

# eNREE

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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.

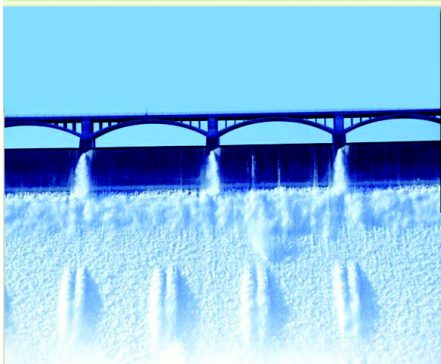


## Technological developments

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

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



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# Renewable sources of power: one year in perspective

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Renewable resources of energy have achieved a very high growth rate in the economical upsurge in India during FY (fiscal year) ending March 2006. This bears special significance since renewable energy sources not only add to the installed capacity of power generation, but also generate clean power having a low gestation period and price that is competitive with the conventional sources. This form of energy qualifies for participation in carbon trading in the international market under the Kyoto Protocol to earn extra foreign exchange through CDM (clean development mechanism) benefits. Oil price has nearly touched 80 dollars/bbl and is expected to reach 100 dollars. This makes it imperative to harness renewable sources, the potential of which is about 85 000 MW (megawatt) exclusive of solar power. Between FY (fiscal year) 2005 and 2006 the overall progress in major sectors is 33.7% (Table 1). Out of 125 000 MW of installed capacity, the share of renewable is nearly 5%, though in terms of generation (because of low PLF [plant load factor]), this may be only 2.5%.

In sector-wise growth, wind power comes first (48.5%) followed by biomass at 45.4%. Encouraging growth in wind power places the country in the fourth position in the world after Germany, US, and Spain. However, while comparing the present wind power generation (5340 MW) against the full potential in India (45 000 MW which might even go up further), there is no room for complacency. Same is the case with biomass power that has a potential of 16 000 MW. Co-generation in sugar mills by use of bagasse with a potential of 3500 MW indicates a rise of 12.3% only, which should have been higher in the context of shortage and expensive grid power. In case of grid failure, other mode of generation is costlier, and mills can hardly put up with break down for want of power in season time. Cogeneration from bagasse addresses these issues. However, cogeneration from resources other than bagasse, mainly rice husk, cotton, and mustard stalks is picking up as can be seen from installation of 7.5 MW in 2006/07.

Small hydro (up to 25 MW) is another resource that calls for fast development at the backdrop of a number of impediments in case of big hydro projects. Many small hydro sites are situated in remote areas inhabited by poorer sections of the society. These projects have the advantages of simple technology and low gestation period. Small hydro projects, in spite of enjoying good incentives and being attractive to private entrepreneurs are delayed mostly on account of inadequate data and procedural bottleneck in conveying clearances by various agencies. Having resolved these two issues, there is no reason for a quantum jump in this sector.

Grid-connected SPV (solar photovoltaic) technology displays zero growth that might not be attributable to high cost per megawatt. It is puzzling to note that standalone SPV power plants, water pumps, streetlights, domestic lighting systems, and solar lanterns also do not show any addition during the year. This leads to a confusion as to whether there is any gap between collection of information and dissemination of the same. Regarding SPV, it may be pertinent to say that the absence of basic ingredients to manufacture solar cells and importing them are the prime factors for losing the edge of competitiveness as an energy resource for mass use. Domestic solar lighting systems and solar water pumping in the dry season while there is plenty of sunshine will be affordable on account of lower cost of modules in the country. Encouraging grid-connected solar PV system in addition to applications in remote areas as has been the practice now, through incentives for 200–1000 W systems to encounter load shedding and also to minimize overall system peak demand will go a long way in the installation of hundreds of megawatt in cities similar to those in developed countries in view of frequent power cuts disrupting normal life. Solar water heating has substantially progressed, rising by 50%. Here again, 1.5 million m<sup>2</sup> (square metres) as on FY 2006 is too small a figure compared to nearly 10 million m<sup>2</sup> in China. Solar cookers are picking

**Table 1 Achievements till March/2005 and March 2006**

<b>A Grid-interactive renewable power</b>				
Source/system	Potential (MW)	March 2005 (MW)	March 2006 (MW)	Growth (%)
Wind power	45 000	3595	5340	48.5
Biomass power	16 000	302.53	440.50	45.4
Biomass/co-gen (bagasse)	3500	447	502.03	12.3
Small hydro (upto 25 MW)	15 000	1705.63	1826.43	7.1
<b>Waste-to-energy</b>				
▪ Municipal solid waste	1700	17	–	–
▪ Industrial waste	1000	29.52	–	–
Solar photovoltaic	20 per square kilometres	2.80	2.80	0
<b>Total</b>	<b>6099.7</b>	<b>157.7</b>	<b>33.7</b>	<b>–</b>
<b>B Decentralized energy systems</b>				
<b>Biogas</b>				
▪ Family size	12 m	3.71 m	3.83 m	2.3
▪ Community size	–	3950	3952	0.05
Improved <i>chulha</i>	120 m	35.2 m	35.2 m	–
<b>SPV systems</b>				
▪ Streetlights	–	54 795	54 795	–
▪ Home lighting	–	342 607	342 607	–
▪ Lanterns	–	560 295	560 295	–
▪ Water heating	150 m <sup>2</sup> (square metre) (collector area)	1 m <sup>2</sup>	1.5 m <sup>2</sup>	50
▪ Solar pumps	–	6818	6818	–
<b>Cookers</b>				
▪ Box type	–	575 000	600 000	4.3
▪ Centric type	–	10	12	20
▪ Dish type	–	2000	2000	–
Wind pumps	–	1087	1087	–
Hybrid system	–	385.70 MW	410 MW	6.2
Biomass gasifiers	–	66.35 MW	76 MW	–
Biomass co-generation	–	–	7.5 MW	–
Village electrification	–	2538	2831	11.1

up, except for dish type that gives immense benefits to community cooking by cutting down fossil fuel use though there are accompanying problems of procurement and cost. Till now only 2831 remote villages and hamlets have been electrified at an yearly growth rate of 11.1%, while there is a commitment for electrifying 125 000 remote villages and hamlets by 2009. The progress achieved so far (only about 2.2%) seems to be discouraging and a slip appears inevitable. Enhancing the pace of growth of renewable resources is dictated not only by

conventional conditions globally applicable, but it also has special bearing due to the remoteness of nearly 20 000 Indian villages. In these villages, rural electrification through extension of grid line is unviable and standalone mode of power generation the is only recourse available. Solar energy, biomass, and biogas are probable options with microhydel power and wind at specific locations. Even within isolated villages solar, biogas, and wind for water pumps, etc., offer good options, since in these villages housing is scattered. While at the national level energy

security is an important issue, village energy security is no less important in addressing the problem of urban and rural imbalances.

There is no information about the progress made in sectors like wind pump and hybrid systems as also with respect to improved *chulhas*. Biogas schemes are also implemented through other agencies like social welfare, rural development, and Khadi and Village Commission. As such to draw a comprehensive picture with regard to progress, close coordination would be necessary which appears difficult, though not desirable. Progress in the biogas sector appears to be slow given that 75% of the potential still remains untapped in spite of its low capital cost and minimum technological input, while there is a 250-million animal population delivering 125 million tonnes of dung that can replace more 50% of oil and gas import. It is unfortunate that proper thrust is lacking here when biogas can resolve energy scarcity in villages where maintaining public distribution for kerosene or supply of gas by oil companies to ultimately replace firewood is a gigantic task.

