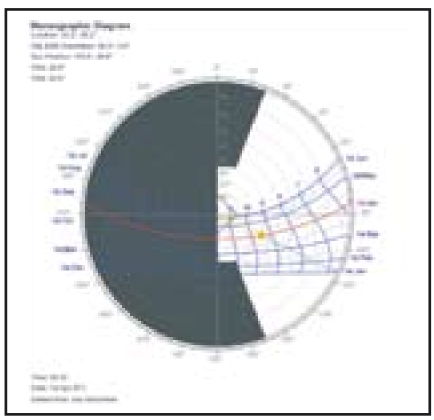

Recommended shading for southern façade

a horizontal shading device of 1500 mm (min), which can be further modified into two parts of 900mm horizontal louver with arch shaped drop of 600 mm on sides to 300 mm at centre (while retaining the shape of the proposed shading pattern of the architect).


Sun path diagram without shading

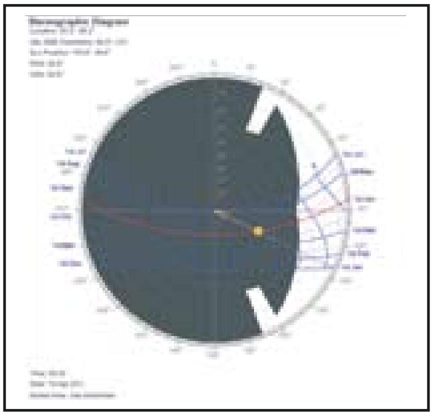

Sun path diagram with shading


Recommended shading for eastern façade


Sun path diagram without shading

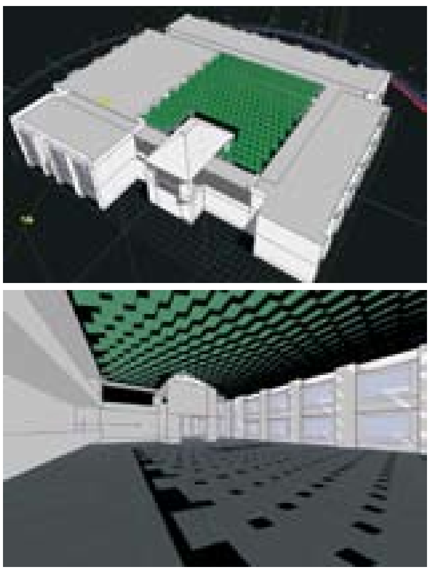
Courtyard shading

The direct solar radiation is maximum on a horizontal surface than that



Sun path diagram with shading

of vertical. So in order to avoid an excess radiation inside the courtyard and to make the space more habitable for the office staff, it is recommended to provide the space frame with sun screen panels over the cut-out or at roof level. The sun screen panels should be angled in such a way that these can eliminate the summer sun but allows the winter sun to come in.



Courtyard shading by space frame

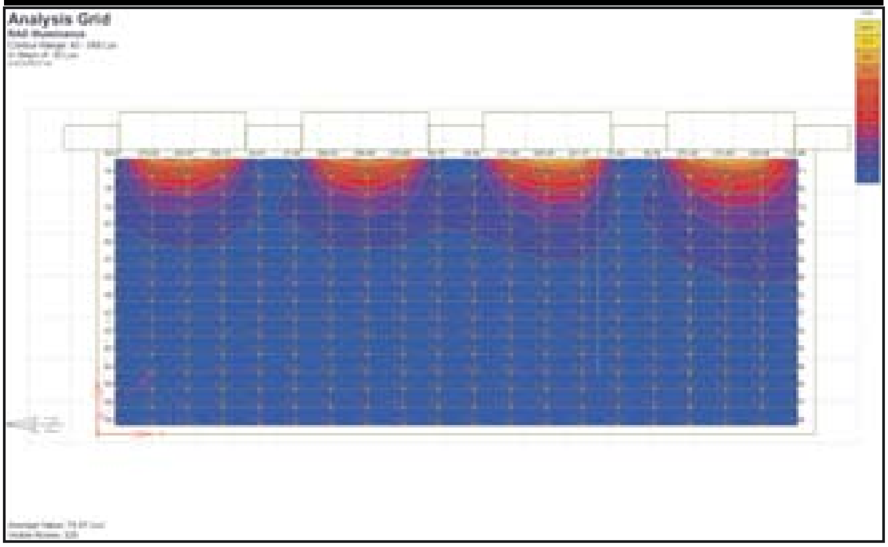
Step-5: Daylight Analysis

Daylight simulation has been done in RADIANCE for various spaces of the office building, as per the daylight guidelines. Radiance is a suite of programmes for the analysis and visualization of day lighting in the design process. Input files specify the scene geometry, materials, time, date, and sky conditions. Simulation results may be displayed as colour images, numerical values, and contour plots. For example.

