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Tapioca: source of biofuels for India

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Current research on renewable energy and development

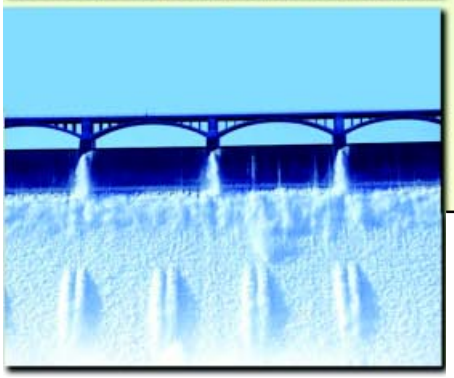
A compilation of annotated bibliographies from different leading periodicals on current research on renewable energy and environment.

Technological developments

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

Web updates

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



Conferences/workshops/seminars

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

Ministry of Environment and Forests, Government of India

The Energy and Resources Institute

Feed-in tariff and solar power

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Electric power through SPV (solar photovoltaic system), though a simple phenomenon, is prohibitively costly for commercial use. The price of solar cell, nucleus to convert solar light to electricity, as prime component of the total device, is decreasing almost at the rate of 50% in each decade over the last 40 years. Still the per unit cost of electricity is beyond competitive price compared with conventional energy. Generally, grid power is priced at about Rs 4 per unit whereas the same from SPV is priced at about Rs 16 (four times that of grid power). The situation is not different in other countries. Notwithstanding such a contrast, growth of SPV power is on a high trajectory of above 40% with the installed capacity world over rising to 3100 MW till 2005. It has been possible through introduction of a system called feed-in tariff that is, tariff at which power is sold to the grid by the entrepreneur setting up SPV units. This is in vogue now in 41 countries that had been facing problems in developing solar energy.

Operational and maintenance cost being negligible, large investment through capital expenditure is the contributing factor for high cost of SPV energy. A favourable feed-in tariff could be the instrument to overcome the problem. Provisions for feed-in tariff, visualized in Electricity Act 2003 empowering regulators to introduce the same, are already under implementation for wind, biomass, and small hydro but exclude SPV power in many states.

Though around the world there is a race for increasing the share of renewable energy (for EU the latest target is 25% by 2020), India is making good progress in harnessing NRE (new and renewable energy) resources. It is hoped that regulatory authorities will look into the possibility of including SPV power in the whole gamut of feed-in tariff system to encourage connectivity to the grid. This will go a long way in boosting a cause following the trend in countries where solar radiation is even poorer to India.

Presently solar power is made available in remote areas and islands through generous subsidies offered by the government, as it is the only recourse to provide electricity as social obligation in absence of other energy resources and approachability to grid power. The number of grid-connected SPV systems installed annually is too small even though India, having a potential of 20 MW/ km^2, exports a substantial quantum of solar modules fabricated out of imported solar cells for grid-connected systems elsewhere in developed countries.

It is on these considerations that feed-in tariffs for SPV should invite the attention of electricity regulators (central and state electricity regulatory commissions) in order to encourage entrepreneurs to set up SPV systems in urban areas on the roof tops. This will ensure energy security and the surplus can be sold to the grid as benign, clean energy. Cluster of such entrepreneurs can claim benefit under the CDM (clean development mechanism), which is now going on at the rate of about Rs 650 per tonne of CO_2 emission replacement. In fact, spurt in real estate activities will attract BIPV (building integrated photovoltaic) to economize cost and promotion of solar power following latest design in environment-friendly housing. West Bengal is fairly advanced in solar power with multifarious applications in the Sunderbans and other places including present impressive work on street lighting and introduction of BIPV in few buildings in Rajarhat New Town. SPV system has also been a boon in finding employment opportunities in the state. Besides, feed-in tariff in SPV systems will enhance employment opportunities for the benefit of unemployed youths.

Presuming a simple case for Kolkata to encourage 10 MW of SPV annually at the rate of 1 kW/household and total of 10 000 consumers, each will have to spend Rs 1.25 lakh/ installation and in lieu, should get Rs 15/per unit of energy sold to the grid as feed-in tariff. Annual sale of energy is estimated as 1250 units per consumer valued at Rs 18 750 a year to enable him to realize investment within seven years or so. CESC (Calcutta Electric Supply Corporation) as distribution licensee for the city will buy 12.5 million units from all these consumers who

have installed SPV systems at a cost of Rs 18.8 crore. This will add a minimal fraction on the energy market of nearly 6500 million units priced at Rs 2600 crore chargeable from nearly 2.5 million consumers of the utility undertaking. This additional burden will virtually have no impact on prevalent tariff structure, but on the contrary, greatly influence boosting SPV installation with scopes to spread out to other states.

