Promoting Renewable Energy:
Global Technology Cooperation, Innovation and Investment

1st World Renewable Energy Technology Congress and Expo held at Hotel LeMeridien New Delhi from 18th to 20th March 2010 was a grand success. The congress was attended by 410 national and international delegates from 30 countries.

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Ministry of New and Renewable Energy
Government of India

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Dear Reader,

Energy is a key indicator and input to the social, economic, industrial, and technological development of a country. Human’s quest for leading a better and comfortable life has compelled him to use all available energy sources, irrespective of the involved cost and environmental degradation. In the present era of massive growth in all spheres of life, which is increasing the energy demand manifolds, the use of all available resources is a must. And renewable energy cannot be ruled out. It is rather emerging as an alternative to conventional fuels.

Everything in this world moves because of energy. The standard of living of a country can be directly related to its per capita energy consumption. Energy plays a major role in the development of a country. Its growth is measured in terms of technological development, industrialization, economical growth, and so on. Today, Japan, US, Germany, and UK are called developed countries due to their advanced technological development, rapid industrialization, and energy production and consumption.

India is poised to gain a high growth rate, and thus, its energy demand is increasing exponentially. Renewable energy is now contributing towards fulfilling the ever-increasing energy demand in the country. The country is, thus, focussing on the growth of renewable energy. Among others, biofuel or biodiesel has a promising future due to its natural availability, 99.9% resemblance with diesel, and versatile applications in all machineries, transport, generator sets, and other such places where diesel is used.

Biodiesel, the renewable liquid fuel produced from biological raw material, is a good substitute for petroleum diesel. It is gaining worldwide acceptance as an environment-friendly solution to the energy problem. The production of oil-producing crops is a major challenge when most of the cultivable area has been occupied by conventional/cultivated crops. So, plant species that can come up in degraded lands need to be promoted. Although a biofuel policy has been announced, it is yet to take off in the country.

The present issue in your hand provides informative material in biofuel areas, that is biodiesel production from non-edible oil of Assam; biomass, biofuel, and food security; and bio-hydrogen production technology. The efforts are also on for generating electricity through algae cells, as presented in the ‘RE Tech Update’. Refrigeration using solar energy is also an upcoming field and has a lot of scope for those places where electricity is yet to reach. This aspect has been presented in two other articles.

I am sure that you will find this issue informative and interesting. Do send us your valuable suggestions to make Akshay Urja more interesting and useful.

Happy reading!

ARUN K TRIPATHI
<aktripathi@nic.in>
Since the last three years, my child has been giving me his environmental studies book to read out to him. I realized then that India, as a developing nation, has to balance our eco system. So now I am trying to open a small business of solar products, which would somewhat, if not fully, reduce the load on electricity generated by polluted means. I would be marketing as well as spreading awareness about solar energy and other energy saving products. Last week, I chanced upon Akshay Urja, Ministry of New and Renewable Energy’s bimonthly magazine, and I am thoroughly impressed and humbled by the enormous amount of useful information in it, which can be used as a guiding tool for people like us.

Krishna M Pamidi
83, off. C H Street,
Near Marine Lines flyover,
Mumbai–400 002

You have been kind enough to send a complimentary copy of Akshay Urja Volume 3 Issue 1 August 2009 issue for the use of our studious students, brilliant faculty, tireless researchers, and dedicated professionals in the pursuit of their curriculum and research activities.

Since your bi-monthly newsletter is very useful and relevant to our clientele, kindly continue its supply to us by including our name in your mailing list. In case some issues of volume 2 are still available, please mail them to us.

Pravin Naidu
75, Kalpataru Housing Society,
Om Nagar, Kalmana Road, near new water tank,
Ranala (G P), Kamptee, Dist.
Nagpur–441002

I have been working as the Director and Chief Executive Officer of TREDU (Tripura Renewable Energy Development Agency) for more than three years. And I am deeply impressed by the publications of MNRE’s (Ministry of New and Renewable Energy) newsletter Akshay Urja, under the leadership of Dr A K Tripathi, Director, MNRE. The editorial written by Dr Tripathi in the last issue has given me deep thoughts which are valuable.

I have developed a keen interest in the different programmes of the MNRE on NCES (non-conventional energy sources) and up-to-date achievements, future programmes, and so on. In fact, I want to be associated with the development of renewable energy sources in India and abroad, even when I shall not be working in TREDU in the future.

Subhash Chowdhury
Director and CEO, TREDU

Dear Reader,
Thank you very much for your encouragement. The editorial team of Akshay Urja will make every effort to make this newsletter highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvement in terms of content and presentation.

Editor
Akshay Urja
RE NEWS

National
- Telcos should come forward in utilization of renewable energy, says Dr Abdullah ...
- Commonwealth Games 2010 to be solar powered by Reliance ...
- Ladakh renewable energy initiative ...
- Biomass gasifier systems in rice mills to substitute diesel ...

International
- Renewable energy investments surge on China, wind ...
- Malaysia looking at alternative energy sources ...
- EDP to buy 1500 MW wind turbines, cut US investment ...
- Indonesia aims to generate 4000 MW of geothermal energy from volcanoes ...
- New Jersey cuts red tape to boost solar efforts ...

RE EVENTS
- Chief Minister of West Bengal inaugurates SPV module manufacturing plant of Vikram Group of Industries at Falta SEZ
- World Renewable Energy Technology Congress: global technology cooperation for renewable energy
  - A ‘sun’day interaction with RWA on solar energy
- CHILDREN'S CORNER ...
- BOOK REVIEW ...
- BOOK / WEB ALERT ...
- FORTHCOMING EVENTS ...
- RE STATISTICS ...
Telcos should come forward in utilization of renewable energy, says Dr Abdullah

Dr. Farooq Abdullah, Union Minister for New and Renewable Energy, highlighted the need for the utilization of renewable energy by telecom players for their towers and urged that industry should come forward in doing so. Dr Abdullah was speaking at a seminar organized by the CMAI (Communications and Manufacturing Association of India).

Green solutions to power-related problems for rural telephony and changing the economics of backup power were discussed at the round table, inaugurated by A Raja, Union Minister of Communication and Information Technology, and Dr Farooq Abdullah, Union Minister of New and Renewable Energy, in the presence of Venugopal Dhoot, Chairman, CMAI.

Currently, the total carbon emission from cell phone towers in India is 5.3 million tones, annually. The annual cost of diesel, incurred on running the towers across India, is estimated at Rs 6400 crores. These facts highlight the growing need to promote the adoption of renewable energy options for the telecom sector in India. Alternative energy options, including solar and wind energy, can address the challenge of unavailability of reliable power supply in semi-urban, rural, and remote areas, enabling telecom connectivity for the remote parts of the country.

Dr Abdullah and A Raja also launched the publication Role of Renewable Energy in Telecom by CMAI’s knowledge partner Mazars. The publication highlights the utility of renewable energy and other related technological innovations in the telecom sector, while also identifying advantages of alternative sources of energy and their impact on reducing costs of running the network critical equipment.

Commonwealth games 2010 to be solar powered by Reliance

The solar energy initiative of RIL (Reliance Industries Ltd), RIL Solar Group, has successfully implemented and commissioned India’s first 1 MW (megawatt) solar plant on the roof of Thyagaraj Stadium in New Delhi. The Thyagaraj Stadium, developed by the Government of Delhi, is planned to be a model green stadium. RIL Solar Group has also implemented power plants in the R K Khanna Tennis Complex and solar LED (light-emitting diode) streetlights and garden lights in the tennis courts in the R K Khanna Tennis Complex. Further, there are 34 back-up solar PV systems of 3 KWp each, along with 180 solar LED street lights and 500 garden lights in the Commonwealth Games Village.

Commenting on the achievement, Mukesh Ambani, Chairman and Managing Director of RIL, said, ‘We have always believed that the renewable energy space is a natural extension
of our strengths in the conventional energy platform. The nature of technical expertise and project execution demonstrated in developing the solar power infrastructure is a defining achievement for our solar group. We will continue our efforts in research, understanding, and scaling up the deployment of these environment-friendly sources of energy. RIL is privileged and honoured to work with the Government of Delhi and the Organizing Committee, and be an integral ‘green’ part of a showcase event like the Commonwealth Games 2010.’

RELIANCE INDUSTRIES LTD

Ladakh renewable energy initiative

The Cabinet Committee on Infrastructure has approved a project to promote the use of renewable energy in the Ladakh region at a total cost of Rs 473 crore. The Ladakh region has extreme environment conditions and faces enormous energy adversities throughout the year. It becomes even more acute during the winter months. The urban areas and all defence establishments use diesel and kerosene extensively. The population in the remote areas faces acute shortage of fuel for cooking and space heating. Considering that the region has a good potential of solar and hydro resources, much of it can be realized and effectively used for minimizing the use of diesel, kerosene, and fuelwood.

Detailed studies were undertaken in the Leh and Kargil districts of the region and after consultations with all the stakeholders, including defence officials, Ladakh councils in Leh and Kargil, districts officials, NGOs (non-governmental organizations), and others, the MNRE (Ministry of New and Renewable Energy) has prepared a plan for the large-scale use of renewable energy with a total financial requirement of Rs 473 crore.

The plan envisages 30 small/micro hydel projects, aggregating to 23.5 MW (megawatt) capacity; setting up of about 300 SPV (solar photovoltaic) power plants of 5–100 KW capacity; 2000 SPV home lighting systems; and about 40 000 solar thermal systems like water heaters, solar cookers, solar passive buildings, solar green house, and so on. The solar greenhouses proposed to be set up in the region would help in increasing the production of green vegetables in winters for the region, which are otherwise procured from far off places.

The implementation of the Plan will start from June 2010 and will be completed by December 2013. The renewable energy projects are expected to result in a saving of about 200 lakh litres of diesel per year.

MNRE

Biomass gasifier systems in rice mills to substitute diesel

In view of the enormous potential for saving fossil fuels, specifically diesel which is presently being used in rice mills for meeting their captive power requirements, the MNRE (Ministry of New and Renewable Energy) has recently launched a new scheme for promoting rice husk-based biomass gasifier systems. These systems would not only save diesel but will also provide cost-effective reliable solution for their captive power requirements, using the rice husk produced in rice mills.

In order to facilitate the rice mills to avail the special financial package expeditiously, a MoU (Memorandum...
A national news")

of Understanding) has been signed between the State Bank of India, Patna, and M/s Beltron Telecommunication Ltd, Patna. Through this technical and financial mechanism, about 500 rice mills would be able to avail the benefit by setting up biomass gasifier systems during 2010, which will lead to the saving of about 20–25 million litres of diesel annually and at the same time, provide the benefits of a reliable power supply.

PRESS INFORMATION BUREAU

MNRE constitutes core group to assess status of improved biomass cookstoves

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n order to make smokeless stoves popular, the MNRE (Ministry of New and Renewable Energy) launched a National Biomass Cookstove Initiative in 2009. The primary aim of the initiative is to develop and enhance the availability of better and efficient family- and community-size biomass cookstoves for household and industrial applications in the country. It also emphasizes the enhancement of technical capacity in the country by setting up testing, certification, and monitoring facilities and strengthening R&D (research and development) programmes in various technical institutions of the country. In this regard, the MNRE has constituted a core group and sanctioned a project to assess present status of various types of improved biomass cookstoves currently available, their suitability, and delivery mechanisms, and to prepare an action plan for the development and deployment of cookstoves. Simultaneously, the MNRE has identified four test centres for carrying out the performance testing.

PRESS INFORMATION BUREAU

Efforts initiated to develop biofuel, says Dr Abdullah

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r Farooq Abdullah, Union Minister for New and Renewable Energy, recently announced that efforts have been initiated to develop coordinated R&D (research and development) projects on second generation biofuels, such as production of ethanol from agricultural wastes/residues and biodiesel from algae.

He also said that the National Policy on Biofuels is aimed at accelerated promotion and development of biofuels like bioethanol and biodiesel. The OMCs (oil marketing companies) have been directed to sell 5% ethanol-blended petrol in the entire country, except northeastern states, Jammu and Kashmir, Andaman and Nicobar Islands, and Lakshadweep. Biodiesel is currently not being marketed commercially for blending with diesel, as the biodiesel industry is still at a nascent stage of development. R&D is also being pursued through different scientific agencies on feedstock development, conversion processes, and production of ethanol, mainly from sugarcane molasses and biodiesel from jatropha.

The Minister further informed that the amount spent by the various ministries/departments during the last three years from 2006/07 to 2008/09 is about Rs 48.98 crores, and is Rs 20.37 crores so far during the current year.

PRESS INFORMATION BUREAU

Areva, Siemens, GE explore offshore wind-ow in India

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long coastline, low installation cost, and ready local availability of key raw materials have made India a favoured destination for offshore wind power, with global majors like Areva, Siemens, and GE (General Electric) queuing up to explore opportunities in the country.

‘Offshore wind is the new growth area and has immense opportunities in India due to cheaper costs,’ Areva Renewables global Chief Executive Officer Anil Srivastava told Economic Times. ‘Faster project building time and lower costs will make it an attractive option in India,’ he said, adding that his company was currently studying the possibilities for such a venture in India.

Areva, the world’s largest nuclear plant builder, has already built 600 megawatts of offshore wind projects in Europe and has estimated that installation costs in India could be 30%–40% less than that in Europe, where it is about $2.2 for every megawatt of offshore wind built.
Like Areva, other majors such as Siemens and GE have also been exploring similar opportunities in the country. Cheaper tariffs will be the driving force for building offshore wind projects, as prices of electricity are expected to grow due to tight coal supplies and surging demand. Spot rates for electricity have more than doubled to about Rs 10 per kilowatt hour, as compared to Rs 4 of last year.

Typically, in offshore wind projects, a large part of the offshore area will be offered to developers, who will build minimum of 200–400 MW (megawatt) of wind power projects. Each such project will have a height of over 80 metres, using about 600–900 tonnes of high-grade steel, which can be sourced locally.

Since offshore wind projects can be built close to big consumption centres that are typically located in coastal areas, the long western coastline will suit such a model, mainly as most large industries are situated along the country’s western coast.

The government did not provide details of how much money it expected to raise through the new coal tax, but it is estimated that about Rs 25 billion a year could be generated for investment in renewables.

The wind energy sector is emerging as an important segment in the global renewable energy map and countries like India and China are expected to become leaders in the future. The total potential for wind power in India is expected to be much more than the government estimate of 45 000 MW and the industry places it at a high 200 000 MW.

‘India has a potential of 70 000 MW of wind power and this can be reassessed up to 200 000 MW by resourcing new wind areas and re-powering through larger and latest technology turbines,’ says D V Giri, Chairman, IWTMA (Indian Wind Turbine Manufacturers Association). The total potential for wind power in India was first estimated at 45 000 MW by the C-WET (Centre for Wind Energy Technology). This figure

coal tax to pay for new renewable energy fund

The Indian government is expected to back up its recent commitment to curb carbon emissions with a controversial move to levy a new tax on coal in order to pay for the roll out of renewable energy technologies.

Indian finance minister Pranab Mukherjee said that a clean energy tax of Rs 50 per tonne will be levied on all domestically produced or imported coal, with the resulting revenue ring-fenced for use in a new national renewable energy fund.

‘Harnessing renewable energy sources to reduce dependence on fossil fuels is now recognized as a credible strategy for combating global warming and climate change,’ he said. He also set out a range of tax breaks designed to accelerate the roll out of solar, wind, and geothermal technologies. In particular, solar equipment, some wind turbine parts, and electric vehicles will be exempted from a production tax on new goods, while heat pump systems will be exempted from import duties, and equipment used in solar power plants will be granted a power import tax rate of just 5%.

The announcement also provided a boost to some of India’s leading clean-tech firms, with wind turbine manufacturer Suzlon Energy and solar specialist Moser Baer India seeing their share prices climb 5% and 7.4%, respectively.

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was adopted by the government as the official estimate following a comprehensive wind mapping exercise by the MNRE (Ministry of New and Renewable Energy), which established a countrywide network of 553 wind-monitoring stations in 25 Indian states.

However, those wind measurements were carried out at lower hub heights of 50–60 m. Hence, IWTMA estimates that the potential for wind development in India is much higher than the past estimates by reassessing at higher hub heights. ‘Compared to the United States and Europe, which are still growing in wind capacity addition, India and China have very large land mass and huge demand potential for electricity, as still hundreds of villages in the country are yet to be electrified,’ said Giri. With several new support initiatives, India is hoping to add 2500 MW capacity in 2010/11 and reach up to an annual capacity addition of 5000 MW by 2015.