Simulation condition:

- Overcast sky condition (outside lux level is 8500)
- Visible light transmittance of glass = 60%
- Required daylight at centre of daylight zone = 152 lux

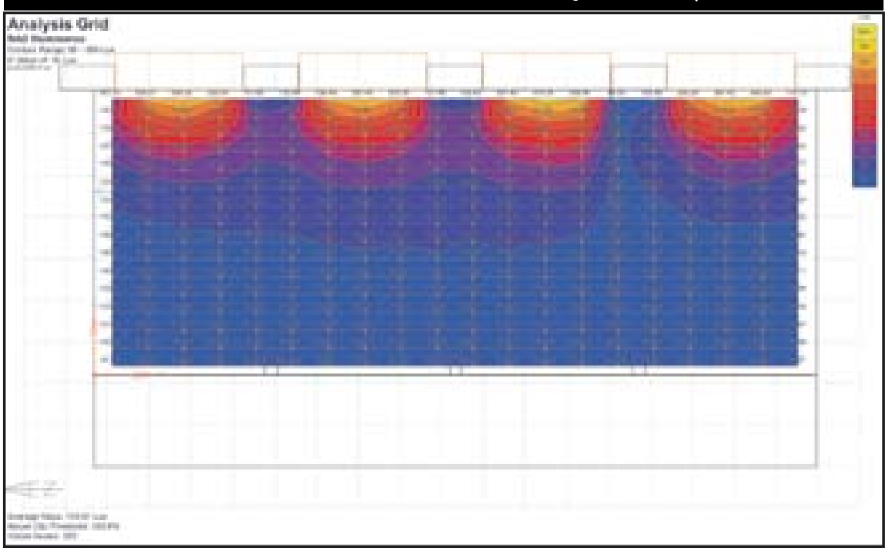
Case-1: Daylight simulation for eastern façade: (With proposed window sizes and recommended shading devices)



Achieved daylight level at centre of daylight zone is 75 lux

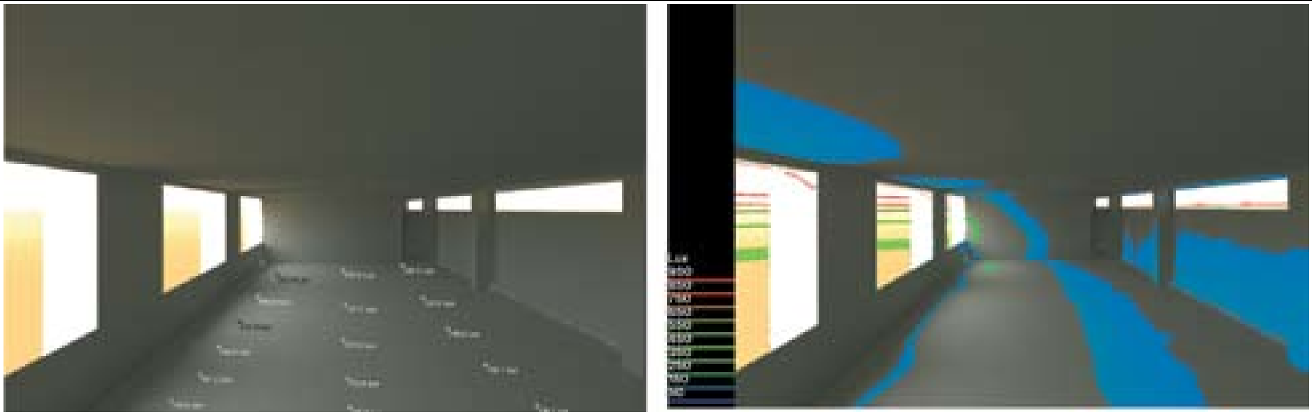
Recommendation: As the achieved daylight level is much less than the required (152 lux), so it was recommended to increase the window area and also provide multiple clerestory windows at the rear wall of the office rooms.

Case-2: Daylight simulation for eastern façade: (With increased window sizes and recommended clerestory windows)



Achieved daylight level at centre of daylight zone is 152 lux

Case-3: Daylight simulation for southern façade: (With increased window sizes and recommended clerestory windows)



Achieved daylight level at centre of daylight zone is >152 lux

Conclusion

Courtyard type buildings are very suitable for the composite climate.As borne out by this case study. External openings do require shading devices during the hot and warm season. Large projections, wide openings besides wide verandahs are needed in the warm humid season so as to provide multiple gains like adequate shading, reduced sky glare and enhanced daylight. However, composite climate with changing seasons sets a difficult task to the building designers so as to adopt suitable solar passive measures round the year. ECOTECT helps the designers in identifying the best possible solar passive structures and quantifying the resultant impact in terms of energy efficiency. It eases the implementation process of solar passive architecture and helps to revive the ancient culture of sustainable buildings in India.

