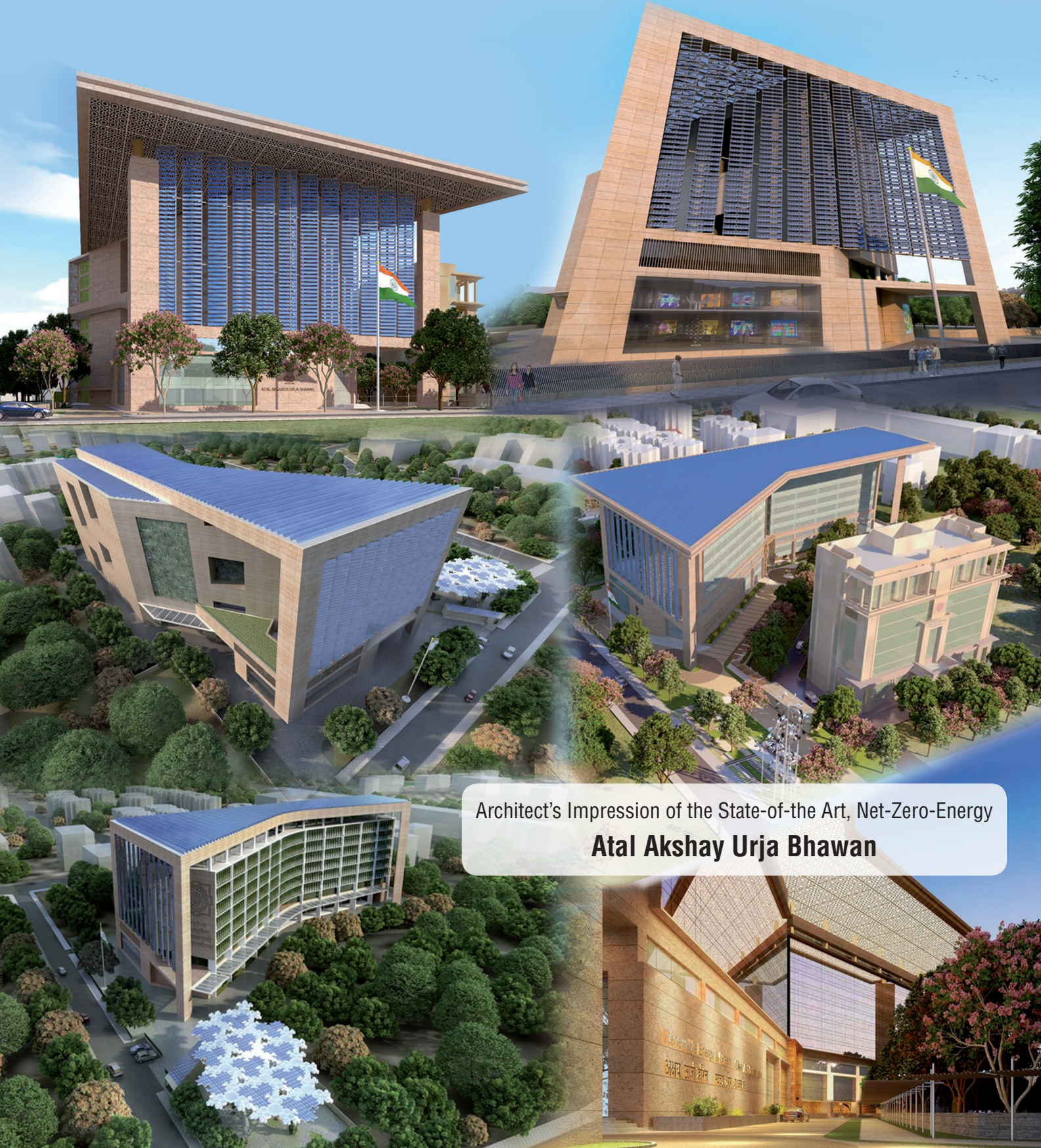




Ministry of New and
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OCTOBER 2016

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Renewable Energy Akshay Urja

COVER STORY



10

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(Published in English and Hindi)

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Bioenergy is an alternative and cheap source of energy which can be made easily available. In this context, **Dr Anil Kurchania, Er B Velmurugan, Dr Madhuri Narra, Er Bipin Vyas, and Shakil U Saiyad** describe the various uses of water hyacinth and the production of biogas using it as a feedstock.



21

Dr S S Verma highlights the journey of development of solar cells from their first to fourth generation, including the next generation solar cells and details the future scope of improvements as a potential source of alternative energy.



26

There is a great scope to further develop and empower the manpower in India in order to ensure the country's global competitiveness. **Dr P Saxena** provides an overview of the various steps taken by the government and key stakeholders towards skilled manpower.

अक्षय ऊर्जा का अगस्त 2016 अंक पढ़ने का सुअवसर प्राप्त हुआ। आवरण कथा 'सौर पार्क: भारत में सौर विद्युत परियोजनाओं का तेजी से विकास' पढ़कर आशा जगी कि यदि इसी तरह इस क्षेत्र में विकास होता रहा तो भारत निश्चित रूप से सन् 2022 तक नवीकरणीय ऊर्जा के क्षेत्र में अपने लक्ष्यों को प्राप्त कर लेगा। ऐसे ज्ञानवर्धक लेखों के लिए आपको अनेकों साधुवाद।

राधाकान्त बैनर्जी

कोलकाता, पश्चिम बंगाल

My hearty congratulations to Akshay Urja (Hindi) for receiving the first prize from 'Rajbhasha Seva Sansthan'. I read the June 2016 issue of the magazine. The Surya Mitra mobile app is a very good idea. It would come handy with respect to O&M repair and maintenance of solar pumps. I also liked reading the article on power from urine. The cheapest way to produce electricity from urine is through electrolysis of urine. Hydrogen is to be purified and the generator is run by hydrogen gas to produce electricity. All the articles in the June 2016 issue are very nice. Thanks for publishing such good and informative articles. These are very useful in my profession.

