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Biotechnological approach to increase the yield of bio-diesel in the Indian context

Burning of fossil fuels, such as oil, has proven to be very harmful to our environment. India has a huge treasure of plant resources with over 45 000 known species representing 11% of earth's flora. Considering the seriousness of the cost of petroleum products and the pollution caused by the use of these products, suitable initiatives have also been made in India. The objective of this investigation is to search for an effective method for the production of fatty acid methyl esters to increase the yield of bio-diesel.

Competitiveness of solar lamps with kerosene lanterns

The recent Five-Year Plan envisaged 100% village electrification by 2009 and lighting for all households by 2012. Progress in this respect is not encouraging as observed by the Tenth Plan. Many villages will remain un-electrified (whether decentralized or grid connected), and people have to invariably depend on other sources of energy. Author in this paper suggested how solar light could be a viable option for providing these households with electricity.

Current research on renewable energy and development

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

Technological developments

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

Web updates

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

Forthcoming events

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

Ministry of Environment and Forests, Government of India

The Energy and Resources Institute

Biotechnological approach to increase the yield of bio-diesel in the Indian context

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Introduction

Burning of fossil fuels, such as oil, has proven to be very harmful to our environment. They are the chief contributors to urban air pollution and a major source of GHGs (greenhouse gases)—considered to be the main cause behind the climate change phenomena (Ghose 2004). Dr Rudolph Diesel developed a unique engine in 1895. This engine was designed to operate on peanut oil or other vegetable-based fuels. After his mysterious death in 1913, Diesel's engine was adapted to use a by-product of the gasoline refining process. The petroleum industry called it diesel fuel. The use of vegetable oils as engine fuels may seem insignificant today but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time (Ali and Hanna 1994). Biofuels are liquid fuels made from esters, alcohols, ethers, and other biomass chemicals. They can be produced in any climate, using already developed agricultural practices. Bio-diesel is a vegetable oil processed to resemble diesel. It is an ester made from fats or oils (Buckingham 1982). Common biofuels include ethanol and bio-diesel. Ethanol is made from starches or sugars, typically grain or corn. Biofuels are renewable and hence, they can supplement hydrocarbon fuels, assist in their conservation, as well as mitigate their adverse effects on the climate.

India imports nearly 70% of its annual crude petroleum requirement. The net oil import bill (import minus exports) was Rs 77 058 crore (Rs 770.58 billion) in 2003/04 as against Rs 74 174 crore (Rs 741.74 billion) the previous year. This expenditure on crude purchase impacts the country's foreign exchange reserves in a big way. The petroleum industry now looks very committed to the use of ethanol as fuel. It is estimated that 75% of the increase in the world demand for oil will come from the transport sector. India's transport sector will consume ever-higher amounts of fuel over the coming years. The combined annual global market for the products derived from bioresources is roughly between $500 billion and $800 billion. India is one of the 12 global megabiodiversity centres, harbouring approximately 8% of the global biodiversity existing in only 2.4% of the land area (Anon 2004a). The country is also home to two of the world's 25 hot spots. India has a huge treasure of plant resources with over 45 000 known species representing 11% of earth's flora. In terms of flowering plant diversity alone, India ranks tenth in the world. About 33% of flowering plants and 29% of total plants are endemic to the country. Therefore, the time has come to explore alternatives and tap traditional wisdom. Considering the seriousness of the cost of petroleum products and the pollution caused by the use of these products, many developed and developing countries have ventured into the use of vegetable oils as a better alternative to diesel. Chemically, bio-diesel is a monoalkyl ester of long-chain fatty acids derived from renewable feedstock like vegetable oils and animal fats through a simple transesterification process. Suitable initiatives have also been made in India by the government agencies, research institutions, and automobile industries. The objective of this investigation is to search for an effective method for the production of fatty acid methyl esters to increase the yield of bio-diesel.

Importance of bio-diesel

Seed oils show promise as fuels, particularly for use in diesel engines (Morgan and Shultz 1981). Biomass could be used to replace petroleum and natural gas (Lipinisky 1981). A major option for converting photosynthetically produced biochemical energy to a form suitable for internal combustion engines is the production of either methanol or ethanol. Either one of these chemicals can be used as a fuel in a suitably designed combustion engine. More commonly, it has been proposed to blend these alcohols in

proportion up to 20% with gasoline to give gasohol, a fuel that can be used in existing internal combustion engine with little or no adjustment (Ghose 2000 a, b). Methanol can also be made from biomass. This is normally accomplished by converting biomass, such as wood, to CO and H_2, and synthesizing methanol from these gases (Haggin 1982). Bio-diesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources. On the other hand, the crops being grown for production of bio-diesel to be used as a fuel actually suck out the same amount of CO_2 (carbon dioxide) that they will release when in fuel form. As such, these renewable fuels do not contribute significantly to global warming. Two major biofuels for the transport sector, bio-ethanol and bio-diesel, are fast becoming popular in many countries around the world. While bio-ethanol (called ethanol) is produced from raw materials such as molasses, beet, sugar cane juice, grains, and tubers, bio-diesel is produced from oil (derived from oil-bearing seeds such as *Jatropha curcas* and *Pongamia pinnata*). A network programme has been supported for developing an effective method for various lignocellulosic materials including forest plant residues and crop products for ethanol production. Laboratory studies on transesterification of Jatropha, Pongamia, Madhuca, Salvadora, and mixed oils using homogenous alkaline catalyst have been completed at the Indian Institute of Petroleum, Dehra Dun. The bio-diesel extract is being used with conventional diesel for test run in normal diesel engine. Further scale-up and process engineering for homogenous catalyst process is under way. Glycerol as a by-product obtained in the process is being purified separately at a bench/pilot scale.

J. curcas, hitherto considered a wild oilseed plant of the tropics, is now being regarded as a promising biofuel crop, ideally suitable for growing in the wastelands of India. This crop is now in great demand even internationally. This study covers the use of jatropha seeds for biofuel production, with special emphasis on increasing the yield of jatropha-seed-derived biofuel by applying biotechnology principles. This potential biofuel crop can bring about major economic benefits, such as providing rural electrification, income, and employment opportunities to the rural communities. The approach taken for the present research project is to increase the production of palmitic acid (C16) and oleic acid (C18) content in the oilseeds employing biotechnology approaches. In the present work, four different *Escherichia coli* cells were grown in the laboratory medium at defined conditions. These bacterial strains had different expression vectors cloned in them, which express different and in some case, novel fatty acids. Production and transesterification were performed simultaneously for the bacterial strains and estimation/identification of the produced fatty acids was tried employing gas chromatograph with flame ionization and mass spectrometer as detectors.

Petro-diesel releases 13 pounds of fossil CO_2 released per gallon burned, but bio-diesel releases no fossil CO_2. There are over 350 different plant types that can supply the oil. Some of them are given below.