Looking at the growth rate, there are reasons to be content, especially in the case of grid-

connected systems through wind power. Not too much information is available on standalone systems especially in the fields of solar and wind power, comprising solar streetlights, domestic solar systems, pumps, power plants, lanterns, and wind pumps. It is essential to adopt steep rate of growth, since they serve the people and mostly in so far neglected villages where renewable energy is the best option to meet energy demand having the advantage of availability of resources locally. There happens to be a confusion and loss of link somewhere in these statistics, since in solar power, other than grid-connected system, Karnataka, Maharashtra, and West Bengal have done fairly well. Punjab has also progressed in the area of solar water pumps, which should have reflected in the progress report for 2005/06. Depletion in oil reserves, high price, environmental pollution, and the rising demand for energy especially in developing countries are some reasons for tapping the unlimited natural resources for energy generation in a sustainable manner. Decentralized power is gaining popularity due to many reasons and it is ideally suitable in a country like India where renewable energy offers the best option.

## 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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# Potential for geothermal energy in the changing business scenario in the Indian context

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## Introduction

Energy is a fundamental factor in determining the quality of life. Reckless use of fossil fuels can have unacceptable environmental consequences at the local and global scale. Thus, there is a need to pursue alternative approaches to sustainable supplies of energy. The rate of increase in energy consumption has been particularly sharp in the last four decades, during which the consumption is estimated to have grown four-fold. Almost all these increases are from non-renewable energy sources, and none of these energy sources can be described as environment friendly (Dayal 1990). Rapid growth of the energy producing sectors has made environmental protection a highly complex and more difficult task. The world, therefore, is faced with the problem of reconciling safe environment with the increased energy supplies (Hafele 1980). The environmental problems arising from the use of such energy sources, however, cut across the national boundaries. Excessive consumption of these fuels in one country can cause problems in the whole region. It is estimated that CO<sub>2</sub> (carbon dioxide) in the atmosphere has grown at the rate of 0.4% per year since 1958, and other GHGs (greenhouse gases) like methane, nitrous oxide, and CFCs (chlorofluorocarbons) are increasing at an annual rate as high as 5% (Barney 1980). The report outlined a number of pressing environmental problems that were present in the year 2000 (Anon 1980). A number of commodities including crude oil have already peaked. About 40% of the world's forests had disappeared by 2000 AD. This means a decline of 50% in commercial timber supply. The atmosphere has been threatened by a significant level of CO<sub>2</sub>, ozone-destroying chemicals, particularly CFCs and N<sub>2</sub>O. The net result was the extinction of up to 20% of the current plant and animal species. It is clear that the ever-increasing use of fossil fuels cannot be the basis for sustainable development. The loss of forest adds another dimension to energy and

environmental questions. It is estimated that about 25% of the present CO<sub>2</sub> levels can be attributed to deforestation (Anon 1988). It cannot be denied that fuelwood is a principle energy source for hundreds of millions of people in developing countries. In India alone we are losing 1.5 Mha (million hectares) of forest cover per year (Ghose 2002a). The main issue is to use natural resources rationally for sustainable development. To maintain the levels of development for improvement of quality of life for present and future generation, resources should be utilized in a sustainable manner (Ghose and Sinha 1999). Geothermal power can be a significant source of energy in some areas of the world (Sung, Houser, Strehler, *et al.*, 1981). There is a limited potential with several renewable energy sources, including hydroelectric energy, tidal energy, and wind power (Calvin 1982). This paper focuses on geothermal energy as a potential source of energy, examines the present scenario of geothermal energy utilization, and identifies some of the key environmental issues.

## Energy minerals

The energy sector plays a crucial role in the overall development of the economy. Of the total energy consumption of approximately 360 MTtoE (million tonnes of oil equivalent) in the country, an estimated 35% is obtained from traditional sources such as fuelwood, agricultural waste, and animal dung, and the other 65%, termed as commercial energy, is obtained from coal, oil, gas, hydel, nuclear, and renewable sources. The share of various energy sources in the primary commercial energy consumption of the country in 1997/98 was as given below.

Coal and lignite	56%
Petroleum	32%
Natural gas	8%
Hydel	3%
Nuclear and renewable	1%

Coal and lignite are mostly used in power stations (75%), steel plants (6.2%), cement plants (3.6%), other industries, and brick-making plants (15.2%). Petroleum and natural gas are mostly used for the transportation sector although significant amounts are used in oil- and gas-fired power stations, fertilizer plants, other industries, and in the domestic sector for cooking and lighting.

Electricity is the preferred form of energy for the industry, and is a crucial requirement for the expansion of the industrial and agricultural sectors. Of the installed generating capacity of 105 000 MW in 2001/02, 71% was based on thermal, 25% on hydel, and the remaining 4% on nuclear and renewable. The Tenth Five-year Plan envisages an expansion of 40% of the installed generating capacity amounting to an addition of 41 000 MW by 2006/07. A further addition of 60 000 MW capacity is planned for the Eleventh Plan Period (2011/12). Bulk of the power generated comes from coal- and lignite-fired power stations, and the proposed expansion of the power sector is based on an expansion of the sector. The expansion of gas-based thermal generation is based on the discovery of new gas deposits in the country or import of gas from nearby countries. Although oil and gas contribute 40% of the primary energy consumption in the country, India has only limited proved reserves of these commodities, and the domestic production accounts for hardly one-third of the consumption of these two items. The reserves-to-production ratio of oil and gas are only 15 and 23 years respectively. Till recently, the oil import bill was accounting for one third of the total value of imports into the country. With the recent spurt in oil price, the share of oil import bill would rise further. The India Hydrocarbon Vision 2025 Report of the Government of India gives the current oil elasticity with respect to GDP (gross domestic product) as 1.1 (that is, for 1% growth in GDP, oil consumption grows by 1.1%). It has proposed to bring it down to 0.7% by 2025. The document also proposes vastly increased exploration efforts towards finding oil and gas resources in the country but no great change (except for a small contribution to the gas resources by exploitation of coal bed methane) in the scenario is expected in the short term or till a major discovery takes place.

Nuclear power stations contributed 17 billion kWh (kilowatt hour) towards the energy generated in the country in 2003/04. The vision document of the Department of Atomic Energy proposes to raise the installed generating capacity of the nuclear power plants from the current 2720 MW to 20 000 MW by the year 2020, which would still be a small percentage of the total generating capacity of the country. Hence, for the foreseeable future, coal and lignite will remain the main source of power generation in the country. The demand for coal by the power sector has been estimated as 317 MT (million tonnes) in 2006/07 and 469 MT in 2011/12. The sector-wise demand and company-wise availability of coal at the end of Tenth and Eleventh Plans are given in Table 1.