Er Anant B Tamhane

Engineer Consultant Renewable Energy
Nagpur, Maharashtra

हर बार की तरह इस बार भी अक्षय ऊर्जा का नवीनतम अंक, विस्तृत जानकारीयों से ओत-प्रोत है। मैं स्वयं बायोगैस उत्पादन क्षेत्र से जुड़ा हुआ हूँ, इसलिए समुद्री शैवाल के बारे में पढ़कर ज्ञान में बढ़ोत्तरी हुई। पढ़कर अच्छा लगा कि समुद्री शैवाल को एक ऐसे स्थायी बायोमास के रूप में पहचाना गया है जो संभावित रूप से जैव ईंधन उत्पादन मांगों को समर्थन दे सकता है। इसमें बेहतर बायोमास उत्पादकता, सस्ते संवर्धन जैसे अमूल्य गुणों की संभाव्यता होती है। भारत की

व्यापक तट रेखा को ध्यान में रखते हुए यह पक्ष समुद्री शैवाल संवर्धन और बायोमास उत्पादन के लिए संसाधन युक्त और नवीकरणीय स्रोत के रूप में देखा जा सकता है।

मनीष सिंह यादव

राँची, झारखंड

The Hon'ble Prime Minister of India rightly reiterates to all the Indians that India should come out of the shadows now and should lead the world in the field of renewable energy. I feel MNRE's magazine Akshay Urja is a vital link to fulfill and nurture this wonderful mission. I really liked reading the Cover Story of the August 2016 issue on Solar Parks. The progress made in the sphere of solar parks is good news for India. Nice to read that due to excellent response and more demand of solar parks coming from the states, the MNRE is contemplating to enhance the capacity of the scheme from 20,000 MW to 40,000 MW.

Tanvi Ahuja

Guwahati, Assam

अभी कुछ ही दिन पहले मैं नई दिल्ली स्थित मंत्रालय के कार्यालय में किसी काम से गया था, वहां अक्षय ऊर्जा पत्रिका संयोग से पढ़ने का अवसर मिला। कहना होगा कि यह पत्रिका वाकई उत्कृष्ट सामग्री एवम् जानकारीयों का समागम है। जैवईंधन के क्षेत्र में आईआईटी खड़गपुर द्वारा नेतृत्व दिया जाना सचमुच सराहनीय है। मुझे पूरा विश्वास है कि ऐसी प्रौद्योगिकियों के विकास द्वारा, स्वच्छ तथा हरित ऊर्जा उत्पादन, खास तौर पर जैव ईंधन के क्षेत्र में अपार प्रगति की जा सकती है। ऐसे सारगर्भित लेख प्रकाशित करने के लिए अक्षय ऊर्जा का समस्त संपादक मंडल बधाई का पात्र है।

अमृतेंदु मिश्रा

नई दिल्ली

I really liked reading the August 2016 issue of your esteemed magazine. It really meets our needs to know about all the latest that is happening on the renewable energy front in India. Needless to say that India is going to be the leader in most of the spheres, including renewable energy, in the future. It was heartening to read that the Gandhigram Rural Institute (GRI) in Tamil Nadu is paving the way for the development of human resource in renewable energy. It is the only rural institute in southern part of India practicing the three-dimensional approach in higher education, i.e., teaching, research, and extension.

T P Swaminathan

Coimbatore, Tamil Nadu

अक्षय ऊर्जा के अगस्त 2016 अंक में प्रकाशित लेख 'गुजरात में कैनाल टॉप सौर प्रकाशवोल्टीय संयंत्र,' वास्तव में ऊर्जा, भूमि और जल में एक अद्वितीय गठबंधन का द्योतक है। कैनाल टॉप सौर विद्युत संयंत्र एक नवाचारी विचार है जिसमें भूमि का दक्ष उपयोग और जल का संरक्षण किया जाता है। पढ़कर अच्छा लगा कि यह स्मार्ट विलेज, स्मार्ट सिटी और सिंचाई परियोजना के लिए एक बेहतर प्रशासनिक मॉडल प्रदान करता है। अन्य लेख भी बहुत पसंद आए। कृपया यह पत्रिका मुझे निरंतर रूप से भिजवाते रहें।

मुदस्सर आलम

भोपाल, मध्य प्रदेश



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

Editor, Akshay Urja



उपेन्द्र त्रिपाठी

Upendra Tripathy

सचिव
भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY



Message

It is a matter of utter pride for us that India is poised to play a global role in promoting universal solar access and India's role as the head of the International Solar Alliance (ISA) is to share achievements and lessons learnt from the National Solar Mission. The ISA is in talks with stakeholders and event managers to host exhibitions and investor meets to promote development of new technologies. The ISA is poised to address many of the major issues we face globally, not just in India, such as access to land, technology, and capital. The ISA will play a major role in promoting universal energy access, bringing in cross-border policies that will increase the deployment of solar, and look to mobilize more than \$100 billion in financing by 2030. We believe that India's National Solar Mission can be a model for other countries. The Ministry is currently training 3,000 students in 150 institutions across India to become clean energy leaders and shape the transition.

With great satisfaction, I want to share with the readers of *Akshay Urja* that the Government of India has taken several measures to promote renewable energy in the country since the last few years. In an effort to boost the country's renewable energy sector, the government is all set to launch a number of policy measures. The government is in the process of instituting a \$400 million fund sourced from the World Bank that will be used to protect clean energy producers from payment delays by distribution firms. We have already seen an eight-fold increase in the clean energy cess on coal; we are now planning to scale up our solar parks. We also plan to scale up the target of solar parks upto 40,000 MW as against the present 20,000 MW. The Ministry has invited tariff-based bidding for 1000 MW wind power capacity for the first time in the country. Similar bidding in solar power has seen a drastic drop in tariffs. In this financial year, we expect 4,000 MW of wind power capacity to be set up. To facilitate this, the Ministry has already prepared a wind map of India to identify the locations with high potential of wind energy.

I always look forward to the opportunity to interact with our readers through '*Akshay Urja*' and I sincerely appeal to all of you to send your valuable suggestions for promoting renewable energy in the country. We must endorse the use of renewable energy in our daily lives and I am very sure that the articles and other information published in *Akshay Urja* would inspire all of you to adopt the clean and renewable sources of energy to propel the country towards rapid sustainable development.

With best wishes!

Upendra Tripathy
Secretary



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TUNE in to **RADIO** Programme

AKSHAY URJA AUR HUM

The Ministry of New and Renewable Energy (MNRE) has started 'Akshay Urja Aur Hum', a Radio Sponsored Programme (RSP) from September 16, 2016 on every Friday and Tuesday. The programme will cover various areas of renewable energy in Hindi and in 19 regional languages, i.e., Assamese, Bengali, Gujarati, Konkani, Kannada, Kashmiri, Khasi, Malayalam, Manipuri, Tamil, Marathi, Mizo, Nagamese, Nepali, Oriya, Punjabi, Telegu, Urdu, and Garo. The RSP is being broadcast from 37 Vividh Bharati Stations, 20 FM Rainbow Stations, 4 FM Gold Stations, and 33 Primary Channels/Local Radio Stations of All India Radio. The topic-wise broadcasting schedule of the programme from October to December, 2016 is given here.