Plant types	*Lb of oil per acre*	*Kilogram of oil per hectare*
Palm oil	4585	5000
Coconut oil	2070	2260
Jatropha	1460	1590
Rapeseed	915	1000
Peanut	815	890
Sunflower	720	800
Safflower	605	655
Soybean	345	375
Hemp	280	305
Corn	135	145

J. curcas (Figure 1) is best suited to the Indian climate. It grows in arid and semi-arid conditions, and wastelands up to a height of 15–20 feet. The yields of *J. curcas* could be more with increased water supply and rainfall. Besides, the plant has a lifespan of 30–40 years. It is already grown in a big way in many states, and its initial investments are between Rs 12 000/acre and Rs 14 000/acre, yield is between Rs 12 000/annum/acre and 15 000/annum/acre, and the yield of seeds is between 800 kg/acre and 1000 kg/acre. About 2 million hectares of land is required for 5% blend, and the total land identified as surplus is 66 million hectares.

The process of producing bio-diesel is simple. It involves mixing the oil with methanol and

Figure 1 *Jatropha curcas*
Source Sambrook, Fritsch, and Maniatic (1989)

caustic soda and leaving it to stand. Glycerin settles at the bottom of the tank, leaving the methyl ester, or bio-diesel, at the top. The glycerin can be used to make a high-quality soap, or it can be refined and sold at a range of prices, depending on its purity, to be used in an immense range of products, including cosmetics, toothpaste, embalming fluids, pipe joint cement, cough medicine, and tobacco (as a moistening agent).

CH_2COOR' |CHCOOR" |$CH_2COOR"'$	3 ROH	Catalyst ——————→	CH_2OH | CHOH | CH_2OH	R'COOR + R''COOR + R'''COOR
60 kg Oil	6.78 kg Alcohol	0.60 kg NaOH	6.5 kg Glycerin	58 kg Bio-diesel (fatty acid methyl esters)

Bacterial genetics

Biochemistry allows the precise analysis of biological phenomena, but it is typically limited to analyses in vitro. Genetic analyses are less precise and direct, but they provide an understanding of the system in vivo (Miller 1992). The generation and characterization of mutants provide insight into the number of genes involved, their relative location, and their transcriptional organization.

The biochemical characterization of a number of altered versions of a gene product provides insight into the relationship of the structure with the function of the protein. This is particularly true for proteins whose structure has been determined by X-ray crystallography. The sequence position of the mutation within the gene allows the correlation of the resulting biochemical defect with a position on the 3-D protein structure. There are obvious biotechnological values in the generation of mutants with desirable properties like overproduction of the desired gene products or metabolites, production of novel gene products or metabolites, or the easily regulated production of gene products or metabolites. The specific power of bacterial genetics derives from the possibility of analysing very large numbers of events (because bacteria are very small) and of performing selections in addition to the fact that bacteria play important biological roles. Genetic information in bacteria and many viruses is encoded in DNA, but some viruses use RNA. Replication of the genome is essential for inheritance of genetically determined traits.

Genetic information in microbes

Bacteria have few structural or developmental features that can be observed easily, but they have a vast array of biochemical capabilities and patterns of susceptibility to anti-microbial agents or bacteriophages (Amann and Brosius 1985). These latter characteristics are often selected as the inherited traits to be analysed in the studies of bacterial genetics. Figure 2 shows the structure of DNA represented as a helical ladder. The double helix has a diameter of 2 nm (nanometre). Each full turn of the double helix contains 10 nucleotide pairs and is 3.4 nm in length. During replication of the bacterial genome, each strand in double-helical DNA serves as a template for synthesis of a new complementary strand. Nucleic acids are large polymers consisting of repeating nucleotide units.

Genetic information encoded in DNA is expressed by synthesis of specific RNAs and proteins, and information flows from DNA to RNA to protein as shown in Figure 3. The DNA-directed synthesis of RNA is called transcription. Since the strands of double-helical DNA are anti-parallel and complementary, only one of the two DNA strands can serve as a template for synthesis of a specific mRNA molecule. mRNAs (Messenger RNAs) transmit information from DNA, and each mRNA in bacteria functions as the template for synthesis of one or more specific proteins. The process by which the nucleotide sequence of an mRNA molecule determines the

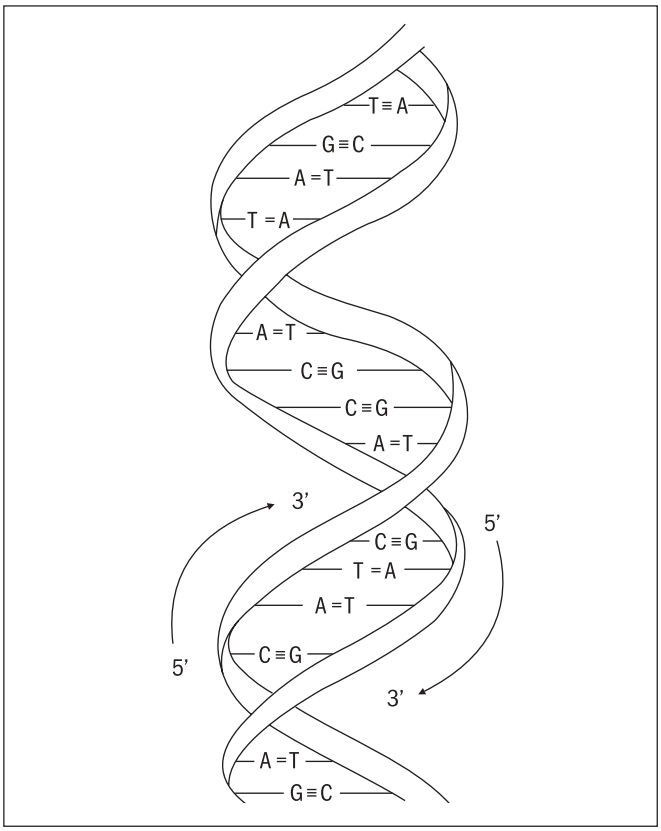

Figure 2 Double-helical structure of DNA
Source Watson, Hopkins, Roberts, Steiz, *et al.* (1987)

primary amino acid sequence of a protein is called translation. Ribosomes, complexes of rRNAs (ribosomal RNAs) and several ribosomal proteins, translate each mRNA into the corresponding polypeptide sequence with the aid of tRNAs (transfer RNAs), amino-acyl tRNA synthesases, initiation factors, and elongation factors. All these components of the apparatus for protein synthesis function in the production of many different proteins. A gene is a DNA sequence that encodes a protein, rRNA, or tRNA molecule (gene product). The genetic code determines how the nucleotides in mRNA specify the amino acids in a polypeptide. Since there are only four different nucleotides in mRNA (containing U, A, C, and G), single nucleotides do not contain enough information to specify uniquely all 20 of the amino acids. In di-nucleotides, 16 (4 × 4) arrangements of the four nucleotides are possible, and in tri-nucleotides, 64 (4 × 4 × 4) arrangements are possible. Thus, a minimum of three nucleotides are required to provide at least one unique sequence corresponding to each of the 20 amino acids. The 'universal' genetic code employed by most organisms is a triplet code in which 61 of the 64 possible tri-nucleotides (codons) encode specific amino acids, and any of the three remaining codons (UAG, UAA, or UGA) results in termination of translation. The chain-terminating codons are also called nonsense codons because they do not specify any amino acids (Sambrook, Fritsch and Maniatis 1989). The genetic code is described as degenerate because several codons may be used for a single amino acid, and as non-overlapping, because adjacent codons do not share any common nucleotides.