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:
Arani Sinha, TERI Press
TERI
Darbari Seth Block, IHC Complex
Lodhi Road
New Delhi: 110 003
Email: arani.sinha@teri.res.in

FREEPLAY-LABL LANTERN

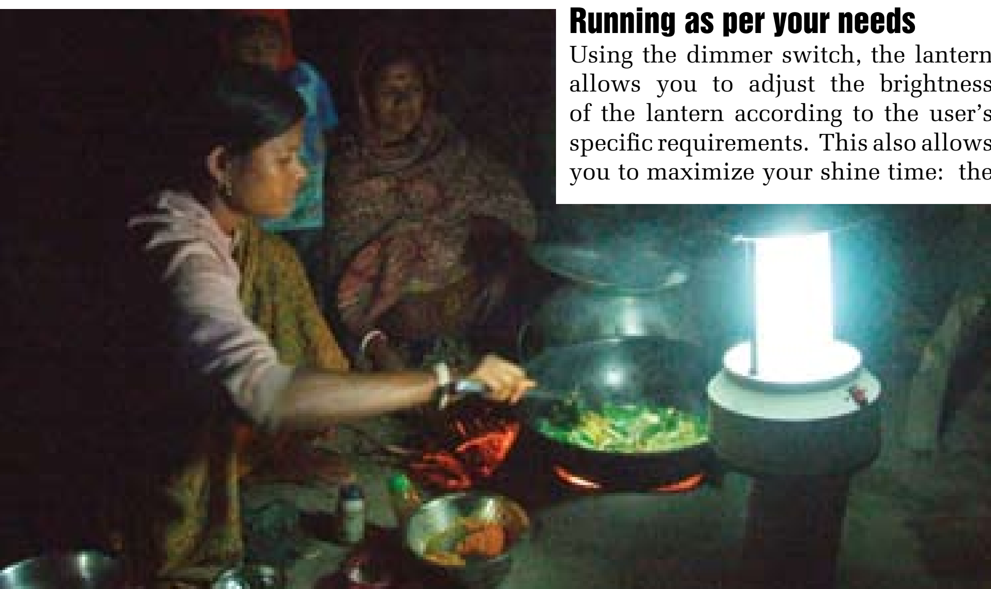
SHIVANIE NARANG, Executive Assistant, Freeplay Energy Group
<shivanie@freeplayenergyindia.com>

From darkness to light

In the last couple of year, the Government of India has taken number of initiatives in the field of renewable energy. However, despite these efforts, a considerable number of villages are still groping in the 'dark'. Driven by its core purpose—'To make energy available to everybody all the time', Freeplay has implemented and produced strong efficiency standards for new appliances and products, and is committed at giving cost-effective renewable energy products to the customers.

Freeplay offers a wide range of products. These include mobile power, emergency essentials, audio, light, integrated and medical equipments. These are efficiency-based products having renewable energy as energy sources, which use less energy in India's high carbon economy.

An example is the Freeplay – LaBL Lantern, which was developed primarily for users to use less energy and enjoy higher efficiency. Freeplay has helped drive down the cost of clean technology and hopes to increase the Indian capacity to respond effectively and sustainably to a booming domestic energy demand. Freeplay – LaBL Lantern is an answer to practically all the portable lighting needs and is also environment friendly.



The long drawn association

The lantern features a cluster of ultra-bright LEDs (light emitting diode) as the primary source of light for space illumination, and also has a single-LED directional light source for use as a reading light or flashlight. In addition to wall recharging ability and solar charging facility one can power it by using the trusted Freeplay self-charge technology, so that one never runs out of power. That, combined with the reliability of ultra-bright white LEDs rated for 100 000 hours, makes it the most dependable lantern in the market. With a long life battery and LEDs in the lantern, the LaBL Lantern will work whenever one needs it, anytime, anywhere. And one will experience excellent brightness and shine time.

Ideal for everyday and emergency use, indoors and outdoor, the lantern puts the power in the user's hand. The self-charging system offers the maximum dependability for those times when the user cannot afford to be left in the dark by dead batteries. A quick wind (for about 60 seconds) provides up to five minutes of light on the lowest setting. An effort indicator LED tells the user the optimal winding speed. The battery status indicator LED tells the user the remaining battery capacity.