TO LISTEN TO THE PROGRAMME 'AKSHAY URJA AUR HUM' YOU MAY LOG ON TO THE MINISTRY'S WEBSITE:
www.mnre.gov.in

Episode No.	Date of broadcast	Topics
6	04/10/16	Solar Rooftops for Residential Sectors/Societies
7	07/10/16	Solar cooking (Box type & Dish type)
8	11/10/16	Solar Pumps
9	14/10/16	Solar Rooftops for Government & Public Sectors undertaking buildings
10	18/10/16	Biogas for cooking and manure National Biogas and Manure Management Programme (NBMMP)
11	21/10/16	Off-Grid Solar Power Plants
12	25/10/16	Solar Rooftop Systems for Industrial and Commercial Applications
13	28/10/16	Biogas Power (off-grid) programme
14	01/11/16	Solar Lighting Systems for Rural Areas (home, street, lanterns etc.)
15	04/11/16	Solar Rooftop Systems for Institutions, Educational buildings, hospitals, etc.
16	08/11/16	Biomass Power & Bagasse Cogeneration in Sugar Industries
17	11/11/16	Concentrating Solar Technology for Community Cooking, Laundry
18	15/11/16	Surya Mitra
19	18/11/16	Biomass Gasifier Programme
20	22/11/16	Concentrating Solar Technology for Space Cooling
21	25/11/16	Wind Power
22	29/11/16	Energy from Urban Wastes
23	02/12/16	Improved Cookstoves (Family sized /domestic cookstoves/ earthen cookstoves)
24	06/12/16	Solar Wind Hybrid Systems, Reliable Source of Renewable Energy
25	09/12/16	Energy from Industrial Wastes
26	13/12/16	Community Cookstoves for MDM Kitchens, Anganwadis, Hostels, Government and Forest Rest-houses, etc.
27	16/12/16	Small Hydro Power
28	20/12/16	Solar Cities
29	23/12/16	National Institute of Solar Energy
30	27/12/16	Gharat and Water Mills
31	30/12/16	Solar Energy Corporation of India and IREDA

Broadcasting schedule for four metro cities

	FM Rainbow	FM Gold	Vividh Bharati
Delhi	9.00 A.M. to 9.15 A.M.	9.20 A.M to 9.35 A.M.	9.30 A.M. to 9.45 A.M.
Chennai	6.45 P.M. to 7.00 P.M.	9.45 A.M. to 10.00 A.M.	9.15 A.M.
Kolkata	A.M to 9.00 A.M.	9.15 A.M. to 9.30 A.M.	9.15 A.M.
Mumbai	8.30 A.M. to 8.45 A.M.	-----	9.30 A.M.



From the Editor's Desk

Dear Readers,

I am delighted to share with you that Shri Piyush Goyal, Union Minister of State (IC) for Power, Coal, New and Renewable Energy and Mines, recently laid the foundation stone for Atal Akshay Urja Bhawan in New Delhi. This will be an iconic landmark building symbolizing energy efficiency and renewable energy, to serve as an integrated building for Headquarters of the Ministry of New and Renewable Energy. This State-of-the Art, Net-Zero-Energy Green Building is designed on the concept of solar passive architecture. The Building is poised to set new standards for resource efficiency in design, construction, and operation stage.

Also, the institutes/agencies of the Ministry of New and Renewable Energy (MNRE), such as The Indian Renewable Energy Development Agency Limited (IREDA) are proficiently supporting MNRE in its various endeavours. As a specialized agency for providing finance to the renewable energy sector, IREDA has geared itself to lead growth of the sector intended in the government's policy to make a substantial jump and achieve accelerated renewable energy capacity addition. It has been continuously developing new, innovative, and appropriate financial instruments that caters to the needs of its existing customers and new investors.

Propelled by efforts of the Government and industry, the renewable energy sector is estimated to generate two million green jobs in the next decade in India. To help bridge the gap in trained manpower, the Skill Council for Green Jobs (SCGJ) is an initiative launched by the Government of India aligned to the National Skill Development Mission. The immediate focus of SCGJ would be skilling the workforce towards green jobs for renewable energy, energy efficiency, and waste treatment. The Suryamitra skill development is doing a remarkable work in this field by developing the skills of youth, considering the opportunities for employment in the growing Solar Energy Power sector in India and abroad. It is also designed to

prepare the candidates to become new entrepreneurs in Solar Energy sector.

The present issue also presents an article on integrated hybrid system for sustainable development of remote isolated communities. It is a novel initiative wherein electricity requirement is fulfilled by renewable energy and an integrated hybrid system is used to generate electricity from the combination of solar and wind energy. The article presents a novel integrated hybrid system of solar and wind energy for off-grid power generation in non-interconnected areas or remote isolated communities. We have also presented in this issue the latest and innovative technologies used for biogas production. Research and development has been undertaken at the Sardar Patel Renewable Energy Research Institute (SPRERI), for efficient bio-methanation of water hyacinth integrated with bubble gun technology. Another research work undertaken to improve the anaerobic digestion of family-size biogas plants based on kitchen waste integrated with phase separation compartments has been presented. Performance evaluation of fibre glass reinforced plastic (FRP) technology based one cubic metre capacity biogas plant has been described.

I am sure that all the articles and information in the present issue will be a useful reading material and you will find it informative and interesting as well. Please do not forget to share your views and suggestions.

Happy reading

ARUN K TRIPATHI
aktripathi@nic.in

RENEWABLE ENERGY NEWS

Lucknow gets UP's First Solar-Powered Collectorate



The district collectorate in Lucknow has become the first solar-powered collectorate in the state. The 98-lakh solar power plant is capable of supplying enough energy to power all of its 49-strong rooms. With the solar power plant in place, the district collectorate is likely to save more than 15 lakh in electricity bills. "Currently, the building consumes around 150 kW of energy, which costs more than 70 lakh annually. Now, this bill would be reduced by almost 22 per cent as the installed solar plant will produce around 135 kW of energy," said District Magistrate of Lucknow, Raj Shekhar. The solar-powered plant can produce 1.89 lakh units of electricity per year or about 500 units per day. The power plant contains 438 solar plates and four grid-connected solar

inverters. The solar grid would produce energy for the next 25 years. The power plant also has a bi-directional meter which can return unused power to the grid. The Lucknow district collectorate building has 49 rooms, including courts, chambers, accounts, and other departments. Every chamber of the magistrate is equipped with 1.5–2.0 tonne capacity of air-conditioners, besides fans and LED lights, along with extra electronic devices. 🇮🇳

