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## Wanted an aggressive outlook on renewable energy

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## Current research on renewable energy and development

A compilation of annotated bibliographies from different leading periodicals on current research on renewable energy and environment.



## Technological developments

Some of the recent technological developments in the field of development are discussed.



## Web updates

This section picks up some of the web resources available in the fields of renewable energy and environment.

## Conferences/workshops/seminars

Covering some of the major forthcoming events in the field of environment, renewable energy, and sustainable development...

# Wanted an aggressive outlook on renewable energy

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## Introduction

RE (renewable energy) has matured and entered into a commercial stage as a viable source of energy, and would soon cease to be termed as a non-conventional resource. In spite of earlier inhibition on high capital cost, extensive R&D (research and development) and feed back from field-level application have finally made it possible for wind, biomass, bio-energy, and micro-hydro power to reach a stage to compete and supplement conventional energy in terms of cost/kWh, and supply of clean energy. The exception is solar power that would soon be inducted as a precious, 100% non-polluting, and sustainable source of energy.

The price of oil is soaring. Coupled with this, concern on depletion of reserves, new discoveries falling short of the rate of rise in demand, and above all, threat of global warming due to GHG (greenhouse gas) effect are prime factors to go in for sustainable and clean energy. This philosophy is the driving force in developed countries that are bound by the Kyoto Protocol to scale down pollution between 2008–12 by 5.2% of the 1990 level. RE has contributed significantly to the Indian scenario. Distributive nature of power generation in isolated places, like remote hilly areas, villages situated at long distances, or in islands, makes it imperative to mitigate demand for power through locally available renewable resources in absence of economic viability of grid line extending there. Another important aspect is that more than 40% of the population is outside the ambit of connectivity with power system, majority being in rural areas. The national policy on power has the commitment to set right the imbalance, and RE has a big role to play on this account.

RE potential is estimated at 90 000 MW (megawatt) approximately. This is exclusive of solar energy that is 20 MW/km<sup>2</sup> (square kilometres). One per cent of land including rooftops earmarked for solar power will generate more than 600 000 MW. Till December 2004, achievement in the RE sector as a whole was

about 5700 MW, which is no doubt a landmark. This was about five per cent of the country's total installed capacity including hydro, thermal, and atomic power. However, this is only about six per cent of the total estimated RE potential. We have a long way to go in this field. With technological development it should be possible to implement schemes for RE to share 10% of total installed capacity by 2012. The 12 000 MW target assigned for RE, about five per cent of total installations by end of Eleventh plan, will expectedly be fulfilled, but that should not give any complacency. The present base is low, and as such a sustained annual growth of 30%–35% should be aimed at. Admittedly, financing is a problem, as it is in other sectors, even though 100% FDI (foreign direct investment) is allowed for RE. There is a need for working out ways and means to attract large investment for new projects, and gain experience in innovations towards further reduction of cost of energy.

## Wind

WEG (wind electric generation) has a good take off, and growth is oriented in commercial pattern with 97% investment from private entrepreneurs. Wind has the highest installed capacity of 3600 MW since March 2005. Considering the potential as 45 000 MW, and 13 000 MW identified as techno-economically viable now, prospect for higher growth rate is bright. Inclusion of offshore areas will revise the potential upwards. Capital cost being almost the same as thermal power, the gestation period being one year, and open access system becoming operational in transmission of power, WEG signals a trajectory of fast growth. However, it is necessary that certain issues be looked into for inviting more investment. In line with steps taken by Reliance Energy, or ONGC mulling the idea, NTPC or thermal power generators and other petroleum companies, as profit-making undertakings, setting up WEG units will boost wind power. Thermal energy-generating companies should be persuaded to purchase at least five per cent of their generation from RE

resources—wind power will be foremost in this case. The quantum of purchase from RE sources will be so low in the whole gamut of energy sale that it will hardly have any impact on the overall tariff ultimately chargeable to consumers. A higher tariff for WEG generation, subject to decision of regulatory commissions, will be an element of incentive to accelerate growth.

WEG industry is providing employment and helping economic growth in many ways. Considering this, assistance from the government in the form of interest subsidy at the rate of two per cent for a certain period with the objective of commissioning additional 10 000 MW may be logical. Budget provision on RE is too small, nearly two per cent of provisions for total energy sector. This calls for doubling up to include the aforesaid subsidy for assuring annual capacity rise at a rate of 2000 MW on an average per year in next five years. Here, technologists also have a great responsibility to raise capacity utilization factor from the present 20%–25% to 25%–30% for enhanced energy output from same investment.

### Micro hydel

In terms of installed capacity, next comes micro hydel that has gone up to nearly 1700 MW by December 2004. Micro hydel power is environmentally benign and free from ecological problems unlike large hydro projects. Small hydropower stations mostly in hilly areas are given priority for local benefits and gainful utilization of energy potential of flowing water. It may be necessary to reassess the potential now estimated as 15 000 MW keeping in view that renovation of many old units will yield higher output. Incentive schemes should include renovation and modernization to rehabilitate old units. Micro hydel stations often encounter peculiar situations on power evacuation for excess quantity after meeting local demand. It is desirable that evacuation of power be integrated into the scheme for promoters to be entitled to benefits. Exploring new areas for micro hydel where head is low (between three and five metres) and discharge is high to generate power from number of canal falls might be of interest.

### Biomass

India is blessed with forest and agriculture. Waste and residues are ingredients for biomass power

through three routes: direct combustion, cogeneration, and gasifier system. In the first two categories installations of 727 MW and 62 MW capacity are commissioned under gasifier system, making a total installed biomass power generation capacity upto 789 MW till December 2004 against an estimated potential of 19 500 MW. Energy from biomass is not 100% pollution free, but the adverse effect is minimal. About 25%–30% of diesel as supplement is required in gasifiers. However, this has now been overcome in the latest model to deliver 100% gas output. A fast rate of progress in biomass energy on 100% gas delivery for small power generation or direct combustion in engines can replace hundreds of diesel-generating sets used for irrigation in rural areas.

The government is commendably attempting to link up biomass availability through new plantations for generating power and afforestation especially in the tribal belt. Cultivation of bio-diesel plants (jatropha and other species) maturing in three to five years in wasteland for extracting oil, and utilizing plants as biomass for heat and power are some new encouraging features of the governmental endeavour.

However, causes for slow progress in ongoing bio-diesel plantation schemes need be examined with a greater thrust since biomass is an important tool having close interaction with rural economy to provide village-level energy security.