The bulk of Indian coal reserves are of inferior grade (that is, E and F grade) and the power stations are designed to burn such high-ash coals. Currently some 60% of the coal produced by CIL (Coal India Ltd) is of inferior grade and by 2011/12 this figure is expected to go up to 69%. As per a 1997 amendment of the Environment Protection Rules 1986, power stations located over 1000 km (kilometres) away from the pit heads or in urban areas with critical air pollution concerns have to use beneficiated coal having an ash content not exceeding 34%. Currently some 34 power stations using 93 MT of coal come under this stipulation, which is met, partly from the operation of the seven non-coking coal

Year	2006/07	2011/12
Sector-wise demand	Million tonnes	Million tonnes
Coking coal	37.2	40
Non-coking coal power (utilities)	317.1	469
Captive power	28.3	32
Cement	24.6	24
Fertilizer	4.2	5
Others	49.1	50
<b>Total demand</b>	<b>460.5</b>	<b>620</b>
Availability of coal		
Coal India Ltd	350	445
Singareni Coal Company Ltd	36.1	35.4
Others	18.9	44.6
<b>Total availability</b>	<b>405</b>	<b>525</b>

washeries of the CIL but mostly by blending the high-ash coals with available low-ash coal. The true spirit of the amendment can, however, be achieved only by setting up of a large number of pithead washeries for which CIL favours the build-own-operate route. Installation of a large number of coal washeries would confront the coal industry with the environmental problem of disposal of washery rejects.

### **Present scenario of geothermal energy utilization**

The solutions to energy are strongly tied with environmental consideration. For example, a massive shift of the energy base from petroleum to coal would involve more strip mining of coal that is potentially deleterious to the environment. Estimates of recoverable are  $7.6 \times 10^{12}$  t. Peak production should be reached shortly after 2100. If this is the case, about 80% of coal production will occur around the year 2300 (Manahan 1983).

There is a huge quantity of heat lying trapped in the earth's interior. The energy extracted from this source is called geothermal energy. In the molten core of the earth, the temperatures are as high as 4000 °C and it is referred to as a form of fossil nuclear energy. The central molten core of the earth is surrounded by a region of semi-fluid material, which is covered by the crust, the depth of which may extend from 30–150 km. The temperature in the crust increased proportionally to depth at the rate of about 30 °C per km. The total amount of energy in the outer 10 km of the earth's crust exceeds the energy obtainable by the combustion of coal, oil, and natural gas. At present only a small proportion of this energy is regarded as economically useful. Nevertheless, this amount is a large energy to make a significant contribution to the energy resources. If one assumes that 0.1% of geothermal resource energy could be exploited with the use of existing technology it would be a continental geothermal energy resource base, which would be more than 1000 years of energy reserves at the present consumption level. It has also been estimated that about 40% to 50% of the total heat required by the society is below 200 °C; 30% require about 150 °C; and 20% require about 100 °C (Abbasi and Ramesh 2002). Thus, there is a vast scope to use geothermal energy for low- temperature applications.

The first commercial utilization of geothermal power was at Larderello, Italy in 1904 with an electric generator that powered four light bulbs. It was expanded subsequently and eventually reached 360 MW in 1981. The second-largest development of geothermal power is at Wairakei, New Zealand, which now has a capacity of about 290 MW. This plant is 10 km north of Lake Taupo in the volcanic zone of North Island. The lake's outlet river provides the cooling water for the power plant. At the wellheads, the geothermal fluid is a mixture of one part of steam to four parts of water. The steam is separated from the water by cyclone separators. The power plant is base loaded, that is, it produces continuously at full power and has an annual load factor of 0.9. In North California, power has been produced since 1960. At present the output is more than 1360 MW, with 19 power plants. The steam is of relatively low pressure (689 000 Pascal) and temperature (205 °C) compared to the pressure (2 067 000 Pascal) and temperature (550 °C) of steam generated in modern fossil fuel power plants. It is about one-third less efficient than the conventional power plants. This resource is estimated to have a total capacity of 2500 MW or more. This is a field of dry steam, a relatively rare situation, and it is not known how long this steam supply would last.

Japan has a total geothermal power production of 215 MW. In Mexico, just south of the US border, a 425-MW power plant is in operation. It is a wet steam plant. In addition there are several small geothermal power plants in operation in Mexico. In Iceland, two-thirds of the dwellings are heated using geothermal energy. The steam from one of its large geothermal reservoirs has been used for heating the entire town of Hveragerdi, and a 17-MW power plant was installed there in 1969. Iceland is an exposed section of the mid-Atlantic ridge, which is a boundary between the Eurasian and American continental plates. The island is literally being pulled apart due to the movement of these two gigantic tectonic plates in opposite directions. The result is the hot basalt flowing to the surface through the fissures underneath. In Russia, geothermal power is being produced at three small plants in Kamchatka with a total capacity of about 40 MW.

In Puna district on the big island of Hawaii, a 3-MW plant is generating electricity and there are plans to build a 25-MW plant there. Hawaii has so many sources of renewable energy other than geothermal that it is not likely to develop this resource extensively. At present 35 countries utilize 11 605 MW of geothermal energy for non-electric application whereas 18 countries utilize 566 MW for electric applications (Abbasi and Ramesh 2002). Construction of plants with a capacity of 502 MW is underway and many countries are planning to increase the use of geothermal energy.

Geothermal resources are of three general types, a high-grade resource that has temperatures above 150 °C and is useful for generating electricity; an intermediate-grade resource that has temperatures between 90 °C and 150 °C and could be used directly for heating dwellings or for industrial process heat; and a low-grade resource that has temperature below 90 °C and in general is not worth exploiting. To be useful, these resources must be at depths less than 6 km. Geothermal reserves are further classified on the basis of presence or absence of natural water: geothermal aquifers where water occurs in association with natural crystal thermal heat and those where HDR (hot dry rock) is situated without water. Exploitation of hot water zones in thermal aquifer, has reached the commercialization stage, whereas energy from HDR zones is still in the experimental stage.

Volcanic formations where high-temperature aquifers are associated with rock formations of basalts, rhyolites, and andesites are potential zones for this type. Exploitation of these aquifers needs detailed integrated surveys such as geological, hydro geological, geochemical, and geophysical. Based on these surveys, systematic thermal gradient analyses are interpreted for further exploitation of these hot reservoirs for power generation. The hot fluids that are pumped out from the aquifer are released into electricity generating turbines. Excess hot fluids are injected into the reservoir through injection wells. Low-temperature aquifers (less than 90 °C) are abundant in nature when compared with high-enthalpy aquifers. Low-temperature aquifers are mainly located in sedimentary basins. These are utilized for space heating, and for industrial and agricultural applications.

When water is trapped in an underground reservoir and is heated by surrounding rocks, it is under very high pressure and can reach high temperatures as hot water is released to the surface. It will flash into steam as the external pressure falls below that necessary pressure to keep it as a liquid. Places where steam escapes through cracks in the surface are called as 'fumaroles'. In some geothermal reservoirs, hot water leaks to the surface, forming hot springs or geysers. Geothermal wells tap these wet steam fields. As the hot water rises in the well, it flushes into mixers of about one part steam and four parts of hot water. The steam is separated from the water and is used to run turbines to generate electricity. The hot water can be used for direct heating or for a desalination plant.