Source: <http://timesofindia.indiatimes.com>

Premier Educational Institutes in Delhi Go Green

The renewable energy venture of one of the leading companies in India has commissioned approximately 1 MW rooftop solar projects for Delhi Technical University (DTU), Netaji Subhash Institute of Technology (NSIT), Indira Gandhi Delhi Technical University for Women (IGDTU), and Shaheed Sukhdev Singh College with (Indraprastha Power Generation Co. Ltd.). The intent of installing solar projects in educational institutes has far reaching impact on the environment and the society. "Energy Efficiency and Renewable Energy Management Centre, Department of Power, Government of National Capital Territory of Delhi (GNCTD) is committed to work towards making Delhi a Solar City. This is the first step towards it, till now solar PV plants with a total capacity of 32 MW have been installed in Delhi," said R K Srivastava, Executive Officer, Government of NCT of Delhi. 🇮🇳

Source: <http://energy.economictimes.indiatimes.com>



🇮🇳 SPV installation at rooftop of Mechanical Engg Dept building of Delhi Technological University (DTU) with 430 kWp capacity and was commissioned in August 2016. It is on RESCO Model installed and the developer is supplying electricity at ₹5.80 per kWh.

Chandigarh Gets Floating Solar Power Plant

A floating solar power plant pilot of 10 kW peak (kWp) has been commissioned at Dhanas lake in Chandigarh amid efforts by the government to develop the Union Territory as a solar city.

It has been designed to supply power to fountains at the lake for aeration. The Unique Selling Proposition is its dual-axis tracking technology that has been developed indigenously, which is capable of generating 30 per cent or more power than conventional solar photovoltaic ones mounted on the ground. In a move towards realizing the broader objective, Yellow 2 Gen Energy Pvt. Ltd, which installed the plant recently, has proposed for innovative development of the land-neutral solar photovoltaic (floating SPV) plants.

"The approximate cost of the 10 kWp floating solar power plant is around ₹12 lakh," Jeevan Mohanty, the Director of Yellow 2 Gen Energy, said. The floating power plant in the planned city is yet another attempt to achieve practical and tangible progress in harnessing solar energy and facilitate large-scale generation of electrical energy through solar radiation at an economically viable cost. ■

Source: <http://www.business-standard.com>



Government to Give Interest Rate Rebate to Low-Capacity Wind Mills

To increase power generation potential of low-capacity wind mills, the government will provide additional interest rate rebate of 0.25 per cent for wind turbine generators of up to 1 MW.

The government has come up with the policy to promote optimum utilization of wind energy resources as a large number of wind-turbines installed up to the year 2000 are of capacity below 500 kW and are at sites having high wind energy potential.

Initially, wind turbine generators of capacity of up to 1 MW would be eligible for repowering under the policy. However, the Ministry of New and Renewable Energy (MNRE) can extend the policy to other projects also after evaluation of their initial experience. As per the policy, the Indian Renewable Energy Development Agency (IREDA) will provide an additional interest rate rebate of 0.25 per cent over and above the interest rate rebates available to the new wind projects being financed by IREDA. The major share of renewable power capacity in India is from wind energy. India started harnessing the wind power prior to 1990. The present installed capacity is over 27 GW which is the fourth largest in the world after China, the US, and Germany. ■

Source: <http://timesofindia.indiatimes.com>



NTPC Commissions 100-MW Solar Plant

A 100-MW solar project has been commissioned by NTPC Ltd in Anantapur, Andhra Pradesh. This is the biggest solar project commissioned using domestically manufactured solar cells and modules. The plant is expected to generate nearly 160 million units of energy per year and help offset approximately 110,000 tonnes of CO₂ in the first year. The key highlights of the project were the innovative design of Balance-of-System (BoS) and cabling along with optimized selection of evacuation systems. The plant has been installed by TATA Power Solar.

Ashish Khanna, Chief Executive Officer, Tata Power Solar, said, "Today, pace of delivery and quality have become crucial benchmarks in the industry and we have delivered a project of this scale in record time. By bringing together our core strengths in domestic manufacturing and EPC services over the last 25 years, this 100 MW plant is the largest project commissioned by us to date." ■

Source: <http://energy.economictimes.indiatimes.com>



Solar Town Installs First Commercial Net-Metered Solar Rooftop System at Bombay Presidency Radio Club

SolarTown Energy Solutions Pvt. Ltd (SolarTown) has installed a 41 kW net-metered solar rooftop system at the historic Bombay Presidency Radio Club. The Radio Club is now the first commercial establishment in Mumbai to have a net-metered solar PV system installed on its building. This will enable the Radio Club to sell its excess electricity back to the grid under Brihanmumbai Electric Supply and Transport (BEST) and further reduce its utility bill. The Radio Club is estimated to save more than ₹850,000 annually from its new solar system. The Radio Club entered into a no upfront cost, 25-year lease agreement with SolarTown at a rate that is 35–40 per cent lower than their utility tariff. The installed system delivers clean power at a fixed cost over the length of the lease and includes maintenance services. The rooftop system will offset 20 per cent of their grid energy consumption and more than 1,189 tonnes of carbon dioxide over the lifetime of the solar installation. 📌



Source: <http://www.powertoday.in>

Police Stations in Kakinada District of Andhra Pradesh Tap into Solar Power

Police stations in Kakinada district of Andhra Pradesh have tapped into solar power installing solar plants. The State police department has identified 14 police stations in the district in which solar plants were installed to harness solar power to meet the day-to-day requirements. Each police station would require 1.5 kW solar panel in addition to inverter and batteries for the system to function. The 14 police stations where solar plants were installed are: Yetapaka, Kunavaram, Chintur, and Edugurallapalli in Chintur police subdivision Y Ramavaram in Agency area and Tuni (general railway police) in sub-plan area and III Town Traffic Police Station, Prakash Nagar, Bommuru, Rajanagaram, Rajamahendravaram II Town, Dowleswaram, Kadiyam and Korukonda police stations under Rajamahendravaram urban police district.