### Solar power

Solar power is unlimited, but it has a constraint in power generation through the SPV (solar photovoltaic) method because of high cost. There is extensive research on improving technology and reduction of cost all over the world since this is the most convenient form to generate power. In fact cost per unit is getting halved in each decade because of upgradation of technology. Hence, by 2010, SPV may become as competitive as other resources. Solar power enjoys good amount of subsidy in rural application along with other modes of rural electrification under a latest directive where the central government bears 90% of the cost. In this country, solar energy is harnessed through SHS (solar home-lighting systems), solar lanterns, and centralized power plants. In islands, Sunderbans and Lakshadweep in particular, solar power plants for distributive

nature of grid quality power are becoming popular. This caters to tiny industrial, commercial, and agricultural load also. Improvements in quality of life, and opening up of employment opportunities are important contributions. Achievement in solar power, in a developing country like India is 191 MW as on December 2004. This includes export of 105-MW products.

Till indigenous manufacturing of basic materials is developed, there is difficulty in substantially lowering capital cost and energy charge per kWh (kilowatt hour) for widespread use of SPV power. This is an area where adequate stress has become inevitable, following China's foot steps for producing basic materials to manufacture solar cells through R&D (research and development) at lower than international market rates. Solar power is subsidized all over the world through budgetary support. There should be no deviation here to gain experience associated with cost reduction through large-scale production.

Other uses of solar power are in the form of solar water heating and air drying, though the former is the most common. Solar water heating has started late, but it is gaining ground. Statutory regulations for incorporation of solar heaters in buildings are being imposed in many states that will foster growth. Against a potential of 140 million m<sup>2</sup> (square metre) of collector area, the achievement till December 2004 is one million m<sup>2</sup> only, or less than one per cent. Also, for solar cookers where against a potential of 120 million units, numbers installed are about 25% during this period. These findings indicate there is a need for good amount of work.

### Bio-energy

Biogas plants and power from biodegradable waste falls under this group. Power potential is envisaged as 1400 MW out of which 46.50 MW (or about three per cent) has been implemented by December 2004. The bottleneck of technological barrier faced so long appears to have been overcome. There is an urgency amongst municipal authorities, because of land filling and sanitation problems, to utilize wastes for both

power and manure. Hopefully, there will be progress now in this direction. The potential assessed is about 12 million biogas plants based on animal population. The achievement so far is 3.7 million (30%+) by December 2004. A biogas plant is highly profitable for generation of income to rural people, and the government assistance is also liberal. Setting up of these plants, involving low investment, is interlinked, like biomass programme, with rural economy and cheap energy supply. Progress depends on promotion through NGOs (non-governmental organizations) and panchayats. A good publicity network for educating people is essential.

### Fuel cell

Fuel cell is predicted to be the future energy, the source being hydrogen. Commercialization is advancing through research, prototypes, and applications from laptops to automobiles and stationary power plants. Projects on fuel cell are still in the laboratory stage here. With talents available in the country there should no reason that fuel cell technology will lag much behind Japan, the US, EU, or China. A hydrogen board is already working on this.

### Conclusion

RE is very important in terms of mitigating greenhouse effect and providing energy security especially at the backdrop of dependence on oil import. Developed countries, and China are also targeting 20% power generation by 2020 from renewable resources. India should also declare a policy and practical road map for each of the resources available to harness full potential. The country is meeting challenges, but recent developments in the international energy market, and with oil price heading northwards to \$100 per barrel, there is now special call for an accelerated development. This obviously demands an aggressive outlook for working out ways and means for growth at a steady rate. The approach lies in attracting private participation by addressing the points standing as hurdles in the way to opening up new opportunities.

# SHP and its development in India

## Introduction

SHP (small hydro power) is a non-polluting eco-friendly, and renewable source of energy. Small hydro systems harness the energy of running water through turbines, and convert this energy into electricity. SHP uses water resources towards inflation-free energy due to absence of fuel cost with easily available technology and equipment. Among the various renewable sources of energy, small hydro is significant in the form of decentralized power generation. This is true even in hilly regions where the terrain is difficult for promotion of other energy sources.

Hydropower contributes to about 20% of the total world electricity generated. It is the preferred source of power generation in many countries including Norway (99%), Brazil (86%), Switzerland (76%), and Sweden (50%). In India about 25% of the total power generated is from hydropower (31 120 MW [megawatt] out of 121 420 MW). Although, hydro power projects have been recognized as an economic and reliable source of power, the share of hydropower in India has been declining over the last few decades. For grid stability the ideal hydro–thermal mix ratio is 40:60. It is therefore, necessary to correct the hydro–thermal mix to meet the grid requirements and peak power shortage. Hydro power projects are categorized into two segments: small and large hydro. All projects below 25 MW are considered as small hydro projects.

## SHP and its benefits

The biggest advantage of SHP is that it is the only ‘clean’ and renewable source of energy available round the clock. It is free from many environmental issues and controversies associated with large hydro projects such as the submergence of forests, siltation of reservoirs, rehabilitation and relocation, and seismological threats. SHP projects are also user friendly, and easy to design and manufacture; they support decentralized power–generation plan; and have a low plant cost, and short gestation period.

In addition to these obvious benefits, SHP has numerous economic benefits as well. It has served to enhance economic development and living

standards especially in remote areas with limited or no electricity. In some cases, rural dwellers have been able to manage the switch from firewood for cooking to electricity, thus limiting deforestation and also cutting down on carbon emissions. On the macro level, rural communities have been able to attract new industries – mostly related to agriculture – owing to their ability to draw power from SHP stations. In countries like South Africa, China, and Nepal, rapid SHP development has also enthused small, local manufacturers to support these hydro power plants.

The main advantages of hydropower are as follows.

- Power is usually continuously available on demand
- Given a reasonable head, it is a concentrated energy source
- The energy available is predictable
- No fuel and limited maintenance are required, so running costs are low (compared with diesel power), and in many cases imports are displaced to the benefit of the local economy
- It is a long-lasting and robust technology; systems can last for 50 years or more without major new investments

Against these, the main shortcomings are as follows.