High-grade HDR resources are substantial. Some HDR sources are clearly discernible from the surface, where hydrothermal activity occurs at the surface. However, the hydrothermal component is only 3.4% of the total underground energy content. The remaining energy may be partially extracted by artificially injecting water into the HDR reservoir. Dry-steam geothermal fields occur when the pressure is not much above the atmospheric pressure and the temperature is high. In this situation water boils underground and generates steam at temperatures of about 350 °C and pressures of about 100 psi. The steam taken from such a geothermal energy source well can be used directly to drive a turbine. Scientist at the Los Alamos National Laboratory, New Mexico, have developed a method to extract energy from hot rocks by injecting water into the underground structure, fracturing the rock, and then bringing the hot water or steam to the surface. They drilled an injection well to a depth of 2.93 km, where the temperature was 197 °C. Then they drilled an extraction 300 m above the input point of the injection well. Some water loss occurred between the injection and extraction wells, but it diminished as the pores of the surrounding rock filled up. Water withdrawn from the extraction well had a temperature of 153 °C and declined only to 8 °C following 288 days of sustained operation.

#### *Geothermal energy: Indian scenario*

Indian coal production, which is of the order of 320 MT per year, is currently supporting some

70 000 MW of thermal power generation. With the plans in place for 2010 AD, this quantum of power generation is expected to increase to 150 000 MW (Ghose 2002b). More specifically, to meet the proposed energy needs, India must produce nearly double the quantity of coal it is mining at present, as fuel requirements will be in the range 550 MT per year (Ghose and Majee 2000 and 2001). India has a vast potential for developing geothermal energy with more than 340 hot water springs all over the country. Many of these have temperatures near boiling point at their places of occurrence (Dhaulakhandi, Sharma, Shukla, *et al.*, 1996). Large tracts of hot ground water are found with temperatures 15–20 °C above the mean ambient values. High bottom hole temperatures (140–200 °C) are also recorded in many of these bore holes drilled in sedimentary basins for hydrocarbons in India. Given below are the located geothermal provinces.

- North-West Himalayan sub province
- North-East Himalayan sub province
- Naga-Lusai geothermal province
- Andaman Nicobar geothermal province
- Cambay Grab geothermal province
- Narmada–Tapti Garben geothermal provinces
- West coast (Konkan) fault geothermal province
- Mahanadi Valley geothermal province
- North India Precambrian geothermal province
- East Indian Archean geothermal province
- South Indian Archean geothermal province
- East Indian Archean geothermal province
- South Indian Archean geothermal province

The GSI (Geological Survey of India) has taken up extensive exploration work in India to study the geothermal heat flow patterns (Sankar 1988). In India, the utilization of geothermal energy has so far been confined to pilot plants. GSI and NAL (National Aeronautical Laboratory) have installed a 5-kW pilot-scale power plant based on geothermal energy at Manikaran. This plant operates on a closed-loop Rankine cycle, employing Freon-113 as the working fluid. It has been designed and fabricated at NAL. But larger scale geothermal power plants have not been developed in India till date. It is hoped that with economic liberalization, private companies may come forward to produce power from geothermal energy. This is quite possible

because geothermal power plants are successfully operating in several countries across the world, most notably Argentina, Bolivia, Canada, China, Costa Rica, El Salvador, Ethiopia, Greece, Guadeloupe (France), Guatemala, Iceland, Indonesia, Italy, Japan, Kenya, Mexico, New Zealand, Nicaragua, Philippines, Romania, Russia, Thailand, the Azores (Portugal), Turkey, US, and Zambia. Space heating experiments have been carried out at Puga. A 62.5-m<sup>3</sup> hut was heated with geothermal water achieving temperatures 20 °C in excess of the ambient.

Geothermal energy was used for the extraction and refinement of locally occurring borax and sulphur at Puga. The extraction plant could handle 2 tonnes/day of borax ore while the refining plant could handle 500 kg/day of borax. The pilot plant for refining sulphur could handle 100 kg/day of sulphur. Geothermal water was utilized at Chhumathang for greenhouse cultivation using discharge from a geothermal drill hole. A temperature of 20–25 °C was maintained inside the greenhouse even when the atmospheric temperature outside went down to 40 °C. A variety of vegetables and flowers could be grown in the greenhouse. At Manikaran, a 7.5-tonne capacity cold storage plant was established. It utilized the geothermal water flowing at 90 °C. The cold storage plant is based on ammonia absorption system.

The Tapovan geothermal field is located in Dhauliganga Valley at an altitude of 1800–1900 m in the Garhwal region of the Himalayas. The objective of the Tapovan project is to demonstrate the feasibility of using geothermal energy. It is also aimed to serve as a model for not only Uttaranchal but also for other part of the centre (Tapovan). The economic feasibility of geothermal energy in any region depends on whether it can compete economically with other available sources of energy in that region: fossil fuels, nuclear, solar, and wind. The Tapovan project is expected to be commercially viable with a payback period of 8–10 years. Some 2500 people in the nearby villages would be direct beneficiaries if the project can find financial support.

Geothermal energy is quite low grade because the temperature of steam in the hot water used is only between 150 °C and 250 °C (at 100 psi). This compares with the steam in a conventional

fossil fuel or stream. Geothermal hot spots are sparsely distributed and usually at some distance from the markets requiring energy. The minimum temperature of steam required for the efficient production of electricity is about 100 °C. Consequently, many reservoirs of hot water can be used only for direct heating (as in Iceland). Since thermal energy cannot be efficiently transported very far, the point of use must be close to the source. Unfortunately, very few geothermal sources are of the dry-steam type. In wet-steam systems, only the part of the water that flashes to steam is used in the generation of electricity. Originally, the rest of the hot water was thrown away into a lake or stream.

### ***Environmental impacts of geothermal energy***

As is the case with most alternative energy sources, geothermal energy is often perceived as a much more cleaner source of energy than conventional sources. It is believed, often naively, that getting power from geothermal energy is a simple matter of letting out hot water or steam from the bowels of the earth. But experience with existing geothermal plants reveals a totally different picture. The environmental effects of geothermal energy sources are highly site-dependant and technology-dependant (open system or closed system) as geothermal reservoirs have a wide range of geothermal and chemical properties. For this reason it is not possible to describe a typical geothermal energy system. Thus, it is important to note that environmental impacts, and the use and effectiveness of mitigation techniques can be realistically considered only on a site-by-site basis.

A primary concern vis-à-vis harnessing geothermal energy is land subsidence following the withdrawal of hot water or steam from an underground field. Several potential pollutants are associated with geothermal sources, including hydrogen sulphide, CO<sub>2</sub>, ammonia, methane, and boric acid, along with trace amounts of mercury, arsenic, and other elements. In order to extract energy from HDR, from molten magma, or from the normal temperature differences underground, it is necessary to force water down boreholes as a working fluid and to return it to the surface for use in a turbine or for direct heating. The chief environmental problem is that very large

quantities of water are needed. Using geothermal concentrate as cooling water can presumably alleviate this problem; this is indeed done at several geysers but the polluted and foul-smelling water is responsible for a good part of the aesthetic problems of these geysers. The amount of water required is less if the geothermal reservoir is very hot so that it converts the water to steam. If the underground reservoir is highly permeable, there is no way to know how much water will need to be injected before a useful amount of steam or hot water is returned to the surface.