According to the official in the department solar power plants were installed at a cost of ₹2.39 lakh at each



police station. It received 30 per cent subsidy from Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and 20 per cent from New and Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP). 📌

Source: <http://www.saurenergy.com>

World Trade Centre in Mumbai Gets 250 kW Rooftop Solar Plant

Solar solutions provider Maxwell Solar and Wind Energy has installed 250 kW grid connected rooftop solar plant at the World Trade Centre in Mumbai. The plant has been set up on the Arcade building of the WTC spread across 25,000 sq. ft and the power from the project will cater to the air conditioning of the building and will generate over 3 lakh units annually. "Through this initiative, WTC Mumbai is participating in government's mission to scale up the solar power to more than 10 per cent of total energy mix by 2022," WTC Mumbai Chairman Kamal Morarka said. 📌

Source: <http://energy.economictimes.indiatimes.com>



World's First Large-Scale Tidal Energy Farm Launched in Scotland

The launch of the world's first large-scale tidal energy farm in Scotland has been hailed as a significant moment for the renewable energy sector. A turbine for the MeyGen tidal stream project in the Pentland Firth was unveiled in the Scottish Highlands. The turbine, measuring about 15 m tall (49 ft), with blades 16 m in diameter, and weighing in at almost 200 tonnes, will begin its journey to the project's site in the waters off the north coast of Scotland between Caithness and Orkney.

The Edinburgh-based developer Atlantis Resources hopes the project which has received £23m in Scottish government funding will eventually have 269 turbines, bringing its capacity to 398 MW, which is enough electricity to power 175,000 homes. Fabrice Leveque, the climate and energy policy officer at the environmental body WWF Scotland, said, "It's great that Scotland is now home to the world's first large-scale tidal stream farm. It comes hot on the heels of Shetland tidal devices exporting power to the National Grid for the first time and the testing of the world's most powerful tidal turbine off Orkney. 🇬🇧"

Source: www.theguardian.com

Chemists Develop Promising Cheap, Sustainable Battery for Grid Energy Storage



Chemists at the University of Waterloo have developed a long-lasting zinc-ion battery that costs half the price of current lithium-ion batteries and could help enable communities to shift away from traditional power plants and into renewable solar and wind energy production. Professor Linda Nazar and her colleagues from the Faculty

of Science at Waterloo made the important discovery, which appears in the journal, *Nature Energy*.

The battery uses safe, non-flammable, non-toxic materials and a pH-neutral, water-based salt. It consists of a water-based electrolyte, a pillared vanadium oxide positive electrode and an inexpensive metallic zinc negative electrode. The battery generates electricity through a reversible process called intercalation, where positively-charged zinc ions are oxidized from the zinc metal

negative electrode, travel through the electrolyte and insert between the layers of vanadium oxide nanosheets in the positive electrode. This drives the flow of electrons in the external circuit, creating an electrical current. The reverse process occurs on charge. 🇬🇧

Source: www.sciencedaily.com



Shri Piyush Goyal, Union Minister of State (IC) for Power, Coal, New and Renewable Energy and Mines, laid the foundation stone for Atal Akshay Urja Bhawan in New Delhi



FOUNDATION STONE LAID FOR ATAL AKSHAY URJA BHAWAN

Atal Akshay Urja Bhawan is an iconic landmark building symbolizing energy efficiency and renewable energy. It is an integrated building for Headquarters of the Ministry of New and Renewable Energy (MNRE). This building will be constructed on a 2.76 acre plot and it has a strategic location in CGO Complex Area, Lodhi Road, New Delhi. This State-of-the Art, Net-Zero-Energy Green Building is designed on the concept of solar passive architecture.

Shri Piyush Goyal, Union Minister of State (IC) for Power, Coal, New and Renewable Energy and Mines, laid the foundation stone for Atal

Akshay Urja Bhawan in New Delhi on October 19, 2016. Shri Upendra Tripathy, Secretary MNRE; Shri P K Pujari, Secretary, Ministry of Power; Shri Balvender Kumar, Secretary,

Ministry of Mines; and Shri Anil Swarup, Secretary, Ministry of Coal; guests from Foreign Embassies in India, industry, and officials from the MNRE, SECI, CPWD, IREDA, etc., and



Architect's impression of the State-of-the Art, Net-Zero-Energy Atal Akshay Urja Bhawan

other dignitaries were also present during the occasion.

The building has been named after the former Prime Minister of India, Shri Atal Bihari Vajpayee. The Atal Akshay Urja Bhawan will be the integrated headquarters building for the Ministry of New and Renewable Energy (MNRE). At present, the office of MNRE is located in three different building blocks at CGO Complex with its current strength of about 400 officials.

While laying the foundation stone, the Minister, while quoting the Prime Minister Shri Narendra Modi, stated that it is time that India comes out of the shadows and leads the world. Energy conservation and Renewable Energy is one area where India is soon going to be a global leader. "The Government of India is committed to strive for this mission and light up peoples' lives in an environment-friendly and sustainable manner," Shri Goyal added. The Hon'ble Minister also mentioned that this iconic

building will be a symbol of India marching ahead to lead renewable energy revolution. The Government of India has set a target of 175 GW renewable power to be achieved by 2021-22. The Ministry of New and Renewable Energy is committed and is putting all efforts to achieve this target. Shri Upendra Tripathy, Secretary, MNRE also addressed the participants and mentioned that this building will provide an environment-friendly atmosphere with renewable energy and energy efficiency utilization in the building. "This iconic building will be a symbol of our country marching ahead to lead renewable energy revolution," he added.

Atal Akshay Urja Bhawan is an iconic landmark building symbolizing energy efficiency and renewable energy. It is an integrated building for Headquarters of the MNRE. This building will be constructed on a 2.76 acre plot and it has a strategic location in CGO Complex Area, Lodhi

Road, New Delhi. This State-of-the Art, Net-Zero-Energy Green Building is designed on the concept of solar passive architecture. This building will have built-up area of 2,60,000 sq. ft, building height of 42 m with the 75,000 sq. ft solar panel area. The design of this unique building was conceived after rigorous competition among top notch architectural firms. This competition aimed at developing an iconic building with net-zero- energy principle and at the same time ensuring elegance and convenience. The building is poised to set new standards for resource efficiency in design, construction, and operation stage. It will be a Net energy positive building with an Urja pavilion showcasing RE systems and devices. It will be an interactive and use responsive building and is strategically located with proximity to the Metro Rail station, central institutions, Jawaharlal Nehru Stadium, and central government offices. **AU**

7TH WORLD RENEWABLE ENERGY TECHNOLOGY CONGRESS AND EXPO-2016



The 7th World Renewable Energy Technology Congress and Expo-2016 (WRETC-2016) was held on August 21–23, 2016 in New Delhi and was organized by the Energy and Environment Foundation and supported by the Ministry of New and Renewable Energy (MNRE), Government of India, and UNESCO, New Delhi Office. The event served as an excellent energy platform for the global renewable energy industry to address various industry issues, including innovations, new technologies, investment opportunities, and project financing. The theme of the event was 'Renewable Energy: What Works'.

