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Dear Reader

India is on the path of rapid economic growth along with speedy development. Simultaneously, it has to face the global threat of climate change. India has unique natural resources and its development path depends on harnessing them to a great extent. While developing infrastructure, meeting energy needs, eradicating poverty, and social development are the overriding priorities before India, these have to be achieved without compromising on the environment and maintaining ecological balance alongside. Maintaining a high growth rate is a necessity for India.

The Government of India has recently announced the NAPCC (National Action Plan on Climate Change), which mainly focuses on mitigation of greenhouse gas emissions by adopting various means. For example, developing appropriate technologies, devising efficient and cost-effective strategies for end use, demand side management, engineering new and innovative forms of market, effecting implementation of programmes, welcoming international cooperation for research development, sharing and transfer of technologies, and so on.

NAPCC entails eight national missions representing multi-pronged, long-term, and integrated strategies for achieving key goals in the context of climate change. These missions are the National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a ‘Green India’, National Mission for Sustainable Agriculture, and the National Mission on Strategic Knowledge for Climate Change. It may be seen that while the National Solar Mission is directly related to renewable energy, the other missions also have indirect dependence on renewable energy. This brings the role of renewable energy to the fore and puts a greater responsibility on it.

It is the responsibility of every citizen of the county to contribute towards controlling environmental degradation, and adopting energy-efficient means and renewable energy in their daily routine. The present issue contains useful information on solar cells, solar tower, and fuel cells.

Akshay Urja, while spreading the message of the use of renewable energy among people, also plays a critical role in disseminating information on technological development and end-use applications of renewable energy in various spheres of life. I am sure that the present issue will be useful to the readers. Your contribution and suggestions are valuable to us.

With best wishes

ARUN K TRIPATHI
<aktripathi@nic.in>
We, the Hema Sri Agro Power Projects Ltd, have incorporated a company with an objective to generate power with non-conventional resources (biomass).

Having registered with MPUVN (Madhya Pradesh Urag Vikas Nigam), we propose to establish a 20-MW biomass-based power project at Magrora village of Dabra Tehasil in the Gwalior District of Madhya Pradesh.

We came across your monthly magazine recently at MPUVN office and found it is very helpful to get acquainted with news about renewable energy sources. We would like to subscribe to the magazine, but the subscription details are not available in the magazine. Please let us know the details.

We further request you to send us details regarding possibilities of setting up a biomass-based power plant in the state of Rajasthan.

P Chandra Reddy
Director, Hema Sri Agro Power Projects Ltd, Hyderabad

Akshay Urja is doing great work in terms of spreading awareness and knowledge on renewable energy. I would like to have more details related to the programme on power generation from municipal and urban waste.

H B Soni
Senior Engineer (Retd), MGVCL, Surat, Gujarat

All India Women’s Conference is a national NGO with more than 550 branches across the country. Energy is one of the major areas wherein we have been active for decades. Akshay Urja is a publication that is helping us in improving programmes as well as identifying new areas for implementation of projects and programmes. We wish the newsletter all success.

Shivani Mehta
Secretary, All India Women’s Congress, New Delhi

I am a Lecturer in Calcutta Institute of Engineering and Management, Kolkata.

I have seen a copy of Akshay Urja recently, and find it very useful. I am happy to note that the Ministry of New and Renewable Energy brings out an important newsletter like Akshay Urja. It is definitely a factor that will give a boost to renewable energy development in the country, and would prove to be a vehicle for conveying information on related development in the field.

Nilanjan De
Lecturer, Calcutta Institute of Engineering and Management, Kolkata

Golden Arch International is a Noida-based consulting company. Considering the importance of renewable energy in mitigating climate change, our company is advising various corporate organizations on the positives of renewable energy as also its importance in sustainable development. In addition, we are also currently test marketing solar energy based lighting solutions. The contents of Akshay Urja are very informative in this regard. We wish the newsletter all the very best.

Mandeep Singh
Executive (Business Development), Golden Arch International Ltd, Noida

We are connected with solar cookers, water pumping, windmills, and solar lighting systems since the last 25 years. I regularly go through every issue of ‘Akshay Urja’ newsletter. It is very helpful to be in touch with news about renewable energy sources. The contents in all issues are useful and cover diverse topics. I congratulate the whole team for this effort that benefits many stakeholders in this field.

Hasmukh Devmurari
Director, Rural Engineering School, Bhavnagar, Gujarat

I was very happy to go through an issue of Akshay Urja. The information provided in the newsletter is very useful to all working in the field of renewable energy including R&D (research and development) personnel and entrepreneurs. The quality of photographs is excellent, the matter is informative, and the news updated. I am presently actively involved in biomass energy generation, and its R&D aspects. I congratulate the team on its efforts

S Murali
Scientist, Regional Research Laboratory (CSIR), Bhopal

Letters to the editor

Dear Editor,

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Scientist, Regional Research Laboratory (CSIR), Bhopal

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

Editor
Akshay Urja
National news

- Advanced photovoltaic facilities inaugurated at Solar Energy Centre
- Green Homes rating system launched
- Solar power lights up villages in Tripura
- HPCL wind power project to shift to Jaisalmer
- West Bengal to set up centre for solar energy

International news

- Fraunhofer to develop offshore wind technologies
- First full scale offshore floating wind turbine to be built
- Algal biomass organization formed
- IBM introduces giant PV magnifying glass

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Power from solar tower

Solar cells grow thinner, but glow brighter

Fuel cells: generating clean energy

From darkness to light: Village Dageriya

Providing opportunities through renewable energy

Individual and community power generation

New wind power policy in Andhra Pradesh

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CASE STUDY

India’s first solar housing complex

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RE STATISTICS >>
Shri Vilas Muttemwar, Minister of State for the Ministry of New and Renewable Energy said that the SEC (Solar Energy Centre) is now well equipped to meet the emerging requirement of industry as per international standards. Inaugurating two advanced solar photovoltaic facilities at SEC at Gwalpahari, Haryana, on 14 May 2008, Shri Muttemwar said that the SEC has achieved a great milestone by updating itself to the international standards. These facilities include a large area Sun Simulator and a Photovoltaic Concentrator Module Test Bed. He said that the government would help SEC in getting accreditation from International Electro Technical Commission on quality assurance in the field of solar photovoltaic. Shri Muttemwar expressed the hope that with the help of dedicated and enthusiastic manpower at SEC the international accreditation would be available shortly.

The minister said there is a boom in the photovoltaic industry all over the world and has also been gearing up to meet the challenge of large-scale demand of solar cells. Referring to the recent announcement of policy for grid-connected power production from both solar photovoltaic and solar thermal route, Shri Muttemwar said that the government would provide generation-based incentives up to Rs 12 kW per hour for getting connected SEC power plant and Rs 10 kW per hour for solar thermal power plant.

The large area sun simulator will make possible to evaluate the performance of PV modules of size 200 cm x 200 cm, the capacity of which...
would help PV module manufacturers of the country to test their product in India and find a market in other countries of the world.

The other system inaugurated by the minister was a 1.2 kWp capacity Photovoltaic Concentrator Module Test Bed facility established in collaboration with M/s Moser Baer Photovoltaic Ltd.. This facility is unique of its kind in India and uses the latest high-efficiency multi-junction concentrator solar cells technology modules. The concentrator modules require less area of solar cells and therefore, use less amount of expensive semiconductor material. These are essentially the third-generation PV technology that promise high-efficiency low-cost systems with economically competitive cost of electricity generation. Earlier in his welcome address Dr B Bandyopadhyay, Head of SEC and Adviser in the ministry gave details about the SEC.

The Hon’ble minister complimented SEC for coming forward to work with industries in developing and fine tuning various solar energy technologies for making them marketable products. He noted with pride that a number of industries are working with the centre in the field of solar power generation, and this is how the industrially developed nations have come up with technological solutions. He especially mentioned the collaboration between the centre and M/s Moser Baer Photovoltaic Ltd for solar photovoltaic modules; and SEC and M/s Su-kam, Gurgaon on inverter development.

He further lauded the efforts of the SEC in initiating collaborative work with BARC, IACS, IITs, CSIR laboratories, industries like CEL, BHEL, and REIL as well as other organizations. He stated that such partnerships develop confidence in technology and also facilitate smooth transition from the experimental stage to commercial stage in future.

PRESS INFORMATION BUREAU, 14 MAY 2008

Shri Vilas Muttemwar, Hon’ble Minister for New and Renewable Energy visiting SPV facility at Solar Energy Centre

can be about 600 W. Initiatives have already been taken by SEC to design and procure environmental chambers to accommodate such large area modules for their qualification testing. It is expected that the complete test facility for large area modules will be in place within a year so that performance and qualification testing of large area PV modules can be undertaken at SEC as per international standards. The centre is also in the process of obtaining international accreditation of the test facility. This facility
Green Homes rating system launched

The IGBC (Indian Green Building Council) launched the IGBC-Green Homes rating system at CII-Sohrabji Godrej Green Business Centre. The IGBC-Green Homes rating system is the first ecological rating programme developed in the country exclusively for the residential sector, and addresses national priorities such as conservation of natural resources, infrastructure, water and energy efficiency, handling of domestic waste, health and well-being of the occupants.

‘The rating system is being put in place to ensure that the residential sector in India contributes towards optimal use of natural resources and results in water savings to the tune of 30%–50%, energy savings to the tune of 20%–30%, excellent day lighting, enhanced ventilation, and effective waste management among others,’ a release issued said.

Solar power lights up villages in Tripura

Perched on Killa Hill, Tobakla, a remote tribal hamlet in Tripura’s South district, now shines in the dark with a non-conventional solar power plant supplying energy under the Rajiv Gandhi Gramin Vidhyutikaran Yojana. A septuagenarian, Bikram Singh Jamatiya is a delighted man today. ‘My village is remote and can be approached only on foot. We lived in darkness at night. Now it is different,’ says Jamatiya. ‘Earlier, we saw electric lights only when we went to Udaipur, the district town, which is about 25 km from the village,’ he said. Bikram Singh is not alone. Altogether 62 tribal families of the village under Kochigang panchayat of Tripura Tribal Areas Autonomous District Council are now beneficiaries of this non-conventional energy source.

The solar photovoltaic plant with a capacity of 10 kW has been installed there at an investment of Rs 40 lakh. ‘After sunset, the village wore a ghostly look, as the only sources of light were kerosene lanterns, but we have bid farewell to darkness,’ said Chandrasandha Jamatiya. The Science and Technology department, the nodal agency for electrifying the remote villages with non-conventional energy, had initially granted only two bulbs for lighting each family’s house. But with the gaon panchayat approving a fan and a TV set, the department agreed to supply energy for a charge of Rs 10 per point, said Abhabananda Jamatiya, sarpanch of Kochigang Panchayat. Tripura power minister, Manik Dey said,
‘solar energy is being given to remote villages where conventional power is yet to reach. We want to electrify all villages in the state.’

THE ASSAM TRIBUNE, 5 MAY 2008

**HPCL wind power project to shift to Jaisalmer**

**H**PCL’s (Hindustan Petroleum Corporation Ltd) wind power foray is facing teething troubles. The state-run company plans to set up 100-MW capacity at an investment of Rs 500 crore. Its first project – a pilot of 25 MW coming up in Maharashtra’s Dhule district – is being shifted to Jaisalmer in Rajasthan following protests by farmers. ‘The company has in principle agreed to shift the present operations to Jaisalmer. Complete clearance for the project will come by this week. We have all the resources in place to start operations in Jaisalmer,’ said an HPCL official. Total investment in the 25 MW project is pegged at about Rs 145 crore.

The company has so far installed only three wind generators with total capacity of 3.75 MW at Dhule. It will now install the remaining 17 wind generators (21.25 MW) at Jaisalmer. ‘HPCL's decision to diversify into a different energy source is promoted by the carbon credit and depreciation tax waivers that such companies get from the government for producing clean energy,’ explained a Mumbai-based analyst. HPCL has similar projects in the offing in other states, too. ‘The board has approved another 25 MW project and has invited tenders for it,’ the official said.

BUSINESS STANDARD, 5 MAY 2008

**West Bengal to set up centre for solar energy**

**F**or the first time in the country, an integrated solar energy park with a 30-MW solar power plant will come up in West Bengal at an investment of about Rs 500 crore. Many companies including Videocon and Reliance Industries and a US firm Astonfield have shown interest for setting up the project. WBGEDCL (West Bengal Renewable Energy Development Agency) will have a minority stake in the project. WBGEDCL managing director, Mr S P Gon Chowdhury, said, ‘The proposed solar energy park will be spread over 120 acres in Purulia district. We will develop the basic infrastructure and set up substations and then we will invite bids from private parties to build the solar power plant.’

The bids will be invited in July 2008 and the selection process will be over by September 2008. The park along with solar power plant will be ready for power generation by May 2009. A senior Videocon official said that the company was interested in taking part in the bidding.