Running as per your needs

Using the dimmer switch, the lantern allows you to adjust the brightness of the lantern according to the user's specific requirements. This also allows you to maximize your shine time: the lower the brightness, the longer the shine. The included reading light / flashlight is also a LED with excellent performance, delivering 10 minutes of brilliant white light per second of wind availability. There is also an additional feature of mobile charging, wherein one can charge a mobile by connecting it to the lantern directly.

The dual mode charging

The lantern is rechargeable, either by winding or by a separately available solar panel. When fully charged, the lantern provides up to five hours of continuous ultra bright light using the LED cluster. Similarly the directional light will shine for up to 35 hours continuously.

The physical gains

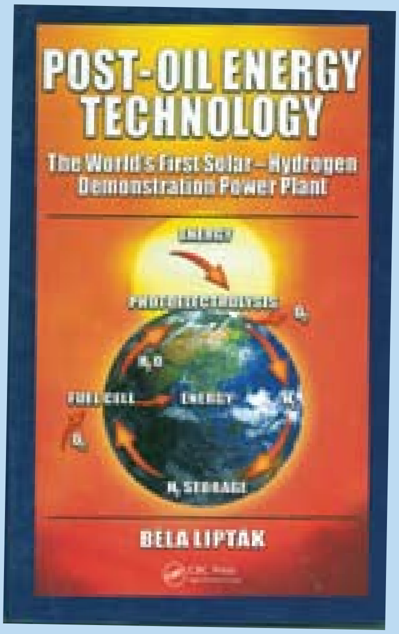
The rechargeable battery means that there is no use of disposable batteries that are harmful to the environment. Internal mechanical components are specified to industrial standards for repeated use and long life. A handle swings up to let the user carry or hang the lantern as required, and the sturdy rubber feet allow for placement on uneven surfaces.

The true freedom

With the Freeplay - LABL Lantern, there is light anytime, anywhere.

Book review

Post-Oil Energy Technology:
The World's First Solar-Hydrogen Demonstration Power Plant



Post-Oil Energy Technology: The World's First Solar-Hydrogen Demonstration Power Plant

Boca Raton: CRC Press

ISBN : 978-1-4200-7025-5

Pages: 571

Demonstrating the feasibility of a clean, renewable global energy future, Post-Oil Energy Technology: the World's First Solar-Hydrogen Demonstration Power Plant describes the detailed design of the first 1000 MW (megawatt) solar power plant with hydrogen storage. In this book, the author explains how a solar-hydrogen economy is technically feasible and cost-effective. He first outlines existing conservation technologies and renewable energy processes as well as evolving technologies, such as energy-free homes, roof shingle solar collectors, and reversible fuel cells. He goes on to discuss energy optimization techniques that could reduce the energy consumption of industrialized countries by 25% and that of third world countries by even more. Liptak also shows that we already have the know-how – optimizing large solar power plants, providing solar energy storage in hydrogen, and operating reversible electrolyzers – to build a full sized renewable energy demonstration plant. With global energy consumption quadrupling in the last 50 years and atmospheric carbon dioxide reaching the highest level ever recorded, now is the time to prevent further damage to the planet and to protect future generations from the collapse of the human civilization. This book provides the facts about renewable energy, proving that it can slowly and eventually stop global warming, stabilize our climate, eliminate the possibility of energy wars, and improve the world's economy. All that we need are leaders who will start this—the 3rd industrial revolution.

The author argues that his main objective behind writing this book is to show the world that the future is not bleak, and we can overcome the present crisis of climate change and global warming. The book describes the technical design of the new type of plant; tries to find ways to solve the energy crisis, eliminate global warming, reduce starvation, and enrich the economy; present a pragmatic and realistic strategy of transiting from a fuel-and nuclear-based economy to an economy based on clean and renewable solar hydrogen; and incorporate process control and optimization techniques for energy conservation. The book is divided into several sections and subsections. And each sections deals with various aspects of how the world can move towards a more sustainable future. It is divided into five major chapters. Chapter one justifies the need for renewable energy in today's world. By analyzing global trends regarding non-renewable energy, global warming, and the existing energy politics, the section places an argument in favour of renewable energy. The next two chapters give various technical information and energy optimization that could reduce the energy consumption of industrial countries by about 25%. These two chapters also brings to the forefront the understanding that we already have the know-how to build a full-sized, renewable energy demonstration plant, optimize large solar power plants, herd the collectors to track the Sun and provide the storage in hydrogen and other forms, energy-efficient homes, burn hydrogen in modern fuel cells, and so on. The technological know-how is there, thus what we need is an attitudinal change to use theses technologies for a better future. The fourth chapter provides with the detailed design of what the author calls the world's first full-sized solar-hydrogen demonstration power. The author provides a detail estimate the technological efficiencies and costs. The final chapter compares the energy options available to mankind.