- It is a site-specific technology; sites that are well suited to the harnessing of water power, and are also close to a location where the power can be economically exploited are not very common
- There is always a maximum useful power output available from a given hydropower site, which limits the level of expansion of activities which make use of the power
- River flows often vary considerably with seasons, especially where there are monsoon-type climates; this can limit the firm power output to quite a small fraction of the possible peak output
- Lack of familiarity with the technology and how to apply it inhibits the exploitation of hydro resources in some areas

## Basics of SHP technology

SHP technology was introduced in India at the 130-kW (kilowatt) plant at Darjeeling in the year 1897. A few other powerhouses belonging to that period are reported to be still functioning properly. Most of these utilized the high head available at the sites, and impulse turbines were generally preferred in such conditions. Initially, the development of SHP was restricted to small hilly streams in the Himalayan region lacking alternative sources of power. Later, between 1930 and 1950, some low-head SHP installations came up on a number of canals on the river Ganga. The major impediment to SHP stations in the early stages was that high-voltage transmission lines had not been developed, resulting in heavy line losses wherever the load centres were spaced far apart.

SHP is not simply a reduced version of large hydro plant. Specific equipment is necessary to meet fundamental requirements with regard to simplicity, high energy output, maximum reliability, and easy maintenance by non-specialists. The main requirement for hydropower is to create an artificial head so that water, diverted through an intake channel or a pipe (the penstock) into a turbine, discharges back into the river downstream. Small hydropower is mainly 'run-off-the-river'. It therefore does not involve significant impoundments, which require the construction of large dams and reservoirs. There are two broad categories of turbines. Impulse turbines (notably the Pelton) are those in which a jet of water impinges on the runner, which is designed to reverse the direction of the jet and thereby extract momentum from the water. This turbine is suitable for high heads and 'small' discharges. Reaction turbines (notably Francis and Kaplan), run full of water and, in effect, generate hydrodynamic 'lift' forces to propel the runner blades. These turbines are suitable for medium to low heads, and 'medium' to 'large' discharges.

The theoretical power ( $P$ ) available from a given head of water is in exact proportion to the head  $H$  and the flow  $Q$ .

$$P = Q \times H \times c, \text{ where } c = \text{constant}$$

' $c$ ' is the product of the density of water and the acceleration due to gravity ( $g$ ).

If  $P$  is measured in watts,  $Q$  in  $m^3/s$  and  $H$  in metres, the gross power of the flow of water is:

$$P = 1000 \times 9.8 \times Q \times H$$

This available power will be converted by the hydro turbine into mechanical power. As a turbine has an efficiency lower than one, the generated power will be a fraction of the available gross power.

Water wheels, commonly known as gharats, have traditionally been used in the Himalayan regions for rice hulling, milling of grain, and other mechanical applications. These water mills are normally of very old design, and work at very low efficiencies. It has been estimated that there are more than 1.5 lakh potential watermill sites in the country. New and improved designs of water mills have been developed for mechanical applications as well as electricity generation of 3–5 kW. The MNES (Ministry of Non-conventional Energy Sources) is providing incentives for development and upgradation of water mills. Local organizations such as water mill associations, cooperative societies, registered NGOs (non-governmental organizations), local bodies, and SNAs (state nodal agencies) are being encouraged to take up these activities. Uttaranchal has taken a lead in setting up electricity-generation watermills. Over 250 such watermills were installed in remote and isolated areas of the state. Nagaland has recently commenced setting up watermills/micro hydel sets for rural electrification.

## SHP potential and development

The estimated development potential of small hydro across the world is about 180 000 MW. An estimated potential of about 15 000 MW of SHP projects exists in India. Of this, 4404 potential sites with an aggregate capacity of 10 477 MW for projects upto 25 MW capacity have been identified. As the nodal agency for renewable power generation India, MNES has created a database of potential sites of SHP projects (Table 1) based on information from various states and studies conducted by the Central Electricity Authority.

The aim of this exercise is to map RE potential in the country and bring it on a GIS (geographic information system) platform so as to take investment decisions to set up projects.

During the last 10–15 years, there have been some achievements in the development of SHP projects due to their benefits—particularly concerning the environment, and their ability to

**Table 1** SHP sites and capacity identified in India

State/union territory	No. of sites	Capacity (MW)
Andaman and Nicobar Islands	6	6.40
Andhra Pradesh	286	254.63
Arunachal Pradesh	492	1059.03
Assam	90	148.90
Bihar	92	194.02
Chhattisgarh	174	179.97
Goa	3	2.60
Gujarat	290	156.83
Haryana	22	30.05
Himachal Pradesh	323	1624.78
Jammu and Kashmir	201	1207.27
Jharkhand	89	170.05
Karnataka	230	652.61
Kerala	198	466.85
Madhya Pradesh	85	336.32
Maharashtra	234	599.47
Manipur	96	105.63
Meghalaya	98	181.50
Mizoram	88	190.32
Nagaland	86	181.39
Orissa	161	156.76
Punjab	78	65.26
Rajasthan	49	27.26
Sikkim	68	202.75
Tamil Nadu	147	338.92
Tripura	8	9.85
Uttaranchal	354	1478.24
Uttar Pradesh	211	267.06
West Bengal	145	182.62
<b>Total</b>	<b>4404</b>	<b>10 477.34</b>

Source *Akshay Urja* 1(5): 29 (2005)

produce power in remote areas. As part of the UNDP-GEF (United Nations Environment Project-Global Environment Facility) Hilly Hydro Project, a detailed exercise was undertaken to prepare zonal plans for 13 participating states of the Himalayan and sub-Himalayan region. As a result 2162 potential sites aggregating 3827 MW have been identified. Of these, 52 projects with an aggregate capacity of 56.26 MW have been commissioned during 2003/04. Models have been developed that take into account the regional flow duration curves, geological and seismological data, vegetation cover, etc., and that use GIS for identification of potential sites.

The Indian SHP development programme received a new dimension and tempo after the liberalization of economy, and invitation to the private sector for investment in power. Today the SHP programme is essentially private-investment-

driven. The focus of the programme is to lower the cost of equipment, increase its reliability, and set up projects in areas which give the maximum advantage in terms of capacity utilization.

The installed capacity of SHP projects as on 31 October 2005 is 1729.23 MW from 534 projects. In addition, 230 SHP projects with an aggregate capacity of 602 MW are under implementation. The state-wise details of capacity additions are given in Table 2. Growth of capacity addition from small hydro projects is about 100 MW per year. A capacity addition of 600 MW during 2002-07 is being targeted through a mix of public and private sector projects.