THE ASIAN AGE, 7 MAY 2008

**Big players line up for solar projects in Haryana**

**W**ith the tariff for generation of power through solar energy being fixed at an attractive rate of Rs 15.96 per unit by the HERC (Haryana Electricity Regulatory
Commission), the state is confident of attracting top corporate houses to set up solar power projects. Being the fourth state after Rajasthan, Punjab, and West Bengal to announce tariffs for power generation through solar energy, Haryana is hopeful to lead the race with maximum tariffs so far. A few leading groups like Reliance Industries Ltd, Albina Power (Indiabulls company), ACME Telepower, Epuron Renewable Energy Power, Emco, RS India Wind Energy, and Admire Energy Solutions (Moser Baer company), and so on have already evinced interest in producing power from solar energy in Haryana.

Sumita Misra, director of HAREDA (Haryana Renewable Energy Development Agency) said, ‘We invited expressions of interest and have received 20 proposals from IPP (independent power producers) with a capacity of producing 127 MW from solar energy. Processing is on and the projects will soon be allocated to the companies. HERC has fixed an attractive tariff rate of Rs 15.96 per unit for projects to be commenced up to 31 December 2009 and Rs 15.16 per unit for projects commencing between 31 December 2009 and 31 March 2010. The centre, under its scheme to promote electricity generation through solar energy, is providing generation-based incentives at Rs 12 per unit for solar photovoltaic power and Rs 10 per unit for solar thermal technology for number of units sold to the state power utilities.’

The solar insolation level of Haryana is in the range of 5.5 kWh to 6.5 kWh per square metre of area and there is a huge potential for using solar energy for various thermal and electrical energy applications in the state. Haryana is likely to earn about Rs 20–25 crore per MW of electricity generated from these projects. The maximum installed capacity of solar power generation in the country is about 200 kW at present and to promote this green technology, the new and renewable energy ministry has set a target of generating 50 MW from solar energy for the entire country with 25 MW of power to be generated by 2010/11 and a state not producing more than 10 MW through solar power projects. A major challenge for the IPPs seems to be the escalating land prices in Haryana.

**THE FINANCIAL EXPRESS, 10 MAY 2008**
from micro hydel projects – considered renewable energy sources – Delhi is yet to take a similar stand.

‘We are also eager to have power generated from renewable sources. The Commission is currently working out the details of how we can have power generated from renewable sources including from the waste that is generated in the city. The proposal is being worked on and we will soon be able to spell out its details,’ said DERC (Delhi Electricity Regulatory Commission) secretary Amarendra Kumar Tewary. The Electricity Act says that the state regulatory commission should ‘promote co-generation and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee.’

Experts in the power sector explain that Delhi’s regulatory commission has to specify the quantum of energy for the state that should be generated from renewable sources and also notify its cost. ‘Once the DERC directs the discoms to have a certain percentage of total supplied power generated from renewable sources, it will also have to notify its price. The discoms then have to meet the criterion laid down,’ said an expert. Referring to the need for cutting down dependence on non-renewable sources for power generation, Delhi power secretary Rajinder Kumar said, ‘Though power generated from the renewable energy sources is costly, it is necessary, taking into account global warming and its impact. We have to look at the bigger picture.

Power generated through renewable sources, which is necessitated for by the law may not look economically feasible now, but it eventually works out well for the environment.’

THE HINDU BUSINESS LINE, 14 MAY 2008

States wheel in ‘green power’ into their energy portfolio

States are increasingly warming up to the idea of including ‘green power’ in their energy portfolio. At the last count, power regulators across 12 states had firmed up RPO (Renewable Purchase Obligation), which makes it mandatory for all distribution utilities in that state to source a minimum quantum of electricity annually from renewable sources—a move that could boost installation of ‘green power’ capacities. Expressed as a percentage of its total consumption, the RPO varies from 1% to 10% across the states that have implemented it so far, with regulators in states such as Karnataka, Madhya Pradesh, and Tamil Nadu pegging the limit at up to 10%.

On an pan-India basis, the total RPO commitment by these 12 states cumulatively adds up to around 35 518 MUs (million units), which is about 5.33% of the total power consumed by in the country during 2007/08 (estimated at 666 007 MUs according to latest CEA data). With the RPO mechanism still in the evolution stage in India, more states are likely to follow the example of the 12 states, where regulators have already implemented the scheme. Coming at a time when prices of hydrocarbon resources across the world are touching all-time highs, the mandatory purchase of ‘green power’ by regulators is expected to give a new lease of life for the renewables sector, according to government officials.

Rajasthan, where the state regulator has fixed the RPO at 7.5%, has gone a step further to prescribe a renewable energy surcharge payment, under which any short fall to meet the RPO will be subject to payment of surcharge by the distri-
bution licensee. The surcharge collected is to be credited to a fund to be utilized for the creation of transmission system infrastructure of renewable energy projects.

THE HINDU, 14 MAY 2008

Nandan plans eco-zones to make biofuel

Nandan Biomatrix, a Hyderabad-based agri-biotechnology and medicinal plantation company, is planning to set up BIEZs (bio-investment eco-industrial zones) across the country. The project aims to bring fallow land under jatropha cultivation, which will be used to make biofuel. B Jaya Kumar, Director (technical), said, ‘BIEZs would work to achieve energy efficiency. The zones will have farms and laboratories for mass production of plantlets along with nursery production centres, demonstration areas and training centres. It will follow the contract farming model, assuring farmers of buying jatropha seeds. IL&FS Infrastructure Development Corporation, which is associated with the development of the project, is preparing a feasibility report.’We are hopeful of announcing a few BIEZs this year,’ said Jaya Kumar, adding the company was targeting cultivation for biofuel on 100,000 hectares.

The project will be implemented on a public-private-panchayat partnership model. The model will be replicated abroad, too. The input cost for jatropha cultivation is estimated at Rs 16,000 per acre spread over two years, with expected returns of Rs 12,000 from the third or fourth year of planting. Nandan managing director Bhaskar Rao signed a memorandum of understanding in this regard with BPCL (Bharat Petroleum Corporation Ltd), one of the stakeholders in the project. ‘BPCL will procure the biofuel produced from the BIEZ and will set up refineries for blending requirements,’ said A K Bansal, executive director (corporate affairs), BPCL. S P (Shapoorji Pallonji), the Germany-based Alphakat and Malaysia’s Platinum Energy also have a stake in the project.

While S P will be the infrastructure partner, Alphakat will bring in patented technology for producing bio-diesel from seeds and jatropha biomass. Platinum will develop jatropha catchment areas in Southeast Asia. ‘About Rs 600 crore each will be invested in seed development, distribution, processing, and other fields,’ said Jaya Kumar. Nandan Biomatrix will cultivate jatropha on more than 800,000 hectares spread across Gujarat, Maharashtra, Andhra Pradesh, Uttar Pradesh, and other states.

BUSINESS STANDARD, 15 MAY 2008

Interaction meet on solar water heating systems

A n interaction meet on solar water heating systems was held in Coimbatore on 6 June 2008. The meeting involved branch managers of various banks, financial institutions, commissioner of corporations/municipalities in and around Coimbatore and manufacturers of solar water heating systems. The programme was organized by the TEDA (Tamil Nadu Energy Development Agency) and the IREDA (Indian Renewable Energy Development Agency). It was sponsored by the Ministry of New and Renewable Energy. Shri D Selvaraj,
Ministry bids farewell to Shri Subramanian

Shri V Subramanian, Secretary, Ministry of New and Renewable Energy, and a patron of Akshay Urja retired on 30 June 2008. A farewell function was organized at the Scope Complex, New Delhi. Shri Vilas Muttemwar, Hon’ble Minister for New and Renewable Energy graced the occasion and appreciated the contribution of Shri Subramanian for developing renewable energy in the country particularly in the renewable power sector during his tenure.

Shri V Subramanian, belongs to the West Bengal Cadre 1971 batch of the Indian Administrative Service. During his stint with the Government of West Bengal, between 1975 and 1983, he was Additional District Magistrate, 24 Parganas District and District Magistrate, Burdwan District. He was also Excise Commissioner and Managing Director of the State Cooperative Bank. Shri Subramanian was deputed to the Government of India in 1983 as Deputy Secretary, Department of Expenditure, and was a Director in the Department of Economic Affairs during 1985–89. In 1990, he went on a Commonwealth assignment on Loan and Grant Management to the Government of Mozambique.

On his return to West Bengal, he was Power Secretary and Labour Secretary in the State Government. He came back to the Centre in February 2000 as Financial Adviser, Ministry of Civil Aviation, Tourism, and Culture. In December 2004, he joined the Ministry of Rural Development as Additional Secretary and Financial Adviser, where, in October 2005, he was promoted as Special Secretary.

Those who were present on the occasion wished him a happy and prosperous post-retirement life.
Fraunhofer to develop offshore wind technologies

Independent research body Fraunhofer is developing technologies for offshore wind parks, complete with testing hangars, computer-aided testing systems, monitoring sensor systems, and personnel training. Germany is planning wind parks both in the North and Baltic Seas to add to its current 20,000 on-shore wind turbines. The German government envisions that these offshore wind parks will generate 25,000 MW by 2030, equivalent to 15% of Germany’s electricity requirement.

With such expected increases in the numbers of turbines, technology will need to develop quickly to improve efficiency and ensure robust technology. For example, turbine blade sizes currently measure 40–60 metres, and there are plans to develop blades up to 90 metres long; this will bring new challenges for materials science. Currently, a rotor blade of 40–60 metres made of glass fibre composite material weighs about 50 tonnes. With even larger blades, lighter materials and new construction methods are called for. It is thought that carbon fibre may take over from fibreglass, as it is lighter at the same time as keeping strength.

To address the need for this testing, several organizations are investing in bespoke test sites for the wind power industry. One of these is NaREC in the UK, and another is the recently opened CWMT (Centre for Wind Energy and Maritime Technology), at Bremerhaven, North Germany, backed by the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research (IFAM), and Fraunhofer Institute for Structural Durability and System Reliability (LBF).

‘Offshore projects present real challenges to design engineers, manufacturers, and operators, because storms, rough seas, salt water, and the harsh climate subject the turbines to extreme stresses,’ says Dr Hans-Gerd Busmann, head of CWMT. One challenge for offshore wind is the repair and maintenance work necessary, which means the demand for turbines to be more durable will be higher. ‘With our work, we want to ensure that the service life of wind turbines – including all the components from the foundations to the rotor blades – is assured for 20 years,’ Busmann adds.

The CWMT is now building hangars for testing rotor blades of up to 90 metres in length, where they can be subjected to tough and lengthy endurance tests. At the same time the centre is developing computer-aided testing procedures for all parts of the wind turbine system, including rotor blades, nacelle, tower, and foundations. Currently, prototypes of different tower constructions made of steel and concrete in Bremerhaven are being tested.

Once the turbines have been erected, it is important to be able to continuously monitor wind parks from land, and CWMT scientists are developing sensors for this purpose. And another major challenge facing the wind energy industry is where to find qualified personnel. With this in mind, Fraunhofer IFAM also offers training for employees who want to be Fibre-reinforced Plastic Technicians. The training course takes four weeks and involves practical as well as theoretical content, the company reports.

First full scale offshore floating wind turbine to be built

Norwegian energy company StatoilHydro is to build the world’s first full scale floating wind turbine, Hywind. It will be tested over a two-year period outside Stavanger on the west coast of Norway. The goal of the pilot is to reduce costs, thus making floating
offshore wind power competitive in the power market. The road to commercialization and large-scale development is still long, however, and still dependent on incentive schemes to be viable. ‘Taking wind turbines to sea presents new opportunities. The wind is stronger and more consistent, areas are large and the challenges we [face that are similar to] onshore projects are fewer,’ says Alexandra Bech Gjørv, Head of New Energy at StatoilHydro.

StatoilHydro will be investing around NOK 400 million, and planned start-up is in autumn 2009. The 2.3 MW wind turbine supplied by Siemens will be attached to a spar-buoy, a solution known from platforms and offshore loading buoys.

The turbine will have a diameter of 80 metres and the nacelle will be 65 metres above the sea surface. The floatation element will have a draft of around 100 metres below the sea surface and will be moored to the seabed with three anchor points. It can be located in waters with depths ranging from 120 metres to 700 metres.

In addition to Siemens, StatoilHydro has signed contracts with Technip, which will build the floatation element and have responsibility for the installation offshore. Nexans will lay cables to shore; and Haugaland Kraft will be responsible for the landfall. In addition, Enova is supporting the project with NOK 59 million.

Entpreneurs, academicians, scientists, and leaders of global corporations announced the formation of the ABO (Algal Biomass Organization) to help accelerate the development and commercial application of algae biomass.

Algae are an ideal low-cost, renewable and environmentally progressive raw material that can be converted into biofuels. They can grow rapidly (doubling in biomass in as little as a few hours), require limited nutrients and can annually deliver up to 2000–5000 gallons of fuel per acre of non-arable land.