Cost of solar power can be reduced through R&D and technological innovations for which more and more field applications are imperative. India, rich in knowledge power, should not lag behind developed countries in this respect. Slow progress in SPV can be set right for wide-scale adoption only through grid-connected system for which feed-in tariff could be the appropriate driving mechanism.

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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Tapioca: source of biofuels for India

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Introduction

India's oil imports are expected to rise to some five million barrels a day by 2020, from about 1.4 million barrels at present. Hence, any attempts made to reduce oil supply by indigenous technology using renewable sources in India will increase the energy security of the country.

Petroleum industries using crude as feedstock at present are facing the problem of fast depletion of raw materials. After the extinction of crude, the petrochemical industries would look upon carbohydrates to be their feedstock as their yield is high from agriculture. However, they should also think of supplementing the crude with starch to produce petroleum products.

Manihot esculenta (tapioca) is a latex-yielding tuber crop. It can, therefore, be a source of both alcohol and hydrocarbons. Its tuber can be used for alcohol production and other parts of the plant for hydrocarbon processing.

Sugar cane is the most energy-efficient crop for alcohol production, but the use of cassava starch is increasing because it can be produced under conditions unsuitable for sugar cane. Large quantities of starch are available from tuber crops like potato, tapioca, and cassava, and grains like maize (corn) and sorghum. Cassava has long been recognized as a potential substrate for alcohol production in tropical areas (Jackman 1987).

Tapioca: a renewable energy source

Climate

Cassava grows best in areas with a mean temperature of 25 °C–29 °C, and a soil temperature of about 30 °C. The plant stops growing at a temperature below 10 °C. While the crop grows best in areas with an annual well-distributed rainfall of 1000–1500 mm, it can tolerate semi-arid conditions with rainfall as low as 500 mm, and may have a competitive advantage over other crops under those conditions. Cassava can grow on a wide range of soils, but is best adapted to well-drained, light-textured, deep soils of intermediate fertility. Under high fertility conditions top growth may be stimulated at the expense of root growth. Optimum soil pH is between 4.5 and 6.5. The crop does not grow well in poorly drained soils, gravelly or saline soils, or in soils with a hardpan (Onwueme and Sinha 1991). These conditions are available in the southern region of India, throughout the year and hence, the yield is high.

The average crop yield of roots and tubers for the world is about 12 958 kg/ha (kilogram per hectares) whereas it is relatively high for India that is, about 16 906 kg/ha. Therefore, the present investigation proposes developing an alternate eco-friendly source for alcohol from starch.

Tapioca starch is selected as the fermentation substrate. This is because compared with the other starches it has very less protein, hence eliminating the de-proteination step in the fermentation process. Absence of proteins makes cassava an interesting candidate as a substrate for a number of fermentation processes, especially when the world price for cassava starch is currently half of maize starch. Tapioca also has higher starch content compared with other tubers.

Modification of cassava starch to improve the functional properties such as viscosity, gelatinization temperature, solubility, and digestibility has been well established. However, the present chemical modification methods produce unwanted by-products and above all, the chemicals can have harmful effects. Biotechnological techniques can be useful in overcoming these problems. A typical example is esterification of starch or lowering the level of saccharides by treatment with lipids in the presence of lipases and esterases. These enzymes, being specific in their action, can bring about substitution at a particular carbon atom, thus providing products with special characteristics.

Starch and sago are used as the major food for people in many parts of India. But the present methodology of tapioca conversion poses many problems in process as well as in effluent

treatment. This requires an efficient and environment-friendly process for such conversions.

Yield

Cassava is not usually grown on soils where it would be most productive that is, the light sandy loams, fertile, and deep, which are reserved for other crops less tolerant of poor soils. When cassava is grown by traditional tropical methods, yields lie between 5 tonnes and 20 tonnes per hectare, varying with the region, variety, soil, and other factors. However, when the crop is given more attention, yields of 30–40 tonnes per hectare are obtained. It has been reported that it is normal for some varieties, under appropriate cultivation methods, to yield over 60 tonnes per hectare.

The high yields frequently achieved at agricultural experiment stations and occasionally by some active farmers show what might be accomplished with improved varieties and better cultural practices.