Exceptions to the 'universal' code include the use of UGA as a tryptophan codon in some species of mycoplasma and in mitochondrial DNA, and a few additional codon differences in mitochondrial DNAs from yeasts, Drosophila, and mammals. Translation of mRNA is usually initiated at an AUG codon for methionine, and adjacent codons are translated sequentially as the mRNA is read in the 5' to 3' direction.

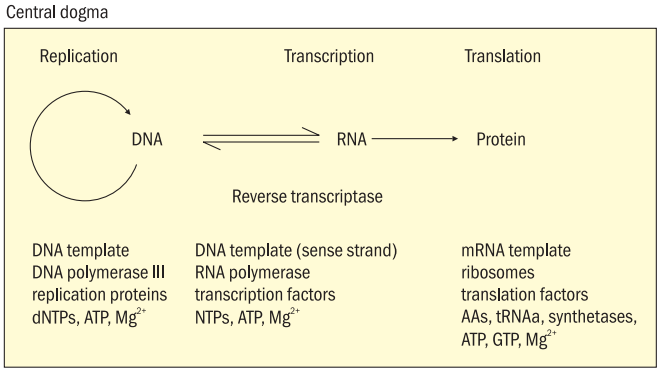

Figure 3 DNA replication sequence

Materials and methods

The plant oils usually contain free fatty acids, phospholipids, sterols, water, odorants, and other impurities (Bagby, Freedman, and Schwab 1987). Because of these, the oil cannot be used as fuel directly. To overcome these problems the oil requires slight chemical modification—mainly transesterification, pyrolysis, and emulsification. Among these, transesterification is the key and most important step for producing cleaner and environmentally safe fuel from vegetable oils. Bio-diesel, which is considered as a possible substitute for conventional diesel fuel, is commonly composed of fatty acid methyl esters that can be prepared from triglycerides in vegetable oils by transesterification with methanol (Akoh and Swanson 1988). Transesterification or

alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except that alcohol is used instead of water (Anon 2004b). This process has been widely used to reduce the high viscosity of triglycerides.

Reagents

Reagent 1, Saponification 45 g sodium hydroxide is dissolved in 150 ml of distilled water after weighing carefully. Then, 150 ml methanol is added to this solution and mixed thoroughly.

Reagent 2, Methylation 325 ml of certified 6.0 N hydrochloric acid and 275 ml methyl alcohol are mixed thoroughly. This drops the pH of the solution to less than 1.5 and causes methylation (for the increased volatility in a partially polar column) of the fatty acids. The fatty acid methyl ester is poorly soluble in the aqueous phase at this point.

Reagent 3, Extraction 200 ml of hexane and 200 ml of methyl tertiary-butyl ether are mixed thoroughly. This will extract the fatty acid methyl esters into the organic phase for use with the gas chromatography.

Reagent 4, Sample Clean-up 10.8 g of sodium hydroxide is dissolved in 900 ml of distilled water. This reduces the contamination of the injection port liner, the column, and the detector.

Preparation of ampicillin solution

1.0 g of ampicillin (98% of ampicillin sodium salt of molecular weight 371.4 and molecular formula C16H18N_3O_4SNa) is added to 50 ml of sterilized distilled water. This solution is preserved in a refrigerator at 4 °C.

Preparation of LB media

10 g	Bactotrypton
5 g	Bactoyeast extract
10 g	Sodium chloride
1000 ml	Distilled water

The constituents are dissolved in distilled water carefully to prevent the formation of froth in the media. Then the media pH is adjusted to 7.5 by adding NaOH solution. The media is then sterilized by autoclaving at 121 °C and 15 lb pressure for 20 minute. After autoclaving, the media is preserved in the refrigerator.

Preparation of IPTG solution

Seventy-six milligrams of IPTG (isopropyl 4-thio-ß-D- galactopyranoside, molecular formula C_9H18O_5S, and molecular weight 238.3) is added to 3.2 ml of distilled water to get 100 mM of IPTG solution. Chromatography is a separation process, which is achieved by distributing the components of a mixture between two phases: a stationary phase, and a mobile phase. Those components held preferentially in the stationary phase are retained longer in the system than those that are distributed selectively in the mobile phase. As a consequence, solutes are eluted from the system as local concentrations in the mobile phase in the order of their increasing distribution coefficients with respect to the stationary phase; ipso facto a separation is achieved.

Results and discussion

As per the flowsheet of the experiment to grow the cloned bacteria, the bacteria were cultured three times in the whole project period. After growing the bacteria, the fatty acids had to be extracted from the culture. There are numerous procedures to extract the fatty acids from culture. Samples obtained from the experiment in GC (gas chromatography)/FID (flame ionization detector) with WAX column were analysed. To obtain an idea about the chromatographs of various fatty acids, extensive laboratory work is done by using standard samples.

The presence of C(16) and C(18) compounds in the all four samples was observed during the study. The results from GC/FID were cross-checked with the results obtained by GC/MS (mass spectrometry). It is required to determine the quantity of the desired fatty acids in the bacterial vector samples. For further study, one can adopt still more efficient methods to extract the fatty acid methyl esters from the samples.

Conclusion

The Indian biotechnology sector is gaining global visibility and is being tracked for emerging investment opportunities (Anon 2004). Human capital is perceived to be the key driver for global competitiveness. There is also a decreasing appetite for risk capital in developed countries,

which has led to a decline in the biotechnology sector in these regions where survival lifelines are being provided by the lower-cost research environs of the developing world such as India. For a country like India, biotechnology is a powerful enabling technology that can revolutionize agriculture, health care, industrial processing, and environmental sustainability. The cultural diversity across the country as well as a very ancient traditional knowledge system associated with the biodiversity represent added assets. Nonetheless, much of this biodiversity is in peril owing, mainly, to anthropogenic causes. Thus, if the goal of converting our bioresources – animal, plant, microbial, and marine – into commercially useful products and processes is to be realized, we need to not only conserve the biodiversity but also utilize it in a sustainable manner. Genetic erosion is rampant and conservation is a priority. Prospecting of wild plant resources using molecular approaches and mechanism-based screening should be used to identify novel genes (temperature, drought, salinity tolerant) and gene products (therapeutic compounds, dyes, essential oils, biocontrol agents, gums, resins, and taxmins).

There are potential ornamentals, including foliage and flower-bearing plants that could be bulked up to be subsequently cultivated on a large scale for domestic and international trade. Bioconversion – both cellular and microbial – can be employed to convert intermediates of secondary metabolism into valued-added products. Application of genomics, proteomics, and metabolomics in carefully selected plants will be very useful. Biotechnology can contribute substantially in providing cost-effective and therapeutically active biomolecules through target/mechanism-based screens, biotransformation, metabolic engineering, and transgenic approaches.

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Competitiveness of solar lamps with kerosene lanterns

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After 60 years of independence and 45 years of rural electrification, 50% of households are still un-electrified in the country, and kerosene happens to be the only source of lighting in most rural areas. The recent plan envisaged 100% village electrification by 2009 and lighting for all households by 2012. Progress in this respect is not encouraging as observed by the Tenth Plan. The spillover will involve time and the cost will run over to another plan period. Obviously, a large number of people will remain outside the ambit of enjoying electricity for nearly another 9–10 years, deprived of an essential instrument for quality living. In all these villages, which will remain un-electrified (whether decentralized or grid connected), people have to invariably depend on other sources of energy, such as kerosene, for lighting. Solar light could be a viable option for providing these households with electricity.