After reading the book, one feels that the shift to a complete renewable-based economy is not something impossible. It is very much possible and can be done in a cost-effective and orderly fashion. The book is a must read for us to work towards a sustainable and energy-efficient future.

Reviewed by
Shantanu Ganguly and
Arani Sinha, TERI

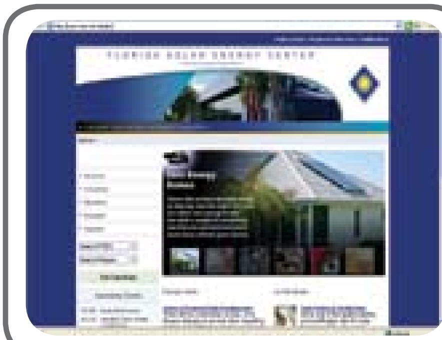
Web update

American Solar Energy Society

The ASES (American Solar Energy Society) is doing untiring work toward promoting solar energy through education. The organization is considered a leader in the field of promoting the use solar energy in the US and in the international community. Apart from presenting news and updates on the organization itself, the site also features articles contained in the Solar Today magazine. The site also has information on the incentives in the field of solar energy, all the important upcoming events and conferences, and people's involvement in making the society energy efficient.

http://www.ases.org./

Florida Solar Energy Centre



The official website of the Florida Solar Energy Centre provides comprehensive information on solar energy. It provides updates and news on research and developments made by the centre toward promoting the use of solar energy in the state. The site provides full information on usages, benefits, and, technological developments in the field of solar energy to contractors, builders, utilities, universities, researchers, teachers, students, colleges, energy professional, home owners, business owners, entrepreneurs, and so on.

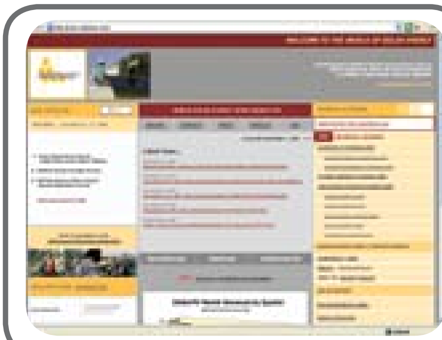
http://www.fsec.ucf.edu/en/

The International Solar Energy Society - A Global Alliance

This site supports the development and use of renewable energy technology. It is maintained by the International Solar Energy Society, a non-governmental organization accredited by the United Nations and aims to promote sustainable energy on a global scale. The site provides information on various books available in the market on solar energy. It gives detailed information on all upcoming ISES conferences and seminars.

http://www.ises.org/ises.nsf

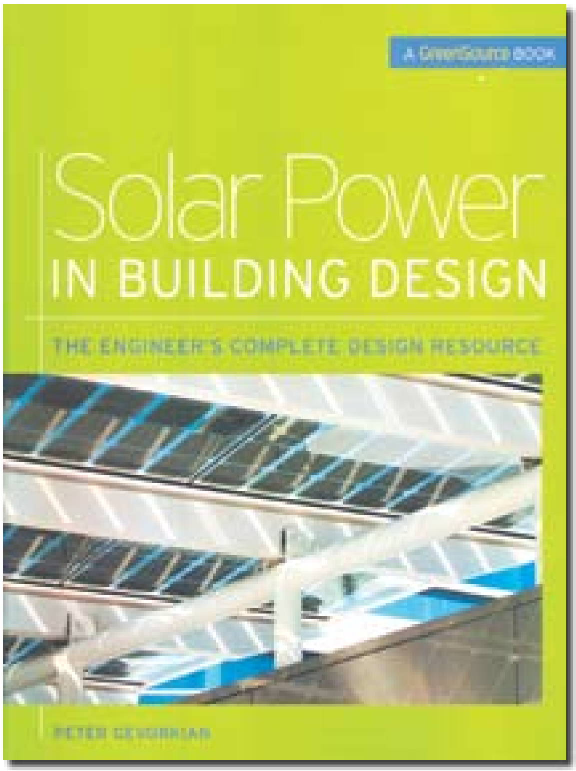
Solar Energy



Solarbuzz is an international solar energy research and consulting company. The mission of Solarbuzz is to be the leading SPV energy consultant in the world. Through the website, the user can get information on Global Solar Market and Supply developments, access to Solarbuzz research and consultancy services, or connect to Solar Energy Companies Worldwide. The website also provides world solar energy news, weekly newsletter on solar energy news, and information on solar energy products.