Nevertheless, cassava yields in total calories per hectare compare very favourably with those of other starchy staples (Table 1) (FAO 1995).

Table 1 Average yields of tropical starchy staples (1948–52)

Crop	*Brazil*	*Java*	*India*	*China (province of Taiwan)*
	Million calories per hectare			
Maize	4.4	2.4	2.3	5.0
Rice	3.9	3.9	2.8	5.5
Yams and sweet potato	7.5	5.4	5.6	8.6
Cassava	14.2	7.1	5.8	11.6

Biochemical constituents of cassava (%)

For industrial development, many efforts are being made to organize research and experiments in various geographical regions for the selection of new varieties with high yields of roots and higher starch content (Table 2).

Importance of tapioca in the context of current status

The production of starch from tropical root and tuber crops could be a way of getting higher economic gains in developing countries. The present method produces starch, which includes tuber crushing, sieving, sedimentation, and drying. This leads to starch losses of up to 20% and also involves high energy inputs, the use of much water, and expensive machinery (Kallabinski and Balagobalan 1994). Hence, this introduces the following problems in tapioca starch and sago industries.

- High energy consumption
- Effluent
- High water consumption

Currently, the bioprocess is not applied anywhere for conversion of tapioca to starch (or) tapioca to higher alcohols in India. Hence, finding out the feasibility of starch processes will definitely improve the utilization of biomass overcoming the environmental problems.

The energy required for operating the plant would be met substantially from biogas generated from biomass formed after extraction of alcohols. Further, the bio-methanated biomass could be recycled to the field as manure. Thus, the entire process becomes eco-friendly without producing any new CO_2 (carbon dioxide) and is sustainable.

Table 2 Average composition of the cassava root (common varieties at harvest time)

Composition	*Percentage*
Moisture	70.25
Starch	21.45*
Sugars	5.13
Protein	1.12
Fats	0.41
Ash	0.54

* Bitter varieties usually average about 30% starch content

Table 3 Outcome of the project (basis: one year)

	Units	*Value*
Tapioca production	Tonnes	1.43 × 106
Alcohols production	Litres	462.6 × 106
Biogas	Cubic metres	109.8 × 106
Manure	Tonnes	34.32 × 106
Power generation	Megawatt	21
CO_2 prevented	Tonnes	1.16 × 106
CO_2 credit	Dollars	4.9 × 106
Crude saved	Litres	437.8 × 106

Utility of the project

Product: alcohols

Available agricultural crop land (ha [hectares])	= 169 700
Average crop yield (kg/ha)	= 16 906
Cultivatable land for tapioca is about 50%	
Yield of starch per tonne of tapioca	= 240 kg
Therefore, total yield of tapioca (tonnes/year)	= 1.43×10^6
Considering fermentation and distillation efficiency, starch converted to alcohol per tonne of tapioca	= 154 kg
Expected yield of alcohol per kg of starch used as a feedstock	= 1.76 litre
1 tonne of tapioca gives	= 271.04 litre of alcohol
Hence, maximum alcohol that could be produced per year	= 462.6×10^6 litres
42 gallons of crude oil	= 44 gallons of petroleum product
462.6×10^6 litres alcohol	= 437.8×10^6 litres of crude oil

Thus, 437.8×10^6 litres of crude need not to be imported

Reduction in CO_2 emission

1.16 kilolitres	= 1 tonne of crude oil
437.8×10^6 litres	= 3.77×10^5 tonnes of crude oil
Energy content of crude oil	= 41.87 GJ (gigajoules) /tonne
CO_2 emission for crude oil	= 73.3 kg / GJ
Hence, CO_2 prevented/annum	= 1.16×10^6 tonnes

By-products

1 Biogas

Starch carried out with effluent per tonne of tapioca processed	= 96 kg
Yield of starch for 1.43×10^6 tonne / year of tapioca processed	= 137.28×10^6 kg
1 kg of starch	= 0.8 m^3
Calorific value of biogas	= 20 MJ / m^3
Biogas to be produced	= 109.8×10^6 m^3
If biogas is used for power production of 30% efficiency	= 21 MW
The exhaust heat from the power plant is used for distillation.	

2 Manure

Bio-sludge produced in the process of biogas production will be utilized as manure.

Manure to be produced = 34.32×10^6 tonnes

3 CO_2 credit

Every tonne of CO_2 reduction reduces the cost of process by an average value of five dollars

Hence, the total cost gain in terms of CO_2 reduction is 4.9×10^6 dollars

- Economical calculations made show that a minimum of Rs 15 000 / tonne of tapioca will be the gain profit for the project, besides the carbon credit.