‘Boeing recognizes that algae biomass holds tremendous potential for use as jet fuel, and it fits into our plan to guide aviation toward commercially viable and sustainable fuel sources—fuels with substantially smaller greenhouse gas footprints that do not compete with food or require unacceptable quantities of land and fresh water resources,’ said Billy Glover, Managing Director, Environmental Strategy, Boeing Commercial Airplanes, and ABO steering committee co-chair.

The Algal Biomass Organization is opening membership to any parties interested in this evolving area of research, development and potential commercialization. The group will gather for the Second Annual Algae Biomass Summit in Seattle during 23–24 October 2008.

IBM introduces giant PV magnifying glass

IBM has come up with a way of increasing the amount of thermal energy that can be concentrated onto PV (photovoltaic) cells during the CPV process. Using a large lens to concentrate the sun’s power onto a 1 cm² cell, IBM reports that it is able to capture a record 230 W (watts). The energy is converted into 70 W of electrical power—five times the electrical power density generated by typical cells that use CPV technology in solar farms. If successfully transferred from the lab to real life, IBM believes its magnifying glass can significantly reduce the cost of a typical CPV based system, as fewer components would be needed. The company says it can cut the number of PV cells and other components by a factor of ten. However, when 200 suns generating 20 W/cm² is converted to 2300 suns generating 230 W/cm², what about the problem of heat?

As IBM researchers experienced first hand, the heat generated is enough to melt stainless steel, but by using IBM’s experience with cooling computer chips, they managed to cool the solar cells from 1600 °C to 85 °C. According to IBM, its liquid metal cooling interface is able to transfer heat from the solar cell to a copper cooling plate much more efficiently than anything else available today. In addition to CPV, IBM is also looking at other areas of PV research; focusing on using current technologies to develop cheaper and more efficient silicon solar cells; developing new solution-processed thin-film PV devices; and future generation PV architectures based on nanostructures such as semiconductor quantum dots and nanowires.
Fuels Cells: new material increases power output by more than 50%

MIT (Massachusetts Institute of Technology) of engineers have improved the power output of one type of fuel cell by more than 50% through technology that could help these environmentally friendly energy storage devices find a much broader market, particularly in portable electronics. The new material key to the work is also considerably less expensive than its conventional industrial counterpart, among other advantages. “Our goal is to replace traditional fuel-cell membranes with these cost-effective, highly tunable, and better-performing materials,” said Paula T Hammond, Bayer Professor of Chemical Engineering and leader of the research team. She noted that the new material also has potential for use in other electrochemical systems such as batteries.

The work was reported in a recent issue of Advanced Materials by Hammond, Avni A Argun and J Nathan Ashcraft. Argun is a postdoctoral associate in chemical engineering; Ashcraft is a graduate student in the same department.

Like a battery, a fuel cell has three principal parts: two electrodes (a cathode and anode) separated by an electrolyte. Chemical reactions at the electrodes produce an electronic current that can be made to flow through an appliance connected to the battery or fuel cell. The principal difference between the two is that the fuel cells get their energy from an external source of hydrogen fuel, while conventional batteries draw from a finite source in a contained system.

The MIT team focused on DMFCs (direct methanol fuel cells), in which the methanol is directly used as the fuel and reforming of alcohol down to hydrogen is not required. Such a fuel cell is attractive because the only waste products are water and carbon dioxide (the latter produced in small quantities). Also, because methanol is a liquid, it is easier to store and transport than hydrogen gas, and is safer (it won’t explode). Methanol also has a high energy density—a little goes a long way, making it especially interesting for portable devices.

The DMFCs currently on the market, however, have limitations. For example, the material currently used for the electrolyte sandwiched between the electrodes is expensive. Even more important, that material, known as Nafion, is permeable to methanol, allowing some of the fuel to seep across the center of the fuel cell. Among other disadvantages, this wastes fuel and lowers the efficiency of the cell, because the fuel isn’t available for the reactions that generate electricity. Using a relatively new technique known as layer-by-layer assembly, the MIT researchers created an alternative to Nafion. “We were able to tune the structure of our film a few nanometres at a time,” Hammond said, getting around some of the problems associated with other approaches. The result is a thin film that is two orders of magnitude less permeable to methanol but compares favourably to Nafion in proton conductivity.

To test their creation, the engineers coated a Nafion membrane with the new film and incorporated the whole into a DMFC. The result was an increase in power output of more than 50%. The team is now exploring whether the new film could be used by itself, completely replacing Nafion. To that end, they have been generating thin films that stand alone, with a consistency much like plastic wrap. This work was supported by the DuPont-MIT Alliance through 2007. It is currently supported by the National Science Foundation. In addition, Hammond and colleagues have begun exploring the new material’s potential use in photovoltaics. That work is funded by the MIT Energy Initiative.

SOURCE: WWW.SCIENCEDAILY.ORG
Sun is the principal source of almost all kinds of energy, both conventional and non-conventional. Although solar radiation is being utilized from time immemorial for drying, heating, and so on, direct production of electrical energy from it is a more recent development. The solar energy received on earth everyday can produce 2500 times more power than we currently consume. But we should have the proper means and technology to harness the energy economically. Electricity can be generated from solar radiation through the following methods.

- Photovoltaic cells
- Solar thermal power

**Photovoltaic cells**

Solar radiation is directly converted to electricity by solar photovoltaic cells. The cell consists of two or more appropriately sandwiched thin layers of semiconducting material, usually silicon. When the solar cells are exposed to sunlight, the incoming photons of radiation separate positive and negative charge carriers of the semiconducting material. This generates voltage and hence electricity. The greater the intensity of light, the greater is the flow of electrons. The electric output from a single cell is small. So a number of cells are connected in series or parallel to get the desired power output. The module containing multiple cells is called solar panel.

**Solar thermal power**

Solar thermal power station is like a conventional thermal power station having steam boiler, turbine, and generator. In a conventional thermal power station, water is heated by coal, gas, or petroleum oil to produce steam, which
rotates the turbine and generator to produce electricity. But in the case of solar thermal power station, steam is produced by heat derived from solar radiation. To achieve this, sunrays are reflected from large mirror surfaces to concentrate on to a point on the solar receiver.

Schematics of a central receiver system used for generating power using solar thermal energy is shown in Figure 1. The surface of the solar receiver may reach to a temperature as high as 1000 ºC. In the receiver, an HTF (heat transfer fluid) is heated. The hot HTF is used to produce steam which turns a turbine to produce power. Presently, the major solar thermal power stations include 354 MW plant in California desert, 64 MW plant in Nevada of USA, and 11 MW plant in Spain. Two 50 MW and one 15 MW plant are under construction in Spain.

**Solar tower / chimney**

A recent development in solar energy is a solar tower/chimney. It is a method used for large-scale generation of electricity from solar radiation. The principle is very simple. It is based on the well-known principle of greenhouse effect, chimney updraft effect, and wind turbine. Ambient air is drawn into a very large circular greenhouse-like collector. The air is warmed by solar energy due to the greenhouse effect. With the help of the greenhouse effect, sunrays are captured and these in turn heat the air beneath the collector. The collector roof is covered with glass or plastic foil. This allows short-wave solar light from the sun to pass through, but block out reflected long-wave heat radiation. The resulting convection causes the air to rise and escape through a tall tower.

The difference in density between the warm air in the tower and the cold air outside causes an upward airflow. As with a convective heater, cold air is simultaneously sucked in at the outer open edge of the collector roof. Turbines with generators are installed inside the tower and while the air moves up inside the tower, it rotates the turbines, which produce electricity. Constant round-the-clock operation is also possible. For this, closed water tubes are positioned under the collector roof. During the daytime, heat energy is stored in water tube and at night, they release the heat to warm the air. The water tubes need to be filled only once and there is no need for any further water inputs during the operation.

**Turbine**

Essentially, the turbines are more closely related to pressure-staged Kaplan-type turbines than to velocity staged wind power plants subject to natural wind. These turbines are manufactured by makers of hydro-electric plant turbines. It basically operates like a hydroelectric power plant but with hot air. Turbines can be installed in a ring around the base of the tower with a horizontal axis. Also, a single large vertical axis turbine can be installed in the chimney for smaller plants.

**Glass collector**

The collector roof is covered with glass or plastic sheets or foils. The longitudinal girders are designed in such a way that vacuum cleaners can run along them to clean the roof. For large plants, the glass roof has to be several kilometres in diameter.

**Tower**

The solar chimney, is erected at the centre of the collector field. As the normal chimneys or flues, the taller the chimney the greater the draught obtained. The greater the wind speed, the more energy does the wind contain that can be harvested. Therefore, the height of a commercial solar chimney has to be more to achieve a large annual output. For the tower/chimney, various types of construction materials have been compared. Among the types of structures that can be used (such as steel truss, cable nets, or textile
membranes), it is reinforced concrete tubes that promise to deliver the longest service life and also it will be most economical for desert areas. A chimney in a desert country made from reinforced concrete tubes promises the longest life span at least costs.

Technically cylindrical, natural draft tower is preferred. More the height of the tower, the more will be the power generation. For a 200 MW plant, a suitable height would be 1000 metre with a tower diameter of 170 metre. Wall thickness of the chimney can be decreased by putting stiffening spoked wheels inside.

Output

The solar tower/chimney works on the principle of updraft. Hence, the generating capacity of this plant depends primarily on three factors namely intensity of solar radiation, the collector area, and the chimney height. With a large collector area, more volume of air is warmed up to flow up the chimney. Collector areas as large as 7 km in diameter have been considered. With a larger chimney height, the pressure difference between the warm air in the collector and the air at the top of the chimney increases the stack effect thus increasing the velocity of air.

This is because as the height of the chimney increases, the atmosphere pressure at the top of the chimney decreases. For a 200 MW solar power plant, chimney of 1000 metre height has been designed. A combined increase of the collector area and the chimney will have a greater effect on the size of the power plant and hence, the energy production. Further, its location in a desert area can have the added advantage of higher intensity of solar radiation.

Advantages

- It is a renewable source of energy. The sun as an energy source is unlimited.
- It has no ecological harm, as it does not emit any harmful gases into the atmosphere.
- It does not require any fuel for generation. Hence, dependence on imported coal, oil, or gas can be reduced for some countries.
- Its operating cost is very less which somehow balances its higher capital cost.
There is no resettlement and rehabilitation problem as it can be installed in a deserted area as well.

**Limitations**

- High capital cost
- High energy cost compared to conventional sources of power
- Large land requirement
- The visual impact of very high towers and tens of squares of kilometres of collector.
- Limited number of industry partners

**Cost and economic feasibility**

Assuming an overall interest rate of 8% and depreciation over 40 years, electricity from a solar tower will cost slightly more than electricity generated by a newly built coal-fired thermal power plant. If we reduce the assumed interest rate to 4%, electricity from the solar tower will be competitive with that from thermal power station. As government of some countries are giving subsidies, concessions, and tax benefits to renewable energy, soft loans are available for this type of project. Further, the entrepreneur of the project can avail benefit on carbon trading as per the Kyoto Protocol. A great amount of investment cost is made up of labour cost. This creates jobs meaning added value to the country.

**Appropriate location**

The appropriate location for a solar tower power station should have the following characteristics.

- High annual solar radiation on horizontal surface (>1700 kWh/m²)
- High insolation (>3000 hours/year)
- Low average annual winds (<3 m/s)
- Limited strong winds (<25 m/s)
- No snows, hail, or sand storms

**History**

In 1903, Spanish Colonel Isidoro Cabanyes first proposed a solar tower power plant in the magazine *La energía eléctrica*. One of the earliest descriptions of a solar tower power plant was written in 1931 by a German author, Hanns Gunther. Beginning in 1975, Robert E Lucier applied for patents on a solar tower electric power generator. These patents were granted in Australia, Canada, Israel, and the USA between 1978 and 1981.

**Prototype in Spain**

In 1982, a medium-scale working model of a solar tower power plant of capacity 50 kW was built under the direction of German engineer Jorge Schlaich in Manzanares, Ciudad Real, 150 km south of Madrid, Spain. The project was funded by the German government. During operation, the optimization data was collected on a second-by-second basis. This power plant operated for approximately eight years, consistently generating 50 kW output but encountered severe structural instability close to the tower due to induced vortices and was decommissioned in 1989. The features of the plant are given below.