### UAE firm in $545 million deal with Aditya Solar Power

UAE-based (United Arab Emirates-based) company Mulk Holding has announced an agreement with Bangalore-based Aditya Solar Power Industries to develop a 200 MW (megawatt) solar thermal project in the UAE. The holding company said one of its subsidiaries, Mulk Renewable Energy, will supply and install solar thermal power plants for Aditya Solar in a deal valued at $545 million.

According to the agreement, Mulk Renewable Energy will create a joint venture with Aditya Solar to develop the project. ‘The project will be implemented in two phases. Phase one will see the execution of a 40 MW plant by 2012 and the balance of 160 MW by 2013,’ said the company in a statement. Mulk Renewable Energy will have a 25% equity stake in the first 40 MW. ‘Major components will be manufactured in the UAE and exported to India for the initial phase and a full-fledged manufacturing facility of 500 MW capacity will be established in India for the next phases,’ it added.

### Punjab mulls to generate 1000 MW power in collaboration with Sunpower and EBS

In a bid to tap optimum potential of solar energy in Punjab, the state government has decided to set up a chain of solar power plants in collaboration with US-based (United States-based) SunPower Corporation and EBS (Enterprise Business Solutions) for generating about 1000 MW (megawatt) power in a phased manner over the next two years.

A decision to this effect was taken at a high-level meeting with the joint delegation of SunPower Corporation and EBS and the Chief Minister of Punjab, Parkash Singh Badal. The minister has directed Viswajeet Khanna, Secretary, Science and Technology, to prepare a comprehensive plan to establish a network of solar power plants in the state in collaboration with SunPower and EBS through PEDA (Punjab Energy Development Agency). He has also asked the representatives of SunPower and EBS to set up demo projects at the rooftops of the government buildings for tapping solar energy, which could be later replicated in other government buildings such as the district administrative complexes, warehousing, and Markfed godowns. Badal also gave in-principle approval to the proposal mooted by the SunPower-EBS group to set up a centre for training...
Punj Lloyd bags Rs 232 crore order from Bihar Government

Punj Lloyd has bagged India’s largest solar-based EPC (engineering, procurement, and construction) contract of Rs 232 crores from the Public Health and Engineering Department of Government of Bihar. The scope of work includes design, construction, and commissioning of 850 solar-powered water treatment plants across the state of Bihar. The solar water treatment plants designed and constructed by Punj Lloyd will resolve severe groundwater contamination.

The contract will be executed by Punj Lloyd’s renewable energy arm, Punj Lloyd Delta Renewables. The combined solar power generation for these plants will be greater than 1.3 megawatt. Punj Lloyd Delta Renewables provides cutting-edge technology in turnkey-integrated development and sustainable solutions based on solar power. With this contract, the order backlog for Punj Lloyd group on consolidated basis has gone up to Rs 26 205 crores.

Harvesting solar energy in Rangilu, Rajkot

In a significant move towards developing Rajkot as a Solar city, Rajkot Municipal Corporation (RMC) is going to set up 200 kilowatt-peak (kWp) grid-connected solar photovoltaic (PV) system power station within the next six months. According to senior RMC officials, the system will be implemented in a phased manner initially—a 100 kWp system will come up in the city’s west zone by 15 August, followed by the second half in the next six months. RMC plans to inaugurate the 100 kWp station during the Independence Day celebrations.

Tele towers face switch to solar power for back-ups

The government may ask telecom companies to install solar panels to generate backup power for cellphone towers. A proposal being finalized by the MNRE (Ministry of New and Renewable Energy) is aimed at containing the use of polluting diesel generator sets to provide back-up power.

The green drive will prevent these engines of development (telecom towers) from becoming grave environmental hazards. The MNRE is discussing the proposal with various stakeholders. A cabinet note is proposed to be finalized thereafter to get the clearance for the scheme. It will also prevent the flow of government subsidy on diesel for purely commercial and profitable activities.

However, the industry fears that the move could increase the cost of network expansion significantly. It is overlooking the fact that the operating costs would come down substantially as diesel-based electricity is expensive, costing as much as Rs 15 per unit. But the initial investment and the long pay-back period makes it unattractive for telecom companies. Also, the government is not keen on providing any subsidy for solar power equipment, but says it could offer them soft loans under refinancing schemes of Indian Renewable Energy Development Agency.
Renewable energy investments surge on China, wind

Global investments in renewable energy surged 31% in the first quarter from the same period last year, driven by wind power and demand in China, says Bloomberg New Energy Finance.

New spending on wind, solar, and geothermal powers through share offerings, venture capital, and asset finance totaled $27.3 billion in the three months through March, compared with $20.8 billion in the first quarter of 2009. ‘We stick to our forecast that 2010 will see record overall new investment in clean energy,’ says New Energy Finance Chief Executive Michael Liebreich in a company statement. ‘We expect the year’s total to end up between $175 billion and $200 billion, compared to last year’s $162 billion.’

Investments in China were the largest of any country at $6.5 billion, 24% more than the first quarter of 2009. Wind farms accounted for $14.1 billion of the total, 43% higher than in the same period a year earlier.

The GWEC (Global Wind Energy Council) said that the wind power capacity is likely grow at an annual average rate of 21% through 2014. ‘Even in the face of a global recession and financial crisis, wind energy continues to be the technology of choice in many countries around the world,’ says Steve Sawyer, Secretary-General of GWEC.

According to the wind energy council, an industry association, the global installed wind capacity would reach 409 GW (gigawatt) by 2014, compared with 158.5 GW at the end of 2009. China and the United States will lead the expansion, with growth in the Asian nation occurring ‘at a breathtaking pace’, says GWEC.

The total investment in renewable energy was lower in the first quarter than the $31.6 billion spent in the fourth quarter, says the New Energy Finance. The total was weighed down by Europe, where spending fell to $4 billion from $7.6 billion a year earlier and $6 billion in the fourth quarter. In the United States, asset finance rose to $3.5 billion in the first quarter from $2.4 billion in the last three months of 2009.

Malaysia looking at alternative energy sources

Malaysia will become a net energy importer before the year 2020 and is, therefore, committed to find alternative means, says Deputy Science, Technology, and Innovation Minister Fadillah Yusof. He said that the country’s energy requirement was estimated to rise by 6.3% annually and by 2030, the level would reach 28%.

‘Towards this end, Malaysia is very much committed to find alternative means of energy that are sustainable,’ said the minister in a keynote address at the European Union-Malaysia Biomass Stakeholders Forum, held in Kuala Lumpur, Malaysia.

Fadillah said that the country was in the midst of implementing a number of initiatives with regard to policy review, R&D (research and development), and applications in this area. The ministry had given emphasis to the R&D of renewable energy since the Seventh Malaysia Plan.

In total, 185 projects related to the development of technologies focusing on harnessing energy from resources such as biomass, solar, hydro, wind, and tidal waves, costing RM158 million (more than $49 million) have been carried out. Fadillah said that the ministry had taken the necessary steps to develop a renewable energy technology roadmap in five focus areas comprising of biomass, solar, wind, micro-hydro, and tidal power.

‘The use of renewable energy plays an ever increasing role in meeting the requirements of our energy security and the effects of climate change due to the greenhouse gases emission,’ he added.
EDP to buy 1500 MW wind turbines, cut US investment

Power utility EDP (Energias de Portugal SA) has recently announced that it has struck a deal to secure half of its needed wind turbines for the next two years, even as it pulls back on its expansion in the coveted US (United States) market due to regulatory uncertainty. EDP Chief Executive Antonio Mexia has revealed that his company will purchase wind turbines with 1500 MW (megawatt) of capacity from Denmark’s Vestas Wind Systems, world’s largest maker of wind turbines. Although financial details were not disclosed, the deal is estimated to be worth as much as €2.1 billion!

The turbine supply deal can also be expanded for another 600 MW, based on the global electricity demand trends and the regulatory framework of key markets like the US, which is the world’s leading producer of wind energy and one of EDP’s fastest-growing markets.

Mexitia said EDP had been negotiating the deal for more than a year, but only made the decision now because the technology for wind turbines had improved and the prices had fallen, all thanks to the competition from low-cost Chinese turbine makers.

Indonesia aims to generate 4000 MW of geothermal energy from volcanoes

The Indonesian government recently announced plans to develop a hot new energy resource. The country’s leaders aim to generate 4000 MW (megawatt) of geothermal energy from volcanoes by the year 2014. If the plan proves successful, the renewable energy generated would decrease the country’s reliance on coal-fired power plants, reduce its greenhouse gas emissions, and help provide power to the 35% of Indonesia’s population who currently live without electricity.

Indonesia is really the perfect place to develop large-scale geothermal projects, as the archipelago’s 17,000 islands hold hundreds of volcanoes, and all that heat can be converted to renewable electricity. But while the country holds about 40% of the world’s geothermal energy potential, it currently lags behind countries like the US (United States) and the Philippines in developing the technology.

Geothermal’s main limiting factor is its high upfront cost. Geothermal plants cost about twice as much as coal-fired power plants, and establishing enough plants to add 4000 MW of energy will cost about $12 billion! But if developers can raise the dough, producing electricity from geothermal energy has lower overhead costs and causes far less pollution than coal plants. The leaders plan to seek the funds to develop more geothermal plants from private investors, the World Bank, the US, and Japan.

Geothermal to supply 10% of energy demands, claims MIT study

MIT (Massachusetts Institute of Technology) has recently released a study claiming that geothermal energy could meet up to 10% of US (United States) energy demand by 2050. It took 30 years and an 18-member MIT-led panel to prepare the new study on geothermal energy, since it was last actively researched in the late 1970s and early 1980s.

The US is already ahead of the rest of the world, being the largest producer of geothermal energy. And according to Nafi Toksöz, a geophysicist at MIT, the combined energy of geothermal plants in California, Hawaii, Utah, and Nevada is comparable to all the solar and wind power produced throughout the US.

Renewable energy to account for 40% of generation mix by 2030

The use of renewable energy sources is expected to be close to half of developing countries’ power
international news

generation mix, said Dr Xiaodong Wang, WB (World Bank)'s senior energy specialist for East Asia and Pacific region. She said the World Bank expects renewable energy to account for 40% of the power generation mix by 2030. ‘For the Philippines, we also expect it to reach 40% of its generation mix by 2030,’ said Wang, adding that clean energy technologies, including renewable energy and nuclear, will account for 50% in a regional basis. She noted that WB’s expectations also took into consideration the technical limitations.

‘Most of the renewable energy projects we see will be mostly based hydro and geothermal…Solar is the only one that has no technical limits, unlike hydro and geothermal. But since our model is to have the least cost, then solar is beyond our model. So we did not put in much solar in the model as it will shoot up the cost,’ said Wang.

HTTP://BUSINESSMIRROR.COM

Chevron and GreenGulf sign agreement to study solar energy in Qatar

Solar Chevron Qatar Energy Technology QSTP-B, an affiliate of Chevron Corporation, and GreenGulf Inc. QSTP-B, a Qatar-based renewable energy and clean technology company, recently announced the signing of a MoU (memorandum of understanding) for a joint study to test solar energy technologies and their application in Qatar.

The research will collect and evaluate the data provided by technologies to be located at a 35 000 sq m solar test site at QSTP (Qatar Science and Technology Park). The project will also study the performance of different photovoltaic and solar thermal technologies. The project supports QSTP's strategy for assisting in the development of a national solar energy industry in Qatar.

Solar technologies vary in their sensitivity to dust and heat and use different amounts of land and water, which can reflect their relative costs. Measurements obtained over a period of years under Qatar climate conditions are expected to help local planners evaluate, select and install technologies best suited to local conditions.

Under the MoU, Chevron and GreenGulf will each invest up to $10 million in the study programme, with Chevron’s investment part of an initial $20 million commitment to QSTP. Technology tests are expected to commence in late 2010 and continue for two to four years.

Chevron announced in February 2009 that it will establish its CSEE (Center for Sustainable Energy Efficiency) at QSTP and is now in the process of building the Center. Through the CSEE, Chevron supports Qatar’s goal for energy sustainability through research, demonstration, and training of solar power and energy efficiency technologies. The Chevron CSEE will identify solar power, solar air-conditioning, and building-efficiency technologies that work best in Middle Eastern conditions. The Center is scheduled to open in mid 2010.

New Jersey cuts red tape to boost solar efforts

New Jersey has scrapped rules that limit the development of solar panels in the state based on their definition as ‘impervious surfaces’. The state’s Governor Chris Christie recently signed a bill into law that amends restrictions on the amount of land on which impervious surfaces can be built. The new measure amends the definition of ‘impervious surface’ in land use and coast development laws, so that it applies only to the base of a solar panel system, rather than the entire panel.

The bill, S-921, had bi-partisan backing and sponsorship, and received unanimous support in the New Jersey Legislature. ‘There is a balance to be struck between responsible land use law and well-intended but burdensome restrictions that do more harm than good...This legislation removes the regulatory burden, serves our
environment by expanding renewable energy assets, and serves the economy by creating demand for solar panel production’, says Governor Christie.

Governor Christie also said that more would be done to promote New Jersey as a site for renewable energy manufacturing companies. A team is being set up by Lee Solomon, President of New Jersey’s Board of Public Utilities, to develop an energy master plan over the next nine months.

WWW.BRIGHTENERGY.ORG

Study shows biofuel could decrease pollution, create jobs, and increase energy security

According to a report issued by Pace Law School’s Energy and Climate Center, New York, United States, biofuel made from wood, grass, and other forms of biomass could reduce New York’s gasoline consumption by as much as 16% of projected use in 2020 and play a significant role in reducing greenhouse gas emissions.

Produced at the recommendation of Governor David Paterson’s Renewable Energy Task Force, the Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York State was developed to evaluate the positive and negative impacts associated with the increased use and production of this renewable fuel, and to help guide state policy on renewable fuels for the NYSERDA (New York State Energy Research and Development Authority), the NYSDEC (New York State Department of Environmental Conservation), and the New York State Department of Agriculture and Markets. The Roadmap evaluates the future of biomass and liquid biofuel production for transportation purposes in New York in order to address increasing greenhouse gas emissions as well as independence from petroleum usage. It presents a snapshot of New York’s current biomass production, including agricultural products and forest products, and addresses biomass feedstock inventory, land uses, transportation and distribution infrastructure, competing uses for biomass, and biofuel conversion technologies.

To conduct the study, the Pace Energy and Climate Center assembled a team of the leading authorities on biofuels throughout the northeast, including researchers from Cornell University and the State University of New York’s College of Environmental Science and Forestry, and from consulting firms on energy and environmental issues such as Energetics, Energy and Environmental Research Associates, and Antares Group. The Northeast States for Coordinated Air Use Management as well as Cornell Cooperative Extension branches throughout New York are also members of the Pace-led team.

NYSERDA

Pathway for EU to achieve 100% renewable energy

The EREC (European Renewable Energy Council) has just released RE-thinking 2050, a report outlining a pathway that would lead the EU (European Union) to 100% renewable energy by 2050. Factoring in everything from electricity, heating, and cooling, as well as transport, the EREC report breaks down how different renewable energy technologies can contribute to a sustainable Europe.

The x-factor is that economic, political, and public support remains strong throughout the first half of the century. If that dedication persists, the report says, millions of green jobs await. As laid out by EREC, by 2020 more than 2.7 million people would be employed in the renewable energy sector, culminating in more than 6 million jobs by 2050.

Furthermore, all energy-related carbon dioxide emissions can be reduced by more than 90% in just 40 years. In the shorter term, an average annual reduction of 1200 mega tonnes would be achieved by 2020.

According to an executive summary of the report, bioenergy will take up the largest portion of its perceived renewable energy mix, followed by a fairly even mix of geothermal, wind power, concentrated solar power, solar thermal, and photovoltaics. Hydroelectric and ocean power would add a relatively small portion as well. But the wind energy industry in Europe thinks it can do even better, as wind energy in the EU has grown by 23% per year on average over the last decade.

HTTP://SOLAR.CALFINDER.COM
In an electrifying first, scientists of Stanford University, California, United States, have plugged in to algae cells and harnessed a tiny electric current. They found it at the very source of energy production—photosynthesis, the process used by plants, and some bacteria and protistans, to convert sunlight into chemical energy. It may be a first step towards generating ‘high efficiency’ bioelectricity that does not give off carbon dioxide as a byproduct, say the researchers.

“We believe that we are the first to extract electrons out of living plant cells,’ says WonHyoung Ryu, the lead author of the paper published in the March issue of Nano Letters. Ryu, who is now a professor at Yonsei University in Seoul, South Korea, conducted the experiments while he was a research associate for mechanical engineering professor Fritz Prinz.

The Stanford research team developed a unique, ultra-sharp nanoelectrode made of gold, specially designed for probing inside cells. They gently pushed it through the algal cell membranes, which sealed around it, and the cell stayed alive. From the photosynthesizing cells, the electrode collected the electrons that had been energized by light. And the researchers generated a tiny electric current!