Conclusions

An analysis of tapioca as a fuel resource for ethanol indicates that it is possible to reduce our crude oil imports by 80%. So, this improves the energy security of India. CO_2 prevented per annum is about 1.16×10^6 tonnes. The waste produced from this biological conversion can also be utilized for biogas production. Hence, it overcomes the problem of effluents from starch and sago industries. Cost analysis shows that a minimum of Rs 15 000/tonne of tapioca will be the profit for the project, besides the carbon credit. This project if implemented will create lot of job opportunities besides the effective utilization of agricultural land.

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http://earthtrends.wri.org, last accessed on 23 December 2006

Current research on renewable energy and development

Chiaramonti D, Oasmaa A, and Solantausta Y. 2007. **Power generation using fast pyrolysis liquids from biomass.** *Renewable and Sustainable Energy Reviews* **11**(6): 1056–1086
University of Florence, Department of Energy Engineering, "S.Stecco" I-50139, Florence, Italy

Power production from biomass-derived pyrolysis liquids has been under development for the past few years. If technically successful, it would make decentralized bio-energy production possible. Several technologies and system components have been developed by academia, R&D (research and development) organizations, and industrial companies in many countries. Much experience has been gained and many useful results published. The present work aims at reviewing the most significant experience in power generation from biomass liquids produced by fast pyrolysis processes. Power plant technologies addressed are diesel engines, gas turbines, and natural gas/steam power plants. The main results are reviewed and R&D needs identified for each technology. The analysis shows that even for the most promising solutions long-term demonstration has not yet been achieved. Pyrolysis liquid use in gas turbine plants and in co-firing mode in large power stations is technically most advanced. Recent work with diesel engines also appears quite promising. (4 figures, 7 tables, 85 references)

Joselin H G M, Iniyan S, Sreevalsan E, Rajapandian S. 2007. **A review of wind energy technologies.** *Renewable and Sustainable Energy Reviews* **11**(6): 1117–1145
Department of Mechanical Engineering, St Joseph's College of Engineering, Chennai – 600 119, India

Wind is caused by differential heating of the earth's surface by the sun. It has been estimated that roughly 10 million MW (megawatt) of energy can be generated from the wind continuously available in the earth. Wind energy provides a variable and environment-friendly option and national energy security at a time when decreasing global reserves of fossil fuels threaten the long-term sustainability of the global economy. This paper reviews the wind resources assessment models, site selection models, and aerodynamic models including wake effect. The different existing performance and reliability evaluation models, various problems related to wind turbine components (blade, gearbox, generator, and transformer), and grid for a wind energy system have been discussed. This paper also reviews different techniques and loads for design, control systems, and economics of wind energy conversion system. (1 table, 225 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. A weather-model-based site matching of equipment and a simple numerical algorithm for generation unit sizing have been presented. The programme 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 (Sukhalai situated near Suktawa in Hoshangabad district of Madhya Pradesh) that satisfies a typical load. Generation and storage units for each system are properly sized in order to meet the annual load demand for the above three scenarios. 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, 4 tables, 20 references)

Sankarlal T and Mani A. 2007. **Experimental investigations on ejector refrigeration system with ammonia.** *Renewable Energy* **32**(8): 1403–1413
Department of Mechanical Engineering, Indian Institute of Technology Madras, Chennai – 600 036, India

A vapour ejector refrigeration system has been designed and developed to operate with ammonia. In this paper, performance of ejector refrigeration system has been experimentally studied with three different area ratio ejectors by varying operational parameters namely generator, condenser, and evaporator temperatures. Effect of non-dimensional parameters like compression ratio, expansion ratio, and area ratio on the system performance is studied. The study revealed that entrainment ratio and coefficient of performance of the system increase with increase in ejector area ratio and expansion ratio, and they increase with decrease in the compression ratio. (9 figures, 4 tables, 18 references)

Hiremath R B, Shikha S, and Ravindranath N H. 2007. **Decentralized energy planning: modelling and application—a review.** *Renewable and Sustainable Energy Reviews* **11**(5): 729–752
Aeronautical Engineering and CST, Indian Institute of Science, Bengaluru – 560 012, India