Out of 125 000 villages estimated to be un-electrified, 5000 are considered to be solely dependent on solar electrification because of their distance from the grid, villager's unaffordability, and constraints on other energy resources. People below the poverty line in these villages cannot even afford kerosene in hurricane lamps and they rely on improvised lamps of cheaper variety. All these people are solely dependent on kerosene. Kerosene lanterns have poor illumination and eyes could be affected due to poor lighting. It cannot be denied that electric lights (incandescent, fluorescent tubes, CFLs [compact fluorescent lamps], and LEDs [light-emitting diodes]) give adequate illumination without straining the eyes. Kerosene lamps emit black soot, release unhealthy gas, and pollute the environment. The other aspects are continuous drainage of subsidy on kerosene, import of crude, rising price, and outflow of foreign exchange. Electric lights enhance the quality of living and do away with all evils associated with kerosene lanterns. These are the vital reasons for kerosene lamps to be gradually withdrawn from use in this country as source of lighting.

Consumption wise, on an average, a family of five requires four litres of kerosene per month. The cost of this consumption is as follows.

- Supply from PDS (public distribution system) @ 0.5 litres/head/month assures 2.5 litres/month/family
- Cost of the above is Rs 27.50 @ Rs 11/litre
- Balance (1.5 litres) is made good by purchase from open market @ Rs 28/litre, costing the consumer another Rs 42/month
- A total of Rs 69.50/month is spent by an average villager
- Consumption/month/head from PDS is based on survey that also speaks of leakage from PDS to open market @ 50% level (Schedule 9 and13 of survey report by India Foundation, March 2004; monthly consumption is based on a TERI report)
- In the above process, outflow of subsidy from the government kitty is Rs 52.50 @ Rs 14/litre for PDS supply (2.5 litre) and leakage quantity (1.25 litre).
- Thus, the total cost on kerosene from private and public resources is Rs 135.75/family/month at a market rate of Rs 25/litre (PDS price plus subsidy) plus open market price of Rs 28/litre
- Because of unhealthy impact on environment and family and also hassles in procuring kerosene on weekly basis, other costs have not been quantified, though it could be substantial.

The costing shown above is relevant to international crude price in the region $50–60/barrel, which is now about $80 and may touch $100, as the forecast goes with the implication that subsidy is bound to go up almost twice the existing calculations. This will increase the financial burden of the poor consumers.

Solar HLS (home lighting systems) with two lamps of 5 W (watts) each (LED) and a plug point comprising 20-W solar HLS, can be reasonably made available at Rs 8000/unit, subjected to following criteria.

* The discussion in this article is based on opinions expressed in a seminar held in Hyatt Regency on 3 February 2007, organized by WEBREDA, Kolkata; TERI, New Delhi; and REAF, Bangalore.

- Encouraging clean energy technology, reducing subsidy on kerosene in the long run, and arresting import of crude
- Not levying taxes

At Rs 4000 (50%) subsidy/unit, financial involvement is Rs 4 billion in six years for 1 million units against outflow of subsidy on 48 million litres (@ 4 litres/month/family), amounting to Rs 672 million/year or Rs 4.03 billion in six years, provided the price of international crude remains at present level, which in all possibilities will rise, calling for higher subsidy.

There is a proposal to spend this amount at one time only as subsidy on solar lights. Presuming villagers pay Rs 50/month (they would have been otherwise spending more for kerosene), in 72 months they contribute Rs 3600/unit or Rs 3.60 billion for 1 million units. In addition, initially, a villager, if asked for one-time payment of Rs 500, will not hesitate to pay this (or Rs 500 million for 1 million units) amount as it will serve as security money in the event of stoppage of monthly payment. The cost of HLS takes into account price of Rs 8000/unit on deferred payment basis.

The proposal in conclusion envisages the following.

- Introduction of 1 million solar HLS to replace kerosene in domestic lighting in villages for better health, light, environment, saving in import of oil, and arresting recurring subsidy as first phase of project to drive out kerosene.
- Consumers in villages on average pays Rs 69.50/month for kerosene. Consumers will contribute Rs 500 as initial payment and a recurring charge of Rs 50/month for six years in lieu of weekly chasing for kerosene from PDS and market.
- Government of India will reduce import of oil to the extent of 48 million litres of crude/year and save recurring subsidy payment on kerosene and instead will spend Rs 4 billion as one-time subsidy for HLS.

This will boost research, upgrade technology, and open up an opportunity for creation of employment in

- manufacturing
- supply chain
- installation
- operation and maintenance

Alternatively, the proposal will be highly attractive, in case solar lanterns are chosen in place of HLS that have better flexibility of movement from one place to other. The former variety will cost 30% of the latter and ensure quicker and smaller repayment schedule.

Solar HLS with Rs 4000/unit as subsidy will find number of buyers ready to give one-time payment for whole of the balance amount as evident from the extreme popularity of the scheme in the Sundarbans and other parts of West Bengal. Applications are pouring in thousands for HLS, but kept as pending, limitations being small numbers allotted to states due to subsidy constraint, which probably does not weigh the benefit of doing away with kerosene with all ill-effects thereof.

The MNRE (Ministry on New and Renewable Energy) will have to convince the finance ministry to correlate distribution of solar HLS with a view to gradual withdrawal of kerosene for home lighting in rural aeas. MNRE budget, which is too meagre (about Rs 4 billion), will have to be accordingly augmented, which will in turn reduce subsidy on kerosene. The scheme should be interlinked with banning sale of kerosene from PDS to the beneficiaries getting solar HLS.

Besides involving renewable energy development agencies as facilitators in the states, private firms in the field of manufacturing and sale of solar HLS or lantern could be entrusted with the project for sale through monthly installment basis on soft interest rate chargeable to beneficiaries and claim subsidy from the governemnt. This will prop up large-scale production, which will result in cheaper price, quality control, and development of employment network.

With climate change apprehensions turning to be a reality, renewable energy resources are envisaged to take a lead role to mitigate the adverse effect of fossil fuel burning. Infinite resource in this respect is solar energy. Promoting the same in rural areas through subsidy for a short regime and also encouraging this in urban areas through feed-in tariff system are the ultimate recourse. It is to be envisaged that less the delay in these matters, better it is for our economy, environment, and, subsequently, it would ensure improved quality of life for neglected villagers.

Current research on renewable energy and development

Huang L. 2007. **A study of China–India cooperation in renewable energy field**. *Renewable and Sustainable Energy Reviews* **11**(8): 1739–1757
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This paper analyses the present situation of international cooperation in renewables in China and India, and the reasons, basis, and conditions of China–India cooperation for renewable energy. It also explores China–India cooperation strategies for renewable energy. The study indicates that (1) the two countries have made a lot of progress in international cooperation in renewable energy, but China–India cooperation for renewable energy is still in its primary stage; (2) there are not only the common benefits but also the solid basis and good conditions for China–India cooperation in the field of renewable energy; (3) there is a need to explore and design the cooperation strategies for renewable energy in China and India in order to strengthen renewables cooperation between the two countries (1 table, 39 references).