http://www.solarbuzz.com/

New Book Information



Solar Power in Building Design: The Engineer's Complete Design Resource

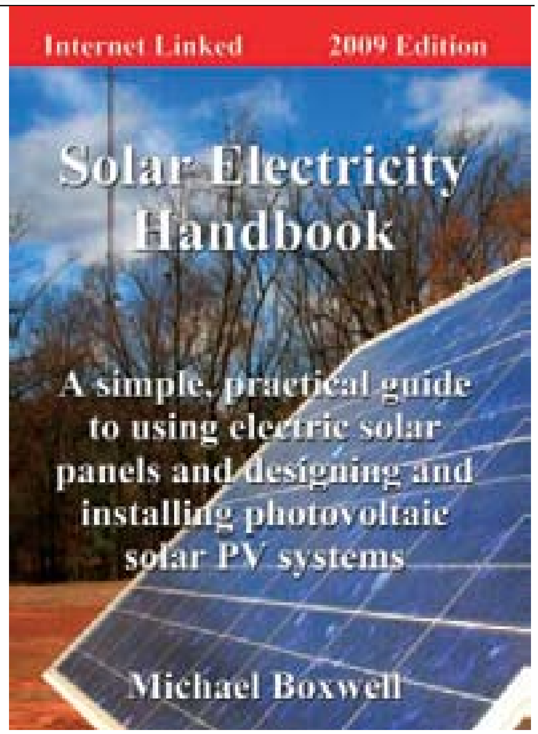
Solar Power in Building Design is a complete guide to designing, implementing, and auditing energy-efficient, cost-effective solar power systems for residential, commercial, and industrial buildings. Filled with case studies and illustrations, this state of the art design tool covers new solar technologies; design implementation techniques; energy conservation; the economics of solar power systems; passive solar heating power; and more. The book features the following aspect.

- Step-by-step instructions for designing, implementing, and auditing solar power systems
- Expert guidance on using solar power in any type of building-from basic theory through project planning, cost estimating, and manufacturing
- Complete details on Leadership in Energy and Environmental Design, plus rebate procedures and forms.

Gevorkian, Peter, 2008
The McGraw Hill, New York, pages 476
ISBN: 978-0-07-148563-0

Solar Electricity Handbook

The Solar Electricity Handbook is a simple, practical guide to using electric solar panels and designing and installing photovoltaic solar PV systems. The book includes numerous examples and is written for anyone interested in finding out more about solar electricity or planning their own solar photovoltaic installation. Readers also gain access to a web site with a comprehensive set of solar calculators and online tools to make solar design as straightforward as possible.



Boxwell, Michael, 2009
Code Green Publishing, pages 152
ISBN: 9781907215018

Events calendar

National events

The first Annual Renewable Energy Business Conference
19–20 January 2010, Mumbai

E-mail leon.dias@informedia-india.com
Web http://informedia-india.com

National Symposium on Energy and the Environment
28–29 January 2010, Coimbatore, India

E-mail principal@kptc.ac.in
Web www.kptc.ac.in/regi.php

DSDS (Delhi Sustainable Development Summit) 2010
5–7 February 2010, New Delhi

Tel +91 11 24682100/ 4150 4900;
Fax +91 11 24682144/ 24682145
E-mail dsds@teri.res.in
Web dsds.teriin.org/2010/index.php

PV+Solar India Expo 2010
1–3 March 2010, Mumbai

Tel 91 22 26730 869
Fax 91 22 26730 547
Web www.electronicstoday.org

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

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

Renewtech India 2010
9–11 March 2010, Pune, India

Tel 49 211 38-6000
Fax 49 211 38-44909
E-mail k.schlickmann@mco-online.com
Web www.renewtechindia.com

International

International Conference on Emerging, trends in energy and environment
7–8 January 2010, Chennai, Tamil Nadu

Tel 044 2251 2220 / 2251 2
Fax 044- 2251 2229
E–mail sairam@ssec.edu.in, career@ssec.edu.in
Web http://www.ssec.edu.in

World Future Energy Summit
18–21 January 2010, Abu Dhabi, United Arab Emirates

Tel 44 208 271 2134
Fax 44 208 910 7823
E-mail rxinfo@reedexpo.co.uk
Web www.worldfutureenergysummit.com

Solar Power Generation USA
20–21 January 2010, Las Vegas, Nevada, USA

Tel 1 207 099 0600
Fax 1 207 900 1853
E-mail info@greenpowerconferences.com
Web www.greenpowerconferences.com

4th China New Energy International Forum and Expo
20–22 January 2010, Beijing, China