Axtmann (1975) has studied the environmental effects associated with the Wairakei, New Zealand geothermal power plant. He chose this plant to study because it is a hot-water rather than a dry-steam geothermal source. He found that the Wairakei plant discharges approximately 6.5 times more heat, 5.5 times more water vapour, and one-half as much sulphur per unit of power produced as would a modern coal plant in New Zealand. It also contaminates the Waikato River with hydrogen sulphide, carbon dioxide, arsenic, and mercury at concentrations that have adverse, if not calamitous, effects. Since the Wairakei plant was initiated prior to expression of much of the current environmental concern it had a greater environmental impact than that acceptable today. Re-injection of the waste water into the geothermal field would reduce the plant's environmental impact greatly. Ground subsidence is not a serious problem at Wairakei but may prove to be so at the nearby Broadlands field. In studying the Wairakei site, Axtmann did not study impacts during the development of the borefield and construction of the plant, the effects of well blowouts, changes in the natural habitat, land use considered, and aesthetic factors. All these issues need to be considered when using any geothermal resource. Geothermal water at the geysers in northern California is cooled as it flows through cooling towers. Apparently this highly mineralized water is killing vegetarians in deposition zones downwind from the power stations (Shinn 1982).

### **Conclusion**

Any consideration of energy needs and production must take energy conservation into

**Table 2** Percentage of energy consumed and wasted in the United States in various categories

Energy use	Total percentage	Percentage utilized	Percentage wasted
Electricity*	24.7	35.3	64.7
Industry	30.7	60.2	39.8
Transportation	32.4	15.1	84.9
<b>Total energy</b>	<b>100.0</b>	<b>40.8</b>	<b>59.2</b>

\* Utilizable electricity is consumed almost equally in industry, household, and commercial applications. Approximately two-thirds of the energy consumed by electrical power plants is wasted in generation and transmission.

account. Table 2 shows the percentage of energy consumed and percentage of waste for the major categories of energy use in the US (Hammond 1972). There is a high potential for energy conservation in industry since 1972, the chemical industry in the US has reduced energy use by 18%, and increased the output by 28% while increasing energy by only 3.4% (Anon 1981). India is developing at a faster rate and a right kind of decision is to be made in selecting alternative sources of energy for industrial development. It has a vast potential for geothermal energy and it can be prescribed as a much cleaner source of energy than conventional energy. Environmental impacts are site specific and technology dependent. With regard to the potential of renewable sources of energy it is clear that much larger investments are needed to utilize these sources in a larger scale while further developing this.

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# Abstracts on renewable energy

Chandrasekar B and Kandpal T C. 2007. **An opinion-survey-based assessment of renewable energy technology development in India** *Renewable and Sustainable Energy Reviews* 11(4): 688-701  
*Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi - 110 016, India*

India has a very large potential for harnessing RE (renewable energy) sources. However, there is a large gap between the estimated potential and the cumulative achievements made so far. Many reasons are attributed to the current low levels of dissemination of RE technologies in India as against their respective estimated potentials. Several of these attributes could, one way or the other, be related to the current status of development of the technology, its

appropriateness, and dissemination strategies adopted for its diffusion and deployment. Results of an attempt to assess the current status of some RE technologies in India are briefly presented in this paper. The main findings of a structured questionnaire-based survey undertaken for eliciting views of different categories of stakeholders on various issues affecting dissemination of RE technologies in India are presented in this paper. (1 figure, 17 tables, 4 references)

Iniyar S, Suganthi L, and Samuel A A. 2006. **Energy models for commercial energy prediction and substitution of renewable energy sources.** *Energy Policy* 34 (17): 2640-2653  
*Department of Mechanical Engineering, College of Engineering, Anna University, Chennai - 600 025*

In this paper, three models have been projected: MEM (Modified Econometric Mathematical) model, MPEEE (Mathematical Programming Energy-Economy-Environment) model, and OREM (Optimal Renewable Energy Mathematical) model. The actual demand for coal, oil, and electricity is predicted using the MEM model based on economic, technological, and environmental factors. The results were used in the MPEEE model, which determines the optimum allocation of commercial energy sources based on environmental limitations. The gap between the actual energy demand from the

MEM model and optimal energy use from the MPEEE model has to be met by the RE sources. The study develops an OREM model that would facilitate effective utilization of RE sources in India, based on cost, efficiency, social acceptance, reliability, potential, and demand. The economic variations in solar energy systems and inclusion of environmental constraint are also analysed with OREM model. The OREM model will help policy-makers in the formulation and implementation of strategies concerning RE sources in India for the next two decades. (8 figures, 4 tables, 27 references)

Dudhani S, Sinha A K, and Inamdar S S. 2006. **Assessment of small hydropower potential using remote sensing data for sustainable development in India.** *Energy Policy* 34 (17): 3195-3205  
*Bharati Vidyapeeth's College of Engineering, A-4, Paschim Vihar, Rothak Road, New Delhi - 110 063*

Sustainable and qualitative growth for developing economics and habitat requires increased energy input from various resources while maintaining balance in the ecosystem during exploitation. This paper discusses resource potential, achievements, and various issues related to the power generation in India. The growing concern over environmental degradation caused by fossil-fuel-based systems, opposition to large hydropower

projects on grounds of displacement of land and population, environmental problems with nuclear-fuel-based systems, and the ever-rising shortage of power highlights the need for tapping alternate energy sources for power generation. Amongst the alternate sources, utilization of hydropower on a smaller scale (small, mini, and micro hydropower) has become the thrust area for sustainable growth in the power sector. Hydropower is an economical

and environmentally clean source of RE abundantly available in the hilly regions of India. The huge hydropower potential in India located in the inaccessible mountainous regions is yet to be explored. However, development of this potential is challenging due to difficult and inaccessible terrain profile. This paper presents application of remote sensing data for identification and selection of probable site for hydropower projects. The algorithm for identification and assessment of water resources, and its perennial is developed in VB (Visual

Basic) platform, and it is successfully applied for IRS-1D, LISS III Geo-coded FCC (False Color Composite) satellite image for plain as well as hilly and mountainous regions. Classification of satellite image in to different objects is modelled as the task of clustering based on the intensity of R-G-B values of pixels. Results obtained are presented and compared with the Survey of India Toposheets (53K/2, 53K/3 and 53J/16). Use of remote sensing data provides a scientific method of hydropower identification and assessment. (7 figures, 4 tables, 34 references)

Reddy B S and Balachandra P. 2006. **Dynamics of technology shifts in the household sector: implications for clean development mechanism.** *Energy Policy* 34 (16): 2586-2599

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The present paper attempts to analyse the dynamics of energy end-use technology shifts in the household sector in India. The technology shifts can be categorized as naturally occurring shifts (with increasing household incomes and availability of energy carriers) and policy-induced shifts (by creating a favourable environment). Initially, the household energy usage patterns, types of energy carriers, and the technologies in use are analysed using the data from the National Sample Survey (1999/2000). The energy consumption is disaggregated according to end-use activity and by income groups for rural as well as urban households. It is observed that large variations in energy use exist across different

sections of households: urban/rural, low/high-income groups, and so on. Further, the paper provides a methodological framework for the diffusion of energy-efficient technologies, and the implications of such diffusions for CDM. It analyses the reasons for the gap between possible and practical implementation of energy-efficient measures, studies the reasons for households not using the cost-effective technologies available to them, the benefits of innovation of energy efficiency, and the required policies and specific proposals for government intervention to achieve the potential for CDM. (1 figure, 15 tables, 7 references)