Energy planning is carried out at a centralized level using computer-based modelling. The centralized energy planning models and approaches have already been reviewed in literature. DEP (decentralized energy planning) is a concept of recent origin with limited applications. Literature shows that different models are being developed and used worldwide. This paper gives an overview of different decentralized energy models used worldwide, their approaches, and their applications along with a few emerging energy models. The central theme of the energy planning at the decentralized level would be to prepare an area-based DEP to meet energy needs, and development of alternate energy sources at least-cost to the economy and environment. Ecologically sound development of the region is possible when energy needs are integrated with the environmental concerns at the local and global levels. Taking into account these features, this paper explains the need of DEP and shows how different types of energy planning and optimization models, supply-demand models, regional models, resource models, and neural models have been carried, adopted, and applied at the decentralized level. (70 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 PV, wind energy, micro-hydro, and may be conventional generators for backup. This paper discusses different system 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. The developed model will help in sizing hybrid energy system hardware and in selecting the operating options. Micro-hydro–wind systems are found to be the optimal combination for the electrification of rural villages in the 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. (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

Renewable-energy-based system can be utilized as an IRES (integrated renewable energy system), which can satisfy the energy needs of an area in an appropriate and sustainable manner. The IRES can be modelled and optimized for meeting the energy needs for renewable-energy-based rural electrification of remote areas. The paper reports the results of optimization of IRES models of the study area of Zone 4 of Jaunpur block of Uttarakhand state 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 resources are 807 MWh/year, whereas the percentage contribution of each resource is as follows: MHP (micro-hydro power) 15.88% (128 166), solar 2.77% (22 363), wind 1.89% (15 251), and biomass energy 79.46% (641 384) kWh/year. The model has been optimized and the results indicated that the optimized model has been found to the best choice for meeting the energy needs of the area. The study revealed that renewable energy sources can contribute up to 15% to the total energy demands of 808 MWh/year. Therefore, at the peak level, total energy demand from other conventional sources would be reduced to 687 MWh/year. The results further indicated that optimized IRES can provide a feasible solution in terms of energy fulfilment in the range of EPDF from 1.0 to 0.75. EPDF is the electric power delivery factor and is also called optimizing power factor-the maximum value of this is 1. (5 figures, 9 tables, 22 references)

Muneer T and Asif M. 2007. **Prospects for secure and sustainable electricity supply for Pakistan.** *Renewable and Sustainable Energy Reviews* 11(4): 654–671
School of Engineering, Napier University, 10 Colinton Road, Edinburgh, Scotland EH10 5DT, UK

Non-judicious exploitation of fossil fuels, presently contributing to 80% of the world's primary energy, is having enormous impacts on environment. There is an urgent need for a quicker switch over of energy systems from conventional to renewables that are sustainable and can meet the present and projected world energy demand. Hydrogen, in the capacity of energy vector and storage medium is expected to be the optimum solution for intermittency and storage of energy produced by renewables. Within the context of Pakistan, solar and wind power are two of the most promising renewables. In this article, the current energy consumption for

Pakistan is presented and the issue of security of electrical energy supply is discussed. Furthermore, the prospects for a large-scale switchover to renewables are also addressed and the relevant economies and underpinning rationale provided. It has been found that solar energy is a much more economical choice for Pakistan as compared to wind energy-respective costs for solar and wind energy are (US cents/kWh) 20 and 77. This is due to the fact that barring the four monsoon months the average wind speed for the remaining eight months does not cross an economic threshold. On the contrary, it was found that solar energy is fairly stable and consistent. (11 figures, 4 tables, 24 references)

Jain D. 2007. **Modelling the thermal performance of an aquaculture pond heating with greenhouse.** *Building and Environment* **42**(2): 557–565
Central Institute of Post Harvest Engineering and Technology, PO PAU Campus, Ludhiana – 141 004, India

A transient analytical model is presented to study the effectiveness of an even-shape greenhouse used for heating the aquaculture pond during extreme winters. The model was solved for the climatic conditions of Delhi for the typical day of winter. A simple trapezoidal design of aquaculture pond is proposed. Parametric studies involved the effects of length, breadth, depth, inclination of lining of fishpond, depth of water, and air change in the greenhouse on the water heating in the fishpond. The performance of fishpond was assessed in terms of temperature gain, mean thermal efficiency, and thermal load levelling. The optimum parameters for fishpond were 30-m length, 16-m breadth, 1.25-m depth, 1-m water depth, 75° lining inclination, and 8 air changes per hour for maximum temperature gain, maximum thermal efficiency, and minimum thermal load levelling. A 20 °C rise in water temperature could be achieved during the day and 11 °C in the month of January. The maximum heat gain and loss are at about 16:00 and 7:00 hours of the day, respectively. (13 figures, 1 table, 11 references)