Asif M and Muneer T. 2007. **Energy supply, its demand, and security issues for developed and emerging economies**. *Renewable and Sustainable Energy Reviews* **11**(7): 1388–1413
School of Engineering, Napier University, 10 Colinton Road, Edinburgh, EH10 5DT, UK

The use of fossil fuels is set to face multiple challenges including depletion of fossil fuel reserves, global warming and environmental concerns, geopolitical conflicts, and fuel price rise. This article highlights that renewable energy resources are the solution to the growing energy challenges. It also provides an overview of the current and projected energy scene for China, India, Russia, UK, and the US, which together present roughly half of the global energy budget. This article quantifies the period of exhaustion of the current major energy sources, that is, coal, oil, gas, and nuclear fissile material. The projected demand for energy is also presented and a feasibility of switchover to renewable energy is discussed. The article also presents the size of respective wind and solar farms that would be required for each of the five countries under discussion to meet their energy demands for 2020. It has been found that to meet 50% of the total energy demands, the proposed area for collection of solar and wind energy by means of ultra-large scale farms in fact will occupy a mere fraction of the available land and near-offshore area for the respective countries (13 figures, 7 tables, 36 references).

Ramachandra T V and Sruthi B V. 2007. **Spatial mapping of renewable energy potential**. *Renewable and Sustainable Energy Reviews* **11**(7): 1460–1480
Centre for Sustainable Technologies, Indian Institute of Science, Bangalore, India

The need to search for renewable, alternative, and non-polluting sources of energy assumes top priority for self-reliance in the regional energy supply. This demands an estimation of the available energy resources spatially to evolve better management strategies for ensuring sustainability of resources. This paper discusses the application of GIS (geographical information system) to map the renewable energy potential (solar, wind, bio-energy, and small-hydro energy) by *taluk* in Karnataka, India. The regions suitable for tapping solar energy are mapped based on global solar radiation data, which provides a picture of the potential. Coastal *taluks* in Uttara Kannada have higher global solar radiation during summer (6.31 kWh/m^2 [kilowatt-hour per square metre]), monsoon (4.16 kWh/m^2), and winter (5.48 kWh/m^2). Mapping of regions suitable for tapping wind energy has been done based on wind velocity data, and it shows that Chikkodi *taluk*, Belgaum district, has higher potential during summer (6.06 m/s), monsoon (8.27 m/s),

and winter (5.19 m/s). Mysore district has the maximum number of small-hydro power plants with a capacity of 36 MW (megawatts). *Taluk*-wise computation of bio-energy availability from agricultural residue, forest, horticulture, plantation, and livestock indicates that Channagiri *taluk* in Shimoga district yields maximum bio-energy. The bio-energy status analysis shows that Siddapur *taluk* in Uttara Kannada district has the highest bio-energy status of 2.004 (ratio of bioresource availability and demand) (12 figures, 2 tables, 20 references).

Varun and Singal S K. 2007. **Review of augmentation of energy needs using renewable energy sources in India**. *Renewable and Sustainable Energy Reviews* **11**(7): 1607–1615
MIT, Moradabad – 244 001 Uttar Pradesh, India

Sustainable and equitable development is the most important challenge before mankind. After food, the most pressing concern is energy for a decent living. Energy consumption has been recognized worldwide as a parameter of development in a society. In the present paper, an attempt has been made to review the demand of energy, the potential of renewable energy sources in India, and its prospects for development in a cost-effective and sustainable manner (2 figures, 8 tables, 9 references).

Katti P K and Khedkar M K. 2007. **Alternative energy facilities based on site matching and generation unit sizing for remote area power supply**. *Renewable Energy* **32**(8): 1346–1362
Electrical Engineering Department, Visvesvaraya National Institute of Technology, Nagpur, Maharashtra – 440 011, India

This paper presents the decision-support technique and influencing factors in the design of an integrated solar–wind power system for stand-alone applications. Results of investigations on application of alternative energy facility like wind, PV (photovoltaic), and integration of wind–PV power generating systems for remote area power supply have been presented. The authors presented a weather-model-based site matching of equipment and a simple numerical algorithm for generation unit size. The program has been used to determine the optimum generation capacity and storage needs for a stand-alone wind, PV, and integrated wind–PV system for a remote site in India. Generation and storage units for each system are properly sized in order to meet the annual load demand. Annual average hourly values for load, wind speed, and insolation have been used for analysis. The results are used to justify the use of renewable energy source as a reliable option for remote areas (13 figures, 3 tables, 20 references).

Joshi A S and Tiwari A. 2007. **Energy and exergy efficiencies of a hybrid PV/T (photovoltaic/thermal) air collector**. *Renewable Energy* **32**(13): 2223–2241
Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi – 110 016, India

In this communication, an attempt has been made to evaluate exergy analysis of a hybrid PV/T (photovoltaic/thermal) parallel-plate air collector for cold climatic condition of Srinagar in India. The climatic data of Srinagar (1998–2001) has been obtained from IMD (Indian Metrological Department), Pune, India. Based on the data for the period of four years, climatic conditions have been defined. The performance of a hybrid PV/T parallel-plate air collector has been studied and exergy efficiencies have been carried out. It is observed that an instantaneous energy and exergy efficiency of PV/T air heater varies between 55%–65% and 12%–15%, respectively. These results are very close to the results predicted by the PV/T solar collectors and their potential in Denmark (8 figures, 5 tables, 26 references).

Ashok S. 2007. **Optimized model for community-based hybrid energy system.** *Renewable Energy* **32**(7): 1155–1164
Department of Electrical Engineering, National Institute of Technology, Calicut, NIT Campus – 673 601, India

Hybrid energy system is an excellent solution for electrification of remote rural areas where grid extension is difficult and not economical. Such a system incorporates a combination of one or several renewable energy sources such as solar photovoltaic, wind energy, micro-hydro, and conventional generators for back-up. This paper discusses different components of hybrid energy system and develops a general model to find an optimal combination of energy components for a typical rural community minimizing the life cycle cost. Micro-hydro–wind systems are found to be the optimal combination for the electrification of the rural villages in Western Ghats (Kerala), India, based on the case study. The optimal operation shows a unit cost of Rs 6.5/kWh (kilowatt-hour) with the selected hybrid energy system with 100% renewable energy contribution eliminating the need for conventional diesel generator. The author suggested that the developed model will help in sizing hybrid energy system hardware and in selecting the operating options (3 figures, 2 tables, 14 references).

Akella A K, Sharma M P, and Saini R P. 2007. **Optimum utilization of renewable energy sources in a remote area**. *Renewable and Sustainable Energy Reviews* **11**(5): 894–908
Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee – 247 667, India

Sustainable energy systems based on renewable energy can be utilized as IRES (integrated renewable energy system), which can satisfy the energy needs of an area. For renewable-energy-based rural electrification of remote areas, the IRES can be modelled and optimized for meeting the energy needs. For this purpose, the Jaunpur block of Uttarakhand has been selected as remote area. On the basis of field data, the resource potential and energy demand have been estimated. The total load is 808 MWh (megawatt-hour)/year and total available micro-hydro power resources are 807 MWh/year, whereas the percentage contribution of each resource is 15.88% (128 166 kWh [kilowatt-hour]/year), solar 2.77% (22 363 kWh/year), wind 1.89% (15 251 kWh/year), and biomass energy 79.46% (641 384 kWh/year. The model has been optimized using LINDO software 6.10 version. The results indicated that the optimized model has been found to be the best choice for meeting the energy needs of the area. Renewable energy sources can contribute to the total energy demands as 16.81% (115 465 kWh/year), solar 2.27% (15 588 kWh/year), wind 1.78% (12 201 kWh/year), and biomass energy 79.14% (543 546 kWh/year) for the fulfilment of 687 MWh (megawatt-hour)/year at the 15% reduced level of 808 MWh/year load. The results further indicated that optimized IRES can provide a feasible solution in terms of energy fulfilments in the range of feasible EPDF (electric power delivery factor) from 1.0 to 0.75 (5 figures, 9 tables, 22 references).