Pohekar S D and Ramachandran M. 2006. **Utility assessment of parabolic solar cooker as a domestic cooking device in India** *Renewable Energy* 31(11): 1827-1838

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The energy need for cooking in households can be supplemented by a PSC (parabolic solar cooker). Policy for energy substitution by renewables has to consider many conflicting socio-economic issues. To know the perceptions of decision-makers and users, a survey is conducted to evaluate nine cooking energy devices available in India. Energy technology issues, economics, environmental/social, behavioural, and commercial issues are considered for the evaluation. Thirty criteria are considered under these five aspects for pair-wise comparison of the

devices. Additive MAUT (multi-attribute utility theory) is employed to evolve ranking of selected devices. It is found that LPG (liquefied petroleum gas) stove is the most preferred cooking device, followed by microwave ovens and kerosene stoves. PSC occupies the fifth place amongst the devices. A sensitivity analysis is also carried out for identifying potential areas of improvement for PSC, which forms a basis for policy interventions required for its better dissemination in India. (1 figure, 5 tables, 22 references)

Prasad A R and Natarajan E. 2006. **Optimization of integrated photovoltaic–wind power generation systems with battery storage.** *Energy* **31** (12): 1943–1954

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In this paper, a new method for optimization of a wind–PV (photovoltaic) integrated hybrid system is presented. Based on DPSP (deficiency of power supply probability), REPG (relative excess power generated), UEP (unutilized energy probability), LCC (life cycle cost), LEC (levelized energy cost), and LUC (life cycle unit cost) of power generation with battery bank, the method addresses a specific location and employs an

iterative scheme. A simulation software code has been developed to carry out the analysis for optimizing the size of the integrated system for a given location. Also, a case study using the software for the selection of optimal size of the integrated system for the site Pompuhar, Tamil Nadu, India has been presented. (4 figures, 1 table, 9 references)

Mukherjee A B and Zevenhoven R. 2006. **Mercury in coal ash and its fate in the Indian subcontinent: a synoptic review.** *Science of the Total Environment* **368** (1): 384–392

*Department of Biological and Environmental Sciences, Helsinki University, P O Box 27, FIN-00014 Helsinki, Finland*

In the Indian subcontinent, power generation is mainly dependent upon the thermal power units, and coal is burnt as a fuel for the production of heat and electricity. In India, bituminous and sub-bituminous coals are used which contain over 40% of ash. At present, 80–90 MT (million tonnes) of fly ash is generated from 85 existing coal-based thermal power plants. Coal contains trace metals, of which, mercury is the most toxic for humans and aquatic fauna. The problem of mercury accumulation is not new, but in the recent years the Indian subcontinent has gained the reputation of being ‘a dumping ground for mercury’. This study focuses on mercury in fly

ash, and its releases to the atmosphere and soils cross the country. The utilization of coal ash in India is also addressed though it is still in its nascent stage. About 10% of produced fly ash is used in India whereas in the western countries its use is typically over 70%. Regulations from the Indian ministry of environment and forests should increase coal fly ash utilization, though this would require that cost-effective new technology be put to use. As to the release of mercury from ash disposed of in the environment, the scarce literature suggests that this is negligible or zero, and less problematic than wet or dry deposition of mercury from flue gases. (4 figures, 6 tables, 49 references)

Bugaje I M. 2006. **Renewable energy for sustainable development in Africa: a review.** *Renewable and Sustainable Energy Reviews* **10** (6): December 2006, 603–612

*Department of Chemical Engineering, Ahmadu Bello University, Zaire, Nigeria*

In this paper, RE usage in Africa has been reviewed using South Africa, Egypt, Nigeria, and Mali as case studies. The various national energy policies of these countries were analysed and areas that require attention to achieve sustainability were highlighted. Overall, the success of sustainable development practices in Africa lies in addressing the imminent energy crisis in the continent. Excessive usage of

fuelwood is already creating considerable environmental problems especially in Sahel. Africa has a lot of potential to solve its energy problems provided appropriate infrastructural support is given for harnessing the abundant renewable resources in the continent, and skills are pooled together, and experiences shared in addressing the key issues. (31 references)

Dudhani S, Sinha A K, and Inamdar S S. 2006. **Renewable energy sources for peak load demand management in India.** *International Journal of Electrical Power and Energy Systems* 28(6): 396-400  
Bharati Vidyapeeth's College of Engineering, A-4, Paschim Vihar, Rothak Road, New Delhi - 110 063

In a developing country such as India, the demand for power is increasing day by day; peak load demand management is also becoming crucial. This paper highlights the gap between peak load power demand and availability of power at the regional level, and proposes power generation from renewable sources to fill the gap. However, the problem has been recognized as the optimum allocation of the various renewable energy options to meet the peak load demand at the regional level of India. This was done through the application of a linear programming algorithm. Due to the geological profile of the

regions of India, the potential of various RE sources such as small hydel power, solar PV, wind power, co-generation, and biomass energy varies from region to region. A computational result indicates that the power generated by renewable resources is quite suitable for meeting the peak load demand. In fact, some of the regions have excess power potential, which can be generated from renewable sources, and can be transferred to the other regions utilizing the existing power transmission line network.  
(2 figures, 4 tables, 15 references)

Limmeechokchai B and Suksuntornsiri P. 2007. **Assessment of cleaner electricity generation technologies for net carbon dioxide mitigation in Thailand.** *Renewable and Sustainable Energy Reviews* 11(2): 315-330  
Sirindhorn International Institute of Technology, Thammasat University, Thammasat Rangsit Post Office, P O Box 22, 12121 Pathumthani, Thailand

The choice of electricity generation technologies not only directly affects the amount of CO<sub>2</sub> (carbon dioxide) emission from the power sector, but also indirectly affects the economy-wide CO<sub>2</sub> emission. In Thailand, although the PDP (power development plan) has been developed for the committed capacity to meet the future electricity demand, there are some undecided electricity generation technologies that will be studied for technological options. The economy-wide CO<sub>2</sub> mitigations between selecting cleaner power generation options instead of pulverized coal-thermal technology of the undecided capacity are assessed by energy IOA (input-output analysis). The decomposition of IOA presents the fuel-mix effect, input structural effect, and final demand effect by the change in technology of the undecided capacity. The cleaner technologies

include biomass power generation, hydroelectricity, and IGCC (integrated gasification combined cycle). Results of the analyses show that if the conventional pulverized coal technology is selected in the undecided capacity, the economy-wide CO<sub>2</sub> emission would be increased from 223 MT in 2006 to 406 MT in 2016. Renewable technology presents better mitigation option for replacement of conventional pulverized coal technology than the cleaner coal technology. The major contributor to CO<sub>2</sub> mitigation in cleaner coal technology is the fuel-mix effect due to higher conversion efficiency. The demand effect is the major contributor of CO<sub>2</sub> mitigation in the biomass and hydro cases. The embedded emission in the construction of a power plant contributes to higher CO<sub>2</sub> emission.  
(6 figures, 6 tables, 20 references)

Dowaki K, Ohta T, Kasahara Y, Kameyama M, Sakawaki K, Mori S. 2007. **An economic and energy analysis on bio-hydrogen fuel using a gasification process.** *Renewable Energy* 32(1): 80-94  
Tokyo University of Science, 2641 Yamazaki, Noda, Chiba, 278-8510, Japan