Nandi P and De R. 2007. **Production of sweetmeat utilizing solar thermal energy: economic and thermal analysis of a case study.** *Journal of Cleaner Production* **15**(4): 373–377
School of Energy Studies, Jadavpur University, Kolkata – 700 032, India

The production of Indian sweetmeats is still dependent upon the use of conventional energy and results in a huge consumption of energy. The use of solar thermal systems by using parabolic concentrators in the production of sweetmeats can be beneficial from many points of view. In this study, conducted in the factory of a processed food manufacturing company, trial runs of the system were made to draw the ultimate conclusion that solar thermal systems can be effectively used in the production of sweetmeats without compromising on the quality or taste of the product and ensuring the sustainability of a green environment as well. The study also addresses the economic and thermal analysis of the solar concentrating system in terms of substituting the diesel fuel, which is being used in the current production systems. The results revealed that the sweetmeat thus produced is matched well in the standard. The authors therefore, suggested that conventional energy can easily be substituted by solar energy for production of sweetmeats. (2 figures, 3 tables, 12 references)

Purohit P and Kandpal T C. 2007. **Techno-economics of biogas-based water pumping in India: an attempt to internalize carbon dioxide emissions mitigation and other economic benefits.** *Renewable and Sustainable Energy Reviews* **11**(6): 1208–1226
Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi – 110 016, India

An attempt for the techno-economic evaluation of biogas-based water pumping systems in India has been made in the present work. The potential reduction in the amount of CO_2 (carbon dioxide) released in the atmosphere due to the use of the biogas-based water pumping systems has also been taken into account in the estimation of economic benefits. The economic figures of merit

such as discounted payback period, net present value, benefit-to-cost ratio, and internal rate of return have been estimated. Results of some exemplifying calculations are presented. The results have shown that biogas-based water pumping systems are viable both technically and economically. (3 figures, 12 tables, 28 references)

Malik A. 2007. **Environmental challenge vis-à-vis opportunity: the case of water hyacinth.** *Environment International* **33**(1): 122–138
Centre for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi – 110 016, India

Although water hyacinth (*Eichhornia crassipes*) is mostly known as a noxious weed, it could be used as a valuable resource with several unique properties. As a result, research activity concerning biological control and waste water treatment of water hyacinth has boomed up. Investigations on biogas/compost production from water hyacinth have also come up very well mainly from few research groups in India. This review presents a comprehensive view of the research related to water hyacinth with special emphasis on the recent investigations on water hyacinth control and utilization technologies conducted in the last 2–3 decades. Based on these significant research achievements, now it is desirable to identify a management strategy so that the excessive growth can be controlled and the plant can be used in beneficial ways. In the rural areas, water hyacinth could be used in an integrated manner for decentralized waste water treatment systems coupled to biogas and compost production from the resulting biomass. There is a need to work out the techno-economic viability of such integrated model systems. (8 tables, 177 references)

Technological developments

New solar absorber reaches 97% efficiency

A new spectrally selective absorber derived from a novel solution-chemistry method has been developed and optimized. The main objective was to investigate the potential of the spectrally selective surface. The absorber consists of absorbing thin films of nickel nano-particles embedded in a dielectric matrix of alumina and an overlying anti-reflection film consisting of one of the following materials: silica, hybrid-silica, alumina, or silica–titania. Solution and sol-gel chemistry were used in the process. The thin films were spin-coated onto an aluminum substrate followed by a heat-treatment that generated the multi-layer selective solar absorber. An optimal three-layer structure was modelled using the experimentally determined optical constants. The theoretical three-layer stack was experimentally confirmed and achieved a solar absorptance of 0.97 and a thermal emittance of 0.05, which definitely are commercially competitive values. The configuration of the three-layer stack is: an 80% nickel–20% alumina film at the base, a 40% nickel–60% alumina film in the middle, and a silica or hybrid-silica film at the top. The three-layer absorber was subjected to high-temperature and condensation accelerated ageing tests. The condensation test did not degrade the absorber whatsoever but the high-temperature test did reveal some oxidation of the nickel particles.
www.diva-portal.org, 12 December 2006