Tel 86 10 6310 0807
Fax 86 10 6310 7703
E-mail wanghaiying@cnecc.org.cn
Web www.neforum.cn

PV Power Plants 2010
25–26 January 2010, Prague, Czech Republic

Tel 49 30 726296304
Fax 49 30 726296309
E-mail miriam.hegner@solarpraxis.de
Web www.solarpraxis.de

Renewable Energy Technology Conference and Exhibition RETECH 2010
3–5 February 2010, Washington, DC

Tel 832-242-1969 ext. 308, 713-343-1875
E–mail hunterj@tradefairgroup.com
Web http://www.retech2009.com

ExpoSolar 2010
3–5 February 2010, Gyeonggi, Korea

Tel 82 2 718 6931
Fax 82 2 715 8245
E-mail InterExpo@infothe.com
Web www.ExpoSolar.org

Solar Future 2010
11–12 February 2010, Istanbul, Turkey

Tel 90 212 2 758359
Fax 90 212 2 113850
E-mail info@solarfutureconference.com
Web www.solarfutureconference.com

PV Expo 2010
3–5 March 2010, Tokyo, Japan

Tel 81 3 33498576
Fax 81 3 33498535
E Mail pv@reedexpo.co.jp
Web www.pvexpo.jp

Semicon China 2010
16–18 March 2010, Shanghai, China

Tel 8621 50495-688
Fax 8621 50495-5788
E-mail semichina@semi.org
Web www.semi.org

Industry Registry

1. Canadian Solar Inc.
650 Riverbend Drive, Suite B, Kitchener
Ontario, Canada N2K3S2
Tel+1-519-9542057
Web www.canadian-solar.com

2. Chint Solar (Zhejiang) Co., Ltd
211 Jiangling Rd. Binjiang District Zhejiang
Hangzhou, China 310053.
Tel +86/571/86621337
Fax 88621316
Web http://www.astronergy.com

3. Photovoltech NV
Grijpenlaan 18 3300 Tienen, Belgium
Tel +32/16/805850
Fax 805905
e-mail info@photovoltech.be
Web www.photovoltech.be

4. Polar Photovoltaics C., Ltd,
268 Tanghe Rd.
Bengbu Anhui, 233030, China
Tel +86/552/3178220
Fax 3178211
e-mail sales@polar-pv.com
Web www.polar-pv.com

5. Q-CelisAG
Guardianstr. 16, OTThalheim 06766
Bitterfeld-Wolfen, Germany
Tel +49/3494/6699-0,
Fax -199
e-mail q-cells@q-cells.com,
Web www.q-cells.com

6. Risen Solar
Tashan Industry Zone, Meilin,
Ninghai Ningbo, China
Tel +86/574/65173-1 07,
Fax -959
e-mail vina@risen-lighting.com
Web www.risen-solar.com

7. Shinsung Holdings
#404-1 Baekhyeon-Dong Bundang-Gu,
Sungnam-si, Kyunggi-Do 463-420
Korea
Tel +82-31-788-9332,
Fax -9584
e-mail solar@shinsung.co.kr,
Web www. shinsung.co.kr

8. Solland Solar Energy B.V.
Aachen-Heerlen Bohr 10 - Avantis
NL-6422 RL Heerlen, Netherlands
Tel +31/45/8800-600,
Fax -605
e-mail info@sollandsolar.com

9. Sunways AG
sunways AG Photovoltaic Technology
Macairestr. 3 - 5, 0-78467 Konstanz
Tel +49/7531/99677-0,
Fax -10
e-mail info@sunways.de.
Web wwwsunways.de

10. Tainergy Tech Co., Ltd,
No 5, Tzu Chiang 1" Road,
Chungli Industrial Zone,
Taoyuan Hsien, Taiwan
Tel +886/3/4555807
e-mail tainergy@tainergy.com.tw

11. Top Green Energy Tech Inc.
No. 330 Hesing Rd., Jhunan Township
Miaoli County 350, Taiwan
Tel +886/37/280588,
Fax 581200
e-mail sales@tgenergy.com.tw
Web www.tgenergy.com.tw

12. Canadian Solar Inc,
650 Riverbend Drive, Suite B,
Kitchener Ontario, Canada
N2K 3S2
Tel +1-519-9542057
e-mail inquire.ca@canadian-solar.com
Web wwwcanadian-solar.com

13. Engineered Solutions
555E. California Avenue
Sunnyvale, CA 94086, USA
Tel 1/408/617-2800
Fax -2850
e-mail esinfo@engrsolutions.com
Web www.engrsolutions.com