This study is an environmental and economic analysis of a biomass energy system that can produce hydrogen fuel for fuel cells (purity of 99.99%) as an example of an environmental business model. The experimental apparatus

was made based on the moving-bed gasifier by the German company, DM2 Inc., and the hydrogen gas yield was measured. Finally, the economic viability of the future hydrogen business was estimated. The experimental results obtained gave

the gas concentration of 57.5% in a steam/carbon ratio of 1.40 at 900 °C. Based on the law concerning waste processing in Japan, a sizeable amount of waste biomass could be expected. Therefore, if the processing fee which is paid to the group (contractor), ranges between 5.0 and 10.0 dollars/tonne, and if the whole investment

cost is 6 million dollars and the depreciation period is 15 years, the bio-hydrogen production cost using the experimental data would be 5.75–7.86 dollars/kg-H<sub>2</sub> without receiving related subsidies. In a one-third grant proportion, the cost would become 4.60–6.72 dollars/kg-H<sub>2</sub>. (8 figures, 4 tables, 16 references)

Tonooka T, Liu J, Kondou Y, Ning Y, Fukasawa O. 2005. A survey on energy consumption in rural households in the fringes of Xian city *Energy and Buildings* 38(11): 1335–1342  
Saitama University, Faculty of Economics, Department of Social Environmental Planning, Japan

A survey, in the form of a questionnaire, of energy consumption patterns in residential households in the rural fringe of Xian city was undertaken during the winter of 2003/04. More than 200 households were sampled during the survey. The status of fuel consumption, including the use of biomass fuels for cooking and space heating, was investigated. The types of stoves, purpose of stove use, and characteristics of the residential houses and residents were also reported and analysed. In rural areas of China, biomass (wood and agricultural waste, such as stalks, corn canes and twigs, and branches of wood) is the most

commonly used fuel. It emits several air pollutants: PM (particulate matter), CO (carbon monoxide), NMHCs (non-methane hydrocarbons), CH<sub>4</sub> (methane), and high levels of BC (black carbon) – a greenhouse effect aerosol – and OC (organic carbon) – a cooling effect aerosol. However, CO<sub>2</sub> emissions from biomass burning are assumed to be zero because of carbon neutrality. From this survey it would then be possible to analyse the fundamentals of emission reduction potential, for air pollutants and greenhouse gases, from the rural household sector in China. (13 figures, 6 tables, 10 references)

## Technological developments

### Solar power could add stars to hotels

The use of renewable sources of energy in hotels may soon be a criterion for the star classification. The MNES (Ministry of Non-conventional Energy Sources), GoI (Government of India) has asked the tourism ministry to consider giving weightage to renewable technologies for awarding star status to hotels. To devise a methodology in this area, the ministry has suggested that the tourism ministry avail expertise of the bureau of energy efficiency. It has also pointed out that existing use of solar thermal, PV (photovoltaic) technologies and biogas generation technologies used by hotels can be taken as a model for implementing the proposal. In an attempt to encourage the use of renewable sources of energy in urban areas, the government has offered fiscal incentives as well. Hotels, being one of the largest consumers of energy, are now the focus of the ministry.

*The Economic Times, 18 September 2006*

### Cummins, IISc in pact for biomass generation systems

Cummins India and the IISc (Indian Institute of Science) have signed an agreement for the commercialization of biomass gasification power generation systems. Under the agreement, Cummins India and IISc will work together for integrated development and release of power generation systems based on open down-draft biomass gasification systems developed by ABETS (Advanced Bio Residue Energy Technologies Society), IISc. An open-top down-draft biomass gasifier generates gas from a range of biomass waste that comprises forest residue, agricultural residue in briquette form, and bagasse. Cummins India will soon launch a new range of generator set systems, which will be developed to work on gasifiers designed as per IISc technology.

*The Economic Times, 6 September 2006*

## **New approach removes sulphur from military-grade fuel**

Fuel cells can generate the electricity necessary to power electronic gadgets and facilitate communication, while avoiding use of generators that are noisy and create heat signatures. Researchers at PNNL (Pacific North-west National Laboratory) have developed a compact and rugged microchannel distillation unit to create a light fraction of JP-8, the standard military fuel. The JP-8 light fraction is then reacted in a catalytic process called hydrodesulphurization, in order to remove sulphur from the fuel. Conventional technology utilizes hydrogen as the co-reactant with JP-8 to power the process, but it is not available in the field. Syngas can be generated by steam reforming of the purified fuel.

Most of the syngas is further purified for use by the fuel cell, but a fraction of the syngas is diverted to the hydrodesulphurization unit. The use of syngas creates some challenges, but it appears that they have been mostly overcome in the PNNL process, and syngas performs almost as well as pure hydrogen. Gas-phase operation of the process allows significant increase in throughput and decrease in operating pressure compared with conventional technology. Residual sulphur concentration in the hydrodesulphurized fuel below five parts per million has been obtained through this process.

*<http://www.physorg.com>, 29 August 2006*

## **Wind mapping station comes up in Vizag**

Visakhapatnam and Medak are the two districts selected for a latest feasibility study for wind power in Andhra Pradesh. A team from CWET (Centre for Wind Energy Technology), Chennai has conducted a preliminary survey in 18 districts of the state and selected the above two districts for 2005/06. CWET is an autonomous research and development institute working under the MNES, GoI. The most important part of the feasibility study is to identify a site with potential for wind energy to set up a wind mapping station. Wind speed will be studied for two years at the identified site. The main parameter is that the average annual wind speed should be more than 12 kmph (kilometres per hour). Speed between 12 kmph and 15 kmph is considered average, between 15 kmph and 18 kmph good, and above 18 kmph excellent.

*The Hindu, 24 August 2006*

## **Mizoram set to make power from bamboo**

The Mizoram government has made advances in setting up an environment-friendly power station that will run on bamboo to help meet growing industrial energy needs. The state, it is claimed, will be the first in the country to use such 'green' power. Possibly it will be one of the first places in the world to tap the energy potential of the fast-growing grass species. The proposed 2.85-crore-rupee power project was designed by scientists at IISc, Bangalore, and Ankur Scientific Energy Technologies. It will be based on gas produced by using bamboo as feedstock, he said. The station is to be located in Sairang, where the state government proposes to set up many bamboo-based industries. The commercial success of gasification of bamboo for generation of electricity would help solve the energy crisis faced by the region, especially by Mizoram. It would then enable experts to pursue such ventures on a bigger scale, he said. More such projects would be proposed, which would generate employment.

*The Hindu, 29 July 2006*

## **Cool nanotechnology can save energy**

Huge reductions in heating bills, safer surgery, and the next generation of miniaturized computers are among the potential benefits of new nanotechnology developed at Leeds University, England. By suspending nanoparticles in water or other liquids, researchers have created 'nanofluids' which can transfer heat up to 400% faster than other liquids. In a central heating system, nanofluids could increase efficiency without the need to use a more powerful pump, thus, saving energy and providing major environmental benefits.