The tidal turbine system

The SRTT (Scotrenewables tidal turbine) system is an innovative free-floating rotor-based tidal current energy converter, which has been under development for over three years. The concept in its present configuration involves dual counter-rotating horizontal-axis rotors driving generators within sub-surface nacelles, each suspended from separate keel and rotor arm sections attached to a single surface-piercing cylindrical buoyancy tube. The device is anchored to the seabed via a yoke arrangement and compliant mooring system. A separate flexible power and control umbilical then connects to a sub-sea junction box. The rotor arm sections are hinged to allow each two-bladed rotor to be retracted so as to be parallel

with the longitudinal axis of the buoyancy tube, giving the system a transport draught of under 4.5 m at full-scale to facilitate towing the device into harbours for major maintenance. Designed above all for access and maintenance, the free-floating SRTT combines many of the design principles and much of the existing technology from the wind energy industry. Some of these key principles include a focus on survivability, use of existing proven equipment, standardization of components, off-site maintenance and quick mooring, and electrical connection and disconnection using modest vessels. Specifically designed for low-maintenance and economic efficiency, the concept incorporates the key design principles of minimization of component numbers and use of existing proven technology. This enables a fast and relatively low-risk route to commercialization.
Details available at, http://www.scotrenewables.com/marine_tech.html, last accessed on 23 November 2006

New and efficient solar cell

A University of Idaho professor is devising a new form of solar cell she says could lead to a breakthrough that would make solar energy commercially feasible. Chemist Pam Shapiro, her graduate students, and her colleagues at the university are working on creating better materials and combining them in new ways that could more than double the efficiency of present solar cells. If successful, she said the new technology could help the US break its oil dependency. So far, Shapiro's team has created a compound called a 'quantum dot' that is made of elements that include copper, indium, and selenium. Shapiro said that the quantum dots would be embedded between layers of a solar cell and would absorb energy that is otherwise wasted due to overheating.
The Times of India, 29 November 2006

BARC's two new reactors to produce hydrogen

Mumbai-based BARC (Bhabha Atomic Research Centre) is designing two new reactors that will produce large quantities of hydrogen, which is increasingly being looked upon as a fuel option for combustible engines. Prototype versions of the compact high-temperature reactor and the Indian high-temperature reactor are being developed. Both these reactors will have reactor core temperatures of over 1000 °C, known as white hot cores. Current reactor temperatures range about 300 °C. White hot cores are said to be more efficient at producing hydrogen.
Business Standard, 24 November 2006

Energy-rated refrigerators and tubelights

Refrigerators and tubelights rated on the basis of their power consumption will be the first energy-efficiency-coded products to hit the market. Star ratings for air-conditioners and general-purpose motors would also be launched subsequently. Though India set up the Bureau of Energy Efficiency four years ago to promote efficient use of power, it is only now that manufacturers will be coming into the market with star rated products.
The Economic Times, 2 November 2006

Rice straw to light up homes, power tractors

Farmers across Punjab have little use for rice straw and other farm wastes generated from the field while harvesting. A commercial power project, a joint venture between Bermaco Energy Systems, Gammon Infrastructure Projects and Archean Granites, will use farm wastes as feedstock to generate power. The total annual fuel requirement is 120 000 tonnes of biomass and no fossil fuels. A total of nine such plants are proposed to be commissioned. The first of nine such power plants being set up at Ghannaur, will have 12-MW capacity, equivalent to about 288 000 units a day. The project will provide valuable additional income to some 10 000–15 000 farmers located around each project area from the sale of agricultural wastes. Each of the nine plants would require some 300 tonnes of feedstock a day to generate power at full capacity. The nine plants, which will become operational within two years, will generate a total of 108 MW of electricity with each plant costing between Rs 55 and Rs 60 crore.
The Indian Express, 22 December 2006

Solar traffic signals

States are all set to solarize traffic signals, thus keeping with the guidelines of the national energy policy that suggests use of renewable sources of energy. While Delhi, Bengaluru, and parts of Andhra Pradesh have long since implemented these guidelines, others joining the league are Maharashtra, Chhattisgarh, Uttar Pradesh, Tamil Nadu, and Haryana. Most of these states have

applied to the Ministry of New and Renewable Energy for subsidies for solar-powered traffic signals, most of which have been sanctioned. Fifty such systems, highest in number for any state, have been sanctioned for Tamil Nadu and are in the process of being implemented. However, there are other contract companies that solarize signals and recover costs through advertisements. Such solar systems can cut traffic in cities by storing energy for a backup period of up to 72 hours, providing continuous power supply for three days.
The Economic Times, 17 November 2006