“We are still in the scientific stages of the research,’ says Ryu, ‘We were dealing with single cells to prove we can harvest the electrons.’

Plants use photosynthesis to convert light energy to chemical energy, which is stored in the bonds of sugars they use for food. The process takes place in chloroplasts, the cellular powerhouses that make sugars and give leaves and algae their green colour. In the chloroplasts, water is split into oxygen, protons, and electrons. Sunlight penetrates the chloroplast and zaps the electrons to a high energy level, and a protein promptly grabs them. The electrons are passed down a series of proteins, which successively capture more and more of the electrons’ energy to synthesize sugars until the entire energy of the electron is spent.

In this experiment, the researchers intercepted the electrons just after they had been excited by light and were at their highest energy levels. They placed the gold electrodes in the chloroplasts of algae cells, and siphoned off the electrons to generate the tiny electrical current. The result, the researchers say, is electricity production that does not release carbon into the atmosphere. The only byproducts of photosynthesis are protons and oxygen. ‘This is potentially one of the cleanest energy sources for energy generation,’ says Ryu, ‘But the question is, is it economically feasible?’

Ryu says that they were able to draw from each cell just one picoampere, an amount of electricity so tiny that they would need a trillion cells photosynthesizing for one hour just to equal the amount of energy stored in a AA battery. In addition, the cells die after an hour. According to Ryu, tiny leaks in the membrane around the electrode could be killing the cells, or they may be dying because they are losing out on energy they would normally use for their own life processes. One of the next steps would be to tweak the design of the electrode to extend the life of the cell, says Ryu.

Harvesting electrons this way would be more efficient than burning biofuels, as most plants that are burned for fuel ultimately store only about 3%–6% of the available solar energy, claims Ryu. His process bypasses the need for combustion, which only harnesses a portion of a plant’s stored energy. Electron harvesting in this study was about 20% efficient, as compared to photovoltaic solar cells that are currently about 20%–40% efficient. Ryu says that it could theoretically reach 100% efficiency one day.

Possible next steps would be to use a plant with larger chloroplasts for a larger collecting area, and a bigger electrode that could capture more electrons. With a longer-lived plant and better collecting ability, they could scale up the process.

Other authors of the paper are Prinz, the senior author; Seoung-Jai Bai, Tibor Fabian, Rainer J Fasching, Joong Sun Park, and Zubin Huang, researchers in the Rapid Protoyping Laboratory at Stanford University; and Jeffrey Moseley and Arthur Grossman, researchers in the Department of Plant Biology at the Carnegie Institution and
A solar cool pill in the scorching sun

In India, it is estimated that cooling consumes about 35,000 MW of electricity. Part of this comes from conventional plants in areas where electricity is easily available, and the rest is being generated through diesel generator sets, which consume huge amounts of fossil fuels. The total post-harvest loss in rural areas due to improper/inadequate post-harvest technologies is estimated to be 30%–40%, particularly in case of fruits and vegetables. In addition, extensive immunization programmes need to store the vaccines at prescribed temperatures. Solar cooling technology can be effectively brought in to preserve agricultural produce and vaccines.

Use of solar energy for cooling applications is an ideal concept because cooling requirement is maximal during day time, when solar energy is also prevalent. Almost every part of the country is blessed with abundant solar radiation for more than 300 days in a year. Cooling has been the most sought-after application of solar energy. While solar energy can be used to produce cooling in different ways, the vapour compression route, powered by electricity generated from solar energy, is found to be the most suitable one for refrigerators of small capacities that are useful for household purposes, primary health centres, veterinary clinics and small community use, and so on in the countryside.

SPRERI (Sardar Patel Renewable Energy Research Institute) has been at the forefront of developing solar vapour compression technology in the country. Its comprehensive research in vapour compression technology emulates the development of a top-opened SPRERITECH refrigerator. The top-opened model has two compartments to store the material at a preset temperature, specifically meant for vaccine storage. The storage temperature varies from product to product. Thus, the top-opened model allows the storage of products, for which the temperature requirement is more or less same. In order to make the refrigerator store a wide variety of products, a front-opened model has been developed at SPRERI through extensive research and field evaluation. A noteworthy feature of the developed model is that it has three compartments—freezer, middle, and bottom rack and vegetable box. Thermal performance analysis conducted on the system revealed that temperature went down to -14 °C in the freezer compartment, 2 °C in the central part, and 6 °C in the vegetable box. Hence, the developed model could be used to store a wide variety of materials like milk, fruits and vegetables, life-saving drugs, and so on at their appropriate temperature to avoid spoilage. This portable device can play a big role in the remote villages of developing countries where the electricity grid is either not available or erratic.

Basic working principle

In SPV (solar photovoltaic) refrigeration, the cooling effect is produced through the ordinary vapour compression refrigeration cycle as shown in Figure 1. The compressed gas leaving the compressor at a high temperature liquefies at the condenser. This liquid gas at a high pressure is then passed through a capillary tube. The resulting low pressure gas evaporates at the evaporator, producing the cooling effect. The DC (direct current) compressor is driven by the DC electricity produced by solar cells.

Major components

The various components of a SPV refrigeration system are PV modules,
storage battery, solar charge controller, DC compressor-based refrigerator, and connecting cables. Here is a brief description of the various components.

- The PV, direct-drive SPRERITECH solar refrigerator is a chest-type cabinet with an 80-litre internal volume, a front-opening door, a corrosion-resistant coated metal exterior, three thermostat settings, and three compartments. PV refrigerators operate on the same principle as normal compression refrigerators, but incorporate low voltage (12 or 24 Volts) DC compressors and motors, rather than main voltage AC (alternating current) types.

- The model named FD80 provides front opening, 80 litre storage capacity in three main compartments to store a variety of essential items that require refrigeration. The design features the state-of-the-art skin condenser and is highly energy efficient.

- The SPV array directly converts sunlight into DC electricity. It has no moving parts and is a highly reliable component. The array size is calculated to meet the power requirements of the system, given the solar irradiance data for the proposed site. Depending on the application, solar PV modules of 150 to 200 Watt can provide satisfactory performance.

- Lead acid type, long life, deep cycle batteries are used to store the electricity produced by SPV and power the refrigerator. With a battery of 24 Volt and 130 Ah (ampere-hour), ‘no sun autonomy’ of up to four days can be obtained, making the refrigerator suitable for most of the critical applications.

- A solar charge regulator is used to protect the batteries against damage due to overcharging or excessive discharge in cloudy weather.

- It has a hermetically sealed compressor, which employs brushless DC motor that operates on 12V or 24V DC power supply. DC compressor that uses environment-friendly refrigerant, R134a (hydrofluorocarbon) and electronic control unit available from Danfoss, Germany, has been used in the solar refrigerator. The unit operates with very low noise level and requires negligible starting current.

- An electronic controller, which converts the DC supply from the batteries into a form appropriate to the compressor, prevents damage to the compressor through over voltage and protects the batteries from deep discharge. It also controls the cooling fan and thermostat.

- The solar array may be either roof type or ground mounting.

**Application**

Their prime application is in the rural healthcare sector. Refrigerators are a must in health centres for vaccine and blood storage and for making ice for outreach immunization operations. But most centres in developing countries are far from the grid electricity and lack reliable fuel supplies. Under such conditions, use of solar refrigerators has been found an ideal solution to the problem of vaccine refrigeration.

**Performance**

Thermostat with three settings enables the user to set a wide range of temperature varying between –14 °C and 6 °C. So far, SPRERI has manufactured three FD-80 model front-opened refrigerators, which will be installed at different places in India for demonstration purposes.

**Maintenance**

Once the system is installed, some regular maintenance is required. SPV...
modules have a life of 15–25 years. For effective use, it should be properly oriented and regularly cleaned. Any obstruction which may throw shadows on the PV modules should be replaced. The refrigerator is expected to work for 10–15 years without any major operational problems and costs. Batteries require regular maintenance to serve their expected life of 5–7 years. The cost of replacing the battery is the only major cost involved in using the refrigerator. The battery should be regularly monitored and cared for.

Table 1 Technical specifications of the front door 80 litre refrigerator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>80 litres</td>
</tr>
<tr>
<td>Door</td>
<td>Front opened</td>
</tr>
<tr>
<td>Type</td>
<td>Vapour compression refrigerator</td>
</tr>
<tr>
<td>Compressor</td>
<td></td>
</tr>
<tr>
<td>Make and model</td>
<td>Danfoss, BD 35 F</td>
</tr>
<tr>
<td>Power consumption</td>
<td>60 Watt</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R–134a (HFC)</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>12 V/24 V DC</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>400 to 600 Wh/day</td>
</tr>
<tr>
<td>Min. and Max. internal temperature</td>
<td>(-) 14 to 6 °C at 32°C Ambient</td>
</tr>
<tr>
<td>Thermostat</td>
<td>3 settings</td>
</tr>
<tr>
<td>Insulation</td>
<td>25 mm thick Polyurethane Foam</td>
</tr>
<tr>
<td>Body colour</td>
<td>Silver Hair Line</td>
</tr>
<tr>
<td>Weight</td>
<td>18 kg</td>
</tr>
</tbody>
</table>

The cost of a complete system with 80-litre gross capacity refrigerator is Rs 85 000. The performance of a PV refrigeration system greatly depends on the proper sizing of the system components. The size of the PV array and the battery capacity should be determined according to the availability of solar radiation at the location where it is to be installed. The major hurdle for the large scale deployment is the cost of refrigerator, which is considerably higher than that of AC compressor-based refrigerators.

Future models

Work is in progress for the development of a 165 litre capacity, front-opened solar refrigerator, which can store a variety of products. The institute is also developing a solar-powered DC compressor-based refrigerator with ice bank to maintain storage temperature below 8 °C during non-solar hours with autonomy of two days without requiring battery back up. It attempts to eliminate the need for a battery, which amounts to a significant portion of the capital cost and much of the maintenance cost. Prototype unit based on this design have shown positive results.

Conclusion

Solar refrigeration facility, independent of grid supply, for storing the medicines, life-saving drugs, semen, fruits, vegetables, milk, and so on provides an ideal solution to the cooling needs in remote areas where power or fuel supply is either not available or highly erratic. Experience shows that solar refrigerators, if installed and operated as per recommended procedure, give good and reliable performance. SPRERI has already developed and commissioned top-opened and front-opened solar refrigerator of 80 litres capacity for preserving life-saving medicines, drugs, and any perishable products, and the technology has been transferred to the industry. The SPRERITECH refrigerators have been sent to selected centres of All India Coordinated Research Programme on Renewable Energy Sources, Indian Council of Agricultural Research, for multi-location trials at the respective institutions and selected rural locations. All the systems are working well. Dispensaries, hospitals, and goshalas in different parts of India are also using the refrigerators with great satisfaction.
The energy sector holds the key to accelerating the economic growth of our country. It is well known that India will continue to experience an energy supply shortfall in the time to come. The energy scenario has become grimmer since 1985, when the country became a net importer of coal. Rising oil demand of close to 10% per year has led to sizable oil import bills. In addition, the government subsidizes refined oil product prices, thus compounding to the overall monetary loss to the government. This calls for reduction in the oil dependence of the economy, possibly through fiscal measures to reduce demand, and by developing alternatives to oil, such as renewable energy.

In fact, it is this recent breathtaking rise in oil prices that has finally awakened professionals in the energy field to the very real need for alternatives. As a result, we are seeing the rise of non-conventional energy sources like bioethanol, biodiesel, bio-oil, biohydrogen, and the likes. Hydrogen is probably the most competitive of the non-fossil fuel production routes. Hydrogen fuel production technologies can make use of either non-renewable sources or renewable sources such as wind and solar. Hydrogen gas is seen as a future energy carrier by virtue of

![World energy scenario: then and now...](chart.png)
the facts that it is renewable, does not evolve the greenhouse gas CO₂ (carbon dioxide) in combustion, liberates large amounts of energy per unit weight in combustion, and is easily converted to electricity by fuel cells.

Many economists and scientists believe that the economy of the 21st century will be powered by hydrogen, just as petroleum did in the 20th century and coal in the 19th century. Although petroleum had been used since the early 20th century for motor vehicles and airplanes, it took about 50 years for petroleum to overtake coal as the main energy source for the world economy. Though hydrogen research still has a long way to go, it is believed that hydrogen will eventually replace petroleum, driving the world economy from high carbon to no carbon fuel.

However, the problem with hydrogen is that it is merely an energy carrier and needs a primary energy source from which the gas can be obtained. If this first source is a fossil fuel, then hydrogen is not really a clean energy carrier. If the gas is made from the electrolysis of water, which is a rather energy-intensive process, then electricity is needed, and the dilemma remains—where do we get the electricity from? There is, however, a more efficient way to produce the gas in such a way that the stages of the conversion process reinforce each other, instead of working against each other. We are talking about the production of hydrogen from biomass—biohydrogen—in a process that is being designed by several scientific institutions across the world. There are four principal ways by which biohydrogen can be produced—Direct photolysis, Indirect photolysis, dark fermentation, and photofermentation.

**BIOHYDROGEN**

Some microorganisms produce hydrogen naturally, and biotechnologies based on these microbial systems could lead to the development of clean, renewable sources of hydrogen. Although microorganisms produce hydrogen by different mechanisms, the step can be represented by a simple chemical reaction: \( 2H^+ + 2e^- \rightarrow H_2 \). This reaction is known to be catalysed by either nitrogenase or hydrogenase, the key enzymes involved in biohydrogen production processes.

Under certain conditions, green algae and cyanobacteria can use water-splitting photosynthetic processes to generate molecular hydrogen (H₂) rather than fix carbon, the normal function of oxygenic photosynthesis. Bidirectional hydrogenases in these organisms use electrons from the photosynthetic electron-transport chain to reduce protons to yield H₂. Biophotolysis holds the potential for the scale of hydrogen production necessary to meet the future energy demand. This approach to hydrogen production is promising because the source of electrons or reducing power required to generate hydrogen is water—a clean, renewable, carbon-free substrate available in virtually inexhaustible quantities. Another advantage of biophotolysis is the more efficient conversion of solar energy to hydrogen. Reengineering microbial systems for the direct production of hydrogen from water eliminates inefficiencies associated with carbon fixation and biomass formation. Theoretically, the maximal energetic efficiency for direct biophotolysis is about 40%, as compared to a maximum of about 1% for hydrogen production from biomass.

**BIOPHOTOTIC HYDROGEN: AIMS AND IMPACTS**

Biological hydrogen production has several advantages over hydrogen production by photoelectrochemical or thermochemical processes. Biological hydrogen production by photosynthetic microorganisms, for example, requires the use of a simple solar reactor such as

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Various approaches of Biohydrogen Production
The Biohydrogen Two- Hybrid Pathway

as a transparent closed box, with low energy requirements. Electrochemical hydrogen production via solar battery-based water splitting, on the other hand, requires the use of solar batteries with high energy requirements. Low conversion efficiencies of biological systems can be compensated for by low energy requirements and reduced initial investment costs. Moreover, in laboratory experiments, light energy conversion efficiency as high as 7% has been obtained using a photoheterotrophic process.

Today, energy and environmental protection are two of the most significant issues for sustainable economic development. Environmental microbiologists are looking for new microorganisms with substantially higher energy recovery efficiency. Meanwhile, many research teams are developing various hybrid two-stage processes—generating bio-hydrogen from wastewater at the first stage and using phototrophic bacteria for further hydrogen production process in the second stage.

The Hydrogen thus produced can be used directly as a fuel for internal combustion engines. Hydrogen cars and buses are already in use in Europe and America. The fuel can also be used for airplanes, as demonstrated by the Russians in the 1960s. Furthermore, converting hydrogen into energy is a mature technology in which hydrogen reacts with oxygen producing electricity at an ambient temperature. However, the full scale application of hydrogen as a fuel will be realized with the development of technologies for its safe storage and an infrastructure for its convenient supply to the users.

India has taken a leading initiative in Biohydrogen research. The MNRE (Ministry of Renewable Energy), DST (Department of Science and Technology), and DBT (Department of Biotechnology), to mention a few, have contributed greatly to initialize basic research in our country. A number of institutes like IIT (Indian Institute of Technology) Kharagpur; BHU (Banaras Hindu University); MRC (Shri AMM Murugappa Chettiar Research Centre), Chennai; TERI (The Energy and Resources Institute), New Delhi; IICT (Indian Institute of Chemical Technology), Hyderabad; IIT Delhi; and several other research groups working in national laboratories and academia have taken a lead to develop biohydrogen as a potential alternative energy fuel.