*<http://www.physorg.com>, 28 July 2006*

## **Arise produces solar grade silicon using new technique**

Arise Technologies of Ontario, Canada has demonstrated in the laboratory a new approach for refining high-purity solar-grade silicon. Arise has been working on this project with a consortium, which includes two universities and several international partners. The new technique produces silicon feedstock that can be fed into the ingot-making process that produces crystalline silicon ingots for solar cells. The silicon produced is intended to meet the specifications of high-

efficiency solar PV cell manufacturers.  
<http://www.renewableenergyaccess.com>, 28 June 2006

### India moves up rank on renewable energy index

Wind, as an emerging energy source, has ensured that India makes it to number four on the renewable energy attractiveness index. Over the past year nearly 1500 MW (megawatt) of wind energy capacity has been added, though some issues on grid connectivity continue to exist as stumbling blocks. However, on the whole, experts feel that India has turned the corner. India has taken over UK's place in the long-term all renewables index while displacing Germany from the third place in both the long-term and near-term Wind Indices, according to Ernst & Young's renewable energy country attractiveness indices. This happy turn of events is due to great receptivity for the injection of wind power into the grid. The supply is also stable due to robust technology. Also, several states and state

regulators have taken a stand on admitting wind power into the grid. Nonetheless, the share of wind energy in India's total power generation capacity is minuscule, at slightly over 2%.  
*The Economic Times*, 26 June 2006

### WBREDA to promote battery-operated cars

The WBREDA (West Bengal Renewable Energy Development Agency) will promote green-fuel-operated vehicles in the state and offer one time financial subsidy to prospective buyers of these vehicles. A Siliguri-based company will manufacture battery-operated two-wheelers with Chinese technology. Another company in Kolkata will assemble Chinese-technology-based battery-operated two-wheelers, that would cost about 27 000 rupees a unit. WBREDA has bought a battery-operated car, REVA, six three-wheelers and two two-wheelers for demonstration to promote green vehicles in the state.  
*The Statesman*, 18 June 2006

## Web updates

### ELDIS

<http://www.eldis.org/>

ELDIS is a gateway to searchable online information on development in countries of the South. The coverage includes social, economic, political, and environmental issues. ELDIS makes a qualitative selection of materials and structures for easy access. The site covers issues related to socio-economics, sustainable development, forestry, irrigation, and pest control; environmental issues including biodiversity and conservation, climate change, desertification, pollution, soils, waste management; and water-related issues.

### IEA Renewable energy database

<http://www.iea.org/textbase/pamsdb/search.aspx?mode=re>

The Renewable Energy Policies and Measures Database provides a list of IEA member countries. The database also provides in-depth information relating to energy efficiency, renewable energy, green pricing, economy, and investments.

### Database on Energy Efficiency

<http://www.ser.d.a.it.ac.th/teenet/efficiency.htm>

DEED provides links to 14 most popular databases on energy efficiency. These include Energy Efficient Appliances, UK EPIC, WEEA, Energy Star, Enerdata, DEEM to Offer Database of Energy Efficiency Measures, MUNEE Database, ACEEE Energy Efficiency Program Database, CADDET Energy Efficiency InfoStore, and DEER (Database for Energy Efficient Resources), etc.

### Environmental Law Information

<http://www.environmentallawnet.com/>

This website provides qualitative, quick, and cost-efficient legal solutions in the changing environmental regulatory arena. The main features of this site include legal information libraries, which are laws and regulations, court and agency decisions, agency documents and databases, compliance counselling, enforcement and litigation, real estate, and corporate transactions. The community attributes of this site

are news, desk reference, and what's new in the relevant field. Besides, the site also provides event information and holds an interactive online forum.

### **Renewable Energy and Sustainable Energy Systems in Canada**

<http://www.newenergy.org/>

The Canadian Renewable Energy and Sustainable Energy website provides help in producing and/or using energy in the most effective and environmentally friendly ways. The website coverage includes information on solar, wind, small hydro, co-generation, biomass, energy services, and space heating and cooling systems. Besides, the site also provides information on publications, business opportunities, events, news, and links to other websites.

### **Source for Renewable Energy**

<http://www.energy.sourceguides.com/>

The Source for Renewable Energy is a comprehensive buyers guide and business directory to more than 4000 renewable energy businesses worldwide.

### **Business Council for Sustainable Energy**

<http://www.bcse.org/>

The Business Council for Sustainable Energy was created to advocate policies to promote the economic, environmental, and security goals in natural gas, energy efficiency, electric utility, and renewable energy industries. The website provides information on efficient, economic, and environmentally sound technologies, such as fuel cells, solar power, cogeneration, wind power, and natural gas combined-cycle systems. Beside it also hosts information on financing, projects reports, consultancy, publications, and related links.

### **Global Energy Marketplace**

<http://www.acca21.org.cn/cres.html>

GEM (Global Energy Marketplace) is a gateway to sustainable energy information on the web. The searchable GEM database covers renewable energy technologies, energy efficiency, and policy. The database also provides transport, planning and development information, and energy company information.

## **Forthcoming events**

18–21 February 2007  
Wellington, **New Zealand**

### **From Restructuring to Sustainability: energy policies for the 21st century**

Conference Manager, Victoria Continuing Education  
Victoria University of Wellington, P O Box 600, Wellington,  
New Zealand

*Tel.* +4 463 6558 • *Fax* +4 463 6550

*E-mail* ce-conferences@vuw.ac.nz • *Web* www.vuw.ac.nz/iaee07

29–31 January 2007  
Brussels, **Belgium**

### **2007 European Renewable Energy Policy Conference**

EREC, Renewable Energy House, 63–65 Rue d'Arlon, B-1040,  
Brussels, Belgium,

*Tel.* +32 2 546 1933 • *Fax* +32 2 546 1934

*E-mail* erec@erec-renewables.org

*Web* www.erec-renewables.org or www.bmu.de

30 November–  
1 December 2006  
Bangkok, **Thailand**

### **International Symposium on Water Resources and Renewable Energy Development in Asia**

Ms Maria Flintan, 123 Westmead Road, Sutton, Surrey, SM14JH, UK

*Tel.* +44 (0) 208 643 5133 • *Fax* +44 (0) 208 643 8200

*E-mail* bkk2006@hydropower-dams.com

*Web* www.hydropower-dams.com

# ENVIS Centre on Renewable Energy and Environment

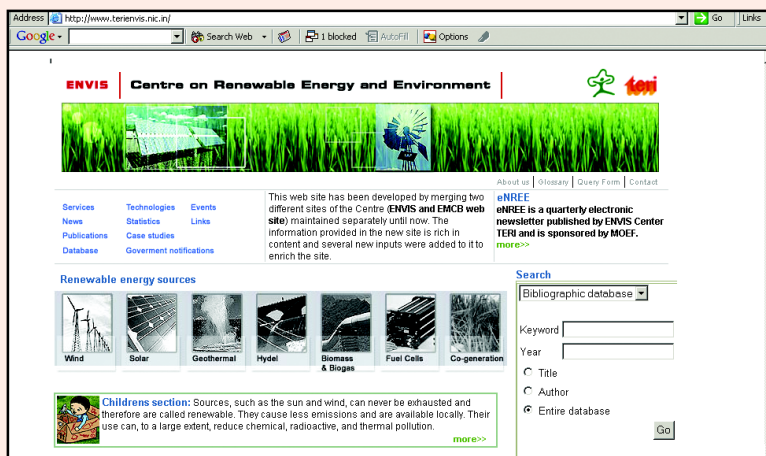
## A knowledge gateway

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'.

■ Editor P K Bhattacharya ■ Assistant Editor Ambika Shankar

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