Bhattacharyya S C. 2006. **Energy access problem of the poor in India: is rural electrification a remedy?** *Energy Policy* **34**(18): 3387–3397
Centre for Energy, Petroleum and Mineral Law and Policy, University of Dundee, Dundee DD1 4HN, Scotland, UK

India accounts for a third of the world's population without access to electricity and about 40% of those without access to modern energy. Such a situation exists despite several initiatives and policies to support poor households. Alarmed by the gravity of the situation, the government has recently announced an ambitious programme of rural electrification. This paper looks into the energy access situation of India and argues that rural electrification alone is unlikely to resolve the energy access problem because of low penetration of electricity in the energy mix of the poor (10 figures, 2 tables, 20 references).

Sharma D C. 2007. **Transforming rural lives through decentralized green power**. *Futures* **39**(5): 583–596
A-65, Parwana Apartments, Mayur Vihar Phase I, New Delhi – 110 091, India

Despite the growing contribution of renewables (5% contribution to the national grid electricity), about 125 000 or 21% villages remain in dark and not all households have power in the villages electrified. The author in this paper has analysed that while government efforts continue to spread solar- and biomass-based lighting, heating, and power systems in villages, efforts in the non-governmental sector have shown that decentralized, off-grid power generation through biomass-based gasifiers and solar photovoltaics offers a viable, long-term solution to rural electrification. Though government policies now recognize decentralized power generation, they do not see it as a preferred mode of rural electrification nor do they foresee a major role for voluntary agencies and people's organizations in decentralized power generation through renewable sources. The author, therefore, highlighted that while technology has shown the way, right policy initiatives and enabling environment are lacking in the use of decentralized power generation through renewables as an input in the overall development process (3 figures, 8 tables, 32 references).

Badarinath K V S, Kharol S K, Kaskaoutis D G, Kambezidis H D. 2007. **Influence of atmospheric aerosols on solar spectral irradiance in an urban area**. *Journal of Atmospheric and Solar-Terrestrial Physics* **69**(4–5): 589–599
Forestry and Ecology Division, National Remote Sensing Agency (Department of Space, Government of India), Balanagar, Hyderabad – 500 037, India

The present study reports the variation of solar spectral irradiance and its relation with aerosols over a typical urban environment in Hyderabad located in central India. Synchronous measurements of aerosol optical depth, UV (ultraviolet) irradiance, aerosol-particle size, BC (black carbon) concentration, and solar irradiance have been carried out. Considerable reduction in the UV intensity has been observed during periods of high aerosol loading. A comparison of the erythemal UV (UV_{ery}) intensities on normal day with those of high aerosol loading suggested a 24% decrease in the UV_{ery} reaching the ground. Satellite observations showed forest fire occurrence over the region. PAR (photosynthetically available radiation) and diffuse-to-direct-beam ratio of solar irradiance showed marked differences under varying aerosol-loading conditions (6 figures, 4 tables, 26 references).

Singh S P, Asthana R K, and Singh A P. 2007. **Prospects of sugarcane milling waste utilization for hydrogen production in India**. *Energy Policy* **35**(8): 4164–4168
Centre for Advanced Study in Botany, Banaras Hindu University, Varanasi – 221 005, India

Cane-sugar-producing companies generate bagasse that is mostly utilized 'on-site' as a replacement to coal in specialized boilers. In addition to sugar and molasses, about 25% by-product of cane milling is bagasse that still retains 2.5% sugar on dry-weight basis. This paper deals with the prospects of bagasse fermentation for hydrogen production. It seems relevant, as India and Brazil are the major sugar cane producers in the world. The results obtained confirm bagasse, annually generated to the tune of 40 MT (million tonnes) in India. The bagasse can be diverted from the conventional burning or composting to fermentative hydrogen production in a cost-effective way. The processing cost of bagasse for hydrogen production equivalent to 1-litre petrol is about half. The authors highlighted that the system optimization for accessibility of polysaccharides in bagasse and the use of genetically efficient bacterial strains for agro-waste-based hydrogen production seem the ideal options for clean energy generation. (2 tables, 39 references).

Devi R, Dahiya R P, Kumar A, Singh V. 2007. **Meeting energy requirement of waste water treatment in rural sector**. *Energy Policy* **35**(7): 3891–3897

Department of Energy and Environmental Science, Ch. Devi Lal University, Sirsa, H. No. 1357, Sector 15, Faridabad, Haryana – 121 007, India

In this paper, waste water treatment requirements for a typical village in Haryana have been discussed. Investigations have been made on the available water resources and waste water generated from domestic applications. Innovative techniques have been described to treat the waste water generated (mainly organic matter) in the villages. The total water consumption in the village from various sources was found to be about 190 m^3 (cubic metres)/day and the waste water generated was nearly 150 m^3/day. Discarded-material-based mixed adsorbents have been used for treatment of the domestic waste water in laboratory conditions for optimizing the process. It was estimated that about 50% of energy would be required for treating the waste water by the adsorption-based process in comparison to the conventional method. The authors suggested that a hybrid energy system involving blending of the non-conventional and conventional energy should be the solution for meeting the energy requirement of the rural sector waste water treatment plants (5 figures, 5 tables, 18 references).

Purohit P. 2007. **Financial evaluation of renewable energy technologies for irrigation water pumping in India**. *Energy Policy* **35**(6): 3134–3144

Research Programme on International Climate Policy, Hamburg Institute of International Economics , Neuer Jungfernstieg 21, 20354 Hamburg, Germany

An attempt to develop a simple framework for financial evaluation of RETs (renewable energy technologies) such as PV (photovoltaic) pump, windmill pump, biogas, and producer-gas-driven dual-fuel engine pumps for irrigation water pumping has been made in this paper. The unit cost of water and that of the useful energy delivered by the RETs have been estimated. The monetary benefits that accrued to the end-user have been quantified in terms of the amount of diesel or electricity saved. Financial figures of merit for the investments made in the RETs have been calculated. The effect of fuel price escalation on these measures of financial performance has also been evaluated along with the estimation of the break-even prices of fuels likely to be substituted by RETs. Results of some exemplifying calculations are presented (1 figure, 9 tables, 39 references).