- Tower height: 200 m
- Collector diameter: 240 m
- Turbine capacity: 50 kW
- Tower diameter: 10 m
- Collector height: 2 m
- Collector area: 45 000 square metre
- Tower weight: 125 tonnes
- Collector weight: 5.5 kg/m² (without glass)
- Roof segment size: 9 x 9 m

The pilot plant conclusively proved the concept of works and provided data for design modifications to achieve greater commercial and economic benefits associated with an increased sale of economy. Based on this experience, there is a proposal to construct a solar tower of height 750 metres to produce 40 MW power at Ciudad Real in Spain.
T
here is growing awareness and deliberations on environmental issues as is evident from international summits on environmental issues. A conference on environment was held in 1972 in Stockholm, the capital city of Sweden. The representatives from different countries thought of sustained development without degrading the natural environment. There were also similar discussions in the UN General Conference in 1972. After 20 years, in June 1992 an ‘Earth Summit’ was held at Rio de Janeiro (Brazil). Representatives from 178 countries discussed environmental issues. Subsequently, at the UN Conference on Global Climate Change, held in Kyoto, Japan on 11 December 1997, delegates from 159 countries signed an agreement on global warming that continued the process begun at the 1992 Earth Summit under clean development mechanism. The agreement known as Kyoto Protocol has come into force from 15 February 2005. Developed nations are to reduce emissions of greenhouse gases by 5.2% below 1990 levels by 2012.

In December 2007, nearly 200 nations agreed at the UN-led talks at Bali, Indonesia. The new pact of Bali summit to combat global warming will replace Kyoto Protocol after three years. According to a report from UK Hadley Centre, global greenhouse gas emissions should be near zero by 2060 in order to restrict average global temperature rise to within 2 °C above pre-industrial level. Therefore, all nations must show leadership by insisting on an equitable framework with clear emission reduction targets. They have no option but carbon-free technologies in order to reach zero emission of...
greenhouse gases. Solar power is treated as the best option in this regard.

**Solar energy**

About $5 \times 10^9$ years of perpetual radiation by the sun is possible due to nuclear fusion, a process in which the lighter nuclei like hydrogen combine into heavier nucleus of helium and release tremendous amount of energy. The interior temperature of the sun is more than 20 000 000 °C and that of the surface is about 5500 °C. A small portion of total solar radiation reaches our upper atmosphere at the rate of 1.36 kW per square metre (known as solar constant). The atmosphere and its clouds absorb or scatter as much as 53% of this radiation and the remaining 47% radiation that reaches the ground consists of nearly 50% visible light, 45% infrared radiation, and smaller amounts of ultraviolet light and other forms of electromagnetic radiation. Unbelievably, solar energy reaching the earth in one hour is equal to the total energy used by the world’s population in one year. The radiations from the sun can be converted into electrical energy using devices like solar cells.

**Solar cells**

The device that can directly convert solar energy into usable electrical energy is known as solar cell or photovoltaic cell. The voltage generated from a single photovoltaic cell is typically only a fraction of a volt. By connecting large numbers of individual cells together, more than one kilowatt of electric power can be generated. A group of solar cells connected in series to produce a desired amount of electricity is called a solar panel. Solar cells are widely used in calculators, watches, toys, satellites, space probes, and so on. Nowadays, scientists are trying to increase the efficiency of solar panel to have easily feasible solar vehicles.

**Structure of solar cells**

A solar cell contains six layers stacked up one on another. They are (i) front electrical contact layer, (ii) antireflection layer, (iii) top junction layer, (iv) absorption layer, (v) back junction layer, and (vi) back electrical contact layer. The two electrical contact layers are present in some widely spaced grid pattern and is composed of a good conductor such as a metal. The back electrical contact layer simply acts like an electrical contact and thus covers the entire back surface of the cell structure. It is always made of metal to ensure good electrical conduction. Materials such as silicon oxide or titanium dioxide are employed as the antireflection layer in solar cells.

The three important layers called energy conversion layers, namely the junction and absorption layers below the antireflection layer, belong to semiconductor materials such as silicon, gallium arsenide, indium phosphide, and copper indium selenide. Semiconductors can absorb the visible light of sunlight by producing excited free electrons. In a solar cell, the sunlight enters the device through the antireflection layer. The layer traps the light incident and transmits this light into the three energy conversion layers below. The middle absorber layer in the structure is the core of the device. The two electrical contact layers allow electric current to flow out of and into the cell.

![Figure 1 Structure of a solar cell](image)
**Principle of operation in solar cells**

The process which causes the cell to convert light directly into electrical energy is called photovoltaic effect. When different types of thin semiconductors are joined together by special fabrication technique to form solar cell, an electrical field is automatically set up at the interface between these materials. The role of the junction layers is to establish this electric field. But electrons are attached to specific atoms and not free to move in a direction dictated by the electric field in order to constitute an electric current. Light striking the cell provides the energy needed to free some electrons from their bound condition. Free electrons cross the junction between two dissimilar semiconductors more easily in one direction than in the other. It leads to accumulation of electrons on one side of the junction.

These energetic electrons are collected by the electrical contact layers for use in an external circuit where they can do useful work. A negative voltage is created with respect to the other side, just as one electrode of a battery has a negative voltage with respect to the other. This is known as open circuit voltage or photovoltaic emf. It is of the order of 0.5 volt for silicon cell and 0.1 volt for a germanium cell. The photovoltaic battery can continue to provide voltage and a direct current as long as light continues to fall on the two materials.

**Development of solar cells**

The solar cell we use today has taken about 170 years to get its present form. In 1839, the French physicist Antoine-César Becquerel, while experimenting, observed that voltage developed when light fell upon a solid electrode in an electrolyte solution. The development of solar cell technology stemmed from this discovery of the photovoltaic effect. But it took another 50 years for the first true solar cell using junctions to be made. Charles Fritts for the first time constructed a solar cell using junctions formed by coating the semiconductors selenium with a very thin layer of gold. No doubt, the device was able to transform less than 1% of the absorbed light energy into electrical energy. But it motivated other researchers to opt for clean power. Another metal–semiconductor junction solar cell made of copper and copper oxide was demonstrated in 1927. Both the selenium cell and the copper oxide cell were being employed in light-sensitive devices, such as photometers, by 1930. All these early solar cells had conversion efficiencies within 1%.

The main aim of the researchers was to enhance the energy conversion efficiency of the cell beyond 1%. The first solar cell with greater efficiency came in 1941 with a silicon solar cell developed by Russell Ohl. In 1954, three American researchers – G L Pearson, Daryl Chapin, and Calvin Fuller – demonstrated a silicon solar cell capable of a 6% efficiency when used in direct sunlight. Solar cells made of gallium arsenide having more than 20% efficiency were fabricated in 1980s. in 1989, the efficiency could be hiked to 37% through convergence of sunlight onto the cell surface by means of lenses. In general, solar cells of widely varying efficiencies and cost are now available.

**Recent developments**

**Research by Walukiewicz and Yu**

Researchers like Wladek Walukiewicz and Kin Man Yu at the Materials Science Division of Lawrence Berkley National Laboratory in USA have developed solar cells with energy conversion efficiency above 40%. They have created a new type of semiconductor material. In conventional single conductor solar cells, the efficiency achieved is only 25%. In this case, the electrons absorb solar energy to jump from a bound state (called valence band) to a free state (called conduction band) to a free state (called conduction band). The incident sunray carried photon with energy, $E = hf$, where ‘$h$’ is a constant known as Planck’s constant and ‘$f$’ is the frequency of light. Electrons only use those photons/sunrays having more...
energy than wide energy gap (called forbidden gap) to jump from valence band to conduction band.

About half of the solar spectrum with the photons having lower energy pass right through the material and are not used in the production of electricity. The newly developed semiconductor material can capture these low-energy photons to produce electricity and hence increase the efficiency, according to www.technologyreview.com.

As shown in Figure 2 (a), the usual semiconductors possess two bands, namely, valence and conduction bands. But the new and more efficient semiconductors have three energy bands instead of the usual two. A third band is created below the conduction band, effectively splitting the energy gap into two smaller parts (Figure 2 [b]). The splitting up of conduction band was possible by introducing a few atoms of oxygen into a sinc–magnesium–teleurium alloy. Similar splitting is also possible by adding nitrogen to a semiconductor such as gallium–arsenide–phosphide to get multi-band semiconductor. The third band acts like a steppingstone for the electron. Thus, a low-energy photon may excite an electron to the intermediate band and then up to conduction band using another low-energy photon. A high-energy photon is represented by H in Figure 2 (a) whereas, two low-energy photons are represented by L1 and L2 in Figure 2 (b).

**Research by Barnett and Honsberg**

According to www.renewableenergyaccess.com, a consortium led by University of Delaware has achieved solar cell efficiency of 42.8% breaking the previous record of 40.7% attained in December 2006. The research was led by Allen Barnett and Christina Honsberg who direct the University’s High Performance Solar Power Programme. With a goal of 50% efficiency they have worked for 21 months before presentation. The previous best of 40.7% was achieved with a high concentration device that requires sophisticated tracking optics and features a concentrating lens the size of a table and more than 1 foot thick. In contrast, the consortium’s devices are potentially far thinner at less than 1 cm. The cell uses a novel lateral optical concentrating system. It splits the solar light into 3 different energy silos of high, medium, and low. Thus, the whole solar spectrum is used by the cell with various light sensitive materials.

**Solar cells thinner than a hair strand**

Scientists have developed thin solar cells that will power the nanoscale gadgetry of tomorrow. The cells are 20 000 times as thin as human air. Charles Leiber and colleagues at the Harvard University have devised this silicon nanowire that can convert sunlight into electrical energy. A single strand of such wire virtually invisible to the naked eye can crank out up to 200 billionth of a watt, that is, 200 picowatt. At nanoscale, this power is enough to provide a steady output of electricity to run ultra-low power electronics. It is so thin that it can be worn on or fitted inside the body. It is no doubt clean, highly efficient, and renewable.

**Future research**

With the introduction of a third band below the conduction band of the semiconductor, the problem is partly solved, but not over. Researchers are trying to introduce more and more intermediate levels to absorb the whole solar spectrum for its 100% conversion into electricity. Regarding the size, people are trying to make thinner and lighter solar cells in order to power the nano-gadgets in future. No doubt, the research in this field sounds promising. 🌞
A single fuel cell generates a tiny amount of DC (direct current) electricity. In practice, many fuel cells are usually assembled into a stack or cell to generate more power.

**Operation of fuel cells**

The purpose of a fuel cell is to produce an electrical current that can be directed outside the cell to do work, such as powering an electric motor or illuminating a light bulb or a city. Because of the way electricity behaves this current returns to the fuel cell, completing an electrical circuit. The chemical reactions that produce this current are the key to how a fuel cell works.

In general terms, hydrogen atoms enter a fuel cell at the anode
where a chemical reaction strips them of their electrons. The hydrogen atoms are now ‘ionized’, and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. If AC (alternating current) is needed, the DC output of the fuel cell must be routed through a conversion device called an inverter.

Oxygen enters the fuel cell at the cathode where it combines with electrons returning from the electrical circuit and hydrogen ions that have travelled through the electrolyte from the anode. In other cell types the oxygen picks up electrons and then travels through the electrolyte to the anode, where it combines with hydrogen ions. The electrolyte plays a key role. It must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction. Whether they combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

The type of fuel also depends on the electrolyte. Some cells need pure hydrogen, and therefore demand extra equipment such as a ‘reformer’ to purify the fuel. Other cells can tolerate some impurities, but might need higher temperatures to run efficiently. The type of electrolyte also dictates a cell’s operating temperature.

Important types of fuel cells

Alkali fuel cells operate on compressed hydrogen and oxygen. They generally use a solution of potassium hydroxide (chemically KOH) in water as their electrolyte. Cell output ranges from 300 W (watt) to 5 kW (kilowatt). Alkali cells were used in Apollo spacecraft to provide both electricity and drinking water. Efficiency is about 70% and operating temperature is 150 to 200 °C.

MCFCs (molten carbonate fuel cells) use high-temperature compounds of salt (like sodium or magnesium) carbonates (chemically, CO₃) as the electrolyte. Efficiency ranges from 60% to 80%, and operating temperature is about 650 °C (1200 degrees F). Units with output up to 2 MW have been constructed, and designs exist for units up to 100 MW. The high temperature limits damage from carbon monoxide ‘poisoning’ of the cell and waste heat can be recycled to make additional electricity.

PAFCs (phosphoric acid fuel cells) use phosphoric acid as the electrolyte. Efficiency ranges from 40% to 80%, and the operating temperature is between 150 to 200 °C (about 300 to 400 degrees F). Existing PAFCs have outputs up to 200 kW, and 11 MW units have been tested. PAFCs tolerate a carbon monoxide concentration of about 1.5%, which broadens the choice of fuels they can use. If gasoline is used, the sulphur must be removed. Platinum electrode-catalysts are needed, and internal parts must be able to withstand the corrosive acid.

There are numerous types of fuel cells that have been made. The most common are shown in Table 1. Each type uses different materials and operates at a different temperature.
Fuel cell stack

With a fuel cell, chemicals constantly flow into the cell so it never goes dead—as long as there is a flow of chemicals into the cell, the electricity flows out of the cell. Most fuel cells in use today use hydrogen and oxygen as the chemicals. The amount of power produced by a fuel cell depends upon several factors, such as fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell. Still, a single fuel cell produces enough electricity for only the smallest applications. Therefore, individual fuel cells are typically combined in series into a fuel stack.