Solar vaccine refrigerator

The first environment-friendly Solarchill vaccine refrigerator was installed at the President's estate clinic. The Solarchill was conceived as a vaccine cooler for remote areas in developing countries where access to power supply is difficult. Powered by three 60-watt photovoltaic panels, it stores the energy of the sun in ice instead of batteries.
In place of the chlorofluorocarbons, and other ozone depleting and global warming substances, Solarchill relies on ozone and climate-friendly hydrocarbon refrigerants. It offers many practical benefits also as it can be used where electricity lines are non-existent or unreliable; it is safer than the kerosene vaccine coolers now used in remote areas; and it is 50%–60% cheaper than the currently available battery-operated solar vaccine coolers.
The Hindu, 2 November 2006

Solar geysers

Reducing power consumption – and more importantly the bill amount – is fast becoming a less expensive proposition. The government is trying to make the 'expensive' solar water heaters affordable for the common man. Solar geysers would have a capacity of between 125 litres and 150 litres, which should be enough for a family of five to six and would cost about Rs 20 000. For government colonies, agencies like PWD (public works department) and CPWD (central public works department) may be asked to do the job.
The Times of India, 25 October 2006

Web updates

Database of State Incentives for Renewables and Efficiency

http://www.dsireusa.org/
DSIRE (Database of State Incentives for Renewables and Efficiency) is a comprehensive source of information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency. It lists financial incentives like tax incentives, grants, loans, rebates, industry recruitment, bond programmes, and production incentives. It also tracks rules, regulations, and policies.

Secondary solar concentrator

http://www.lerc.nasa.gov/WWW/RT1997/5000/5490donovan.htm
This website focuses on refractive secondary solar concentrator for achieving super high temperatures (2000 K and above) in solar heat receivers, its design, and development. These concentrators refocus the already highly concentrated solar energy provided by a primary solar collector. The website provides an illustrated demonstration of technicalities, working principle, etc., and a bibliography for further reading.

Canadian Solar Industries Association

http://www.cansia.ca/
CANSIA (Canadian Solar Industries Association) is a national organization supported by the Government of Canada, industry members, and the public to promote renewable energy applications in the country. The site hosts a rich collection of resources including news, events, directory, photo gallery, opportunities, government initiatives, educational materials, publications, and so on.

Energy Development Co-operative

http://www.unlimited-power.co.uk/
The online shopping centre EDC (Energy Development Co-operative) Ltd, provides the

latest solar energy and wind power technologies, and solar and wind energy services at excellent prices. This site provides an online energy catalogue and ordering system. It also provides links to other websites.

Indian Wind Power

http://www.windpowerindia.com

This website provides information on wind energy generation in India and around the world. It provides information on wind power installed capacity in India by state, manufacturer, and year, and cumulative generation from wind power projects in India by state. Besides, it also provides information on wind energy generator manufacturers, service providers, government agencies, and policies.

World Council for Renewable Energy

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

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

Forthcoming events

19–22 March 2007
San Antonio, **Texas**

NHA Annual Hydrogen Conference 2007
NHA (National Hydrogen Association), 1800 M Street NW, Suite 300 North, Washington, DC 20036-5802, US
Tel. 202 223 5547 • *Fax* 202 223 5537
E-mail info@HydrogenConference.org, Kahne@hydrogenconference.org
Web www.hydrogenconference.org/index.asp

14–16 February 2007
Jabalpur, Madhya Pradesh, **India**

International Conference on Sustainable Agriculture for Food, Bio-energy, and Livelihood Security
General Secretary and Director of Research Services, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Adhartal, Jabalpur – 482 004, Madhya Pradesh, India
Tel. +91 761 248 1074 • *Fax* +91 761 248 1074
Web www.jnkvv.nic.in

7–9 February 2007
Japan

Third International Hydrogen and Fuel Cell Expo
FC Expo Show Management, Reed Exhibitions Japan Ltd, 18F Shinjuku-Normura Bldg, 1-26-2 Nishishinjuku, Shinjuku-ku, Tokyo 163-0570, Japan
Tel. +81 3 3349 8502 • *Fax* +81 3 3349 4900
E-mail fc@reedexpo.co.jp • *Web* www.fcexpo.jp

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

European Renewable Energy Policy Conference 2007
EREC, Renewable Energy House, 63-65 Rue d'Arlon, B-1040, Brussels, Belgium
Tel. +32 2 546 1933 • *Fax* +32 2 546 1934
E-mail erec@erec-renewables.org
Web www.erec-renewables.org, www.bmu.de

ENVIS Centre on Renewable Energy and Environment

A knowledge gateway

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

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

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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