The group at IIT Kharagpur has been involved in the endeavours of biohydrogen production for more than a decade now. Its achievements during this period have been remarkable in terms of strains isolation/manipulation, bioprocess development, reactor design, and bench- and pilot-scale studies on 20L and 800L capacity reactors, respectively, producing around 90L of hydrogen from 180 g of glucose. The laboratory now plans to take biohydrogen research in India to all new heights. With its ambitious project with the MNRE, biohydrogen plants (producing hydrogen from biomass) of 10 000 L capacity may soon be set up under a pilot ‘Technology Mission Project’ in Kharagpur, Delhi, and Hyderabad.

Whilst IIT Kharagpur has taken a lead role in biohydrogen production from biomass, BHU has taken a lead in fundamental research on hydrogen storage and its application. Under a MNRE project granted to BHU, ICML (International Cars and Motors Limited), Jallandhar (Punjab), is in the process of manufacturing 10 three-wheelers. These will ply between the Central Secretariat and Lodhi Road in
New Delhi. This naturally makes hydrogen-motorized transport obvious to the masses at the heart of the nation’s capital. This will be followed by production of 100 hydrogen three-wheelers. Similar efforts are being made for two-wheelers with the help of SIAM (Society for Indian Automobile Manufacturers), which has access to various two-wheeler manufacturers in India. With this, it is clear that Biohydrogen research has taken long strides globally with remarkable contributions to science and technology. This is a landmark achievement, as energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environment-friendly.

The author is thankful to Namita Khanna, Senior Research Scholar, Department of Biotechnology, IIT Kharagpur, for her help in the preparation of this manuscript.
Electrification of remote rural area with hybrid energy system

ABHA RAJORIYA, Research Scholar, and EUGENE FERNANDEZ, Associate Professor, Electrical Engineering Department, Indian Institute of Technology, Roorkee, Uttarakhand—247 667

Despite technological advancement in all parts of the world and development in all avenues, there are several areas which are far from supply grid and are not electrified as yet. It is a major challenge for all technical communities to supply electricity to such remote areas. It is often more feasible to get supply from an independent system for such areas, rather than investing in transmission line. An efficient alternative is hybrid energy system, which combines a generation module of renewable sources with backup source. The generation module is often complimentary in nature, appropriately sized to minimize the cost. Backup can be a diesel generator or an energy storage system to achieve a dependable supply. Here is the description on how to design a hybrid energy system for delivering power to a remote village community. The study area for describing the process is a remote village cluster in the state of Uttarakhand.

Introduction
An important form of application of renewable sources of energy is standalone power generation systems for locations where conventional generation is not practicable. These sources are environment-friendly, inexhaustible, and inexpensive in nature, and hence, are attractive...
energy alternatives for sustainable development. A single renewable energy system, however, would be either too costly or would be an unreliable system due to the intermittent nature of renewable resources. But, supplying electricity from diesel generators alone will increase the pollution level of the area. The solution is the combination of both the sources. Combining diesel generator with renewable energy mix increases the reliability of the supply system, and restricts pollution. Thus, a hybrid energy system could be used to supply power to the remote areas with lesser environmental degradation and reliable power delivery. Any renewable source such as SPV (solar photovoltaic), wind, biomass, small hydro, fuel cell, or a combination thereof added with backup sources such as diesel generator or energy storage devices (battery) is called a hybrid energy system. The schematic of a typical hybrid energy system is shown in Figure 1.

**Study area**

To supply power with hybrid energy system, a remote village cluster of the Tehri Garhwal District of Uttarakhand state has been selected as a study area. A map of the study area has been shown in Figure 2. A cluster of 12 unelectrified villages (the area within the circle) has been considered for electrification, employing a hybrid energy system.

The study area has difficult, hilly access and the populace belongs to most poor income group. The area of the district is 4421 sq km² and its population is 604 608 as per the 2001 census. It has 1760 villages out of which 1344 villages are electrified and 416 are unelectrified. The study area is in the Tehri tehsil of the Tehri Garhwal district and is an economically weak zone. The inhabitants use kerosene lamps for lighting and employ manual labour for drinking and irrigation water needs. A hybrid energy system for meeting the electricity needs of the region will undoubtedly help in improving the living conditions of the residents of the area.

**Proposed approach**

The problem of planning and designing a hybrid energy system is quite complex due to the intermittent nature of the renewable energy sources, load demand uncertainties, nonlinear characteristic of the components involved, and the fact that the sizing and operating strategies of hybrid systems are
interdependent. To transact with such multifaceted problem, NREL’s (National Renewable Energy Laboratory) HOMER software has been utilized to realize some significant outputs. Although there are other softwares that also deal with size optimization of renewable energy mix, such as PVSYST, SOMES, RAPSIM, SOLSIM, INSEL, PV-Design Pro, and so on, the advantage of HOMER is that it can simulate all types of renewable sources into a hybrid system and also, carry out optimization of such system. Moreover, it is a free software available on the site of the NREL.

Based on the availability of renewable energies in the remote village cluster, a hybrid system consisting of wind turbine and SPV system, along with a diesel generator backup and battery storage, is proposed for the area (as shown in the Figure-4). A converter is additionally required to convert the DC (direct current) output to AC (alternating current) and vice versa. The optimum combination of these resources obviously bears minimum NPC (net present cost), which is the cost of a system spread over its lifetime, and the cost of energy of the system. It must also possess some other features such as dependable supply, lesser reliance on fossil fuel, efficient use of renewable sources, and least environmental degradation.

For the proposed scheme consisting of all the selected resources, the software offers a list of feasible schemes capable of fulfilling the power requirement of the area. The schemes are ranked in the programme output on the basis of NPC (also known as life cycle cost).

Data inputs for analysis

Depending upon the components involved in the proposed hybrid supply system, the required inputs of various components and study area are to be put in for simulation and optimization. Mainly, three types of data are required—renewable energy potential of the intended area; the capital, replacement, and O&M (operation and maintenance) cost of the components involved; and the load profile or estimated load requirement of the study area. Here is the description of the required data put in for the present work.

Renewable energy resources

Wind resource is the monthly average wind speed in m/s (metre per second) for each month of a year, whereas solar resource is the average monthly radiation in kWh/sq m/day (kilowatt hour per square metre per day) for a year. Details of wind speed available throughout the year in the study area and solar irradiance potential of the study area throughout the year have to be put in for simulation and optimization. Annual average wind speed between 4–5 m/sec would be sufficient to install a wind turbine to achieve efficient wind power output, whereas higher solar irradiance potential will always be helpful for efficient PV system output.

Two renewable resources have been found to be potentially available in the area and suitable for renewable energy mix—wind and solar. Annual average wind speed obtained from nearest meteorological station is 5.1 m/s. This wind potential is sufficient for erection of wind energy system. Same wind data has been utilized for analysis of study area. Solar energy potential

Figure 3  Figure giving an idea of hilly village terrain; its agriculture [Figure 3(a)], difficult access [Figure 3(b)], village living [Figure 3(c)]

Figure 4  Plan of proposed hybrid energy system
in the area has been found to be 
≈5 kWh/sq m/day, which is quite 
sufficient to install a SPV system.

Load profile of the area
Intended area is not yet electrified. 
Hence, no present load profile is 
available for the area. Expected 
load profile has been obtained by 
estimating the load requirement 
of the area, keeping in mind the 
population and other characteristics 
such as its geographical location, 
demographic data, and socioeconomic 
state of the area. Load profile of other 
similar villages also helps in the same. 
Figure 5 gives the yearly load profile of 
the area.

Size and costs of components in 
proposed system
A grave market search is required to 
obtain available sizes as well as capital, 
replacement, and O&M costs of various 
components connected in proposed 
hybrid energy system. While selecting 
the range of sizes of components, the 
availability of size, cost of component, 
maintenance requirement, available 
land area, and so on have to be kept in 
mind. Capital, replacement, and O&M 
costs of these components has been 
obtained from various manufacturers, 
considering various factors supplied 
by the manufacturer such as efficiency, 
power output, operating hour, nominal 
voltage, and so on. Sizes of various 
components in the search space of 
the software used for simulation are 
depicted in Table 1.

Results and discussion
Required input of the study area 
and components involved, enable 
HOMER to perform hourly time series 
analysis on hundreds or thousands 
of combinations of such systems 
available in the search space. The 
criterion of optimization is lifecycle 
cost of the feasible combinations out 
of several available ones. In other 
words, the combination that obeys the 
power balance equation and employs 
minimum lifecycle cost will be ranked 
first in the output table of feasible 
systems. For all the inputs of sizes and 
cost of components in the present 
work, the software provides most 
feasible system on the top of the list of 
feasible systems. This will be the system 
with the least of NPC. In the present 
case, the software performs time series 
analysis on thousands of combinations 
of components in order to find out 
the most feasible system. The system 
so obtained is shown in Table-2. This 
would be the system on top of the 
list with five wind turbines (AR 10), 
65 kW DG, 25 batteries (6V.6.94 kWh), 
and 35 kW converter. The system’s 
initial cost is $94 233 (approx. 
Rs 4 700 000), whereas its cost of energy 
is $0.292 (approx. Rs 14.50). Other 
details of the system, such as renewable 
fraction, generator hours, and dispatch 
strategy of generator, would also be 
seen in the programme output.

Various characteristics related to 
the feasible systems such as excess 
energy available, unmet electrical load, 
and capacity shortage could also be 
observed with the help of the software. 
Some other details such as power

<p>| Table 1 Size and cost of components connected in the proposed hybrid energy system for simulation and optimization |
|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Unit size</th>
<th>Unit cost($)</th>
<th>Range/No. of component</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>PV Array</td>
<td>1 kW</td>
<td>5600</td>
<td>0-30 kW</td>
</tr>
<tr>
<td>2</td>
<td>Wind Turbine</td>
<td>10 kW</td>
<td>11000</td>
<td>0-5 no.</td>
</tr>
<tr>
<td>3</td>
<td>Diesel Generator</td>
<td>70 kW</td>
<td>18000</td>
<td>60-100 kW</td>
</tr>
<tr>
<td>4</td>
<td>Battery</td>
<td>6V,6.94 kWh</td>
<td>700</td>
<td>0-50 no.</td>
</tr>
<tr>
<td>5</td>
<td>Converter</td>
<td>1 kW</td>
<td>140</td>
<td>20-65 kW</td>
</tr>
</tbody>
</table>
contribution by each component, annualized cost of various components, fuel cost, salvage value of components, and emissions made by each feasible system may also be seen in the various output windows.

However, sometimes, the problem of unavailability of a given selected system necessitates the selection of the next best system. Hence, the list of all feasible hybrid schemes is provided in Table 2. By compromising on NPC, the next best system as per the requirement of the energy planner can be selected. Sometimes, the initial capital in hand or diesel fuel consumption may rank higher while selecting the most suitable system. Thus, the range of feasible systems provides a fairly flexible selection opportunity for the energy planner. Here are some figures demonstrating such hybrid systems. Figure 6 shows a hybrid system installed in Akshi (Maharashtra), Figure 7 shows how erection of wind turbine takes place in such a system, and Figure 8 provides a view of the proposed solar wind hybrid system.

**Conclusion**

A description of the process of sizing and optimizing hybrid energy system intended for supplying power to remote rural area is provided here. A typical case study of a village cluster in Tehri tehsil in the Tehri Garhwal District of Uttarakhand shows the process of how to utilize a dedicated software HOMER to achieve the objective. The result so obtained provides optimum hybrid system with the least NPC. The results, however, offer a view of all the feasible systems that are able to provide dependable power supply to the area. This detailed view makes available flexible selection options to the energy planner for supplying power to the area.

The same process, however, can be applied to any remote area to obtain power supply through available renewable resources of the area. The supply can be without grid or can be grid-interactive to supply excess power to the nearby grid and hence, could make revenue out of it.

---

**Table 2** List of all feasible hybrid schemes ranked in the order of NPC

<table>
<thead>
<tr>
<th>PV (kW)</th>
<th>AR10</th>
<th>Gen 1 (kW)</th>
<th>Batt. Conv. (kW)</th>
<th>Disp. Strgy</th>
<th>Initial capital</th>
<th>Total NPC</th>
<th>COE ($/kWh)</th>
<th>Ren. Frac.</th>
<th>Capacity Shortage</th>
<th>Diesel (L)</th>
<th>Gen 1 (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>65</td>
<td>25</td>
<td>35 CC</td>
<td>$94,233</td>
<td>$1,252,018</td>
<td>0.292</td>
<td>0.16</td>
<td>0.00</td>
<td>126,950</td>
<td>7,897</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>65</td>
<td>25 35 CC</td>
<td>$99,833</td>
<td>$1,253,590</td>
<td>0.292</td>
<td>0.17</td>
<td>0.00</td>
<td>126,412</td>
<td>7,887</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>20</td>
<td>35 CC</td>
<td>$74,633</td>
<td>$1,268,695</td>
<td>0.296</td>
<td>0.16</td>
<td>0.01</td>
<td>131,452</td>
<td>8,760</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>65</td>
<td>20 CC</td>
<td>$80,233</td>
<td>$1,272,035</td>
<td>0.297</td>
<td>0.17</td>
<td>0.01</td>
<td>131,112</td>
<td>8,760</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>20</td>
<td>CC</td>
<td>$19,633</td>
<td>$1,329,979</td>
<td>0.310</td>
<td>0.00</td>
<td>0.02</td>
<td>146,027</td>
<td>8,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>20</td>
<td>CC</td>
<td>$25,233</td>
<td>$1,332,678</td>
<td>0.311</td>
<td>0.00</td>
<td>0.02</td>
<td>145,612</td>
<td>8,760</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>5</td>
<td>20 LF</td>
<td>$23,133</td>
<td>$1,334,711</td>
<td>0.311</td>
<td>0.00</td>
<td>0.02</td>
<td>146,023</td>
<td>8,760</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>20 LF</td>
<td>$28,733</td>
<td>$1,337,411</td>
<td>0.312</td>
<td>0.00</td>
<td>0.02</td>
<td>145,608</td>
<td>8,760</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thermoelectric devices gained importance in recent years as viable solutions for applications such as spot cooling of electronic components, remote power generation in space stations and satellites, and so on. These solid state devices are free from moving parts and have good reliability. However, their efficiency depends on the selection of materials. Such devices with higher efficiency can be implemented for refrigeration as well. The combination of Seebeck Effect and Peltier Effect is the absolute advent for such refrigeration. And solar energy is a viable option. The various modes of this technology are discussed in this paper.

The cooling of residential houses and offices with minimum cost and energy consumption is a challenge for these technologies. Nowadays, a lot of techniques focus on the cooling of machines, instruments, computers, laptops, and so on to increase their efficiency and to help them to have a long life by delaying the unexpected heating effects. Computer components have to be kept cool to keep temperatures within design limits (and without the noise of a fan) and to maintain a stable functioning when over clocking. But all this require electric power, which is short of supply and results in energy crisis. This is because electricity is mainly produced by traditional techniques, with high input cost. So, the output generation of electrical power becomes costly.

There is also a method of refrigeration which requires a compressor. Here, cooling is achieved either by vapourizing a refrigerant such as Freon or by absorption, in which the cooling is achieved by vaporizing a refrigerant (ammonia gas). These systems are more expensive and short-aged. Also, compressor systems can leak Freon, which can be extremely dangerous, especially if heated. Absorption systems may use propane, which, too, can be extremely dangerous in the event of a leakage. Hence, to overcome this problem, there should be a technique which is simple, less expensive, easy-to-operate, pollution-free, efficient, and reliable. And all this is possible by the utilization of solar energy. The wonder of converting sun’s heat into cooling has been made possible through the advent of thermoelectricity.

Advantages of thermoelectric conversion
The major advantage of this technique is that it is pollution free. The entire device arrangement does not have moving parts. It does not contain any gas, compressor, or refrigerator like the other refrigeration systems. Due to these reasons, its operation is very easy. Also, it is a technique which converts the low-grade waste heat into electricity. Although it demands more efficient materials, which may be expensive, but it influences the reliability and leads to better results. The thermo emf (electromotive force) can also be stored, and sometimes recycled, to improve the output of the system.

Availability and utilization of solar energy
The input or raw material for solar refrigeration is the sun’s heat. As the sun’s energy can be utilized by solar cells, solar cell panels can be integrated with this technique. Wind energy can also be utilized to get maximum output, especially in regions where wind energy farms are available. However, solar energy is available in adequate amounts everywhere (though it can vary), and is free of cost and can be utilized without pollution, without any special agent, or other requirements. In the hot regions, the results better as compared to cold regions.
**Principle**

The well-known phenomenon, Seebeck effect, is implemented in the form of thermocouples, which are assemblies of two different metals joined at the two ends called junctions. When temperature gradient is established at the two junctions, thermo emf arises (see figure 1). This is due to the arising of contact potential at the junctions when the electrons tend to drift from the high density (charge carrier) region to lower density regions. Common metals which are inexpensive and easily available can be used for thermocouples. If a series of thermocouples is piled in a suitable cover and one of their ends is heated by solar energy (without any combustion), and the other end is kept cold (at low temperature) by alternate means, then it will generate thermo emf. In other words, it is a technique to convert the sun’s heat into electricity. However, if the electric and magnetic fields are available along with the waste heat, then the thermo emf will be enhanced. When this emf is applied to any one junction of a thermocouple, at the same temperature, then one of its end becomes hot and the other one will remain cold (see Figure 2).