14. Ningbo Ullca Solar Science&Technology Co.,
NO.1,Shanshan Road,
Wangchun Industrial District, Ningbo, China
Tel +86/21/54234527, +86/574/28828976
e-mail sales@ulsolar.com.cn, info@ulsolar.com.cn
Web wwwulsolar.com.cn

15. REC ASA
Kjorboveien 29 NO-1337
Sandvika, Norway
Tel +47/67574450,
Fax 67574499
Web www.recgroup.com

16. Risen Solar
Tashan Industry Zone,
Meilin, Ninghai Ningbo, China
Tel +86/574/65173-1 07,
Fax -959
e-mail vina@risen-lighting.com,
Web www.risen-solar.com

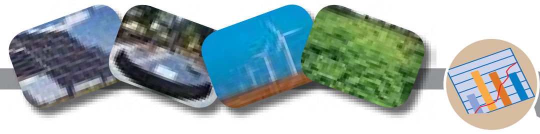
17. Solar Swiss
5 CH-8280 Kreuzlingen, Switzerland
e-mail info@solar-swissch
Web www.solar-swiss.ch

18. ABET-Technologies, Inc.
168 Old Gate Lane
Milford, CT, USA
Tel +1/203/540-9990
Fax 301-0059
Web abet-technologies.com

19. Atlas Material Testing Technology
4114 North Ravenswood Avenue
Chicago, IL 60613 USA
Tel +1/773/3274520
Fax + 1/773/3275787
e-mail info@atlas-mts.com
Web www.solar.atlas-mts.com

20. Newport Corporation
1791 Deere Ave, Irvine, CA, USA
Tel + 1 949 8633144
e-mail sales@newport.com
Web www.newport.com

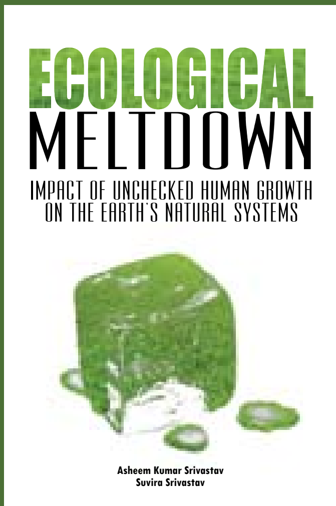
Renewable energy at a glance



S.No.	Source/system	Estimated potential	Achievement as on 31 October 2009
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	10891.00
2	Bio power (agro residues and plantations)	16 881	816.50
3	Bagasse cogeneration	5 000	1 241.00
4	Small hydro power (up to 25 MW)	15 000	2 519.88
5	Energy recovery from waste (MW)	2 700	67.41
6	Solar photovoltaic power	—	6.00
	Sub total (A)	**84 776**	**15541.79**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	181.37
8	Biomass gasifier	—	108.37
9	Energy recovery from waste	—	37.97
	Sub total (B)	**—**	**327.71**
	Total (A+B)	**—**	**15869.50**
II	**Remote village electrification**	—	5554 villages/hamlets
III	**Decentralized energy systems**		
10	Family-type biogas plants	120 lakh	41.42 lakh
11	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting system	—	82 384 nos
	ii. Home lighting system	—	510 877 nos
	iii. Solar lantern	—	767 350 nos
	iv. Solar power plants	—	2.39 MW_p
	v. Solar photovoltaic pumps		7247 nos
12	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	3.12 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

FORTHCOMING TITLE



The Ecological Meltdown:

impact of unchecked human growth on the earth's natural systems

By

Asheem Kumar Srivastav is a senior civil servant (Indian Forest Service) professionally trained in environment and natural resource management

Suvira Srivastav is a development communicator and an environment journalist

ISBN: 978-81-7993-278-0; Number of Pages: 250 (approx)
Year: 2010; Size: 6 x 9 inches

Description

The book rings alarm bells of the ecological meltdown, footsteps of which are getting louder with every passing day. The difference between the current recession, and the one mentioned in the book is that there are ways and means to recover from a financial crisis. However, the picture that emerges from the exhaustive analysis of international data drawn from the most reliable sources clearly indicates that we have reached a point of no return: humanity has gained access to the gateway of extinction where the other biological species will disappear first followed by humans.

The book reinforces the key findings of the millennium ecosystem assessment report of the UN that humans have made unprecedented changes to the ecosystems and this pressure will increase globally, in coming decades, unless human attitudes and actions change.

Features

- Thoroughly researched and analytical
- Authoritative and up-to-date data from the most authentic sources
- Scientific data supported by graphs, figures, and tables
- Offers a global as well as Indian perspective on the issues
- A must read for all those who are concerned for the planet's future

Contents

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