**Table 2** Existing and ongoing SHP projects by state (as on 31 August 2005)

State/union territory	Existing projects		Ongoing projects	
	No. of sites	Capacity (MW)	No. of sites	Capacity (MW)
Andaman and Nicobar Islands	1	5.25	—	—
Andhra Pradesh	57	178.81	9	13.90
Arunachal Pradesh	62	34.30	52	51.42
Assam	3	2.11	7	26.00
Bihar	5	45.90	9	14.00
Chhattisgarh	4	11.00	2	8.00
Goa	1	0.05	—	—
Gujarat	2	7.00	—	—
Haryana	5	62.70	—	—
Himachal Pradesh	52	114.08	11	57.50
Jammu and Kashmir	30	109.74	7	7.31
Jharkhand	6	4.05	8	34.85
Karnataka	52	288.88	23	122.74
Kerala	14	84.62	7	57.75
Madhya Pradesh	8	41.16	3	24.20
Maharashtra	27	207.08	5	25.75
Manipur	8	5.45	3	2.75
Meghalaya	3	30.71	9	3.28
Mizoram	16	14.76	3	15.50
Nagaland	8	20.47	6	12.40
Orissa	6	7.30	7	40.92
Punjab	23	111.40	7	28.35
Rajasthan	10	23.85	—	—
Sikkim	12	35.60	5	15.20
Tamil Nadu	12	77.70	2	7.90
Tripura	3	16.01	—	—
Uttaranchal	76	75.45	37	23.01
Uttar Pradesh	8	21.50	1	3.60
West Bengal	20	92.30	7	5.80
<b>Total</b>	<b>534</b>	<b>1729.23</b>	<b>230</b>	<b>602.13</b>

Source *Akshay Urja* 1(5): 30 (2005)

## Government initiatives

The Government of India announced, in August 1998, a policy on hydropower development, followed by a 50 000 MW hydro-electric initiative in May 2003. Realizing the fact that small hydro power projects can provide a solution for the energy problem in remote and hilly areas where extension of grid system is comparatively uneconomical, and also along the canal systems having sufficient drops, promoting small- and mini-hydel projects is one of the objectives of the policy.

Most capacity addition now is being achieved through private investment. SNAs for RE provide assistance for obtaining necessary clearances in allotment of land and potential sites. SERCs (state electricity regulatory commissions) are now determining preferential tariffs for renewable electricity. Sixteen states have RE policies in place for private sector participation. These states have offered sites to private SHP projects. Over 100 private-sector SHP projects have already been set up with an aggregate capacity of about 400 MW mainly in Andhra Pradesh, Himachal Pradesh, Karnataka, Maharashtra, Punjab, and Uttaranchal.

The nodal ministry, MNES, has been providing subsidy for the public- and private-sector SHPs. Subsidy is provided to the developer for the purpose of offsetting the capital investment and subsequent running cost against the term loan provided by the financial institution. Conditions imposed in such cases include: (1) quality of equipment should meet the international standards, and (2) projects tested for performance by an independent agency.

As there is still an unidentified potential of about 5000 MW in India, MNES has introduced a new scheme for providing financial support for identification of new potential sites, and the preparation of a perspective plan for SHP development. Financial support upto Rs 30 lakh will be provided for the estimation of the SHP potential in a state, identification of new potential SHP sites, and for the preparation of a perspective plan. Besides, Rs 5 lakh are also provided by the MNES to carry out DPR (detail project report) and survey. Survey and

investigation, and preparation of DPRs of 363 potential sites under this scheme has been supported by MNES.

## Conclusion

The SHP sector (upto 25 MW station capacity) is moving towards attaining commercial status in India. SHP projects are increasingly becoming economically viable. It has been recognized that SHP can play a role in improving the energy position in some parts of the country, and in particular in remote and inaccessible areas. The gestation period and capital investments are getting reduced in SHP projects.

Besides, to achieve 8%–10% economic growth rate that India is aspiring for, the country's energy needs will increase accordingly with the growing economy. Supplying best quality power in a sustainable manner, and at a reasonable cost would be one of the biggest challenges that the country would face. Under this perspective, there is a need to tap all possible sources of energy to meet this challenge, and SHP is considered as a reliable and eco-friendly option. The nodal ministry, MNES also aimed that two per cent of the total grid-interactive power generation capacity should come from small hydro so as to provide sustainability to the power grid.

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## Abstracts of current literature

Latha K M and Badarinath K V S. 2006. Influence of local waste burning on atmospheric aerosol properties in urban environment. *Journal of Quantitative Spectroscopy and Radiative Transfer* 98(2): 180–188  
Forestry and Ecology Division, National Remote Sensing Agency, Department of Space, Government of India  
Balanagar, Hyderabad – 500 037, India

Aerosols affect the radiative energy budget on both the regional and global scales. The wavelength-dependent AOD (aerosol optical depth) is a fundamental determinant of the amount by which extra-terrestrial incoming sunlight and outgoing terrestrial radiation are being attenuated in the atmosphere. The present study addresses the influence of local waste burning on aerosol characteristics, BC (black carbon) aerosol mass concentration, and spectral solar irradiance using ground-based measurements over the tropical urban environment of Hyderabad, India. AOD has been observed as maximum during burning days compared to normal days. Aerosol size spectra suggest bimodal distributions during pre- and post-burning periods, and trimodal distributions

during burning periods. Angstrom wavelength exponent estimated from spectral variation of AOD suggested dominance of accumulation mode particle loading during burning days compared to normal days. Diurnal variation of BC on normal days showed a broad nocturnal peak during 20:00 to 24:00 hours with a maximum value of BC aerosol concentration of  $14\ 000\ \text{ng m}^{-3}$  (nanogram per cubic metre). On the other hand, on local waste-burning days enormous increases in BC concentrations have been observed with a peak at  $60\ 000\ \text{ng m}^{-3}$ . Relative attenuation of global solar irradiance during burning days has been found to be of the order of 30% in the visible, and 28% in the near-infrared regions. The results are discussed in detail in this paper. (2 figures, 4 tables, 9 references)

Jain D. 2005. Modelling of solar passive techniques for roof cooling in arid regions. *Building and Environment* 41(3): 277–287  
Central Institute of Post Harvest Engineering and Technology, PAU Campus, Ludhiana – 141 001, India

In this paper, thermal models are presented for the typical methods of passive cooling of roof in the arid region of Rajasthan, India. The periodic analyses for hourly variation of roof cooling are presented for bare roof, insulation beneath the roof, evaporative cooling above the roof, and roof pond with movable insulation system. Calculations were carried out for a typical summer day of May for Jodhpur (India). The models have been tested with the published

experimental data of roof temperature. The predicted values of roof temperature obtained from the proposed models exhibited good agreement with the coefficient of correlation ranging from 0.94 to 0.96, and standard error 1.76–2.80. The water depth (0.05 m) of roof pond with movable insulation is appropriate for better comfort condition in arid regions. (6 figures, 2 tables, 16 references)