This principle is known as the Peltier effect. This can be explained by imagining the electron clouds within the two metals. One electron cloud will be denser than the other, and consequently, electrons will want to jump to the lower electron density, producing a potential difference. When the moving electrons collide in high electron density, it causes resistance and hence, produces heat in the junction. But the other junction will have negative resistance, leading to cooling. This means the Peltier effect cools one end and heats the other, which can again be recycled to the Seebeck. Hence, the sun’s heat can be converted into cooling by the combination of Seebeck and Peltier principles as shown in Figure 3.

**Coefficient of performance**

In 1912, Altenkirch introduced the concept of figure of merit when he showed that good thermoelectric materials should possess high Seebeck coefficients, high electrical conductivity to minimize Joule heating, and low thermal conductivity to retain heat at the junctions that will help to maintain a large temperature gradient. Ioffe in 1957 presented the figure of merit as $Z = \alpha^2/\lambda$. The performance of a thermocouple for the emf generation is given by the dimensionless quantity, $Z_T = \alpha^2/\lambda$; where $\alpha$ is the Seebeck constant, $Z_T$ is coefficient of performance, $\sigma$ is the electrical conductivity of the thermoelectric material and $\lambda$ is the thermal conductivity of the thermoelectric material. This is crucial as there are two aspects of cooling—of electronic devices and of buildings. The Seebeck–Peltier combination can be applied on both only by some variations in designing, introduction of solar panels, voltage storing systems, and thermocouple chip devices. The output will also vary in these proportions.

**History of developments**

Initial thermoelectric materials that were studied were metals, which display Seebeck coefficients of a few tens of $\mu$V/K. But other materials, including semiconductors, are studied from the point of view of Phonon Drag theory, according to which the thermal conductivity can be reduced by providing the interactions to phonons; which are the heat carrying particles. Such results are possible by alloying the semiconductors, by changing their structures, their compositions, and from the use of nanotechnology. In 1956, Ioffe et al. suggested that alloying a semiconducting thermoelectric material can be converted into cooling by the combination of Seebeck and Peltier principles as shown in Figure 3.
with an isomorphous substance – materials with the same crystalline structure – would enhance the coefficient of performance by reducing lattice thermal conductivity without affecting the carrier mobility. Birkholz in 1958 and Rosi in 1959 showed that alloying Bi2 Te3 with Sb2Te3 greatly reduced the thermal conductivity. Similarly, in nanowires/nanomaterials, in which the particle size is very small and high volume to surface ratio, the phonons face some interactions but at the same time the electrons drift without any obstacles. This reduces the thermal conductivity and increases or maintains the electrical conductivity. The biggest advent was silicon nano wires. The advent of quantum well nanofilm and nanowire superlattice structures that improve the value of ZT due to a number of advantages has shifted to understand the carrier transport behavior in nanostructures. Quantum confinement in nanostructures increases the local carrier density of states per unit volume near the Fermi energy, increasing the Seebeck coefficient, while the thermal conductivity decreases due to phonon confinement. One of the advanced developments is the study of thermo emf in the regions where the low-grade waste heat is available along with the electric and magnetic fields, which can improve the conversion efficiency.

So, for better performance of such devices, materials with high electrical conductivity and low thermal conductivity are being selected. Thermocouples in the form of wires can be used. They are also available in powder form, thin films, gel, alloys, and nanotubes for better achievements. The nanowires, which have large volume to surface ratio, cause some interactions with phonons. This helps to reduce the thermal conductivity and increase the performance of the instruments. Hundreds of thermocouples on a single chip, making use of solar-assisted thermoelectric modules, are also in practical use as shown in Figure 4.

This makes the devices compact and handy. Such devices can be applied to industries, buildings located in hot regions, and to the houses in summer. However, they require some modifications related to their size and the selection of materials. But their advantages, like cost effectiveness and low level of pollution, are enough to motivate the engineers for implementations. In instruments like computers, laptops, dynamos, and vehicles, the low-grade waste heat can be utilized for cooling and can also be recycled to improve their performance. To reduce the thermal conductivity, the heat-resistant membranes can also be used. In large number of devices, metallic blocks are used, which causes eddy currents due to non uniform magnetic fields. If these magnetic fields are synchronized to the thermo coupled devices, it is observed that the thermo emf is enhanced, which results in more cooling.

At present, the noble thermoelectric materials with high COP (coefficient of performance) like Bismuth Telluride, Lead telluride, and Silicon Germanide are more expensive. But the researches are oriented to develop cheap, easily available, and efficient metals and semimetals, as this technology is of great interest because it does not require a compressor or refrigerant, is low noise, and has no moving parts. For this reason, they are very suitable for the cooling of lasers or microprocessors. It involves the utilization of solar energy. In most thermo-coupled devices, there are not many precautions, risks, or extra requirements for designing and fabrication.

The advent of thermocouples by Seebeck and Peltier principles to get cooling may face some problems in the beginning, but its reliability, cost-effectiveness, and environment-friendly characteristics will attract the engineers and scientists to overcome energy crisis. The nanomaterials have the capacity to improve the performance of such devices, but need further research. The advanced mathematical models, quantum well models, and alloying techniques of both metals and semiconductors can enrich this technique.
The results of the study show that the seed oil of Mesua ferrea L. tree can be used as the source of feedstock for biodiesel production. Density, flash point, water content, ash content, and sulphur content of neat biodiesel were found to be within the acceptable limits as per the ASTM (American Society for Testing and Materials) standards for biodiesel.

**Introduction**

In recent years, the interest in biodiesel has been increasing, motivated on the one hand by the need for reducing greenhouse gas emissions and on the other hand, by the desire to improve energy security by reducing our dependence on imported oil.

Biodiesel is a generic name for fuels obtained by transesterification of vegetable oils and animal fats. The term 'biodiesel' was first introduced in the US (United States) in 1992 by the National Soy Development Board (now called the National Biodiesel Board). Non-edible plant oils are in focus for the production of biodiesel in recent times due to the limited availability and high demand for edible oil. Biodiesel can be produced from a variety of feedstocks, including Karanja, Polanga, Mesua ferrea L., Semaruba, Rubber seed, Cotton seed, Neem, and Sal.

The use of vegetable oils as an alternative renewable fuel to compete with petroleum was proposed in the beginning of the 1980s. However, this oil could not be used directly in the diesel engines because of its high kinematic viscosity. High viscosity of oils would reduce the fuel atomization and increase fuel spray penetration, which would be responsible for high engine deposits. One of the technologies to reduce the viscosity is by transesterification of plant oil. Transesterification reaction can be achieved either by a base or an acid catalyst, based on the acid value of plant oils.

Transesterification or alcoholsysis is the chemical reaction between triglycerides and alcohol in the presence of catalyst to produce monoaesters and glycerol. That is why transesterification of vegetable oils appears to be more suitable because the byproduct, glycerol, has commercial value. The transesterification reaction can be represented by the following equation.

Stoichiometrically, three moles of alcohol are required for each mole of triglyceride. But in practice, a higher molar ratio is employed in order to displace the equilibrium for getting greater ester production. The important factors that affect the transesterification reaction are the amounts of methanol and catalyst, reaction temperature, and reaction time. Some of the commonly
used short-chain alcohols are methanol, ethanol, propanol, and butanol. Methanol is used commercially because of its low price. Alkaline hydroxides are the most effective transesterification catalysts, as compared to acid catalysts. Potassium hydroxides and sodium hydroxides are the commonly used alkaline catalysts. Transesterification process may be accomplished with the help of base, acid, or lipase as catalyst. However, base catalysed transesterification of oils is the widely accepted method for preparing biodiesel, particularly for low acid number oils.

The chemical composition of fat and oil esters depends upon the length and the degree of unsaturation of the fatty acid alkyl chains. The most important compositional differences between petroleum diesel and biodiesel are oxygen content. Biodiesels contain 10%–12% wt oxygen, which lowers energy density. Acids may be saturated or unsaturated (contain one or more double bonds). Depending on the nature of the fatty acids present in the source, the fuel properties of the biodiesels may differ to varied extents. Table 1 shows the chemical structure of the fatty acid chains found in the most common biodiesel source materials.

Biodiesel generally provides significant emission benefits with respect to CO (carbon monoxide), UBHC (unburned hydrocarbon), and PM (particulate matter), but slightly higher NOx (oxides of nitrogen).

Mesua ferrea L. tree is a mid-sized tree that grows mostly in the mountains of the eastern Himalayas, eastern Bengal, eastern and western Peninsulas, and Andaman Islands. In Assam, it is generally found in Upper Assam, the Darrang district, and North Cashar Hills. Its seeds contain 75% of oil on the basis of shelled kernel weight. Flowering starts in April–May, and seeds become mature in August–October. A fully mature tree yields about 30–60 kg of seeds annually. Mesua ferrea L. is one of the hardest trees of North East India. Its timbers are used in construction of houses, furniture, cart wheels, and so on. In early days, when kerosene and electricity were not available, the rural people of this region used the seeds of Mesua ferrea L. for illumination at night. Mesua ferrea L. oil and seeds are shown in Figures 1 and 2. In the present investigation, non-edible plant oil of Mesua ferrea L. was taken for transesterification. Biodiesel samples obtained from the experiments were tested for density, ash content, carbon residue, pour point, flash point, water content, kinematic viscosity at 40 °C, oxidation stability, and calorific value as per the ASTM D287, D874, D4530, D97, D93, D2709, D445, D2274, and D240. It was found that the biodiesel obtained from Mesua ferrea L. oil conformed to

<table>
<thead>
<tr>
<th>Acid chain</th>
<th>No. of carbon atoms</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprylic</td>
<td>8</td>
<td>CH₃(CH₂)₆COOH</td>
</tr>
<tr>
<td>Capric</td>
<td>10</td>
<td>CH₃(CH₂)₈COOH</td>
</tr>
<tr>
<td>Lauric</td>
<td>12</td>
<td>CH₃(CH₂)₁₀COOH</td>
</tr>
<tr>
<td>Myristic</td>
<td>14</td>
<td>CH₃(CH₂)₁₂COOH</td>
</tr>
<tr>
<td>Palmitic</td>
<td>16</td>
<td>CH₃(CH₂)₁₄COOH</td>
</tr>
<tr>
<td>Palmitoleic</td>
<td>16</td>
<td>CH₃(CH₂)₁₄CH=CH(CH₂)₂COOH</td>
</tr>
<tr>
<td>Stearic</td>
<td>18</td>
<td>CH₃(CH₂)₁₆COOH</td>
</tr>
<tr>
<td>Linoleic</td>
<td>18</td>
<td>CH₃(CH₂)₁₈CH=CHCH=CH(CH₂)₂COOH</td>
</tr>
<tr>
<td>Linolenic</td>
<td>18</td>
<td>CH₃CH₂CH=CHCH=CH=CHCH=CH(CH₂)₂COOH</td>
</tr>
<tr>
<td>Arachidic</td>
<td>20</td>
<td>CH₃(CH₂)₁₈COOH</td>
</tr>
<tr>
<td>Eicosenoic</td>
<td>20</td>
<td>CH₃(CH₂)₁₈CH=CH(CH₂)₂COOH</td>
</tr>
<tr>
<td>Behenic</td>
<td>22</td>
<td>CH₃(CH₂)₂₀COOH</td>
</tr>
<tr>
<td>Erucic</td>
<td>22</td>
<td>CH₃(CH₂)₂₁CH=CH(CH₂)₂₁COOH</td>
</tr>
</tbody>
</table>

Figure 1 Mesua ferrea L. oil
the standard specified by the ASTM and was comparable to diesel fuel.

Materials and methods
About 100 kg of Mesua ferrea L. seeds were collected from mature trees grown in the forests of Assam and dried in a hot air oven. The dried seeds were shelled and milled. The oil was extracted from the milled kernels, with petroleum ether using the Soxhlet extraction method. The solvent was removed from the extract and the oil content was found to be 75% by weight of the milled kernel. About 10 litres of the oil were extracted and kept over anhydrous sodium sulphate for three days and filtered through glass wool to remove the PM present in it. The filtered oil was then stored in glass bottles. The Mesua ferrea L. oil (3 litres) was heated up to 65°C in a round bottom flask. A solution containing about 30 grams of KOH (Potassium hydroxide) dissolved in methanol (1.5 litres) was poured into the round bottom flask, while stirring the mixture continuously. The mixture was kept at 65 °C for three hours and then allowed to settle under gravity in a separating funnel. Out of the two layers formed, the upper layer was of MOME (Mesua ferrea L. oil methyl ester) and the lower layer was of glycerol. The lower layer was separated and the ester was mixed with 10% (by volume) hot water, shaken properly, and allowed to settle down for 24 hours. The water containing KOH in the lower layer of the separating funnel was removed. The remaining moisture from the purified ester was removed using crystals of silica gel. The yield of esters thus produced was 95%. Various properties of the biodiesel thus obtained from Mesua ferrea L. seed oil was determined by the ASTM methods. Methyl ester quality was checked by NMR (nuclear magnetic resonance) spectroscopy (Bruker ARX-400 spectrometer; Bruker, Rheinstetten, Germany; 400 MHz for 1H NMR; solvent CDC13).

Results
The maximum yield of biodiesel obtained from Mesua ferrea L. SVO (straight vegetable oil) is 95%. The uncertainty was calculated and found to be ± 0.0254. Proton NMR [1H (hydrogen) NMR] is a reliable technique for the estimation of biodiesel formed in the transesterification process. 1H NMR spectrum of Mesua ferrea L. methyl ester was taken. The result reveals a more accurate quantification of biodiesel content in the reaction mixture. Figure 3 presents a typical NMR spectrum of Mesua ferrea L. methyl ester. A triplet at 2.3 ppm (parts per million) and a singlet at 3.7 ppm correspond to signals due to methylene protons adjacent to the ester group in triglycerides and the methoxy protons of the methyl esters. All tests were carried out in triplicate and the average values are shown in Table 2.

Conclusion
Transesterification is a process which brings about a change in the molecular structure of the vegetable oil molecules, thus bringing down the kinematic viscosity of vegetable oils. The density and kinematic viscosity of MOME formed after transesterification were found to be very close to diesel fuel. The flash point of methyl ester of the plant oils was higher than the diesel fuel. The present analysis reveals that biodiesel from Mesua ferrea L. oil is quite suitable as an alternative to diesel fuel.