Shri Upendra Tripathy, Secretary, MNRE, delivered the inaugural address and highlighted the importance of promoting renewable energy, green technology for its sustainability. The Energy and Environment Foundation awarded the prestigious 'Energy and Environment Foundation Global Excellence Awards 2016' in the renewable energy sector to Shri Upendra Tripathy, Secretary, MNRE; Smt. Arundhati Bhattacharya, Chairperson State Bank of India; Mr Ramesh Kymal, CMD, Gamesa India; Mr Walter Howard, CEO Alter NRG Corporation; and

Dr Bibek Bandyopadhyay, Former Advisor, MNRE.

The 7th WRETC-2016 conference deliberated on various issues, such as 'Renewable Energy Innovative Financing'; 'Renewable Regulatory Issues—Roadmap'; 'Smart Cities, Energy Storage and Electric Vehicles'; 'Role of Mini Grid for Enabling 24x7 Power for All'; 'Waste-to-Energy, Make-in-India: Developing Solar-Wind Industries'; 'Solar Rooftop—Emerging Opportunities'; 'Bio-Energy'; 'Biomass: Future Energy for Transportation'; and 'Indo-Swiss Cooperation in Clean Energy: Promoting Innovation'. The conference and expo was attended by national and international delegates. The conference brought together leading international and domestic players, policymakers, government officials, and technocrats on a common platform. The concurrent conference sessions comprised of interesting workshops, interactive panel discussions on 'Energy: UN Sustainable Development Goals'; 'Greening Smart Grid: Renewable Energy Integration'; and Thought Leadership Summit on 'Renewable Energy: Skill Development and Capacity Building'. The conference served as an important gateway for worldwide new energy companies to access the Indian market to foster partnerships and collaborations with local players.

Some of the main features of the resolutions adopted in the conference are as follows:

- Renewable energy has come to the centre-stage with the support given by various governments through setting up of RE targets and through their intended nationally determined contributions (INDCs). It is time now to identify initiatives that work and scale these up to achieve these targets.
- Financial commitments and innovative financial measures will be essential for large scale adoption of RE options.
- The market based mechanism for spread of RE needs to be further strengthened by addressing policy and regulatory issues so as to accelerate the 'ease of doing RE business'.
- The sharp reduction in the cost of the solar PV modules and consequently the energy, provides an opportunity to boost storage options in tandem with Solar PV through various innovative mechanisms.
- Given the large opportunities that would be created by the RE markets, development of requisite manpower and generation of employment thereof is essential to sustain the momentum that has been generated. **AU**

CONFERENCE OF MINISTERS FOR POWER, NEW AND RENEWABLE ENERGY AND MINES AT SWITCH GLOBAL EXPO IN VADODARA

Shri Piyush Goyal, Union Minister of State (IC) for Power, Coal, New & Renewable Energy and Mines inaugurated the Conference of Ministers for Power, New & Renewable Energy and Mines of States & Union Territories at the first SWITCH Global Expo in the presence of Shri Upendra Tripathy, Secretary, MNRE. Deliberation sessions were held with State Governments during the Conference, with the aim to review the implementation of various ongoing Schemes/ Programmes and discuss a host of issues pertaining to Power, Coal, Renewable Energy, and Mines sectors. Ministers and senior officers from 20 States and two Union Territories along with chairpersons of Public Sector Undertakings under Central and State Power Ministries



attended the two-day conference. The conference was organized on the sidelines of the International Energy Conference-SWITCH Global Expo organized by the Government of Gujarat. The first SWITCH Global Expo—an exhibition and summit for

national and international participants in electrical engineering was held in Vadodara, Gujarat, from October 6–10, 2016. The Gujarat Chief Minister Shri Vijay Rupani inaugurated the five-day event in the presence of Shri Piyush Goyal; Deputy Chief Minister Shri Nitin Patel, State Energy Minister Shri Chimanbhai Shapariya, and other leaders.

In his Inaugural address of the Energy Conference, Shri Goyal congratulated the Government of Gujarat for organizing the conference on such a large scale. He urged State Ministers and their officers to use this platform to deliberate and work collectively towards achieving sustainable growth of each citizen and become the fulcrum of growth and prosperity of the Nation as a whole.

The Minister gave the motto, 'Together We Can' and asked States to look beyond individual State and departmental issues and keep



Shri Piyush Goyal addressing the inaugural session of the Conference of Ministers for Power, New & Renewable Energy and Mines of States & Union Territories, in Vadodara, Gujarat on October 7, 2016. The Power Minister of Gujarat, Shri Chimanbhai Dharamshi Shapariya; the Secretary, Ministry of Power, Shri P K Pujari; the Secretary, Ministry of Mines, Shri Balvinder Kumar; and the Secretary, Ministry of New & Renewable Energy, Shri Upendra Tripathy are also seen



a national perspective in solving the challenges faced by the common man. "Improvement is best change that is possible", the Minister inspired the august gathering in his address. Shri Goyal, while congratulating the Government of Gujarat on its achievements in efficient functioning of the power sector, cited its shining example where good governance and good economics lead to good politics.

The Minister delved into various issues of the Ministries of Power, Coal, New & Renewable Energy and Mines and the challenges faced at State level along with the collective solutions that can be worked out through cohesive working between the centre and the States. He also laid great stress on the importance of transparency, accountability, and the use of modern technology in achieving an efficient working profile in these sectors.

Shri Goyal, while acknowledging a positive response from the States in various policies and programmes of the Union Government, said that "I am greatly satisfied with the encouraging response from the States. We are not here to give out doles to States, rather the Union Government encourages States to become efficient in their functioning, more transparent and self

reforming so as to work for the wider interests of the society and achieve the goal of 24x7 Affordable Power for All."

The Minister pointed out elementary challenges that affect the efficient functioning of the renewable energy sector at the State level. These include State Governments not signing Power Purchase Agreements (PPAs) with the power suppliers, not paying for purchased power in time, not implementing the 'Must Run Status' for the power plants and non-compliance of renewable purchase obligation (RPO) strictly by all the States. The Minister observed that without addressing these basic issues at the earliest, the country's power scene would not be able to meet the high standards set by this Government.

During the inaugural session, the Union Secretaries of the Ministries of Power, Coal, New & Renewable Energy and Mines highlighted various issues and challenges facing their sectors and stressed upon the need of cooperation from the States in achieving the respective goals. The focus areas of discussions were on issues like implementation of Ujwal DISCOM Assurance Yojana (UDAY), 24x7 Power for All, feeder

monitoring, IT enablement of urban and rural feeders, rural electrification programme, energy conservation, Right of Way (RoW) compensation for transmission lines in urban areas, national power demand and national electricity plan, issues related to open access and captive generation, energy/peak shortage and increase in transparency by introduction of mobile apps.