Direct hydrogen fuel cells produce pure water as the only emission. This water is typically released as water vapour. Fuel cells release less water vapour than internal combustion engines producing the same amount of power.

Applications of fuel cells

There are many uses for fuel cells. They are put to use in the automobile industry. Fuel cells are powering buses, boats, trains, planes, scooters, forklifts, and even bicycles. There are fuel-cell-powered vending machines, vacuum cleaners, and highway road signs. Mini fuel cells for cellular phones, laptop computers, and portable electronics are on their way to the market. Hospitals, credit card centres, police stations, and banks are all using fuel cells to provide power to their facilities. Waste water treatment...
plants and landfills are using fuel cells to convert the methane gas they produce into electricity. Telecommunications companies are installing fuel cells at cell phone, radio, and 911 towers. The possibilities are endless.

**Stationary uses**

More than 2500 fuel cell systems have been installed all over the world—in hospitals, nursing homes, hotels, office buildings, schools, utility power plants—either connected to the electric grid to provide supplemental power and backup assurance for critical areas, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines.

Fuel cell power generation systems in operation today achieve 40% fuel-to-electricity efficiency utilizing hydrocarbon fuels. Since fuel cells operate silently, they reduce noise pollution as well as air pollution, and when the fuel cell is sited near the point of use, its waste heat can be captured for beneficial purposes ( cogeneration ). In large-scale building systems, these fuel cell cogeneration systems can reduce facility energy service costs by 20% to 40% over conventional energy service and increase efficiency to 80%.

**Telecommunications**

With the use of computers, the Internet, and communication networks steadily increasing, there comes a need for more reliable power than is available on the current electrical grid, and fuel cells have proven to be up to 99.999% ( five nines ) reliable. Fuel cells can replace batteries to provide power for 1 kW to 5 kW telecom sites without noise or emissions, and are durable, providing power in sites that are either hard to access or are subject to inclement weather. Such systems would be used to provide primary or backup power for telecom switch nodes, cell towers, and other electronic systems that would benefit from on-site, direct DC power supply.

**Landfills/waste water treatment plants/breweries**

Fuel cells currently operate at landfills and waste water treatment plants across the country, proving themselves as a valid technology for reducing emissions and generating power from the methane gas they produce.

**Transportation**

**Cars** All the major automobile manufacturers have a fuel cell vehicle either in development or in testing right now and several have begun leasing and testing in larger quantities. Automakers and experts speculate that the fuel cell vehicle will not be commercialized until at least 2010.

**Buses** Over the last four years, more than 50 fuel cell buses have been demonstrated in North and South America, Europe, Asia, and Australia. Fuel cells are highly efficient, so even if the hydrogen is produced from fossil fuels, fuel cell buses can reduce transit agencies’ CO2 emissions. And emissions are truly zero if the hydrogen is produced from renewable electricity, which greatly improves local air quality. Because the fuel cell system is so much quieter than a diesel engine, fuel cell buses significantly reduce noise pollution as well.

**Scooters** In spite of their small size, many scooters are pollution powerhouses. Gas-powered scooters, especially those with two-stroke engines, produce tailpipe emissions at a rate disproportionate to their small size. These two-stroke scooters produce almost as much particulate matter and significantly more hydrocarbons and carbon monoxide as a heavy diesel truck. Fuel cell scooters running on hydrogen will eliminate emissions – in India and Asia where many of the population use them – which is a great application for fuel cells.

**Trains** Fuel cells are being developed for mining locomotives since they produce no emissions. An international consortium is developing the world’s largest fuel cell vehicle, a 109 metric tonne, and 1 MW
locomotive for military and commercial railway applications.

**Planes** Fuel cells are an attractive option for aviation since they produce zero or low emissions and barely make any noise. The military is especially interested in this application because of the low noise, low thermal signature, and ability to attain high altitude. Companies like Boeing are heavily involved in developing a fuel cell plane.

**Portable power** Fuel cells can provide power where no electric grid is available, and they are quiet, so using one instead of a loud, polluting generator at a campsite would not only save emissions, but also won’t disturb nature. Portable fuel cells are also being used in emergency backup power situations and military applications. They are lighter than batteries and last a lot longer, especially important to soldiers carrying heavy equipment in the field.

**Consumer electronics** Fuel cells will change the telecommuting world, powering cellular phones, laptops, and palm pilots hours longer than batteries. Companies have already demonstrated fuel cells that can power cell phones for 30 days without recharging as aksı laptops for 20 hours. Other applications for micro fuel cells include pagers, video recorders, portable power tools, and low-power remote devices such as hearing aids, smoke detectors, burglar alarms, hotel locks, and meter readers. These miniature fuel cells generally run on methanol, an inexpensive wood alcohol also used in windshield wiper fluid.

**Temperament vs temperature**

A fuel cell creates electricity, which is a form of external energy, directly from the energy in chemical fuels without an intermediate conversion into thermal energy. When a hydrogen atom bonds to an oxygen molecule, not as much total energy is required in the newly formed water molecule as in the separate hydrogen and oxygen molecules. A certain amount of energy can be released. When the hydrogen–oxygen bonding occurs, the excess energy under ideal conditions can be released in a single package for each newly created bond. In other words, the excess energy is not dribbled out in multiple randomly sized amounts of energy. This single package is called a virtual photon and is illustrated in Figure 6. Photons are not marble-like objects but rather tiny localized vibrations of energy that travel through space. They cannot be detected and so are called virtual. They are referred to as a package because this energy does not split up while travelling to its destination and neither do the two packages join together. This virtual photon can under ideal conditions be transferred directly to other chemical system through, for example close contact, without being spilled to the surroundings. Such a transfer of energy can be equated to the transfer of grains of sugar from one tank to another through a pipe. No sugar would be spilled to the outside environment. Real photons on the other hand are packages of energy that have broken away as separate entities. It is as if the pipe between the tanks of sugar is missing and the sugar spills on the floor. Light is composed of such real photons.

We could use joules or BTU (British thermal unit) as a measure of the amount of energy that each
real or virtual photon contains but it would be a very small fraction of a joule indeed. It is simpler to use a scale that merely represents the amount. We already use the scale called temperature to measure thermal energy. This represents the average collision energy between molecules. Real photons are created during these collisions, which are equal in energy to each collision as shown in above figure.

**Fuel cells vs heat engines**

The virtual photons that are transferred during the chemical reactions in a fuel cell have a very high temperament somewhere between 3500 K and 25 000 K. It is this extremely high temperament that allows the fuel cell to be theoretically so efficient. The amount of external energy that can be extracted from all types of internal energy is called the Carnot ratio. The Carnot ratio for virtual photons of 3500 K is however about 92% under normal conditions. This is much higher than for real photons in a gas turbine with a mean temperament of 1000 K and a Carnot ratio of 72%. The Carnot ratio is based on a particular ambient temperature of the surroundings. The Carnot ratio only relates to the absolute temperature scale where 0 °C = 273.15 K.

Heat engines such as gas turbines are considered to be inferior to fuel cells because they must convert the high-temperament chemical energy into low-temperature thermal energy first. A gas turbine cannot operate at the temperament of the chemical energy without melting. As can be seen from the graph when the temperament is reduced, the Carnot ratio is reduced. A large percentage of the Helmholtz energy that was available at the higher temperament is lost; it is converted into useless bound energy. The fuel cell does get hot but only because of the resistance and inefficiencies during the ion and electron flow during the production of electricity. Thus, many types of fuel cells can run efficiently at low temperatures while at the same time converting very high temperament energy.

Present highly advanced gas turbines do not achieve a mean temperature of more than 1150 K or 877 °C. In spite of these gas turbines (with addition of heat exchanging or steam turbines) can be highly efficient in the large sizes and produce little pollution. The latest is 57% efficient in converting fuel to electricity. In the future, ceramic gas turbines could reach 70% efficiency. This would result in a higher efficiency than what the fuel cell can achieve by itself. There is even some possibility of using energy transformers in the combustion process to increase the efficiency to 80%. In the future, medium and large power plants using SOFC (solid oxide fuel cell) will be fuel cell gas turbines combined cycles. In this way, the benefits of each type of conversion technology are utilized.

**Fuel cell vehicles**

Significant research and development is being carried out by several countries to reduce cost and improve performance. It is also found that effective and efficient ways are being invented by scientists to produce and store hydrogen and other fuels.

Automakers, fuel cell developers, component suppliers, government agencies, and others are working hard to accelerate the introduction of FCVs (fuel cell vehicles). Partnerships such as the DOE-led freedom car initiative and the California fuel cell partnership have been formed to encourage private companies and
government agencies to move these vehicles toward commercialization. The advantages of FCVs are as follows.

- Cheaper to operate
- Pollution-free
- Competitively priced
- Free from imported oil

Advantages of fuel cells

- Fuel cells create electricity chemically rather than by combustion, which subject to thermodynamics law limits a conventional power plant.
- It is efficient enough to widely replace traditional ways of hydroelectric or even nuclear plants.
- Fuel cells are catalytic and relatively stable.
- Fuel cells generate electric power efficiently without pollution.
- This emerging technology has the potential to significantly reduce energy use and harmful emissions.

Conclusion

Fuel cells are an important enabling technology for the hydrogen economy and have the potential to revolutionize the way we power our nation, offering cleaner, more-efficient alternatives to the combustion of gasoline and other fossil fuels. Fuel cells have the potential to replace the internal combustion engine in vehicles and provide power in stationary and portable power applications because they are energy-efficient, clean, and fuel-flexible. Overall saying one unit of energy saving is equal to twice of energy generated.

Inviting articles for Akshay Urja

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

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

Editor, Akshay Urja
Ministry of New and Renewable Energy, Block – 14, CGO Complex, Lodhi Road, New Delhi – 110 003
Tel. +91 11 2436 3035 • Fax +91 11 2436 3035 • E-mail akshayurja@nic.in

www.mnre.gov.in
From darkness to light

Village Dageriya

Sagar M Agravat, S Mohana,* Naveen Kumar, Tilak Chavda
Scientists, Sardar Patel Renewable Energy Research Institute, Vallabh Vidyanagar, Gujarat

The conventional grid-based electricity has not been able to reach many remote rural areas and small settlements. The Planning Commission has identified over 80,000 villages in the country, which are yet to be electrified. Of these, about 18,000 villages are unlikely to be ever electrified through grid-based system due to remoteness or low energy demand. The SEBs (state electricity boards) often consider such locations financially not viable due to the high cost of laying transmission lines coupled with low power demand resulting in low returns. In this scenario, SPV (solar photovoltaic) power generation system has emerged as the most feasible and economical solution for electrification in such locations. Electrification through SPV system is also favoured to wind power, which is restricted to coastal areas and few other pockets. A good amount of solar energy is available at almost all places in the country for most of the days in a year. Moreover, the economic viability of a stand-alone PV system in comparison to the most likely conventional alternative system, that is, a diesel-powered system, analysed for energy demand through sensitivity analysis, shows that the PV-powered systems are the lowest cost option at a daily energy demand of up to 15 kWh, even under unfavourable economic conditions. When the economic parameters are more favourable, PV-powered systems are competitive up to 68 kWh/day. With reducing cost of PV systems and continuous price hikes in fossil fuels, chances are on horizon to meet even higher energy demands.

The village

Prior to designing the system, feasibility of installing such systems in adverse geographic conditions, a reputed local NGO to help people as immediate source of guidance, and so on were taken into account. Several unelectrified villages of Madhya Pradesh and Gujarat were surveyed. From the data, village Dageriya that falls in Dahod District in Gujarat was found suitable for such work. Inter-house distances vary from 50 feet to 300 feet in the village and it has a population of 1400, mostly comprising the Bhil community. The village has highly scattered clusters of houses with well-demarcated un-electrified segments, which has been developed into sustainable self-managed stand-alone SPV power units. The village owns about 200 animals in the cluster comprising of cows, buffaloes, bullocks, calves, and goats/sheep. Tribal people of the area depend on agriculture or employment as labourers for livelihood. The village has one primary school, two anganwadis, and a small milk cooperative society. Preliminary discussions with the

*Contact author
villagers have been found optimistic and receptive, and their response to the work was very encouraging.

A reputed NGO called Sri N M Sadguru Water and Development Foundation is working for the last several years in this area. The Sadguru foundation is a professionally managed NGO with vast experience in rural development activities. It has been engaged in massive watershed management programmes, biogas plant installation, sustainable development activities for women, manpower training at various levels, and so on.