Tiwari A, Sodha M S, Chandra A, Joshi J C. 2006. Performance evaluation of photovoltaic thermal solar air collector for composite climate of India. *Solar Energy Materials and Solar Cells* 90(2): 75–189  
Centre for Energy Studies, Indian Institute of Technology, New Delhi – 110 016, India

The objective of the present study is to evaluate the performance of the PV (photovoltaic) module integrated with air duct for composite climate of India. In this case, thermal energy is produced along with electrical energy generated by a PV module with higher efficiency. An analytical

expression for overall efficiency (electrical and thermal) has been derived by using energy balance equation for each component. Experimental validation of thermal model of hybrid PV/T (photovoltaic/thermal) system has also been carried out. It has been observed that

there is a fair agreement between theoretical and experimental observations. Further it is concluded that an overall thermal efficiency of

PV/T system is significantly increased due to utilization of thermal energy in PV module. (7 figures, 4 tables, 19 references)

Jain D. 2005. **Modelling the performance of greenhouse with packed bed thermal storage on crop drying application.** *Journal of Food Engineering* 71(2): 170-178  
*Central Institute of Post Harvest Engineering and Technology, PAU Campus, Ludhiana - 141 004, India*

This paper presents a transient analytical model to study the application of a greenhouse with packed bed thermal storage to crop drying. The performance of an even shape greenhouse with a packed bed and crop dryer was evaluated for drying of onions. The model was solved to compute the air temperatures and various functional components of the drying systems for a day of the month of May for the climatic condition of Delhi, India. The parametric study involved the effect of length and breadth of greenhouse, and mass flow rate of air on

the temperatures of crop. The thin layer drying equation was used to study the drying rate and hourly reduction in moisture content in the crop trays. It has been observed that the crop moisture content and drying rate decreases with the drying time of the day. A greenhouse of 6 (metre) length, 4 m breadth with a  $0.278 \text{ kg s}^{-1}$  (kilogram per second) air mass flow rate with a 0.25 m height of packed bed could dry 2280 kg of onion from a moisture content of 0.14–0.21 kg of water/kg of dry matter in a 24-hour drying period.

Murugesan G S, Sathishkumar M, and Swaminathan K. 2006. **Arsenic removal from groundwater by pre-treated waste tea fungal biomass.** *Bioresource Technology* 97(3): 483-487  
*Department of Biotechnology, Bannari Amman Institute of Technology, Sathyamangalam - 638 401, Tamil Nadu, India*

Arsenic contamination in groundwater poses a serious threat to human health. The tea fungus, a waste produced during black tea fermentation has been examined for its capacity to sequester the metal ions from groundwater samples. Autoclaved tea fungal mat, and autoclaving followed by  $\text{FeCl}_3$  (ferric chloride) pretreated tea fungal mat were exploited for removal of As (III), As (V) and Fe (II) from groundwater sample collected from Kolkata, India. The biosorption rate tends to increase with the increase in contact

time and adsorbent dosage.  $\text{FeCl}_3$  pretreated and autoclaved fungal mats removed 100% of As (III) and Fe (II) after 30-min (minute) contact time and 77% of As (V) after 90-min contact time. The optimum adsorbent dosage was 1.0 g/50 ml (millilitre) of water sample. The results revealed that the  $\text{FeCl}_3$  pretreated fungal mat could be used as an effective biosorbent for As (III) and As (V); autoclaved fungal mat for Fe (II) removal from groundwater sample. (3 figures, 1 table 22 references)

Parashar D C, Gadi R, Mandal T K, Mitra A P. 2005. **Carbonaceous aerosol emissions from India.** *Atmospheric Environment* 39(40): 7861-7871  
*Radio and Atmospheric Sciences Division, National Physical Laboratory, New Delhi - 110 012, India*

Budget estimate for carbonaceous aerosols including BC (black carbon) and organic carbon, emitted from the combustion of various fuels, is very important for regional climate studies. Emission factors for carbonaceous aerosols from biofuels and soft coke were determined in a controlled combustion study. The emission factors thus obtained along with those available for other fossil fuels consumed in different sectors have been

applied to assess the budget for carbonaceous aerosols from India. Preliminary calculations give a range of 1.6-1.8 Tg of carbonaceous aerosols that include 0.4-1.4 Tg of BC. A major (80%) portion of carbonaceous aerosols emitted from India is found to originate from the use of biomass for energy as 70%–80% of energy requirement in rural India is met by combustion of traditional biofuels. (1 figure, 5 tables, 45 references)

Kamala C T, Chu K H, Chary N S, Pandey P K, Ramesh S L, Sastry A R K, Sekhar K C\*. 2005. Removal of arsenic (III) from aqueous solutions using fresh and immobilized plant biomass. *Water Research* 39(13): 2815-2826

\*Analytical Chemistry and Environmental Sciences Division, Indian Institute of Chemical Technology, Uppal Road, Habsingda, Hyderabad - 500 007, Andhra Pradesh, India

The ability of *Garcinia cambogia*, an indigenous plant found in many parts of India, to remove trivalent arsenic from solution was assessed. Batch experiments were carried out to characterize the As (III) removal capability of fresh and immobilized biomass of *G. cambogia*. It was found that the kinetic property and uptake capacity of fresh biomass were significantly enhanced by the immobilization procedure. The uptake of As (III) by fresh and immobilized biomass was not greatly affected by solution pH with optimal biosorption occurring at a pH of about 6-8. The presence of common ions such as Ca (calcium) and Mg (magnesium) at concentrations up to 100 mg/l (milligram per litre) had no effect on As (III) removal. However,

the presence of Fe (III) at 100 mg/l caused a noticeable drop in the extent of As (III) removal but the effect was minimal when Fe (III) was present at 10 mg/l. The adsorption isotherms quantitatively predicted the extent of As (III) removal in groundwater samples collected from an arsenic-contaminated site in India. Immobilized biomass loaded with As (III) was amenable to efficient regeneration with NaOH (sodium hydroxide) solution. Column studies showed that immobilized biomass could be reused over five cycles of loading and elution. The excellent As (III) sequestering capability of fresh and immobilized *G. cambogia* biomass could lead to the development of a viable and cost-effective technology for arsenic removal in groundwater. (9 figures, 5 tables, 43 references)

Barnwal B K and Sharma M P. 2005. Prospects of bio-diesel production from vegetable oils in India. *Renewable and Sustainable Energy Reviews* 9(4): 363-378

Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee - 247 667, India

The indiscriminate extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Alternative fuels, energy conservation and management, energy efficiency, and environmental protection have become important in recent years. The increasing import bill has necessitated the search for liquid fuels in India as an alternative to diesel. Bio-diesel obtained from vegetable oils has

been considered a promising option. In this paper, an attempt has been made to review the work done on bio-diesel production and utilization, resources available, process(s) developed/being developed, performance in existing engines, environmental considerations, the economic aspect, and advantages in and barriers to the use of bio-diesel. (4 figures, 5 tables, 34 references)

Fernandez E, Saini R P, and Devadas V. 2005. Relative inequality in energy resource consumption: a case of Kanvashram village, Pauri Garhwal district, Uttarakhand (India). *Renewable Energy* 30(5): 763-772

Electrical Engineering Department, Indian Institute of Technology Roorkee, Roorkee - 247 667, India

Energy-planning exercises for rural areas make use of a mix of locally available renewable resources with some commercial resources to cater to the energy needs of the population. Such exercises are economically attractive in developing countries. The implementation of an energy-planning exercise requires study of energy consumption and utilization habits of the population to be served. In the present paper, an attempt is made to assess the level of energy resource consumption inequality in a

typical hilly rural Indian village. The Gini Coefficient of Inequality, a measure of inequality in the field of econometrics, has been applied for this assessment. The population is segregated into different categories based on their income levels and certain socio-economic criteria, which are also felt to exercise an influence on consumption levels of energy. The results of the analysis are also discussed in the light of the findings. (9 figures, 1 table, 15 references)

Asokan P\*, Saxena M, and Asolekar S R. 2005. **Coal combustion residues: environmental implications and recycling potential.** *Resources, Conservation, and Recycling* 43(3): 239-262

\*Scientist, Regional Research Laboratory (CSIR), Habib Ganj Naka, Bhopal - 462 026, India

Indian coal typically has an ash content of 30%–60%, which results in low calorific value however low in sulphur, radioactive elements, and heavy metals content. Mostly, the CCRs (coal-combustion residues) are disposed to the ash pond as thin slurry, and more than 65 000 acres of land is occupied in India for storage of this huge quantity of ash which leads to ecological and environmental problems. Presently about 27% of the total CCRs produced in India are being

recycled and used in various applications. The major utilization is in cement, concrete, bricks, wood substitute products, soil stabilization, road base/embankment, and consolidation of ground, land reclamation, and for agriculture. In this paper, an attempt has been made to assess the global generation of CCRs, present utilization and acceptability in Indian context, implications, and future potential to achieve environmental sound management. (7 figures, 3 tables, 95 references)

Reddy M S\*, Basha S, Joshi H V, Sravan Kumar V G, Jha B, Ghosh P K. 2005. **Modelling the energy content of combustible ship-scraping waste at Alang-Sosiya, India, using multiple regression analysis.** *Waste Management* 25(7): 747-754

\*Department of Marine Algae and Marine Environment, Central Salt and Marine Chemicals Research Institute, Gijubhai Badheka Marg, Bhavnagar - 364 002, India

Alang-Sosiya is the largest ship-scraping yard in the world, established in 1982. Every year, an average of 171 ships having a mean weight of  $2.10 \times 10^6 (\pm 7.82 \times 10^5)$  of LDT (light dead weight tonnage) being scrapped. Apart from scrapped metals, this yard generates a massive amount of combustible solid waste in the form of waste wood, plastic, insulation material, paper, glass wool, thermocol pieces (polyurethane foam material), sponge, oiled rope, cotton waste, and rubber. In this study, multiple regression analysis was used to develop predictive models for energy content of combustible ship-scraping solid

wastes. The scope of work comprised qualitative and quantitative estimation of solid waste samples, and performing a sequential selection procedure for isolating variables. Three regression models were developed to correlate the energy content (net calorific values [LHV]) with variables derived from material composition, proximate, and ultimate analyses. The performance of these models for this particular waste complies well with the equations developed by other researchers (Dulong, Steuer, Scheurer-Kestner, and Bento's) for estimating energy content of municipal solid waste. (11 figures, 4 tables, 11 references)

Chaturvedi O P\* and Das D K. 2005. **Energy dynamics in Populus deltoides G3 Marsh agro-forestry systems in eastern India.** *Biomass and Bioenergy* 29(2): 93-101

\*National Research Centre for Agroforestry, Jhansi - 284 003, India

Energy efficiency of *Populus deltoides* G3 Marsh agro-forestry of a three-year-old system with intercropping of maize-wheat in crop I and pigeon pea in crop II, and of a nine-year-old system with turmeric, a shade-loving crop was studied at Pusa, Bihar in eastern India. Energy fixation, storage, net allocation in agronomic yield, and energy released and exit from the nine-year-old system was 1.53, 4.30, 0.43, and 3.37 times in crop I, and 1.67, 4.60, 0.53, and 3.30 times in crop II of the three-year-old agro-forestry system. The energy-conservation efficiency in the nine-year-

old system was higher (1.91%) as compared to crop I (1.24%) and crop II (1.15%) of the three-year-old agro-forestry system. The energy accumulation ratio in the nine-year-old system was 2.82 and 2.77 times higher in crop I and crop II, respectively, of the three-year-old agro-forestry system. The three-year-old agro-forestry system showed lower energy-accumulation ratio resulting from less energy accumulation in perennial turnover in the form of leaf of tree and agricultural crops. The crop II system of the three-year-old poplar agro-forestry was more

efficient system of management due to higher quanta of energy and higher cash return but one has to opt for shade loving intercrop turmeric

with increase in age of the poplar plantation and more canopy closure. (2 figures, 3 tables, 22 references)

## Technology news

### Power from grass

Chinese scientists from Shandong University have developed a technology to generate power from English cordgrass, an alien plant that has been blamed for biological invasion. The new technology anoxically turns carbon and hydrogen elements in the cordgrass into flammable gas. After it has been decontaminated, the gas can be used for cooking, power generation, and heating. Experiments have shown that one kg (kilogram) of English cordgrass can produce two m<sup>3</sup> (cubic metres) of flammable gas, which can generate one kWh (kilowatt-hour) of electricity. If all of its 3.3 million hectares of English cordgrass were processed, China would be able to harvest 50 billion to 75 billion kWh of electricity.