Apart from the above aspects, mandatory adoption of Energy Conservation Building Codes by States and Agricultural Demand side management was discussed. Discussions were also held on policy interventions for hydro development, including small hydro under the broad aspects of progressive hydropower policy.

In the area of renewable energy, State wise review was taken on issues regarding solar power, wind power as well as the compliance of renewable purchase obligations (RPOs) and renewable energy certificates (RECs).

The concluding session of the conference consisted of comments and feedback by States/UTs and adoption of conference resolution by the delegates. **AU**

INDIA'S RE SECTOR POISED FOR HIGH GROWTH WITH IREDA



IREDA has geared itself to spearhead growth of the RE sector envisioned to make a quantum jump and achieve accelerated capacity addition, 'moving from megawatt to gigawatt'. It has been continuously developing new, innovative, and appropriate financial instruments that caters to the needs of its existing customers and new investors. The high growth path in the coming years for IREDA will require new ideas and strategies to remain as the market leader, to help meet the Government of India's scaled up targets for renewable energy capacity to 175 GW by 2022.

India's path towards sustainable development has made a remarkable shift in priorities since 2015. Renewable energy sector landscape in India has witnessed tremendous changes in the policy framework with accelerated and ambitious plans to increase the contribution of solar energy. India has an estimated renewable energy potential of about 1,095 GW from commercially exploitable sources with 750 GW solar power

potential assuming only 3 per cent wasteland is made available. Wind power development has reached to commercial stage in India and is fastest growing renewable energy option today with revised estimated potential of 302 GW at 100 m hub height, as estimated by the National Institute of Wind Energy (NIWE). The estimated potential biomass and small hydro in the country is about 23 GW and 20 GW, respectively. India also has around 7,600 km of coastline which offers

great potential for off-shore wind power development. The Government has scaled up the target of renewable energy to 175 GW by the year 2022 which includes 100 GW from solar, 60 GW from wind, 10 GW from biopower, and 5 GW from small hydropower. The above capacity of 100 GW of solar is proposed to be achieved through deployment of 40 GW rooftop solar projects and 60 GW large and medium scale solar projects. With this increased target, India will become one of the

largest green energy producers in the world, surpassing quite a few developed countries.


Further, India's submission to the UNFCCC on Intended Nationally Determined Contribution (INDC) firmly stated that India will achieve 40 per cent cumulative power generation from non-fossil fuel based energy resources by 2030 (equivalent to 26–30 per cent of generation in 2030), and to create an additional (cumulative) carbon sink of 2.5–3 GtCO₂e through additional forest and tree cover by 2030 with transfer of technology from advance countries and low-cost international funding.

Investments and Financing

To achieve the 175 GW of renewable energy capacity, it would need approximately \$120 billion in capital investment and \$40 billion in equity. The \$160 billion needed over the period of next 6–7 years (until 2022)—at an average of \$23 billion a year—will help meet the stated goal.

Towards this end, Renewable Energy Sector has been given 'Priority Sector Lending' status by the Reserve Bank of India (RBI). Banks can extend loans up to a limit of ₹15 crore to corporate borrowers and up to ₹10 lakh to individual borrowers for



 Picture 1: 100.50 MW Wind Power Project of M/S Orange Mamatkhedda Wind Pvt Ltd. at Mamatkhedda site, District Ratlam/Mandsaur, Madhya Pradesh

RE projects under priority sector. Investors' interest in India from domestic and foreign investors has grown significantly in the last two years. India recently surpassed the USA and China as the biggest FDI destination in the world. India has permitted uninterrupted foreign investment for renewable energy development and deployment, allowing 100 per cent FDI in the renewable energy sector. The market opportunities in renewable energy have attracted a number of strategic and financial investors to India. Many have leveraged international financing to build their initial portfolio and are now looking at alternative financing models for their operating assets.

Role of IREDA

Renewable energy projects are capital intensive in nature and generally associated with a long payback period, making the commercial banks wary in providing lending services to these projects. Government of India had in 1987 created a dedicated public finance institution— 'Indian Renewable Energy Development Agency' (IREDA), under the administrative control of the Ministry of New and Renewable Energy, with an objective to provide financial services to the renewable energy sector in India.

IREDA has well defined mission, objectives and also a strategically aligned motto that defines its purpose. IREDA's motto is 'ENERGY FOREVER. IREDA's Mission is to 'be a pioneering participant friendly and competitive institution for financing and promoting self-sustaining investment in energy generation from renewable sources, energy efficiency, and environmental technologies for sustainable development.'

The key objectives of IREDA are:

- To give financial support to specific projects and schemes for generating electricity and/ or energy through new and renewable sources and conserving energy through energy efficiency.

- To maintain its position as a leading organization to provide efficient and effective financing in renewable energy and energy efficiency/ conservation projects.
- To increase IREDA's share in the renewable energy sector by way of innovative financing.
- Improvement in the efficiency of services provided to customers through continual improvement of systems, processes, and resources.
- To strive to be competitive institution through customer satisfaction.