Table 2 Fuel characteristics of biodiesel obtained from Mesua ferrea L. seed oil

<table>
<thead>
<tr>
<th>Property</th>
<th>MOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 15 °C g/cm³</td>
<td>0.897</td>
</tr>
<tr>
<td>Kinematic viscosity at 40 °C cSt</td>
<td>4.2</td>
</tr>
<tr>
<td>Water content % vol</td>
<td>0.035</td>
</tr>
<tr>
<td>Ramsbottom carbon residue %wt.</td>
<td>0.250</td>
</tr>
<tr>
<td>Pour Point °C</td>
<td>-1</td>
</tr>
<tr>
<td>Flash point °C</td>
<td>150</td>
</tr>
<tr>
<td>Sulphur content %wt.</td>
<td>0.007</td>
</tr>
<tr>
<td>Ash content %wt.</td>
<td>0.01</td>
</tr>
<tr>
<td>Oxidation stability g/100ml</td>
<td>0.120</td>
</tr>
<tr>
<td>Copper strip corrosion</td>
<td>1a</td>
</tr>
<tr>
<td>Calorific value MJ/kg</td>
<td>42.23</td>
</tr>
</tbody>
</table>

Figure 3 NMR spectrum of Mesua ferrea L. methyl ester.
Food and energy security are at the forefront of environmental issues, engaging the attention of all countries. And climate change poses fundamental threats to Asia’s food and energy security, which if left unchecked, will result in an upsurge of migration into the already overburdened mega cities. Biofuels have come into prominence as they are considered to be an environment-friendly energy source with the potential for reduced gas emissions. Energy inputs into biomass production, transportation, and conversion are assumed to be biomass based, resulting in a CO₂-neutral (carbon dioxide-neutral) fuel cycle. The CO₂ released in biomass combustion is assumed to be balanced by the CO₂ removed from the atmosphere when the biomass was grown. Biofuels are a viable option for achieving the targeted gas emission reduction by many countries. But, any attempt to divert land for biofuel is not a viable option, as the demand for food is rising rapidly. More alarming is the forecast that food prices will increase by 20%–40% in the next decade. Problem is not about choosing food versus fuel production, but it really centres on poor (inequitable) distribution of food between those who produce food surpluses and those who need food but are at some distance from where it is produced or to purchase it in the marketplace. If it is not a food shortage problem but one of distribution of existing food supplies, it is not necessary to be concerned about a ‘fabricated’ conflict between food vs fuel needs.
Cellulosic biomass resources are abundant and have multiple application potential and can be converted to ethanol by hydrolysis and subsequent fermentation. In India, the total crop residue including fodder and non-fodder production during 1996/97 was estimated to be 626 Mt (million tones) of air-dry weight. The dominant residues are those of rice, wheat, sugarcane, and cotton, accounting for 66% of the total residue production. Crop residues, which are used as fodder, will not be available as feedstock for energy. The total potential of non-fodder crop residues available for energy is estimated to be 325 Mt and 450 Mt for 1996/97 and 2010, respectively. Besides this, a portion of the agri-residues (rice, wheat straw, corn stover, stalks, leaves, and branches), which are presently burnt or left in the field due to mechanized farming (especially in Punjab, Haryana, and other parts of the country) may, therefore, be utilized for biofuel production. Ethanol production technologies for sugar (cane, beet molasses, and in small quantity sweet sorghum) and starch crops (grains) are well-developed, but have certain limitations. Oil from Jatropha curcas seeds is used for making biodiesel fuel in Philippines and Brazil, where it grows naturally. Likewise, Jatropha oil is being promoted as an easily grown biofuel crop in hundreds of projects throughout India and other developing countries. However, Jatropha suffers from certain limiting factors such as the availability of high yielding Jatropha saplings to the grower, low yield on marginal land, and land availability. But the real challenge lies in the efficiency and cost effectiveness of the technology that requires focused R&D (research and development) and governmental policies.

**Introduction**

The total world consumption of energy equivalent is about 10 billion tonnes of crude oil, of which 80% comes from fossil fuels. The commercial energy consumption in the developed world has increased during the last three to four decades and is more than 80% of the total world consumption. And 20% of the energy is consumed by 70% of the world population in developing and social countries. India ranks sixth in the world in terms of energy demand with total energy consumption of around 480.4 Mt, of which 53% is from fossil fuels. But India produces only about 25% of the total energy requirement. The country has imported about 99Mt of crude oil during 2005/06, as reported by the Ministry of Petroleum and Natural Gas, causing a burden of Rs 171 702 crores on foreign exchange.

The global energy security concern, along with the growing interest in the environmental benefits associated with the use of renewable energy, has resulted in wide-ranging government policies that promote biofuel production. It is also driven by the Kyoto Protocol, which mandates greenhouse gas reduction to the member countries. Biofuels are, thus, considered to be a viable option for achieving the targeted reduction by many countries. India has experienced a dramatic growth in fossil fuel CO₂ emissions at the rate of 5.9% since 1950. Biofuel is carbon-neutral and environment-friendly, and therefore, it decreases the emission of greenhouse gases. As biofuel is carbon-neutral, it does not add CO₂ to the atmosphere and has been supported with lifecycle analysis. The analysis shows that biofuel emits less greenhouse gases than fossil fuels like petroleum and diesel. Ethanol produces 13% less greenhouse gases than fossil fuels (Science Daily, 2007) and biodiesel
can reduce carbon emissions by 78% (United States Agency for International Development). Ethanol was found to have a 21% reduction in CO₂ equivalent production in comparison to 2.44 kg CO₂ equivalent/liter production from gasoline. The reduction in greenhouse gas emission is larger with lignocellulosic ethanol than for starch-derived ethanol due to the lower overall oil input required in the process. Table 1 indicates the reduction in emissions.

**Food shortage, soaring prices**

Most of the nations in the world are dependent on food imports. Cereal surpluses are produced only in those countries that have relatively low population densities and practice intensive agriculture. For instance, the US (United States), Canada, Australia, Oceania, and Argentina provide 81% of the net cereal exports in the world market. The per capita availability of world grains, which makes up 80% of the world’s food, has been declining for the past 15 years and food prices will increase by 20%–40% in the next decade. To ensure smooth implementation of the Energy Independence and Security Act, mandating an increase in corn ethanol production to 15 billion gallons by 2015 and 36 billion gallons by 2022, the US government has promised a subsidy of $0.51 per gallon of corn ethanol. This will inevitably cut back on market supply of corn and push the already inflated prices higher. Also, there are concerns regarding the shifting of cropping pattern of the farmers in some developed countries from food grains to crops being used for biofuels. Farmers are shifting to the cultivation of crops which are used for the production of biofuels, decreasing the area under food grains. This creates gaps between the demand and supply of food grains. The use of corn for ethanol production and their demand for soya bean oil has increased world food prices by about 10%, according to an International Monetary Fund report.

But the so-called ‘food versus fuel’ controversy appears to have been exaggerated in many cases. The subject is far more complex than has generally been presented, as agricultural and export policies and the politics of food availability are factors of far greater importance. The argument should be analysed against the background of the world’s or an individual country’s real food situation of food supply and demand, the use of food as animal feed, the under-utilized agricultural production potential, the increased potential for agricultural productivity, and the advantages and disadvantages of producing biofuels. The specific aims of food security ensures production of adequate food supplies, maximizing stability in the flow of supplies and securing access to available supplies on the part of those who need them.

It is estimated that the country will need about 260–264 Mt of food grains, 130–150 Mt of vegetables, 80–106 Mt of fruits, 10–14 Mt of meat, 35 billion eggs, 10–14 Mt of fish, and 12 Mt of edible oils to provide adequate nutrition to 1.35 billion people by 2020. India achieved food self-sufficiency 30 years ago through dramatic investments in technology, institutions, and infrastructure. In 1952/53, the total food production was 59.2 Mt. While 102.09 million hectares was used for food grain production, the yield was only 580 kg per hectare (Fig1). By 2007/08, 122.4 million hectares were covered and food production increased to 230.7 Mt with a productivity of 1854 kg/ha.

India is well-placed in meeting the challenge of food security. It is one of

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emission (%)</th>
<th>Emission (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter</td>
<td>27 41</td>
<td>0.08 0.02</td>
</tr>
<tr>
<td>NOx</td>
<td>4 5</td>
<td>0.45 0.34</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>20 27</td>
<td>0.76 0.65</td>
</tr>
<tr>
<td>Unburned hydrocarbons</td>
<td>– 0.004 0.02</td>
<td>0.064 0.0</td>
</tr>
</tbody>
</table>

**Table 1** Reduction in pollution emission with different percentages of ethanol blending
the largest producers of food grains in the world, feeding 17% of the world population on only world’s 3% of arable land. It is the second largest producer of wheat and rice in the world, growing 12%–22% of the world’s total wheat and rice crop, respectively. The country has food management initiatives like procurement of food grain from farmers at remunerative prices, distribution of food grains to the consumers particularly the vulnerable sections of the society, and maintaining a buffer stock of food grains to ensure food security. The Food Corporation of India, the biggest buyer of grains, bought a record 233 lakh tonnes of wheat and 291 lakh tonnes of rice last year, which should suffice for two years according to the officials. Our food grain buffer stock is enough to feed our people for 13 months.

In the beginning of 2009, there were 180.6 lakh tonnes of wheat in the central government’s pool, which is more than twice the buffer stock requirement of 82 lakh tonnes. Similarly, there was 173.4 lakh tonnes of rice, which is greater than the buffer stock requirement of 118 lakh tonnes. Rice and wheat are two food grains whose production growth determines India’s capacity to feed itself. The total food grain stock stood at 354 lakh tonnes, which is way above the buffer stock requirement of 200 lakh tonnes. However, despite the huge stockpile, there are thousands of people who are not able to buy the food grains offered at subsidized rates through the government outlets. Yet, in some of the regions, improper storage and lack of proper distribution system has led to people going hungry and even facing starvation deaths. There is a need for both short- and long-term policy to meet the emerging surplus situation to solve the problems of excess stock and acute shortage of storage space, and levy carrying costs, while ensuring effective price support to farmers.

Food insecurity exists when people are under-nourished as a result of the physical unavailability of food, the lack of social or economic access to adequate food, and/or inadequate food utilization. The population and per capita availability of food grains over years are given in Table 2.

![Figure 1](image-url) Area and production of food grains over decades

### Table 2 Population and per capita per day net availability of food grains

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (million)</th>
<th>Per capita net availability per day (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cereals</td>
<td>Pulses</td>
</tr>
<tr>
<td>1952</td>
<td>369.2</td>
<td>325.4</td>
</tr>
<tr>
<td>1962</td>
<td>452.2</td>
<td>398.9</td>
</tr>
<tr>
<td>1972</td>
<td>563.9</td>
<td>419.1</td>
</tr>
<tr>
<td>1982</td>
<td>703.8</td>
<td>415.6</td>
</tr>
<tr>
<td>1992</td>
<td>867.8</td>
<td>434.5</td>
</tr>
<tr>
<td>2002</td>
<td>1050.6</td>
<td>458.7</td>
</tr>
<tr>
<td>2003</td>
<td>1068.2</td>
<td>408.5</td>
</tr>
<tr>
<td>2004</td>
<td>1085.6</td>
<td>426.9</td>
</tr>
<tr>
<td>2005</td>
<td>1102.8</td>
<td>390.9</td>
</tr>
<tr>
<td>2006</td>
<td>1119.8</td>
<td>412.8</td>
</tr>
<tr>
<td>2007</td>
<td>1136.5</td>
<td>407.4</td>
</tr>
</tbody>
</table>

**Source**: Economic Survey 2008/09

### Food Security

The government has been implementing a wide range of nutrition intervention programmes for achieving food security at the household and individual levels. The PDS (Public Distribution System) supplies food items, such as food grains and sugar, at administered prices through fair price shops. There have been a range of food-for-work and other wage employment programmes. Another approach adopted by the government is to target women and children directly. This includes mid-day meal programme for school-going children and supplementary nutrition programme for children and women; ICDS (Integrated Child Development Scheme) for providing nutrition and healthcare services to children and pregnant women; and the Antyodaya Anna Yojana for providing affordable food to BPL (below poverty line) households. The proposed NFSA (National Food Security Act) may be an important step towards eradicating hunger and reducing malnutrition in the country. Implementation of this act will ensure that every BPL cardholder gets 25 kg
Biofuel production in India

India does not produce any ethanol from cereal grains, and thus, there has been no impact of the ethanol programme on the domestic market for food, feed, and trade of cereal grains and byproducts. As the production of ethanol for fuel is basically from sugar molasses, it has not had a significant impact on the production, prices, and trade of sugar for food and industrial use. Despite a decline in the production of sugarcane/sugar and consequently, sugar molasses, higher prices of alcohol vis-à-vis fixed ethanol prices have limited fuel ethanol production. If ethanol prices are allowed to be linked to sugar molasses prices, it may impact the availability of sugarcane juice and sugar molasses for alternative uses.

India has about 320 distilleries, with a production capacity of about 3.5 billion litres of rectified spirits (alcohol) per year, almost all of which is produced from sugar molasses, and not from sugar juice, food grains, or other cellulose feed stocks. More than 115 distilleries modified their distillation facilities to produce ethanol, with a total ethanol production capacity of 1.5 billion litres per year. Current ethanol production capacity is enough to meet the estimated ethanol demand for the 5% blending ratio with gasoline. However, for a 10% EBP, current ethanol production capacity has to be expanded by increasing the number of molasses-based ethanol plants and by setting up sugarcane juice-based ethanol production units.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total residue production (Mt air dry weight)</th>
<th>Non fodder crop residues (Mt air dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1996/97</td>
<td>2010</td>
</tr>
<tr>
<td>Rice</td>
<td>146.5</td>
<td>213.9</td>
</tr>
<tr>
<td>Wheat</td>
<td>110.6</td>
<td>157.6</td>
</tr>
<tr>
<td>Jowar</td>
<td>22.3</td>
<td>12.2</td>
</tr>
<tr>
<td>Bajra</td>
<td>15.8</td>
<td>13.6</td>
</tr>
<tr>
<td>Maize</td>
<td>26.3</td>
<td>32.5</td>
</tr>
<tr>
<td>Other cereals</td>
<td>9.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Red gram</td>
<td>13.5</td>
<td>11.2</td>
</tr>
<tr>
<td>Gram</td>
<td>9.3</td>
<td>13.5</td>
</tr>
<tr>
<td>Other pulses</td>
<td>17.1</td>
<td>17.1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>20.7</td>
<td>28.1</td>
</tr>
<tr>
<td>Rapeseed and mustard</td>
<td>13.8</td>
<td>24.1</td>
</tr>
<tr>
<td>Other oilseeds</td>
<td>18.2</td>
<td>27.1</td>
</tr>
<tr>
<td>Cotton</td>
<td>50.0</td>
<td>55.7</td>
</tr>
<tr>
<td>Jute</td>
<td>15.7</td>
<td>10.5</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>110.8</td>
<td>185.4</td>
</tr>
<tr>
<td>Coconut and Areca nut</td>
<td>20.0</td>
<td>28.2</td>
</tr>
<tr>
<td>Mulberry</td>
<td>3.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Coffee</td>
<td>3.42</td>
<td>3.9</td>
</tr>
<tr>
<td>Total</td>
<td>626.5</td>
<td>840.6</td>
</tr>
</tbody>
</table>
Potential of crop residues as feedstock for ethanol

Crop residues have 30%–35% cellulose, 20%–35% hemicellulose, and 15%–20% lignin, which could be used for fuel production. About 73.9 Tg (teragram) per year of dry wasted crops and 1.5 Pg (pentagram) per year of dry lignocellulosic biomass from seven common crops in the world could potentially produce 49.1 GL (giga litre) per year and 442 GL per year of bioethanol, respectively, leading to a total production of 491 GL per year. The major crop residues produced in India are straws of paddy, wheat, millet, sorghum, pulses, oilseed crops; maize stalks and cobs; cotton stalks; jute sticks; sugar cane trash; mustard stalks; and so on. Some past and future projected data for various agro-residues at the national level are given in Table 3. The total crop residue production during 1996/97 is estimated to be 626 Mt. The dominant residues are those of rice, wheat, sugarcane, and cotton, accounting for 66% of the total residue production.

Sugarcane and cotton residue production is 110.8 Mt and 50.0 Mt, respectively. As 390 Mt of crop residues, which are used as fodder, will not be available as feedstock for energy in the year 2010, the total potential of non-fodder crop residues available for energy is estimated to be 325 Mt and 450 Mt for 1996/1997 and 2010, respectively [Table 3]. India has the potential to produce around 713 million gallons of bioethanol annually, in comparison to its present production of 4% to the world total production. Besides this, a portion of the agri-residues (rice straw, wheat straw, corn stover, and so on) that are presently burnt or left in the field due to mechanized farming may also be harvested for bioethanol production. The crop residues are available throughout the year and dependency on a single feedstock is, hence, not required. The amount available depends upon the harvesting time, storage-related characteristics, storage facility, and other such factors.

‘Smart’ biofuel crops ensure food and environmental security

The ‘smart’ biofuel crops developed, utilized, and promoted by the ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Patancheru, Andhra Pradesh, ensure energy and environmental security. Smart biofuel crops are those that ensure food security, contribute to energy security, provide environmental sustainability, tolerate the impacts of climate change on shortage of water and high temperatures, and increase livelihood options. ICRISAT-bred sweet sorghum varieties and hybrids have increased sugar content in their stalks. It has a strong pro-poor advantage, as it has a triple product potential—grain, juice for ethanol, and bagasse (waste) for livestock feed and power generation. Its highlight is that there is no compromise on farmers’ food security, since the grain is available for the farmers, along with sugar-rich juice from the stalk that can be distilled to manufacture ethanol.

Biofuel from non-edible oils

As the biodiesel programme is based on the use of non-edible vegetable oil, biodiesel production should not have an impact on feed, food, and trade of oilseeds, vegetable oils, and other edible products. Biodiesel production efforts are focused on using non-edible oils from plants (Jatropha curcas, Pongamia pinnata, and other tree-borne oilseeds) and animal fats like fish oil. The focus is to encourage the use of wastelands and other unproductive land for the cultivation of these relatively hardy ‘new’ biofuel crops. The GOI (Government of India) does not want biofuel feedstock crop cultivation...
to compete with food crops for scarce agricultural land and water. An estimated 55.3 million hectares are considered wasteland in India, which could be brought into productive use by raising biodiesel crops. The GOI policy is also driven by the fact that biofuel crop cultivation in wastelands would provide additional employment to the vast rural population in India.