*Details available at, <<http://www.sci-tech-today.com>>, last accessed on 27 December 2005*

### Mersey river tidal power station proposed

The Mersey river may soon become the first river in Britain to generate electricity by tidal activity. River hydro fence project would tap two GW (gigawatts) of electricity—enough power to meet 15% of north-west England's electricity requirements. Scientists say the Mersey has more tidal power potential than virtually any other river in Europe, by virtue of its 33-foot tidal range and strong currents. Under the plan, a fence would be built across the width of the river. Water would be trapped behind gates that would be shut at high tide, and then allowed to escape through the turbines of a hydroelectric plant.

*Details available at, <<http://www.physorg.com>>, last accessed on 10 December 2005*

### Chicken fat to fuel

Researchers at the University of Arkansas have developed a way to convert chicken fat to a bio-diesel fuel, which could essentially help power automobiles and trucks. Researchers found that fuel from chicken fat burns better, create less particulate matter, and actually lubricates and

cleans things like cylinders, pistons, and fuel lines. Traditionally, bio-diesel producers have used refined products like soybean oil because they are easier to convert to fuels. However, the refining process makes soybean oil more expensive—and fuel producers must compete with grocers for the oil supply. Chicken fat can be a less-expensive substitute because it is available at a low cost. However, fatty acids in raw chicken fat can lead to the creation of soap during the various chemical processes. In the study both high-quality fat (less than two percent fatty acid content) and low-quality, feed-grade fat (six per cent fatty acid content) were used. High-quality fat is more expensive than feed-grade fat, but both are less expensive than soybean oil. It took different steps to refine the different fats.

*Details available at, <<http://www.enn.com>>, last accessed on 1 December 2005*

### NIST develops energy-efficient cooling

Scientists at NIST (National Institute of Standards and Technology) have developed a way to improve energy efficiency in cooling large commercial buildings. The method, if confirmed through experiments with full-scale chiller systems, could save as much as one percent of the 320 billion kWh of electricity now used annually to cool such buildings—that's an equivalent 920 000 barrels of oil each day. This advancement has been built on past NIST research designed to optimize mixtures of chiller refrigerants with lubricants. The researchers discovered that some lubricants, when injected in small amounts, can significantly enhance evaporator heat transfer, increasing the efficiency of chillers. Studying the method more closely, they found the most efficient heat transfer occurred when the added oil's surface tension, viscosity, composition, and chemical characteristics complemented those of the chiller's base lubricant.

*Details available at, <<http://www.physorg.com>>, last accessed on 18 November 2005*

## Global energy meet agrees roadmap on renewables

Environment officials from around the world agreed to work to increase reliance on renewable sources of energy, underscoring a commitment to renewables after oil prices hit record highs. The draft statement stopped short of setting a firm goal but it recommended the UN (United Nations) Commission on Sustainable Development consider the launch of a 10-year framework to 'substantially increase the use of renewable energy'. The Beijing Declaration was the culmination of a two-day international conference that was a follow-up to meetings in Johannesburg in 2002, and last year in Bonn that aim to promote cooperation on renewable energy. 'The 10-year framework is much more specific than Bonn. They now have an official request of the UN Commission that feeds back into the UN system,' Christine Woerlen, of the Global Environment Facility, said.

*Details available at, <<http://www.planetark.com>>, last accessed on 9 November 2005*

## Nanotech breakthrough in alternative energy sources

Researchers at Wake Forest University's Centre for Nanotechnology and Molecular Materials have made significant strides in improving the efficiency of organic or flexible solar cells. Traditional silicon solar panels are heavy and bulky, and convert about 20% of the light that hits them to useful electrical power. For years, researchers have worked to create flexible organic solar cells that can be wrapped around surfaces, rolled up, or even painted onto structures, but the best achievement was about three percent. The researchers used a set of polymer coatings and constructed a nanophase within the polymer called a 'mesostructure'. The mesostructure changes the properties of the plastic, and makes it better for collecting light. The researchers also removed the current from the polymer coating. A test system at Wake Forest's Nanotechnology Centre was used to simulate the sun, and the simulated spectrum was precisely measured and shot onto the organic solar cell, which appeared

as a thin coat of paint. Devices at the Centre have registered almost six percent efficiency, and have a potential to reach 10% to make it commercially viable.

*Details available at, <<http://www.physorg.com>>, last accessed on 8 November 2005*

## Waste water to electric energy

A team at the University of Queensland in Australia has developed new technology to turn waste water into electricity. The complex process involves extracting the chemical energy from pollutants in waste water and converting it to electricity using microbial fuel cells. According to the researchers the process is being carried out within a thin biofilm, a sort of slime layer on the electrode where bacteria are growing and directly producing electrical current. The electricity is generated from the slime in much the same way energy is released when wood is burned. The most obvious application of this electricity would be powering waste water-treatment plants, particularly in developing countries or areas with an unreliable power supply.

*Details available at, <<http://www.opensourceenergy.org>>, last accessed on 1 November 2005*

## Moser Baer to develop solar technology

Rising oil prices combined with the need for alternative sources of energy is opening up new segments for Indian companies. Moser Baer, which specializes in high-tech manufacturing, is looking at manufacturing solar panels. The company is working on silicon wafer coated with chemicals, which can help cut the price of producing energy from the sun. Currently, Moser Baer manufactures compact disks in different forms. Now, the company has identified solar panels as a target market. The rationale is based on the fact that it involves expertise of coating and material technology. Silicon wafers are coated with light-sensitive chemicals to develop solar panels. Companies, which are trying to cut the cost of these panels, are looking at thinner wafers and thinner coatings, along with manufacturing techniques which can ensure mass production at shop floor level.

*The Economic Times, 27 October 2005*

## Website links

### World Council for Renewable Energy

<http://www.world-council-for-renewable-energy.org/index.html>

As a globally working, non-profit, and non-governmental organization, WCRE (World Council for Renewable Energy) is focused on developing policies and strategies for RE (renewable energy). Its mission is to bring RE into the mainstream of world economy and lifestyle. The website carries a rich collection of publications, policy documents, news, events, and links to other related sites.

### European Forum for Renewable Energy Sources

[www.eufores.org](http://www.eufores.org)

EUFORES (European Forum for Renewable Energy Sources) is a not-for-profit organization aiming at promoting RE sources at the regional level. Through its websites it promotes legislation and energy efficiency, and develops network across Europe. EUFORES website hosts political consulting, news, publications, legislations, energy efficiency and projects information, events, and links to other sites.

### European Small Hydropower Association

[www.esha.be](http://www.esha.be)

ESHA (European Small Hydropower Association) is a non-profit international association representing the small hydropower sector. It groups together all main European RE industry and research associations so that they get benefits at economic and environmental levels. This website provides information on policies, research papers, presentations, news, articles, newsletters, Association's publications, and events. Besides, it also covers projects information in the specific subject area.