The power network

The power network in the village was divided into four individual units or power packs. These units were carefully designed considering geography of the cluster and its power requirements. It comprised a suitable number of SPV panels, battery bank, inverters, and other monitoring and controlling devices, poles and cable, and so on. Each household was provided with two CFLs (compact fluorescent lamps) of 11 Wh, with estimated power consumption of 110 Wh per house at an average usage of 5 hours a day. Apart from this, 12 houses, which were distantly located, were provided with individual home lighting systems. Taking the power requirement of the village into account, a 3 kW system was suggested. The schematic plan below will further help in understanding the power distribution in the village.
Empowering the tribal people with the management responsibility of a modern power sharing system is a huge task. For those who had been used to the lifestyle of getting some subsidized benefits from the government, to take up the responsibility of sharing and managing a modern benefit like SPV power system and more importantly make it sustainable is a great challenge in their life. In contrast, people of Dageriya village, have organized themselves into a *Saur Urja Samiti* for coordinating with SPRERI and Sadguru Foundation for proper operation and maintenance of the system. The Samiti has successfully resolved key issues like undertaking the responsibilities of system management and maintenance. It has deputed a cluster coordinator in each cluster to take care of the costly equipment like inverters, battery banks, and to look after proper functioning of the system. One operator is also appointed from the village itself for the maintenance of the whole system, for data collection and to keep in touch with the concerned person at SPRERI. He is paid a monthly amount of Rs 500 towards his service. To meet such operational and other maintenance expenditures the Samiti collects Rs 30 per household per month as electricity charges, amounting to about Rs 20 000 per year. This fund is insufficient to meet the replacement cost of components like batteries or inverters. Hence, the Samiti is trying to raise funds through other means such as providing the community hall on rent for organizing events like marriage ceremonies and public meetings.
Life after electricity

The stand-alone SPV system at Dageriya has not only brought some definite changes in the lifestyle of the villagers but has also widened their vision about the village and their role in its development. This is evident from their overwhelming response. Though it is a new experience for the residents of Dageriya, people are warmly welcoming the new air of development in the village.

Ms Seetaben Dangi (Cluster I), a resident of Dageriya, was impressed by the impact of the SPV light on the education of her children. According to her, the children are motivated to study till late night due to the new lighting system. It was a great change for them, from studying under the dull kerosene lamp with the smell of the fumes to the clean and bright solar light.

Motibhai Bhuria (Cluster II) felt that the solar light had changed the overall environment in the house during the night. In early morning during the winter season, it helped in attending the cattle and milking.

Moreover, Sri Mukheshbhai Dangi (Cluster I), one of the enthusiastic youngsters of the village, was inspired to start a small shop in his house. He runs this shop till late night and supplies daily requirements to the villagers. Subsequently, he has installed a TATA telephone outlet in his shop. It has not only helped in communicating with the people outside the village, but has also put the village on the globe. It has helped improve his earnings and also eased the monitoring post project situation considerably.

At last...

The stand-alone SPV project at Dageria has brought some definite changes in the life style of the villagers and has helped in improving their economics to certain extent. It is evident that providing light alone is not sufficient to raise the living standards of the rural people in such areas. Their economic status also needs to be strengthened through intense income generation activities, as the root cause of rural backwardness is energy scarcity. Hence, wherever found feasible, installation of hybrid energy system based on agro wastes and solar energy should be considered.

Moreover, the concept of users owning the responsibility for managing both aspects of the system that is, generation and marketing is totally new for the simple village users. Hence, all such work requires adequate external monitoring, and appropriate guidance and support, without which many a times the system can fail to meet the planned objectives. In the light of above facts, it is advisable to all future aspirants that a thorough study of the technical, economical, and social aspects of a typical decentralized village should be made. This will yield very useful outcome for designing and installing a suitable system. The data and experience generated out of such an attempt with proper long-term planning could become the basis for future activities. ☀️
In our country, new and renewable energy technology based programmes have been expanding continuously. The awareness about renewable energy has increased in urban and rural areas. Despite socio-economic, infrastructural, and technological constraints, the importance of renewable energy has spread quite widely in rural areas. The socio-economic barriers to adoption of renewable energy systems are low economic level, adherence to traditions, and lack of proper awareness on the potential of renewable energy.

The limited outlets of renewable energy devices in the vicinity of villages, high cost of devices/systems, recurrence of breakdowns in the systems, and lack of proper after-sale repair and maintenance facilities are the factors that have made adoption of renewable energy systems/devices difficult, particularly in rural areas.

To overcome the constraints on the progress of rural energy programmes and to provide better services in rural areas, there is a need for creation of opportunities for local employment in the new and renewable energy sector. This would also give thrust to the rural energy movement in the country. After assessing the energy need of the rural people and a suitable technology for the same, an appropriate methodology should be evolved for more involvement of local people and entrepreneurs. This would not only fulfill the minimum energy needs of rural masses for cooking, lighting, and heating, but can also provide employment at the local level.

There could be some opportunities for employment of local people in rural areas in the new and renewable energy sector.

- Repair and maintenance of the systems like solar photovoltaic lighting devices, solar thermal systems, biogas plants, improved/smokeless wood stoves and gasifiers, and so on.
- Construction of improved/smokeless wood stoves and biogas plants
- Small shops or sale outlets for renewable energy systems and their accessories could be opened.
- Booking centres and information kiosks for renewable energy devices could be set up.

A large number of renewable energy systems have been installed in rural areas thanks to the committed efforts by the Ministry of New and Renewable Energy and its state nodal agencies. The most popular devices in rural areas are solar home lights, solar streetlights, solar lanterns, solar pumps, biogas plants, improved / smokeless wood stoves, solar cookers, and so on. Though these systems are reliable, many a times,
breakdowns occur and repair and maintenance is required. At the village level, these facilities are seldom available, and thus, even for repair of a minor fault in the devices, one has to approach the nearby district headquarter.

The recurrence of breakdowns or unavailability of the repair and maintenance facility at the village level results in poor response for adopting the systems. It also creates a wrong impression about the programme. To overcome this problem, it seems appropriate to train unemployed youths or self employed workers, having basic knowledge of science or electronics, for repair and maintenance of systems. After proper training they can provide R&M facility for the renewable energy devices and earn money in lieu of their services.

The construction of improved chulhas and biogas plants need skilled and semi-skilled mason. Interested people could also take up this job after getting the training for construction of these devices and earn their living, in the rural areas. For easy availability of new and renewable energy devices and their accessories including CFLs and batteries, shops or sale outlets are needed in rural areas. By venturing into this area, one can provide the renewable energy devices.

Endeavours have been made by the ministry and state nodal agencies to develop renewable energy shops in every district of the country. The Akshay Urja shops in the private sectors are the results of these endeavours. Not only are the renewable energy systems or gadgets available in these shops, but these shops also provide the repair maintenance facilities. Renewable energy shops also provide some opportunity for mechanics and counter attendants.

The information kiosks and booking centres for renewable energy devices in the rural areas could be another sector for self-employment. These centres may work as a hub for providing information about renewable energy or other developmental programmes of the government to the people of rural areas. For opening an information kiosk, only online facilities through computer systems will be needed. It is certain that there is a lot of scope and opportunity for employment in rural areas through renewable energy programmes. As the renewable energy programmes pick up pace, new avenues will open up, for the youth of rural areas. This will result in livelihood opportunities for them and a bright future for renewable energy sources as well.
Introduction

In the present day energy scenario, many efforts have come into focus, for meeting the ever-increasing energy demand, with a view to develop new generation technologies. The major goals of these approaches are: to have reduced environmental damages, conservation of energy and exhaustible sources, and increased safety. In this context, during the past few years, renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques. Majority of the population in our country resides in the rural areas and a large number of the villages are still not served by the national grid due to the cost involved for laying of the transmission line.

Conventional sources of energy have a long generation period, draw heavily on exhaustible deposits, and adversely affect ecological balance. New and renewable sources of energy are not only economically viable but also do not suffer from any of the above disadvantages.

Developing new generation technologies and renewable energy sources

There are many reasons for developing new generation technologies.

- Ever-increasing energy demand
- Reduced environmental damages and increased safety
- Conversion of energy and inexhaustible sources
- Greater attention to developing efficient energy conversion and utilization techniques
- The realization of the enormous need to electrify and energize remote, rural areas
- They are adequately available and have lesser impact on the environment and ecology
- They are ideally suited for decentralized variety of applications
- The future of fossil fuels is limited time, that is, it is estimated that it could about 70 to 100 years.
- Renewable energy is well-suited for inaccessible areas and hilly terrain

Hybrid systems (wind–solar)

A hybrid plant combines wind, solar, and hybrid power conditioning unit with a battery (Figure 1) to supply electricity to remote areas. Locations that relied on conventional fuel can now take advantage of natural energy.

A stand-alone wind system with a SPV (solar photovoltaic system) is the best hybrid combination of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. They also complement each other during lean periods, for example, additional

Individual and community power generation

A look at wind and hybrid power systems

Dr H Nagana Gouda
Technical Officer, Karnataka Renewable Energy Development Ltd, Bangalore
Energy production through wind during monsoon months compensates the less output generated by solar. Similarly, during winter when the wind is dull, SPV takes over. The ground space required for wind generator is hardly 4 x 4 square feet. It can be easily erected on towers of 9 metres up to 18 metres with foldover mechanism on the ground. It can also be mounted on roofs of tall buildings. The low inertia comes in handy to start generating wind speeds as low as 2.5 metres per second. The energy generated can be easily combined with that of SPV through an integrated controller, which will ensure continuity of energy transfer into the battery bank system. This DC stored energy can be converted by power conditioning unit to AC single-phase 230V/50Hz—power that can be used for lighting load.

**Solar and solar photovoltaic modules**

Solar energy is a very large, inexhaustible source. The power from the sun intercepted by the earth is approximately $2.9 \times 10^{15}$ MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy source. Thus, in principal, solar energy could supply all the present and future energy needs of the world as a continuous basis. This makes it one of the most promising of the unconventional energy sources.

The solar modules generate DC electricity whenever sunlight falls on solar cells. The solar modules should be tilted at an optimum angle for that particular location, face due south, and should not be shaded at any time of the day.

**Advantages/disadvantages of photovoltaic systems**

**Advantages**

- Direct room temperature conversion of light to electricity through simple solid-state devices
- Absence of moving parts
- Ability to function unattended for long periods as evidence in space program
- Power levels: voltage/current can be achieved by more integration
- Maintenance cost is low, as they are easy to operate
- They do not create pollution
- They have a long effective life
- They consume no fuel to operate, as the sun’s energy is free
- Rapid response in output to input radiation
- Wider power handling capabilities

**Disadvantages**

- The solar radian flux availability is a low value: 1 kW / m² for technological utilization
- Large collecting area is required and the cost is more
- Its availability varies with time
- In many applications, energy storage is required because of insolation at night
- It has relatively poor conversion efficiency

**Aero wind generator**

Wind energy is a clean, renewable energy source, cheaper to maintain, saves fuel, and can give decentralized energy all through the day. This is one of the main components in this system and converts kinetic energy of wind into electrical energy in the wind into mechanical energy. An electric generator is coupled to the propeller shaft directly. This propeller in turn rotates the rotor of the electric generator and generates DC electricity. The output from the wind generator varies as per the wind speed. Wind electricity for decentralized system or hybrid generation of electricity using other energy sources as complementary to wind energy has now been given some attention and this could be suitable in low wind regimes for localized small off-grid
systems or battery charging for low wind speed. Wind pumps could also be a viable option. This needs strengthening of necessary data and manpower base, setting up some more demonstration plants at appropriate locations, and carrying out research and studies for improvements in technology. The energy generated can be easily combined with that of SPV through an integrated controller, which will ensure continuity of energy transfer into battery bank system. This DC stored energy can be converted by power conditioning unit to AC single-phase 230v/50 Hz, power which can be used for lighting load.

**Features of aero wind generator**
- 20 years’ equipment life
- Microprocessor-based smart internal regulator with peak power tracking safety protection electronics controls voltage and rotor RPM.
- Maintenance-free: only two moving parts, exclusive auto-brake feature that slows the system to a silent spin when the batteries are charged thus extending bearing life and reducing noise.
- Sophisticated internal charge controller: externally adjustable for any type of battery.
- Low cost, low maintenance cost, no fuel cost
- No pollution, easy installation
- Designed to be used in combination with PV modules to balance system energy output during times of seasonal fluctuations.