Kumar A and Kandpal T C. 2007. **Renewable energy technologies for irrigation water pumping in India: a preliminary attempt towards potential estimation**. *Energy* **32**(5): 861–870

Policy Analysis Division, The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003, India

Simple frameworks have been developed for estimating the utilization potential of (a) SPV (solar photovoltaic) pumps; (b) windmill pumps; (c) producer-gas-based dual-fuel engine pumps; and (d) biogas-based dual-fuel engine pumps for irrigation water pumping in India. The approach takes into account factors such as solar radiation intensity, wind speed, availability of bovine dung and agri-residues, and their alternative uses, groundwater requirements for irrigation and its availability and affordability, propensity of the users to invest in renewable energy devices, and so on. SPV pumps are estimated to have the maximum utilization potential in India, followed by windmill pumps (1 figure, 9 tables, 24 references).

Technological developments

New process to produce solar panels

Researchers at the NJIT (New Jersey Institute of Technology) have developed an inexpensive solar cell that can be painted or printed on flexible plastic sheets. When sunlight falls on an organic solar cell, the energy generates positive and negative charges. When these charges are separated and sent to different electrodes, current flows. The solar cell developed at the NJIT uses a carbon nanotubes complex, which is a molecular configuration of carbon in a cylindrical shape. The carbon nanotubes were combined with tiny carbon buckyballs to form snake-like structures. Buckyballs trap electrons, although they cannot make electrons flow. Add sunlight to excite the polymers, and the buckyballs will grab the electrons. Nanotubes, behaving like copper wires, will then be able to make the electrons or current flow. Using this unique combination in an organic solar cell recipe can enhance the efficiency of future painted-on solar cells.

http://www.physorg.com, last accessed on 19 July 2007

Hydraulic-battery-powered electromagnetic generator

A trio of inventors from Tennessee has designed a system that can run a home or a vehicle, or other devices without fuel. The system consists of a 12-volt battery running an AC (airconditioned) motor via an inverter. A hydraulic pump forces the fluid to a hydraulic motor, which turns the flywheel. The flywheel is what is connected to the transmission in a gasoline engine. From the flywheel to the back wheels, nothing has been modified. The key to the design is in the charging system. The hydraulic pump is powered by 24 volts via two 12-volt car batteries wired in series. In their set-ups, one of the two 12-volt batteries powers a small off-the-shelf AC motor via an inverter. The AC motor turns an alternator, which recharges both the 12-volt and another battery that is connected in series. The 24-volt battery array then powers a hydraulic motor to turn the flywheel.

http://peswiki.com, last accessed on 19 July 2007

Running cars on hydrogen made from starch

Using a set of 13 commercially available enzymes isolated from yeast, bacteria, spinach, and rabbit muscle enzymes, researchers have developed a way to convert starch, available from numerous sources including corn and potatoes, into hydrogen gas at low temperatures and pressures. The method produces three times more hydrogen than an older enzymatic method does, suggesting that it might be practical to use such enzymes to produce hydrogen for fuel-cell vehicles. The hydrogen comes from two sources: the starch and the water used to oxidize the starch. The enzymes facilitate chemical reactions in which the water and starch can be completely converted into hydrogen and carbon dioxide. The new system produces a higher yield of hydrogen than previous experimental systems that used enzymes for converting sugars into hydrogen. But while the yield of hydrogen is high, so far the rates at which the gas is produced are extremely low. One of the first applications of the system could be generating hydrogen for fuel cells in portable electronics since the starch could be a safer way of storing energy than using methanol. The researchers estimated that it would take about six to eight years to improve the rates enough for such applications.

http://www.technologyreview.com, last accessed on 12 July 2007

Record efficiency for plastic solar cells

Researchers at the UCSB (University of California, Santa Barbara) along with counterparts in South Korea have discovered a new way to make cheap and flexible PV (photovoltaic) cells that involves a process for printing plastic solar cells. They have achieved an efficiency of 6.5%—a new record in plastic PVs. The new process stacks multiple polymer layers within a single PV device to produce a 'tandem' cell. Tandem cells, commonly employed in conventional solar panels, increase power output in two ways: (1) different layers can be optimized to capture different bands of light, thus enabling the tandem device to absorb a broader spectrum

of sunlight and (2) the multiple layers boost the voltage of the tandem device, yielding more power from every photon absorbed. Until now, however, the tandem architecture spoiled plastic PV since layers of different plastics sprayed on top tended to mix, degrading rather than enhancing power output. The new technology has overcome the mixing problem by finding an effective spray-on separator to keep the layers in place. The bottom cell is filled with a proprietary polymer. The polymer (a derivative of polythiophene) absorbs both infrared and ultraviolet light. Next comes a titanium-suboxide layer, which seals in the bottom cell, provides a foundation for building the top layer, and, since it is a metal, it efficiently carries away the charged electrons generated in both layers. Finally, the top layer sports a different type of conducting polymer that absorbs mostly blue and green light. The tandem architecture offers plenty of room for further improvement—enough to eventually make plastic solar cells practical in rooftop solar panels.
http://www.technologyreview.com, last accessed on 12 July 2007

Remote sensing to help mine wastelands for bio-diesel

Recent research has found that energy and economic woes could find a new solution with *J. curcas*. With a dual goal of boosting the village economy and helping farmers fulfil their own energy needs, a research project funded by the ISRO (Indian Space Research Organisation) at the University of Pune's Geography department is harnessing remote sensing technology to identify suitable wastelands for cultivation of the perennial bio-diesel-generating plant. Launched a year ago, the project will be completed within one-and-a-half years. The project aims at preparing a *taluka*-wise digital map of the state detailing potential land for cultivation, along with information on the possible productivity of each land depending on its unique agro-climatic conditions, and suggestions for the location of the processing systems. If successful, the project could become a model for implementation in other states.
The Indian Express, 3 July 2007

EnviroArc technology

A new EnviroArc process to recover material and energy from waste, leaving virtually no toxic or non-toxic residuals, has been developed. It is built on four core technologies: gasification, plasma decomposition, vitrification, and flash smelting. The principles of the waste process are also applicable to gasification of biomass into a fuel gas. These processes are built on four core technologies, uniquely combined in solutions and plants that effectively solve the waste treatment challenge.

- The gasification technology converts combustible solid waste materials into a gas
- The plasma technology, a cost-effective and environmentally sound technique for transferring electrical energy into very high temperatures, required for complete decomposition of liquids and gases into a fuel gas
- The vitrification technology converts and binds non-combustible material into a glass-like and leach-resistant material (vitrified slag)
- The flash smelting technology facilitates melting and vitrification of fly ash

http://www.peswiki.com, last accessed on 15 June 2007

New technique for producing thin-film solar cells

Micromorph technology from Applied Films, USA, is widely seen as a superior one for the production of thin-film solar cells. Cells manufactured with this technology have higher efficiencies than amorphous solar cells, owing to improved spectral sensitivity. The technique produces solar cells with a surface area of 1.4 m^2 (square metres) (1.5 m × 0.9 m). This rectangular substrate format allows for flexibility in designing modules with either high-voltage/low-current or low-voltage/high-current power modes. Cell manufacturers can also maximize cell efficiencies by adjusting the parameters of the TCO (transparent conducting oxide) coating in interaction with the light-absorbing layer and back contact coatings.
http://www.techmonitor.net, last accessed on 4 June 2007

Vehicles may run on 'hithane'

An ambitious project to ensure fuel efficiency, cut down emission levels, and slash dependence on oil imports is finally being kick-started. The project, which aims to develop an optimal mix of CNG (compressed natural gas) and hydrogen for use in existing vehicles, is being commissioned under the aegis of the Society of Indian Automobile Manufacturers. It would involve five Indian automobile majors, entail between Rs 100 million and Rs 120 million investment and should begin yielding results within two years. The centre has agreed to bear about Rs 30 million of the total project cost, with a similar amount being invested by the IOC (Indian Oil Corporation). The rest would come from the five automobile majors participating in this project. The idea is to use various combinations of CNG and hydrogen – called hithane – in existing vehicles to determine an optimum mix, which not only ensures fuel efficiency but also allows minimum engine modification.