### European Wind Energy Association

[www.ewea.org](http://www.ewea.org)

The main objective of EWEA (European Wind Energy Association) is to promote progress of wind power among the media, decision-makers, and politicians. The Association's website is a rich

collection of resources including policies, publications, news, events, and links. It also hosts projects information in the related subjects.

### The Source for Renewable Energy

<http://energy.sourceguides.com>

The Source for Renewable Energy is a comprehensive online buyer's guide and business directory to more than 9000 RE businesses and organizations worldwide. The database provides search facility to identify RE businesses by geographic location, product type, business type and company name, or search facility using keywords.

### Alternative Fuels Data Centre

<http://www.eere.energy.gov/afdc/>

The Alternative Fuels Data Centre is a vast collection of information on alternative fuels and the vehicles that use them. Alternative fuels described here include bio-diesel, electricity, ethanol, hydrogen, natural gas, and propane. This site has more than 3000 documents in its database, an interactive fuel station mapping system, current listings of available alternative fuel vehicles, and lots of alternative fuels information, toolkits, buyer's guide, educational resources, legislations and laws, and links to other sites.

### Energy Information Centre

<http://www.worldenergy.org/wec-geis/edc/>

The EIC (Energy Information Centre) provides a geographic approach to the energy data and other information collected by the WEC (World Energy Council). The principal data source for the Energy Information Centre is WEC's *Survey of Energy Resources 2001*, which provides detailed information on a global scale about conventional and RE reserves. The site emphasizes on energy efficiency information, energy forecasting, energy policies, surveys, research and development, and energy technologies. International energy indicators and data series are also available from a number of other sources. Besides, the site also hosts news, events, supply source directory, publications, and energy-related web links.

## Forthcoming events

27 February–2 March 2006  
Megaron, Athens, **Greece**

### **European Wind Energy Conferences 2006**

*Tel.* +32 2 546 19 80 • *Fax* +32 2 546 19 44

*E-mail* [exhibition@ewec.info](mailto:exhibition@ewec.info) • *Website* <http://www.ewea.org>

24–25 May 2006  
Aberdeen, **Scotland**

### **All-Energy 2006: the renewables show in the Energy City**

All-Energy, 34 Ellerker Gardens, Richmond, Surrey TW10 6AA

*Tel.* +44 (0) 20 8241 1912 • *Fax* +44 (0) 20 8940 6211

*E-mail* [info@all-energy.co.uk](mailto:info@all-energy.co.uk) • *Website* <http://www.all-energy.co.uk>

13–16 June 2006  
Lyon, **France**

### **16th World Hydrogen Energy Conference**

AFH2, Stephanie Paysant, 28, rue Saint Dominique - F - 75007 Paris

*Tel.* +33 (0)1 53 59 02 11 • *Fax* +33 (0)1 45 55 40 33

*E-mail* [info@afh2.org](mailto:info@afh2.org) • *Website* [www.whec2006.com](http://www.whec2006.com)

19–25 August 2006  
Florence, **Italy**

### **World Renewable Energy Congress IX and Exhibition**

Prof. Ali Sayigh, WREN, P O Box 362, Brighton BN2 1YH, UK

*Tel.* +44 (0)1273 625 643 • *Fax* +44(0)1273 625 768

*E-mail* [asayigh@netcomuk](mailto:asayigh@netcomuk) • *Website* [www.wrenuk.co.uk](http://www.wrenuk.co.uk)

## eNREE invites contributions

eNREE is meant for ENVIS members and all stakeholders interested in advancing, promoting, and sharing the knowledge in renewable energy and environment in India and abroad. We sincerely welcome your help in enriching this newsletter by sending us articles, case studies, etc. and also welcome feedback on the contents of the newsletter to help us make it more informative and rich in content.

### **Please send in your contributions to**

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# ENVIS Centre on Renewable Energy and Environment

A knowledge gateway

To work towards saving the environment by understanding its myriad facets, the ENVIS (Environmental Information System) network was established under the MoEF (Ministry of Environment and Forests), Government of India, in December 1982. The objective was clear and urgent: work towards bridging the data gaps by developing an environmental information system that will help disseminate information to decision-makers, scientists, and other stakeholders.

The ministry selected certain institutions/organizations, universities, academic/research bodies in state governments, corporate houses, and NGOs as ENVIS centres, based on their excellence in research activities. Each centre would work on a specialized subject from the vast expanse of environmental studies available.

TERI became the host to the ENVIS Centre on Renewable Energy and Environment in July 1984. The mandate for the TERI centre is to collect, collate, store, retrieve, and disseminate information on renewable energy and environment as well as to support and promote research and development. The Institute has also hosted the EMCB (Environment Management Capacity Building) Node on Renewable Energy and Environment since 2000/01, a sub-component of ENVIS that aims to build capacity through the development and maintenance of a web site that serves as an information clearing house.

This new-look, revamped website has helped achieve just what the centre set out to do display a world of information at a glance. TERI's ENVIS Centre and the EMCB Node have been actively engaged in resource generation, data collection, problem recognition and provision of solutions, capacity building, and information dissemination. Rich in content that is constantly updated, the site



<http://www.terienvis.nic.in>

does an impressive job of plugging information gaps that existed in the renewable energy and environmental sectors. Besides, it draws the attention of the Indian scientific community, a fact that becomes evident from the hundreds of technical queries received through the website.

Here's a snapshot of some of the main features of the site.

- Regular sections – news, events, statistics, etc. – provide updates on the environmental impact of power, renewable energy, transport, pollution control technologies, hazardous waste management, and other related subjects spanning local and national boundaries.
- Recently developed renewable energy technologies and case studies are added attractions.
- Review articles from the Centre's premier publication *TIDEE* (TERI's Information Digest on Energy and Environment) enrich the knowledge base of the scientific community by providing information on the latest developments in energy and environment.
- *eNREE* (E-Newsletter on Renewable Energy and Environment), a quarterly, non-priced, electronic newsletter (also uploaded on the site) highlights recent issues in the sector.
- The search function for the bibliographic database and the directory of experts can further be screened through categories such as title, author, etc. The online bibliographic database includes bibliographic records of selected fields from 1991 onwards, covering over 11 000 records. The centre is also building up an exhaustive Directory of Experts on Renewable Energy and Environment.
- The colourful and lively children's section, *Edugreen*, lives up to its tag line—'making environmental learning fun for the young'.