**Advantages/salient features of hybrid systems**
- Eliminate expensive mains cable installation costs
- Eliminate any associated electricity bills
- Increase public safety aids by providing a safe working environment in areas where mains power is difficult to access
- Fully automatic operation; easy to operate and maintain
- High quality construction and components
- Designed for easy servicing and maintenance where required
- Most eco-friendly and clean source of power
- No pollution and no recurring fuel costs
- Highly reliable and consistent power supply. Very good quality power output with steady voltage and frequency
- Long life span for SPV modules and modular design
- Simple installation
- Very few moving parts: negligible maintenance required
- Lower total system cost, contribution of solar and cost-effective electric power for remote application. Wind is beneficial even on low-wind sites and smoothens out seasonal weather fluctuations
- Environmental pollution is controlled thus improving health
- Laying of expensive grid line, and transmission and distribution losses, can be avoided
- Can generate DC power as long as sun and wind are available

**Major components of a hybrid system**

**Hybrid power-conditioning unit**

A hybrid power-conditioning unit is used to combine SPV array and wind generator. This unit prevents the overcharging and the deep discharging of the battery bank. It is the brain of the whole set up. When batteries are fully charged then it stops the further charging of the batteries and when the batteries are deep discharged then it disconnects the load and allows the battery to charge. The output from batteries is in DC form. To supply power to loads such as CFLs (compact fluorescent lamps), street lights, and television, this DC power needs to be converted to AC. Power conditioning is an electronic device in which an in-built inverter, converts DC power to AC with the help of IGBTs. The advantage of using AC is that we can use energy-efficient lights such as CFLs (for example, 11-W CFL gives same lumen output as that of 60-W ordinary bulb). The overall system size can be optimized, thereby saving in the initial higher investments.

**Battery**

Once the power output from solar and wind is converted to DC, it is supplied to batteries and the
batteries get charged. Depending upon the load requirement and the number of hours of operation of loads the adequate battery size is calculated.

Applications of hybrid systems
- Ideal for cell phone recipient stations
- Farm houses, guesthouses, hospitals, hotels, laboratories, primary health care centres, police communications centres, literacy centres, tribal hostels, and R&D centres
- Remote and rural village electrification
- Residential colonies and apartments for general lighting
- Street lighting
- Transmissions and communication tower and many more applications.
- High output, making it ideal for virtually any remote battery charging application

MNRE guidelines
The rated capacity of individual aero generator unit covered under the MNRE programme will be to a maximum of 30 kW.
- Stand-alone system based on combination of various renewable energy sources, that is, wind, solar, and biomass
- Warranty for a minimum of 2 years on the entire system from the date of installation of the system.
- SPV modules used in the hybrid system will be warranted for a period of at least 10 years from the date of installation of the system.
- The selected site should be free from any obstacles (for example, tall trees, high buildings, electricity transmission lines, and so on) within the radius of about 100 metres.
- Installation of an aero generator should be preferred for a site, which has the annual average wind speed of 4.17 metres/second or above.
- Aero generator of capacity more than 500 W should not be installed on the roof of a building.
- The minimum height of the tower should be 18 m from the ground level.

Energy generation details
- The energy generated from the wind aero generator is considered 1 kwh/day
- The energy generated from the solar module by considering a working of 6 hours/day
  - For 75 W × 6 hours = 450 Whours and for 150 W × 6 hours = 900 Whours
- Energy generation Hybrid system: 550 W = 400 W wind + 150 W solar; Power generated (kilowatt-hour per day): 1.9; Power generated (kilowatt-hour per month): 57; Power generated (kilowatt-hour per annum): 684.

Conclusion
- Stand-alone wind with SPV is known as the best hybrid combination of all renewable energy systems and is suitable for most of the applications taking care of seasonal changes.
- Hybrid wind and solar systems provide more consistent year-round performance and reduce the need for back-up generation.
- The major advantage of solar–wind hybrid system is that when solar and wind power production are used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced, as there is less reliance on one method of power production.

### Daily load consumption: for domestic applications

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<tr>
<th>Connected load details</th>
<th>Total load (watt)</th>
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<tbody>
<tr>
<td>Nos</td>
<td>No. of hours</td>
</tr>
<tr>
<td>CFL - 11 W</td>
<td>8</td>
</tr>
<tr>
<td>Radio/tape recorder - 50 W</td>
<td>1</td>
</tr>
<tr>
<td>TV - 80W</td>
<td>1</td>
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<tr>
<td>Ceiling fan/table fan - 40 W</td>
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</tr>
<tr>
<td><strong>TOTAL</strong></td>
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### Daily load consumption: for community street light applications

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<tr>
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<td>CFL- 18 W</td>
<td>10</td>
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### Sizing of equipment

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</thead>
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<td>400</td>
</tr>
<tr>
<td>Solar PV module</td>
<td>W</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>12 - V battery</td>
<td>Ah</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>Solar PV module: charger</td>
<td>A</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Hybrid power conditioning: (inverter and charge controller systems)</td>
<td>VA</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>
The DISCOMs are permitted to purchase wind power at the rate of Rs 3.10/kWh for a period of 10 years, with the consent of the Electricity Regulatory Commission. In case any eligible developer offers less than this tariff, he will be given preference for allotment of government land.

- The government land will be allotted at market value. This land will be given in ‘advance possession’ to enable developers to execute the project.
- Each eligible developer will be allocated available government land to harness up to a maximum of 200 Mw of wind power initially. After commissioning of 100-MW-capacity wind farms in the first stage, the government may lease land for another 100-MW-capacity wind farms.
- The power purchase agreements will be for a period of 20 years.
- The wheeling arrangement for captive use or sale to third parties will be as per the Open Access Regulations approved by the commission from time to time. The third party sale will be permitted only to HT-1 category consumers. The concessional wheeling and transmission charges for captive use or third party sale may be in kind at 5% of energy delivered into the grid. This includes transmission and distribution losses, subject to the approval of the regulatory commission.
- Banking of energy is not allowed. If the developer fails to consume the power during the month, it would be treated as sold to respective DISCOMs and the tariff equivalent to 75% of Rs 3.10/unit or 75% of the lowest tariff resulting from the bidding process under this policy, whichever is lower will be paid, subject to the approval of the regulatory commission.
- The eligible developers who opt for sale of energy to DISCOMs shall share carbon credits with DISCOMs. Ten per cent of the CDM benefit shall be passed on to the distribution companies.
- NEDCAP is the nodal agency for the promotion of wind power projects and would approve projects up to 20-MW capacity.

For more details, visit <www.nedcap.org>
Many renewable energy technologies have matured over the last decade and moved from being a passion for the dedicated few to a major economic sector attracting large industrial companies and financial institutions. Renewable energy technologies such as wind power and solar photovoltaic devices have achieved major cost reductions over the last decade, and are expected to continue to do so. Renewable Energy in the Global Context by Dr P C Maithani provides an analysis of technology development trends at the global level, future R&D directions for efficiency improvement and cost reduction, and also the major challenges ahead. The book provides information on the global energy scenario including energy demand and supply, policies to promote renewable energy in the developed countries and developing countries like India and China, financing structures, and the role played by the World Bank and the Global Environment Facility.

Detailed status and future projections of matured renewable energy technologies such as solar photovoltaics, solar thermal energy systems, wind energy, and bio-energy have been covered. Emerging and future renewable energy technologies have also been covered in great detail in the book. The chapters provide detailed information on various enabling mechanisms and laws enacted in the USA, European Union countries, Japan, China, and India to promote renewable energy technologies in meeting the energy requirements in centralized and decentralized modes. The importance of renewable energy policies in countries like USA has also been emphasized in the book.

In India, non-commercial energy also plays a very important role in meeting the energy requirements of both the urban and rural poor. The book also brings out the various energy projects and the policies required to meet the energy requirements up to 2031/32. The main recommendations of the Integrated Energy Policy document have also been taken note of, particularly with regard to new and renewable energy sources such as solar, wind, small hydro, biomass, biofuels, biogas, hydrogen, ocean energy, and geothermal energy. Implications of the National Electricity Policy and Tariff Policy on the growth of electricity production from renewable energy sources have also been covered.

Finally, the book defines future directions for carrying out research and development in different sectors such as photovoltaics, wind, biomass, biofuels, and hydrogen. Policy directions for matured renewable energy systems have also been clearly brought out in the book. This book is a must read for all stakeholders dealing with energy planning and policy. It can also be used as a reference book for initiating research and development activities in the area of renewable energy systems and devices.
Green buildings are being seen as an emerging business opportunity in India. The construction industry is estimated to contribute about 10% of the GDP (gross domestic product). India Green Building Council (which is part of CI–Godrej Green Building Council) has undertaken the initiative of promoting the green building concept in the country. Today, a variety of green building projects are coming up in the country—residential complexes, exhibition centres, hospitals, educational institutions, laboratories, IT parks, airports, government buildings, and corporate offices. Many of these may use technically well-proven solar technologies in different ways. One of these is the BIPV (building integrated photovoltaic) application, which is well suited to such ambiances. By 2010, about $100 million would be generated through the use of solar PV in green buildings in India. Of late, the use of both solar PV and solar thermal systems in the urban buildings is gaining momentum. A common practice is to connect solar PV system to the grid.

PV grid system

The solar PV technology involves direct conversion of available solar energy into some useful electrical energy. It can realistically contribute to greater global sustainability in the medium to long term. PV is becoming more and more accessible both in urban and rural areas due to declining costs. One common PV application today is to connect a PV system with the conventional grid. This is called grid-connected PV. A grid-connected system works in parallel with the conventional grid network, and offers the following advantages.

- Supplies energy to loads at the point of generation
- Exports power when there is excess energy
- Allows the import of energy if there is a shortfall

Recently, there has been a worldwide focus on the architectural integration of PV modules in the building envelope. Such type of modules can effectively replace conventional building materials like roof tiles, shingles, facades, and normal glazing. PV building materials can be manufactured in a manner that they are quite similar to the conventional building products, blending well with the surrounding environment. Integration of PV materials means that the costs of the replaced building products can be

India’s first solar housing complex
Rabi Rashmi Abasan
S P Gon Chaudhuri

Building integrated photovoltaics
thereby improving the economics of the project. Such PV systems are often termed as BIPV (building integrated photovoltaics). Today, there are a large number of houses with such built-in features in countries like Germany, Spain, Japan, and California. The regulators also provide clear tariff orders for construction of such houses. This mainly relates to export of surplus solar power to the grid against a tariff structure fixed for the purpose.

The Indian scenario

West Bengal is the first state in India to come up with a well-formulated tariff order for promoting the use of small-capacity BIPV systems. The SERC (state electricity regulatory commission) of the said state issued such an order on 5 March 2008, which had many salient features.

- Rooftop solar PV systems with 2-kWp capacity can be put up for delivering power into the distribution system of a licensee.
- Institutional consumers comprising government hospitals, health centres, schools (including aided ones), academic institutions, offices, and organizations besides any housing complex already promoted for the purpose by the government or any government agency (includes local bodies like municipalities, panchayats, and cooperative societies) for development of renewable sources are eligible for the specially announced tariff structure.
- Such injection from rooftop solar PV sources of the above-mentioned consumer(s) shall not be more than 90% of the consumption from the licensee's supply by the above-mentioned consumer(s) in a financial year. It shall be settled on net energy basis at the end of each financial year.
- Any excess energy injected by the above-mentioned consumer(s) from the rooftop solar PV sources more than the 90% of the consumption of energy by that consumer(s) from the licensee's supply in each billing period shall be carried over to the next billing period within that financial year.
- Slab tariff, as per tariff order, shall be applicable for the net energy supplied by the licensee in a billing period if the supplied energy by the licensee is more than the injected energy by the rooftop solar PV sources of the consumer(s). It will be so after taking into account the quantum of energy, if any, carried forward from earlier billing period(s) of that financial year.
- If in a billing period the supplied energy by the licensee is less than or equal to energy injected by the rooftop solar PV sources of the consumer(s) after adding the cumulative carried over injected energy from previous billing period(s) of that financial year the billed amount for energy will be nil for that billing period(s).
- At the end of the financial year, if the total energy supplied by the licensee to the consumer(s) for that financial year is found to be less than the energy injected by the rooftop solar PV sources of that consumer(s) for that financial year, the licensee shall not pay any charge to the consumer(s) for that net energy, in excess of 90% of consumption of that consumer(s) from the licensee's supply in that financial year and the same shall be treated as unwanted/inadvertent injunction.
- At the beginning of each financial year, the cumulative carried over injected energy will be reset to zero. Payment in a billing period by the consumer(s) (owning roof-top solar PV sources) to the licensee shall be
produce his own power for domestic use and feed any surplus power into the local grid. He can also draw power from the grid as and when needed. The utility will pay the house owner and vice-versa on net monthly metering.

Solar systems at the complex

There are 25 independent apartments in the complex, each of which has been provided with a rooftop solar PV system of 2-kWp capacity. Sixteen single crystal silicon modules of 125 Wp have been put up in each case. These will produce power during the day and any surplus power that is not consumed by the individual household will be supplied to the local grid. In addition, each household has a 100-litre solar water heating system. Seventeen solar streetlights have been installed to light up the entire area. The streetlights are unique in the sense that batteries are placed on the top with a proper nicely designed colourful fabricated pole. The community centre has a solar swimming pool and an 8-kW BIPV in the southern side of the building.