In April 2003, the GOI launched a National Mission on biodiesel that identified Jatropha curcas as the most suitable tree-borne oilseed for the production of biodiesel, and focused on promoting plantations of Jatropha on ‘wastelands’. The Planning Commission set an ambitious target of 11.2-13.4 million hectares to be planted with Jatropha by 2012, in order to produce sufficient biodiesel to blend at 20% with petro-diesel. According to Dr Abdul Kalam, former President of India, out of the 600 000 sq km of wasteland that is available in India, over 300 000 sq km is suitable for Jatropha cultivation. Indian Railways has already taken a significant step of running two passenger locomotives (Thanjavur to Nagore section) and six trains of diesel multiple units (Trichirapalli to Laligudi, Dindigul, and Karur sections) with a 5% blend of biofuel sourced from its in-house esterification plants. The Reliance Industries has selected 200 acres (0.81 sq km) of land at Kakinada in Andhra Pradesh to grow Jatropha for high quality biofuel. Chhattisgarh has decided to plant 160 million saplings of Jatropha in all its 16 districts during 2006 with the aim of becoming a biofuel self-reliant state by 2015. Farmers of Karnataka, Tamil Nadu, Rajasthan, and Maharashtra have also planted Jatropha to produce biodiesel.

However, Jatropha suffers from certain limiting factors such as the non-availability of high-yielding Jatropha saplings to the grower, low yield on marginal land, and land availability. But the real challenge lies in the efficiency and cost effectiveness of the technology that requires focused R&D and governmental policies. If right species and right plantation materials are selected and the right agronomic practices are adopted, the results might be profitable, viable, and sustainable.

**Conclusion**

Biofuels are considered to be the most important option for energy security and environmental protection from greenhouse gas emissions. The diversion of grain and oilseed crops from dinner tables to fuel tanks imbalances the food security. So it is a challenge to the scientific community to develop an integrated approach for energy production without compromising on our feed priority.

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**Inviting articles for Akshay Urja**

The need to have a sustainable supply necessitates the exploitation of available energy sources, and among these, renewable resources are at the forefront. It is now an established fact that RE (renewable energy) can be an integral part of sustainable development because of its inexhaustible nature and environment-friendly features. RE can play an important role in resolving the energy crisis in urban areas to a great extent. Today RE is an established sector with a variety of systems and devices available for meeting the energy demand of urban inhabitants, but there is a need to create mass awareness about their adoption. *Akshay Urja* is an attempt to fulfil this need. 20 000 copies are being disseminated in India and abroad.

*Akshay Urja* publishes news, articles, research papers, case studies, success stories, and write-ups on RE. Readers are invited to send material with original photographs and statistical data. The photographs should be provided on hard copy or as high resolution (minimum 300 DPI) files on a CD. *Akshay Urja* will pay suitable honorarium for each published article of about 1500 words and above to the authors. The publication material in two copies, along with a soft copy on CD/floppy/e-mail may be sent to

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[www.mnre.gov.in](http://www.mnre.gov.in)
In 2008, when the HP (Himachal Pradesh) government announced the free distribution of 64 lakh power-saving CFLs (compact fluorescent lamp) to all its domestic consumers, most people read a political motive behind it. But, it was a pure and simple business for the state government that would profit everybody and prove to be win-win to all. From the end domestic consumers to the state exchequer, everybody is at an advantageous position.

The Bijli Bachat Yojna probably made it the first state in the entire South East Asia region to successfully replace all domestic electricity-guzzling incandescent bulbs with power-saving CFLs. A small decision, which costed just about Rs 70 crores, proved to be one of the most profitable ‘green’ business decisions taken by the state government in the past two years.

While it gave free CFLs to all domestic consumers, it gave additional revenue of Rs 99 crores to the government. Also, the HPSEB (Himachal Pradesh State Electricity Board) would also be able to lessen its burden of transmission and distribution, and improve its power quality in remote areas. It also indirectly helped to reduce emission of greenhouse gases because of less consumption of power. A rough estimate made by the state government claimed that the decision would prevent an annual emission of carbon dioxide to the tune of 188 496 tonnes and might earn 188 496 CERs (Certified Emission Reductions), which is worth Rs 20 crores on selling the CERs in the international market. And the saving of 75 to 150 MW (megawatt) of power during peak hours would save an investment of nearly Rs 420 crores, which was otherwise required to build the power generation capacity of the state.

The green decision

The ‘green’ scheme, named Atal Bijli Bachat Yojna, provided every consumer with four CFLs – two 15-watt and two 20-watt – free-of-cost, as a replacement of two 60-watt and two 100-watt incandescent lamps at a premises. The state received overwhelming response and within a few months, the CFLs were distributed all over the states. The state government also ensured its consumers that it would replace all the defective CFLs within 18 months of distribution. The feedback it received was quiet impressive.
Energy bills of the consumers reduced by 25%–30%, depending upon the usage pattern of the consumers and the number of electric gadgets being used. It would have been a profitable venture for consumers even if the state government had not distributed the CFLs for free. While the cost of CFLs is 5–10 times higher than incandescent bulbs, it consumes 4–5 times less power and has 6–7 times more shelf life. The consumers would be benefitted and compensated in the long run by the savings in the huge electricity bills. ‘You can calculate the addition of earning to the state revenue from the fact that we sell one unit of power to domestic consumer at 80 paise, whereas during peak hours in summers, the same power is sold to other states at as high as Rs 7.50 per unit. Energy we saved is energy we generated,’ said the State Power Secretary, Mr Deepak Sanan. The state government says that the present trend shows that the state exchequer would earn additional annual revenue of Rs 99 crores by selling the saved energy.

**Power advantage**

It is estimated that the scheme contributed to a saving of 270 million units of electricity, annually. This helped the HPSEB to earn five times more revenue. The replacement of CFLs saved approximately 115 MW of energy for six hours on a daily basis. The maximum demand on the system was reduced by 75–150 MW during the peak hours, which was made available to other consumers who were paying almost five times more than the domestic consumers. ‘You can calculate the addition of earning to the state revenue from the fact that we sell one unit of power to domestic consumer at 80 paise, whereas during peak hours in summers, the same power is sold to other states at as high as Rs 7.50 per unit. Energy we saved is energy we generated,’ said the State Power Secretary, Mr Deepak Sanan. The state government says that the present trend shows that the state exchequer would earn additional annual revenue of Rs 99 crores by selling the saved energy.

**Investment advantage**

The one-year experiment with CFLs has revealed that the replacement of conventional bulbs is equivalent to the installation of one hydel project of 70 MW capacity. It would avoid investment of about Rs 420 crores. ‘Indirectly, it means that the state government had to invest only Rs 70 crores to save investment of Rs 420 crores on account of building power generation capacity. Moreover, by investing Rs 70 crores, the state government is expected to fetch additional annual revenue of Rs 99 crores,’ said a senior officer of the HPSEB.

**Carbon trading advantage**

The project is the first major effort of the state government to earn resources through carbon trading. The scheme qualifies for earning through CERs under the CDM (Clean Development Mechanism). CERs are also called carbon credits. One CER is equivalent to reduction of one tonne of carbon dioxide or equivalent greenhouse gases from the environment. It is issued by the Executive Board of the UNFCCC (United Nations Framework Convention on Climate Change) for emission reduction achieved by CDM projects and verified by a DOE (department of energy) under the rules of the Kyoto Protocol. The CERs are purchased by the developed countries in order to comply with their emission reduction targets or by operators of installations covered by the European Union Emission Trading Scheme. The HPSEB has already initiated the process for acquiring the approval of the CDM Executive Board of the UNFCCC. If all goes well, the HPSEB would be entitled for an estimated 188 496 CERs, which might fetch revenue to the tune of Rs 20 crores at the present rate.

**Just a beginning…**

The successful implementation of the Bijli Bachat Yojna is just the beginning of power-saving experiments by HP. ‘We are now replacing traditional bulbs with CFLs in government buildings and educational institutions. The state government is further planning to give incentives to commercial and industrial houses to use power-saving gadgets. The announcement would come soon, and we would issue guidelines and provisions for industrial houses,’ said Choudhary. In another move, the state government would start a pilot project to replace traditional streetlights with LEDs (light emitting diodes). ‘LEDs are more rough and tough, and more power-efficient than even CFLs. First, the pilot project would be confined to a few municipal areas and subsequently, it would spread to all municipal areas in the state,’ said Choudhary.
On 10 March 2010, Buddhadeb Bhattacharya, Chief Minister of West Bengal, inaugurated the SPV (solar photovoltaic) Module Manufacturing Plant of Vikram Group of Industries at Falta SEZ (Special Economic Zone). ‘Vikram Solar has invested about Rs 100 crores in this project, with an initial capacity of 25 MW (megawatt) per annum. We are already in the process of expanding its capacity to 50 MW by the middle of this year’, says H K Chaudhary, Chairman, Vikram Group of Industries.

The establishment of this solar plant is expected to provide the masses green and clean energy, making solar industry the backbone of the Indian economy in the near future. Vikram Solar has already provided employment to more than 100 people. Once the full expansion is implemented, more than 800 people would be provided employment, directly and indirectly, with a focus on skill development and training in the high technology solar industry.

To deliver solar power to non-grid areas, Vikram Solar has initiated a R&D (research and development) project in collaboration with BESU (Bengal Engineering and Science University) for applied research in the field of long-life solar battery systems to sustain a lifecycle of 15–20 years, as compared to the current life of 3–5 years. This initiative has been taken up under the MNRE (Ministry of New and Renewable Energy) research proposals for the development and demonstration of electricity storage systems. The event was attended by Debesh Das, Minister-in-Charge of the Department of Information Technology, Government of West Bengal; and S P Gon Choudhuri, Managing Director, West Bengal Green Energy Development Corporation Ltd; Arun Bit, Development Commissioner, Falta; Khalil Ahmed, Deputy Manager, South 24 Parganas; Chandana Ghosh Dastidar, Member of Legislative Assembly, Falta; and other dignitaries and industrialists.

The World Renewable Energy Technology Congress and Exhibition-2010 was held at Hotel Le Meridien, New Delhi, from 18–20 March 2010. The congress was organized by RAGA Integrated Technology Management Services, and inaugurated by B K Chaturvedi, Member, Planning Commission of India. It was attended by 410 delegates, dignitaries, and speakers from 30 countries. The exhibition of green technology, services, equipment, and know-how of various renewable energy sectors was inaugurated by Her Excellency Daniele Smadja, Ambassador, Head of Delegation of European Union. During the three-day conference, theme, keynote, and technical sessions were conducted to exchange ideas and discuss technology development to improve efficiency and future technology development in the various segments of renewable energy. The role of renewable energy today and tomorrow was also discussed, along with climate change and green power programmes.

Some of the eminent speakers were Deepak Gupta, Secretary, MNRE; B M Bansal, Chairman, Indian Oil Corporation Ltd; Dr Pramod Deo, Chairman, Central Electricity Regulatory Commission; Dr Ajay Mathur, Director-General, Bureau
of Energy Efficiency; Mark Ginsberg, Senior Executive Board Member, United States Department of Energy.

Gauri Singh, Joint Secretary, MNRE; Dr N P Singh, Advisor, MNRE; Dr A R Shukla, Scientist-G/Advisor, MNRE; Dr Bibek Bandyopadhyay, Director, Solar Energy Centre, MNRE; and Dr Ahmar Raza, Director, MNRE, chaired various technical sessions. The participants enjoyed the glimpses of traditional dances of India, the taste of Indian food, and the cultural programmes on the second day of the congress.

The congress was concluded, with support from various sponsors and compliments from the participants. A common view emerged—‘promotion of renewable energy sources and technologies is one of the crucial strategies to bridge the demand–supply gap in the power sector in an environmentally sustainable and benign manner. It can also pave the way for strategic shift from future dependence on the import of fossils fuels and enhance the contribution of renewable energy in the energy mix, leading to enhanced energy security—a step forward towards the “Energy Independence of India”.

During the valedictory session, a joint declaration was signed by eminent personalities from the US, Australia, Germany, and India on behalf of all participants. Few of the important resolutions are as follows.

- Making solar energy competitive in India by 2020.
- Formation of permanent society for holistic development of renewable energy and green technologies.
- The world green technology community to assemble again from 21–23 April 2011 for the Second WRETC and Exhibition in New Delhi.

A ‘sun’day interaction with RWA one solar energy

The National Power Training Institute (NPTI) organized a close-group interaction with Resident Welfare Association (RWA) Vasundhara, Delhi, on rooftop solar power system and community-level applications of solar energy on 25 April 2010. The aim was to instill confidence; encourage and elicit direct response from the end-user community; and raise their interest in solar photovoltaic (SPV) and solar water heating systems (SWHS). The event included live demonstration of solar power panels, charge controllers, battery, solar fan, and lighting interconnection setup and various techno-commercial aspects of the support schemes from the MNRE and the state governments.

The programme was chaired by Dr N S Saxena, Director General, NPTI, and was attended by eminent personalities like S K Sharma, President of the RWA federation; Dr P C Pant and Dr Arun K Tripathi, Directors, MNRE; R K Sharma, Principal Director, NPTI(N R), and the residents of Vasundhara Society. It was an initiative of Sandeep Dixit, Assistant Director and Faculty at NPTI.

While R K Sharma highlighted the significance of such interactions, Dr Saxena talked about the importance of SPV systems, despite the initial high cost. Dr Pant and Dr Tripathi talked about the renewable energy developmental activities; applications; and the subsidy and support schemes of the MNRE. The various queries of the participants, relating to the cost, development of specifications, warranty, life, aging, and space requirements of systems, were also clarified. S K Sharma assured full support and cooperation in taking up system studies covering the society needs.
MAKE A SOLAR DISTILLER

Imagine you are stuck on a deserted island, without even a drop of water! All you can see around you is either the salty seawater or some muddy water in the interiors. How will you survive? Well, if you have the following materials, you can make a solar water distiller!

Materials
- Two large plastic containers
- Clear plastic wrap
- Masking tape
- Two small rocks
- Two small glasses
- Muddy/salty water

Procedure
- Fill both the plastic containers with one inch of the muddy/salty water.
- Place one empty glass in an upright position into the middle of each plastic container. Make sure it remains empty.
- Cover both plastic containers tightly with plastic wrap and seal them with the tape.
- Place a small rock in the middle of the plastic wrap, directly over the glass but not touching it.
- Place the stills in a sunny place for two hours.

Now go about your other survival activities, like procuring food and shelter. The distiller will make about 1 litre a day in 12 hours of sunshine, if your container is big enough. It may not be much, but it will sustain a person for quite a while. And you might be able to replicate several distillers if you are able to find enough equipment. Putting the apparatus over a fire/stove, if it is available, will make the production much faster. But in a survival situation, do weigh the fuel cost versus the benefits of doing so.

How it works?
Solar distillers work by mimicking the natural water cycle. The sun provides energy to warm the water, the water evaporates (forms clouds), and finally, condenses when it meets a cooler surface (makes rain).

Distillation utilizes the principle that chemicals vaporize at different temperatures. Most contaminants in water have vaporization points that are higher than that of water. A simple solar distiller removes salts, heavy metals, bacteria, arsenic, and many other contaminants. When untreated water is heated in a solar distiller, pure water vaporizes first, leaving contaminants behind.
A re you confused about the carbon industry? Do you need help to understand the basics and how it all works? Do you know the difference between carbon credits, offsets, and permits? Would you like to know more about the carbon industry but do not know where to start? Then you need a copy of Understanding Carbon Credits to help you understand the industry better and how it all works.

This book has been written to help individuals, businesses, and organizations to understand the basics of carbon trading, carbon credits, and the emerging carbon market in a simple, concise, and informative document. It has been written in a simple, laymen’s language, unlike a lot of the current industry books that are filled with jargon that are currently being used. After reading this book, you will be confident to talk about the basics of carbon trading and carbon credits with anyone in the industry. It will also help you to decide about what you should and can do next. You will be in a better position to make informed decisions about the marketplace and figure out if carbon trading is right for you.

There is an urgent need to understand global warming and the tipping points for dangerous impacts that we have already crossed as a sustainability emergency, which takes us beyond the politics of failure-inducing compromise. We are now in a race between climate tipping points and political tipping points. As the threats posed by global warming become more obvious, not only to scientists but also to the general public, the concept of being able to go ‘carbon neutral’ is an attractive one. Carbon neutrality offers individuals, businesses, and other institutions like universities the opportunity to take personal responsibility for the global warming implications of their lifestyles.

With global emissions of carbon dioxide exceeding 25 billion tonnes per year and growing, it will take radical changes in energy production and use to avoid the ‘dangerous anthropogenic interference’ with the climate system that the United Nations Framework Convention on Climate Change warns against. National and international policies will be pivotal to any successful long-term effort to reduce GHG (greenhouse gas) emissions and to moderate global warming. At the same time and, partially, in response to the absence of such policy, voluntary GHG markets are proliferating.