DNA, 1 June 2007

Geothermal rice drying

A geothermal field in Kotchany (Macedonia, Yugoslavia) has very advantageous characteristics for direct application purposes. Low content of minerals, moderate temperature (78 °C) and substantial available geothermal water flow (up to 300 l/s enabled the establishment of a district-heating scheme, comprising mainly agricultural and industrial uses. A rice-drying unit of 10 tonnes/hour capacity was installed eight years ago, using the geothermal water as the primary heat source. A temperature drop of 75 °C/50 °C enables the adaptation of conventional drying technology, already proven in practice in the surrounding rice growing region. Water-to-air heat exchanger and all necessary equipment and materials are of local production, made of copper and carbon steel. The use of such drying units is strongly recommended for the concrete district-heating scheme because it offers a very simple geothermal application and enables improvement in the annual heating load factor without high investments in geothermal water distribution lines.

http://www.osti.gov/, last accessed on 16 May 2007

Solar power at half the cost

Researchers at a commercial establishment in Pasadena, California, USA, have developed a new mechanism for focusing light on small areas of PV (photovoltaic) material, which could make solar power in residential and commercial applications cheaper than electricity from the grid. Initial systems, which can be made at half the cost of conventional solar panels, are set to start shipping later this year. In the new system, a solar concentrator has been designed that tracks the sun throughout the day but is lighter and not pole-mounted. The system design combines both lenses and mirrors to create a more compact system. Each module is made of rows of aluminium troughs, each about the width and depth of a gutter. These troughs are mounted inside a rectangular frame and can tilt in unison from side to side to follow the sun. Each trough is enclosed on top with a clear acrylic lid. Inside each trough, a strip of silicon PV material runs along the bottom. As light enters, some of it reflects off the inside surface of the trough and reaches the strip of silicon. The rest of the incoming light is focused on the strip by a lens incorporated into the acrylic lid. The system fits in a rectangular frame and is mounted to the roof with the same hardware that is used for conventional flat solar panels. As a solar-concentrating system, this design has a few drawbacks: (1) electricity production decreases as the troughs are shading each other and (2) troughs also only track from side to side hence absorbing less sunlight across the sky.

http://FreeEnergyNews.com, last accessed on 12 May 2007

Web updates

Solar Energy

http://www.indiasolar.com/

This website provides information about renewable energy with focus on solar energy in India. It provides statistical information on solar photovoltaics, solar water heating systems, solar cookers, suppliers and manufacturers, biomass and wind energy use in India, useful links, and events.

Australian Wind Energy Association

www.auswind.org

Australian Wind Energy Association (Auswind) represents the Australian Wind Energy Industry by working with all levels of government, community groups, and interested organizations to raise awareness of the benefits of wind energy and promote its use. Auswind site provides membership information. The website hosts rich wind energy statistical information, wind industry data, news, publications, reports and submissions, best practice studies, conferences, and links.

Alternative Technology Association

www.ata.org.au

The ATA (Alternative Technology Association) is Australia's leading not-for-profit organization, promoting sustainable technology and practice in order to protect our environment. This frequently updated website hosts publications, links, events, and technology information. The site also has separate space for members.

International Geothermal Association

http://iga.igg.cnr.it/index.php

The IGA (International Geothermal Association) is a non-profit organization dedicated to encourage R&D (research and development) and utilization of geothermal resources worldwide through the compilation, publication, and dissemination of information. The association website provides valuable documents, links, publications, laws, statistics, and events information.

International Association for Hydrogen Energy

www.iahe.org/

The International Association for Hydrogen Energy stimulates the exchange of information in the hydrogen energy field through awareness generation programmes, publications, and events. The website contains a rich collection of journals, books, documents, events, technology information, links, and news. The society also brings out a regular monthly journal called the *International Journal on Hydrogen Energy*.

Interstate Renewable Energy Council

http://www.irecusa.org/

The US IREC (Interstate Renewable Energy Council) emphasizes education and outreach, stakeholder coordination, technical assistance, workforce development, the adoption and implementation of uniform guidelines and standards, consumer protection, and building networks to share experiences and information. The website presents publications, programme details, news, and events.

Iowa Energy Center

http://www.energy.iastate.edu/

The IEC (Iowa Energy Center) conducts and sponsors research on the use of energy-efficient and renewable energy technologies. Consequently, the IEC website contains electronic copies of some of its 'Home Series' publications for energy-conscious consumers and offers information about the office's mission, news, and scheduled events. The site also describes its research grant initiatives, loan programmes, and facilities, and establishes links to other related sites.

Forthcoming events

19–21 February 2008
Las Vegas, **USA**

POWER-GEN: Renewable Energy and Fuels 2008
PO Box 973059
Dallas, TX 75397-3059
Tel. +1 888 299 8016, +1 918 831 9160 (toll free)
Fax +1 888 299 8057, +1 918 831 9161(toll free)
Web http://pgre08.events.pennnet.com

12–14 December 2007
Amsterdam,
The Netherlands

Hydrogenation Technology
Corporate Office
The Center for Professional Advancement
25 Kennedy Boulevard, Suite 400, P O Box 7077
East Brunswick, NJ USA 08816-7077
Tel. 732 238 1600 • *Fax* 732 238 9113
E-mail info@cfpa.com • *Web* www.cfpa.com

26 October 2007
New York, **USA**

Future Technologies and Future Markets Worldwide 2015
Mr Marek, ACON AG, Science and Business Consulting, CH-8004 Zurich, Switzlerland
Tel. 041 (0) 432 439 621 • *E-mail* hkc22@bluewin.ch
Web www.hkc22.com/marketstudy.html

3–7 September 2007
Milano, **Italy**

22nd European Photovoltaic Solar Energy Conference and Exhibition
WIP-Renewable Energies
Sylvensteinstr. 2, 81369 München, Germany
Tel. +49 89 720 12 735 • *Fax* +49 89 720 12 791
E-mail pv.conference@wip-munich.de
Web www.wip-munich.de, http://www.photovoltaic-conference.com

eNREE invites contributions

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

Please send in your contributions to

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ENVIS Centre on Renewable Energy and Environment

A knowledge gateway

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

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

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

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

This new-look, revamped website has helped achieve just what the centre set out to do display a world of information at a glance. TERI's ENVIS Centre and the EMCB Node have been actively engaged in resource generation, data collection, problem recognition and provision of solutions, capacity building, and information dissemination. Rich in content that is constantly updated, the site does an impressive job of plugging information gaps that existed in the renewable energy and environmental sectors. Besides, it draws the attention of the Indian scientific community, a fact that becomes evident from the hundreds of technical queries received through the website. Here's a snapshot of some of the main features of the site.

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

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