This specially designed complex not only uses active solar

The birth of Rabi Rashmi Abasan

Rabi Rashmi Abasan (meaning a solar housing complex), India’s first solar complex came into being mainly due to the above-mentioned tariff order. This complex conceived by WBREDA (West Bengal Renewable Energy Development Agency) is located at New Town Kolkata and is spread over an area of 1.76 acres. Each house owner within the complex will produce his own power for domestic use and feed any surplus power into the local grid. He can also draw power from the grid as and when needed. The utility will pay the house owner and vice-versa on net monthly metering.

Guided by the provisions of the regulations made by the Commission under section 50 of the Act.

- For each billing period in a financial year the licensee shall show the quantum of injected energy from rooftop solar PV sources in the billing period, supplied energy from its source in the billing period, net billed energy for payment by the consumer(s) for that billing period, and net carried over energy to the next billing period separately.

- Any delay in payment shall attract surcharge at the agreed rate. The MoU/PPA to be signed between the licensee and developer of rooftop solar PV sources shall include necessary terms and conditions of meter reading, billing, payment, payment of security arrangements, rate of delayed payment surcharge, and so on.
systems but also incorporates solar passive features.

Passive solar components

About 25% of the total commercial energy in India is spent on lighting, air-conditioning and ventilation, and so on. The Rabi Rashmi complex incorporates several features specific to solar passive architecture. This keeps houses cool during summer months, and also reduces the daily peak demand. A unique feature is the use of solar chimney. A small lily pool in the southern side with proper ducting arrangements has been kept in the building for smooth flow of hot air in and out of the building. This also ensures proper ventilation inside the room. Natural lighting has been arranged in all rooms as far as possible.

Insulated walls and windows

Thermal comfort of the buildings is enhanced through insulation on the south-, west-, and east-side walls of each individual unit in the housing complex. The insulation material used here is extruded polystyrene block of 50-mm thickness inside walls that are 250 mm thick. Double-glazed windows have also been provided in the openings on such walls to exercise radiant energy control in the buildings. Double-glazing has been done maintaining complete vacuum inside.

Intelligent water supply system

The housing complex has also been provided with energy-efficient hydro pneumatic pumping arrangement to supply pressurized water. This intelligent system design based on auto-start/auto-off mode and installed centrally is expected to match the end user requirements fully. The underlying idea is to do away with the conventional individual household pumping arrangement and thus save some energy in the process. The system comprises a pump-motor set, micro processor/controller-based control unit, pressure gauge, pressure transmitter, pressure tank, and different control valves. There is also an emergency tank for each house.

Clean ride: electric vehicle

Two battery-powered vehicles will be available to the residents to commute within the surrounding areas. The basic idea is to showcase the green spirit of the complex in every possible manner.

Present status of the Rabi Rashmi project

This aesthetically done solar complex is expected to be completed by June 2008. It would be handed over to the residents after a formal inauguration. The solar systems will be maintained by the system supplier for a period of five years from the date of its commissioning and thereafter the resident’s body is expected to care for it.

Conclusion

Rabi Rashmi Abasan is expected to serve as an example of transition to the sustainable use of energy. Use of both active and passive solar devices will lead to energy savings of about 60%. It will prove to be a role model for upcoming housing complexes and encourage them to adopt clean energy technologies for a sustainable future.
Internet resources

**Micro hydropower**  
www.microhydropower.net

The micro web portal provides information related to (micro) hydropower. The website provides access to business directory with an overview of manufacturers and consultants. The website includes information resources such as case studies, news events, links, literature, and downloadable documents.

**Photovoltaic systems**  
www.pvresources.com

This web site is devoted to promote photovoltaic applications and technologies. It was developed as non-commercial helpful information to serve teachers, students and others interested in photovoltaics. The website provides many interesting information on photovoltaic technologies, systems, applications, and so on. Further detailed information and answers on the most complex questions about solar electricity use are accessible through links leading to web sites of many different organizations and institutions.

**Solar utilities network**  
http://www.solarnet.org/

The SUN (solar utilities network) is a not-for-profit informational website sponsored by the Caspar Institute in support of global efforts to reform energy use. The web site provides practical information and strategies for saving energy and using renewable resources in the home. On this site are links to case studies describing the actual applications of sustainable energy technologies, do-it-yourself project ideas, and a schedule of 1996 training courses taught by experts from the SUN.

**Source for Renewable Energy**  
http://energy.sourceguides.com

The Source for Renewable Energy is a comprehensive online buyer’s guide and business directory to more than 12,000 renewable energy businesses and organizations worldwide. One can locate renewable energy businesses by geographic location, by product type, by business type and by name, or search for renewable energy businesses using keywords.

Hansen M O L. 2008  
*Aerodynamics of Wind Turbines (second edition)*

*Website* www.earthscan.co.uk

This book, now in its second edition, has been entirely updated and substantially extended to reflect advances in technology, research into rotor dynamics and the structural response of the wind turbine structure. The topics covered in this issue include increasing mass flow through the turbine, performance at low and high wind speeds, assessment of the extreme conditions under which the turbine will perform, and the theory for calculating the lifetime of the turbine.

Boyle G. 2007  
*Renewable Electricity and the Grid: the challenge of variability*

*Website* www.earthscan.co.uk

This book examines the significance of the issue of variability of renewable electricity supplies, and presents technical and operational solutions to the problem of reconciling different patterns of supply and demand. Its chapters are authored by leading experts in the field, who aim to explain and quantify the impacts of variability in renewable energy, and in doing so, dispel many of the myths and misunderstandings surrounding the topic.

Wade H A. 2003  
*Solar photovoltaic project development*

France: UNESCO Publishing  
*Website* www.unesco.org/publishing

This book is primarily intended as a teaching aid to support its companion volume, the Technical Training Manual, which contains detailed text and graphics, as well as discussion of wider issues relating to project development for solar photovoltaic systems. The overall goal is to provide comprehensive training material on installation, operation, monitoring and evaluation, management, maintenance, and rehabilitation of PV systems, as well as information on awareness raising, advocacy, innovation, policy and planning.
Forthcoming Events

National events

Renewable Energy India 2008 Expo
21–23 August 2008, New Delhi

Mr Rajneesh Khattar
General Manager
Exhibitions India Pvt. Ltd
217-B (2nd floor) Okhla Industrial Area
Phase III, New Delhi – 110 020
Tel. 91 11 4279 5000
Fax 91 11 4279 5098/99
E-mail exhibitionsindia@vsnl.com
Web www.exhibitionsindia.com

Renewable Energy Finance Forum 2008
20–21 November 2008, Mumbai, India

Euromoney Energy Events
Nestor House, Playhouse Yard
London, EC4V 5EX
Tel. +44 (0) 20 7779 8945
Fax +44 (0) 20 7779 8946

International Congress on Renewable Energy 2008
16–17 October 2008, Hotel Le-Royal Meridien, Chennai

Mr Jagat Jawa
Director General, SESI, A-14
Mohan Cooperative Industrial Area, Mathura Road
New Delhi – 110 044
Tel. +91 11 6564 9864 • Fax +91 11 2695 9759
E-mail info@sesi.in • Web www.sesi.in

Renewable Energy Asia 2008: international conference and fourth SEE forum meeting
11–13 December 2008, IIT Delhi

Dr Virendra Kumar Vijay
Centre for Rural Development and Technology,
IIT Delhi
Web www.iitd.ac.in

19th International Photovoltaic Science and Engineering Conference
19–23 January 2009, Science City, Convention Centre,
Kolkata

E-mail ersr@iacs.res.in

International events

National PV Conference 2008
14 August 2008, Putrajaya, Malaysia

Web www.mbipv.net.my/NPVC2008.html

23rd European Photovoltaic Solar Energy Conference
1–4 September 2008, Valencia, Spain

WIP-Renewable Energies, Sylvensteinstr. 2
81369 München, Germany
Tel. +49 89 720 12 735 • Fax +49 89 720 12 791
Web www.wip-munich.de
E-mail pv.conference@wip-munich.de

AWEA Offshore Wind Project Workshop
9–10 September 2008, Wilmington, DE, USA

American Wind Energy Association
1101, 14th Street, NW, 12th Floor
Washington, DC 20005
Tel. (202) 383-2500 • Fax (202) 383-2505
Web http://www.awea.org/events/

10th Renewable Energy Finance Forum
15–16 September 2008, London

Web www.euromoneyenergy.com

Bioenergy 2008
23–24 September 2008, Oxford, UK

Web www.r-p-a.org.uk

BiomassWorld 2008
23–24 September 2008, Beijing, China

### Renewable Energy at a Glance in India

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Source/system</th>
<th>Estimated potential</th>
<th>Achievement as on 31 March 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MW)</td>
</tr>
<tr>
<td>I</td>
<td>Power from renewables</td>
<td></td>
<td>(MW)</td>
</tr>
<tr>
<td></td>
<td>Grid-interactive renewable power</td>
<td>(MW)</td>
<td>(MW)</td>
</tr>
<tr>
<td>1</td>
<td>Wind power</td>
<td>45 195</td>
<td>8757.00</td>
</tr>
<tr>
<td>2</td>
<td>Bio power (agro residues and plantations)</td>
<td>16 881</td>
<td>606.00</td>
</tr>
<tr>
<td>3</td>
<td>Bagasse cogeneration</td>
<td>5 000</td>
<td>800.00</td>
</tr>
<tr>
<td>4</td>
<td>Small hydro power (up to 25 MW)</td>
<td>15 000</td>
<td>2180.00</td>
</tr>
<tr>
<td>5</td>
<td>Energy recovery from waste (MW)</td>
<td>2 700</td>
<td>55.25</td>
</tr>
<tr>
<td>6</td>
<td>Solar photovoltaic power</td>
<td>-</td>
<td>2.12</td>
</tr>
<tr>
<td></td>
<td>Sub total (A)</td>
<td>84 776</td>
<td>12 400.37</td>
</tr>
<tr>
<td></td>
<td>Captive/combined heat and power/distributed renewable power</td>
<td>(MW)</td>
<td>(MW)</td>
</tr>
<tr>
<td>7</td>
<td>Biomass/cogeneration (non-bagasse)</td>
<td>-</td>
<td>95.00</td>
</tr>
<tr>
<td>8</td>
<td>Biomass gasifier</td>
<td>-</td>
<td>100.11</td>
</tr>
<tr>
<td>9</td>
<td>Energy recovery from waste</td>
<td>-</td>
<td>26.70</td>
</tr>
<tr>
<td></td>
<td>Sub total (B)</td>
<td>-</td>
<td>221.81</td>
</tr>
<tr>
<td></td>
<td>Total (A+B)</td>
<td>-</td>
<td>12 622.18</td>
</tr>
<tr>
<td>II</td>
<td>Remote village electrification</td>
<td>-</td>
<td>4 198 villages/hamlets</td>
</tr>
<tr>
<td>III</td>
<td>Decentralized energy systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Family-type biogas plants</td>
<td>120 lakh</td>
<td>39.94 lakh</td>
</tr>
<tr>
<td>11</td>
<td>Solar photovoltaic systems</td>
<td>50 MW/km²</td>
<td>120 MWp</td>
</tr>
<tr>
<td></td>
<td>i. Solar street lighting system</td>
<td>-</td>
<td>70 474 nos</td>
</tr>
<tr>
<td></td>
<td>ii. Home lighting system</td>
<td>-</td>
<td>402 938 nos</td>
</tr>
<tr>
<td></td>
<td>iii. Solar lantern</td>
<td>-</td>
<td>670 059 nos</td>
</tr>
<tr>
<td></td>
<td>iv. Solar power plants</td>
<td>-</td>
<td>2.22 MW</td>
</tr>
<tr>
<td></td>
<td>v. Solar photovoltaic pumps</td>
<td>-</td>
<td>7148 nos</td>
</tr>
<tr>
<td>12</td>
<td>Solar thermal systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>i. Solar water heating systems</td>
<td>140 million m² collector area</td>
<td>2.30 million m² collector area</td>
</tr>
<tr>
<td></td>
<td>ii. Solar cookers</td>
<td>-</td>
<td>6.20 lakh</td>
</tr>
<tr>
<td>13</td>
<td>Wind pumps</td>
<td>1284 nos</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Aero generator/hybrid systems</td>
<td>-</td>
<td>675.27 kW</td>
</tr>
<tr>
<td>IV</td>
<td>Awareness programmes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Energy parks</td>
<td>-</td>
<td>504 nos</td>
</tr>
<tr>
<td>17</td>
<td>Akshay Urja shops</td>
<td>-</td>
<td>269 nos</td>
</tr>
<tr>
<td>21</td>
<td>Renewable energy clubs</td>
<td>-</td>
<td>521 nos</td>
</tr>
<tr>
<td>22</td>
<td>District Advisory Committees</td>
<td>-</td>
<td>560 nos</td>
</tr>
</tbody>
</table>

MW – megawatt; kW – kilowatt; MWp – megawatt peak; m² – square metre; km² – kilometre square
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6. Can also be charged with solar panels
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Phone.: 011-24262214-21 Extn.: 239

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