This book presents the writing of Gurmit Singh, a research scientist in climate change-related damage to global ecosystems and the resulting competition for natural resources, with regard to the pressing environmental issues of today. He has a persistent clarity of vision of a future where human beings transform their greed into a profound respect for nature.

Interest in carbon offsets has grown dramatically in the last few years. The New Oxford American Dictionary even chose ‘carbon neutral’ as its ‘Word of the Year’! This is a clear evidence of the fact that this is the wave of the present and that understanding offsets and the role they play in attaining ‘carbon neutrality’ is increasingly important.

The cap-and-trade system is one of the most sophisticated and comprehensive methods of combating global warming. Despite being an environmental issue, it has integral financial and economic aspects. Cap-and-trade is a policy that aims to limit GHG emissions by requiring certain industries to buy carbon offsets if emissions exceed the legal cap.

Carbon trading is carefully regulated in developed countries that signed the Kyoto Protocol. But so far, the offset market in the United States has been voluntary and free from any industry-wide oversight or standards for certification, projects, or business models. However, those days may be numbered.

This book is a comprehensive and accessible guide to understand the opportunities offered by regulated and voluntary carbon markets for tackling climate change. Combining theoretical aspects with practical applications, this book is for business leaders, financiers, carbon traders, lawyers, bankers, researchers, policy makers, and anyone who is interested in market mechanisms to mitigate climate change.
**100 PER CENT RENEWABLE: ENERGY AUTONOMY IN ACTION**

Edited by Peter Droege. 2009
UK: Earthscan

The greatest challenge of our time is to build a world based on the sustainable use of renewable power. A 100% renewable world is seen by many as an impossible dream in anything but the very long term. But not only do a growing number of initiatives and plans dare to make the change but many have already achieved it.

This rich collection presents a series of pioneering efforts and their champions, and the paths to their successes. Ranging from initiatives by individuals to visions for companies, communities, and entire countries, it defeats tired economic and technical counter-arguments, showing how the schemes featured not only can and do work but do so economically and with available technology. The book is introduced by incisive writing by Peter Droege, explaining the challenges and framing a roadmap towards a 100% renewable reality.

ISBN: 978-1-844-07718-2 • Price: £35.00

**BIOFUELS: SECURING THE PLANET’S FUTURE ENERGY NEEDS**

Edited by Ayhan Demirbas. 2009
UK/US: Springer

Biofuel is a renewable energy source produced from natural (bio-based) materials, which can be used as a substitute for petroleum fuels. The benefits of biofuels over traditional fuels include greater energy security, reduced environmental impact, foreign exchange savings, and socioeconomic issues related to the rural sector. And the technology is relevant to both developing and industrialized countries. For these reasons, the share of biofuels in the automotive fuel market is expected to grow rapidly over the next decade.

The most common biofuels, such as ethanol from corn, wheat, or sugar beet and biodiesel from oil seeds, are produced from classic food crops that require high-quality agricultural land for growth. However, production of bioethanol from biomass is one way to reduce both the consumption of crude oil and environmental pollution. There is also a growing interest in the use of vegetable oils for making biodiesel, which is less polluting than conventional petroleum diesel fuel.

The book, one of the series Green Energy and Technology, discusses options for the production of transportation fuels from biomass (such as wood, straw, and even household waste). The book is an important text for undergraduates, postgraduates and researchers in energy engineering, as well as professional fuel engineers.

ISBN 978-1-848-82010-4 • Price: £81.00

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**Internet resources**

**SOLAR BUZZ**
Solarbuzz is an international solar energy research and consulting company, staffed with a team drawn from some of the largest companies in the solar energy industry today. Its Solarbuzz.com is a portal on solar energy, through which you can access Solarbuzz research reports and consultancy services, follow global solar market and supply developments, and connect to solar energy companies worldwide.

The portal gives links to companies and topics related to the solar industry. While the primary focus of the site content is photovoltaics (solar electric), it also includes companies in our listing that market solar thermal systems. Solarbuzz.com also maintains on-site content, so that site users can receive a speedy understanding of both the commercial and environmental potential of solar energy. Potential purchasers of solar energy and products can use the country pages, which not only provide information on the closest solar companies, but you can also gain valuable information regarding how to get the best out of solar power.

**EUROPEAN BIOFUELS TECHNOLOGY PLATFORM**
The European Biofuels Technology Platform is a common interest group that aims to promote the development of biofuels for transport in Europe. It is supported by a secretariat that receives some funding from the European Commission under the Sixth Framework Programme. The project aims to facilitate the entry of European manufactures of sustainable energy technologies, know-how and European research results into the emerging markets, provoked by the European Union Emission Trade Scheme, and Clean Development Mechanism markets in Asia. The main tools are information dissemination, project brokerage, and partnering events. Additionally, this website provides details of good practice, technology, and service providers, and background information.
**FORTHCOMING EVENTS**

**National**

**Green Energy World Expo 2010**
14–16 October 2010
Chennai, India
E-mail: daisy@gsnaworldwide.com
URL: www.gsnaworldwide.com

**Delhi International Renewable Energy Conference**
27–29 October 2010
Expo Centre – Expo XXI
National Capital Region of Delhi, India
URL: www.direct2010.gov.in

**Intersolar India**
14–16 December 2010
Mumbai, India
Tel: 49 7231 58598–0
Fax: 49 7231 58598–28
E-mail: info@intersolar.in
URL: www.intersolar.in

**Renewtech India 2011**
17–19 February 2011
Bombay Exhibition Centre, Mumbai
Tel: 022–2660 5550/7755
Fax: 022-26603993
E-mail: conference@india-tech.com
URL: www.renewtechindia.com

**Windpower India 2011**
7–9 April 2011
Chennai Trade Centre Complex, Chennai–600 089
Tel: 91 20 2661 3832
E-mail: info@windpowerindia.in
URL: www.windpowerindia.in

**International**

**Intersolar North America**
13–15 July 2010
San Francisco, California, US
Tel: 49 7231 585982-2
Fax: 49 7231 585988-2
E-mail: doeppe@intersolar.us
URL: www.intersolar.us

**Exhibition: Indo Renergy 2010**
28–30 July 2010
Jakarta, Indonesia
Tel: 62 21 865096-2
Fax: 62 21 865096-3
E-mail: info@indorenergy.com
URL: www.indorenergy.com

**Soltec**
2–5 September 2010
Hameln, Germany
Tel: 49 571 2 9150
E-mail: kontakt@rainer-timpe.de
URL: www.rainer-timpe.de

**25th European Photovoltaic Solar Energy Conference**
6–10 September 2010
Valencia, Spain
Tel: 49 89 720 12 735
Fax: 49 89 720 12 791
E-mail: pv.conference@wip-munich.de
URL: www.wip-munich.de

**PV Rome Mediterranean**
9–11 September 2010
Rome, Italy
Tel: 39 02 6630 6866
E-mail: info@zeroemission.eu
URL: www.chinasolarcity.cn

**4th International Solar Cities Initiative (ISCI) Congress 2010**
16–19 September 2010
Dezhou, China
Tel: 86 534 22396-29
Fax: 86 534 22396-17
E-mail: jwsjk@sina.com
URL: www.chinasolarcity.cn

**World Renewable Energy Congress XI**
and Exhibition
25–30 September 2010
Abu Dhabi, United Arab Emirates
Tel: 44 1273 625643
Fax: 44 1273 625768
E-mail: asayigh@netcomuk.co.uk
URL: www.wrenuk.co.uk/wrecxi.html

**2nd International Photovoltaic Solar Energy**
27–29 September 2010
Beijing, China
Tel: 86 10 87194-788
Fax: 86 10 87194-417
E-mail: ipvsee@solarpromotion.org
URL: www.ipvsee.com

**3rd Renewable Energy Finance Forum - West**
28–29 September 2010
San Francisco, California, US
Tel: 44 207 779 8995
Fax: 44 207 779 8946
E-mail: energyevents@euromoneyplc.com
URL: www.euromoneyenergy.com

**Solar Power 2010**
12–14 October 2010
Los Angeles, California, US
Tel: 1 202 857 0898
Fax: 1 202 682 0559
E-mail: info@solarelectricpower.org
URL: www.solarelectricpower.org

**PV Taiwan 2010**
26–28 October 2010
Taipei, Taiwan
Tel: 886 2 2725 5200
Fax: 886 2 2725 7324
E-mail: pv@taitra.org.tw
URL: www.pvtaiwan.com

**4th Annual International Concentrated Solar Thermal Power Summit**
15–17 November 2010
Hotel Barcelo Renacimiento, Seville, Spain
Tel: ++44 207 3757 555
E-mail: belen@csptoday.com
URL: http://www.csptoday.com/csp/
# Renewable energy at a glance in India

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Source/system</th>
<th>Estimated potential</th>
<th>Achievement as on 31 March 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong></td>
<td><strong>Power from renewables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Grid-interactive renewable power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wind power</td>
<td>(MW)</td>
<td>11807.00</td>
</tr>
<tr>
<td>2</td>
<td>Bio power (agro residues and plantations)</td>
<td>(MW)</td>
<td>861.00</td>
</tr>
<tr>
<td>3</td>
<td>Bagasse cogeneration</td>
<td></td>
<td>1338.30</td>
</tr>
<tr>
<td>4</td>
<td>Small hydro power (up to 25 MW)</td>
<td>15 000</td>
<td>2735.42</td>
</tr>
<tr>
<td>5</td>
<td>Energy recovery from waste (MW)</td>
<td>2 700</td>
<td>65.00</td>
</tr>
<tr>
<td>6</td>
<td>Solar photovoltaic power</td>
<td>—</td>
<td>10.28</td>
</tr>
<tr>
<td><strong>Sub total (A)</strong></td>
<td></td>
<td>84 776</td>
<td>16817.00</td>
</tr>
<tr>
<td>B</td>
<td>Captive/combined heat and power/distributed renewable power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Biomass/cogeneration (non-bagasse)</td>
<td>—</td>
<td>232.17</td>
</tr>
<tr>
<td>8</td>
<td>Biomass gasifier</td>
<td>—</td>
<td>122.14</td>
</tr>
<tr>
<td>9</td>
<td>Energy recovery from waste</td>
<td>—</td>
<td>46.72</td>
</tr>
<tr>
<td>10</td>
<td>Aero generator/hybrid systems</td>
<td>—</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Sub total (B)</strong></td>
<td></td>
<td>—</td>
<td>402.02</td>
</tr>
<tr>
<td><strong>Total (A+B)</strong></td>
<td></td>
<td>—</td>
<td>17219.02</td>
</tr>
<tr>
<td><strong>II</strong></td>
<td><strong>Remote village electrification</strong></td>
<td></td>
<td>5554 villages/hamlets</td>
</tr>
<tr>
<td><strong>III</strong></td>
<td><strong>Decentralized energy systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Family-type biogas plants</td>
<td>120 lakh</td>
<td>41.85 lakh</td>
</tr>
<tr>
<td>12</td>
<td>Solar photovoltaic systems</td>
<td>50 MW/km²</td>
<td>120 MWp</td>
</tr>
<tr>
<td>i.</td>
<td>Solar street lighting system</td>
<td>—</td>
<td>88297 nos</td>
</tr>
<tr>
<td>ii.</td>
<td>Home lighting system</td>
<td>—</td>
<td>550 743 nos</td>
</tr>
<tr>
<td>iii.</td>
<td>Solar lantern</td>
<td>—</td>
<td>792 285 nos</td>
</tr>
<tr>
<td>iv.</td>
<td>Solar power plants</td>
<td>—</td>
<td>2.39 MWp</td>
</tr>
<tr>
<td>v.</td>
<td>Solar photovoltaic pumps</td>
<td>—</td>
<td>7247 nos</td>
</tr>
<tr>
<td>13</td>
<td>Solar thermal systems</td>
<td>140 million m²</td>
<td>3.25 million m²</td>
</tr>
<tr>
<td>i.</td>
<td>Solar water heating systems</td>
<td>collector area</td>
<td>collector area</td>
</tr>
<tr>
<td>ii.</td>
<td>Solar cookers</td>
<td>—</td>
<td>6.72 lakh</td>
</tr>
<tr>
<td>14</td>
<td>Wind pumps</td>
<td>—</td>
<td>1347 nos</td>
</tr>
<tr>
<td><strong>IV</strong></td>
<td><strong>Awareness programmes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Energy parks</td>
<td>—</td>
<td>511 nos</td>
</tr>
<tr>
<td>16</td>
<td>Aditya Solar Shops</td>
<td>—</td>
<td>302 nos</td>
</tr>
<tr>
<td>17</td>
<td>Renewable energy clubs</td>
<td>—</td>
<td>521 nos</td>
</tr>
<tr>
<td>18</td>
<td>District Advisory Committees</td>
<td>—</td>
<td>560 nos</td>
</tr>
</tbody>
</table>

MW – megawatt; kW – kilowatt; MWp – megawatt peak; m² – square metre; km² – kilometre square
The JNNSM (Jawaharlal Nehru National Solar Mission) is a major initiative of the Government of India and the state governments to promote ecologically sustainable growth, while addressing India’s energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change.

**The Mission phases**
- Phase 1: the remaining period of the Eleventh Five-year Plan and the first year of the Twelfth Five-year Plan (2012/13)
- Phase 2: the remaining period of the Twelfth Five-year Plan (2013–17)
- Phase 3: the Thirteenth Five-year Plan (2017–22)

**The Mission targets**
- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected solar power generation to 1000 MW by 2013; an additional 3000 MW by 2017 through the mandatory use of the RPO (renewable purchase obligation) by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000 MW installed power by 2017 or more – based on the enhanced and enabled international finance and technology transfer.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal, for indigenous production and market leadership.
- To promote programmes for off-grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.
- To achieve 15 million sq m solar thermal collector area by 2017 and 20 million by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

<table>
<thead>
<tr>
<th>Application segment</th>
<th>Target for Phase I (2010–13)</th>
<th>Target for Phase II (2013–17)</th>
<th>Target for Phase III (2017–22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar collectors</td>
<td>7 million sq m</td>
<td>15 million sq m</td>
<td>20 million sq m</td>
</tr>
<tr>
<td>Off-grid solar applications</td>
<td>200 MW</td>
<td>1000 MW</td>
<td>2000 MW</td>
</tr>
<tr>
<td>Utility grid power, including rooftop</td>
<td>1000–2000 MW</td>
<td>4000–10 000 MW</td>
<td>20 000 MW</td>
</tr>
</tbody>
</table>

For further information and updates, visit the Ministry of New and Renewable Energy website [www.mnre.gov.in](http://www.mnre.gov.in)
India is hosting the next International Renewable Energy Conference (DIREC, 2010) during October 27–29, 2010 at New Delhi. The Conference in Delhi is a part of initiative taken at the 2002 World Summit on Sustainable Development in Johannesburg, acknowledging the significance of renewable energies for sustainable development – especially for combating poverty and for environmental and climate protection.

The Delhi Conference is the fourth in the series, following events at Washington in 2008, Beijing in 2005 and Bonn in 2004 and is expected to be the premier all-Renewables gathering in India ever, with an attendance of over 9,000 delegates, over 250 industry leading speakers, experts, academicians, Government leaders, financial institutions and around 500 exhibitors from all over the world, which will make it the largest event of its kind.

DIREC 2010 aims to showcase India as an investment destination for renewable energy; to provide a platform for technology displays, new applications and innovations; to display global research & development with respect to climate change and green environment; to demonstrate the sectoral strength of the global renewable energy industry; and to facilitate: (i) buyers and sellers matching (ii) one to one meetings for setting up of joint ventures in the Renewable Energy Sector and (iii) to provide an opportunity to Indian Renewables Manufacturers to benchmark their products against the best in the world and enhance their competitiveness. The Conference will ultimately lead to renewed commitment, with concrete proposals in support of activities at the country level.

The DIREC 2010 will build on the success of the previous conferences with the support of National and International Sponsors. REN21 — the Renewable Energy Network — will be a key partner in the DIREC, 2010. Cabinet-level government functionaries from a number of countries will join civil society partners and private sector leaders to discuss the opportunities and challenges of a global, rapid deployment of renewable energy. The conference will bring together ministers, highlevel decision makers and policy level thinkers from a number of participating countries. DIREC, 2010 offers industry leaders the ability to share their insights, strategies, technologies, new products and staff capabilities with their audiences.

For further details, visit

www.direc2010.gov.in

Organized by

Ministry of New and Renewable Energy
Government of India

Supported by

Managed by

Exhibitions India Group

REN21