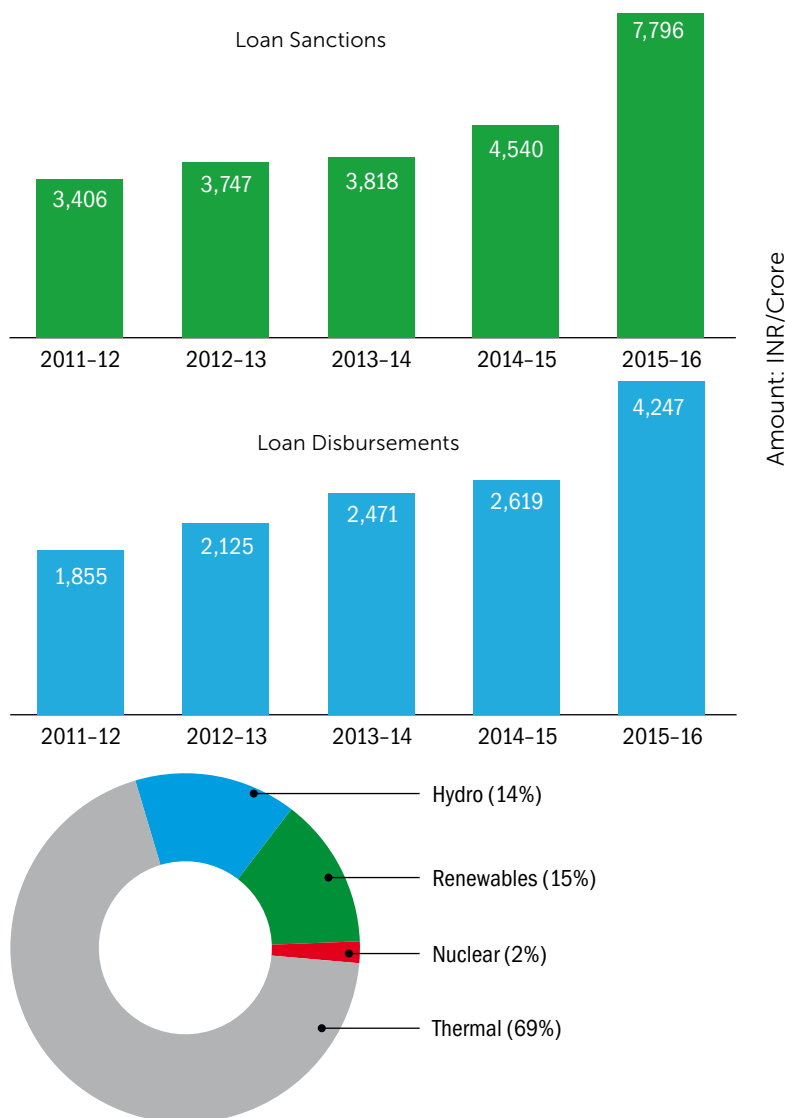
IREDA has been playing pivotal role in developing renewable energy. IREDA has been maintaining its leadership position in renewable energy space for the last 29 years and developing several innovative financial schemes/solutions for meeting the market requirement from time to time. IREDA has an excellent track record of financing more than 2,200 clean energy projects in the country. It has been profit making since inception, with successful business operations.

As a result of efforts made by IREDA towards development of the Renewable Energy sector in the country, the Indian Renewable Energy sector has experienced a year-on-year growth. The current installed RE capacity has reached more than 45,916 MW approximately, which is contributing about 15 per cent in country's installed capacity of 307 GW.

Innovative Schemes and Models

IREDA has always been the prime mover and showing the way to its peers. As part of its business operations to meet growth aspirations, IREDA has been constantly developing new instruments/innovative products for the renewable energy sector. A few new and innovative schemes/models introduced by IREDA are:

- Structured financing
- Additional finance through 'securitization of future cash-flows'



for raising Bonds towards Renewable Energy Projects (Solar/Wind)'.

Impact of IREDA's Efforts on Indian RE Sector

The unstinted and pro-active efforts being made by IREDA have enabled the commercialization of renewable energy sector in India, resulting in active participation from domestic commercial banks, international funding agencies and FDI, enabling the sector to attain a critical mass. IREDA's principal focus has remained towards financing those renewable energy sectors where the technological efficacy has been adequately demonstrated but market and industry dynamics make it difficult to make a dent in the country's energy mix. Today, several commercial banks and financial institutions are actively financing renewable energy projects. IREDA has constantly been in dialogue with all stakeholders, often impressing upon the government to suitably change policies to address any critical problem afflicting the sector.

Conclusion

Renewable energy is seen as the next big technology industry, with the potential to transform the trillion dollar energy industry across the world. Investing in renewable energy would enable India to develop globally competitive industries and technologies that can provide new opportunities for growth and leadership by corporate India. The renewable energy sector in India that is full of opportunities and merits, is becoming increasingly attractive for investment. In addition to increasing share of renewable energy in India's energy supply mix, India could become a manufacturing hub for renewables. **AU**

Courtesy: IREDA

- Bridge Loan Scheme to project developers
- Short-term loan assistance to RE developers/ suppliers/contractors
- Underwriting of debt/loan syndication
- Take-over financing
- Co-financing/consortium with banks
- Refinancing banks and FIs—Lines of Credit (LoC)
- Guarantee Assistance Scheme to re suppliers/promoters
- IREDA loan/SDF Scheme for IPP cogeneration in cooperative sugar mills
- Intermediary Loan Scheme—

- financing farmers for SPV water pumps through an aggregator SPV/ sugar mills.
 - IREDA support for supplier credit/ letter of comfort for RE projects
 - IREDA scheme for solar rooftop through aggregator (RESCO)
 - Direct discounting of GBI for grid interactive wind and solar power projects
 - Direct discounting of capital subsidy payable to channel partners/SNAs for their solar water heaters
 - NCEF Refinance Scheme to banks/FI
- During the year 2016–17 IREDA has launched another new scheme, namely: 'Credit Enhancement Scheme

WATER HYACINTH

An Option for Biogas Production

Due to continuous depletion of the natural resources by an increased consumption of the energy, alternatives of fossil fuels must be searched out. Bioenergy is the only alternative and cheap source of energy which can be made easily available.

In this context, **Dr Anil Kurchania, Er B Velmurugan, Dr Madhuri Narra, Er Bipin Vyas, and Shakil U Saiyad** describe the various uses of water hyacinth and the production of biogas using it as a feedstock.



Water hyacinth (*Eichhornia crassipes*), one of the important invasive aquatic species, commonly covers the surface of rivers and lakes and causes a series of environmental problems due to its

rapid growth and high reproducibility in both clear water and wastewater. Thus, it is also considered as a noxious weed as it grows very fast and depletes nutrients and oxygen rapidly from water bodies, adversely affecting flora and fauna. There have

been instances of complete blockage of waterways by water hyacinth thus, making fishing and recreation very difficult. Under favourable conditions, water hyacinth can achieve a growth rate of 17.5 metric tonnes per hectare per day. Loss of water, through evapo-

transpiration, also occurs due to the presence of water hyacinth in water bodies, such as lakes and dams. It also provides a favourable habitat for mosquitoes and diseases.

Since the plant has abundant nitrogen content, it can be used a substrate for biogas production. Studies have been carried out which establish that methane can be produced from water hyacinth. However, aquatic weeds have a tendency to float due to air gaps, makes a scum layer at the top of slurry which hinders the biogas production. In view of this, research and development has been undertaken at the Sardar Patel Renewable Energy Research Institute (SPRERI), for efficient bio-methanation of water hyacinth integrated with bubble gun technology.

⚡ Biogas Potential of Water Hyacinth

Fresh water hyacinth was collected from nearby ponds/lakes and chopped to 2–4 cm size. Physico-chemical properties of water hyacinth were measured using standard protocols (Table 1).

Table 1: Physico-chemical properties of water hyacinth

Parameters	Values
Total Solids (%) (wb)	9.62
Volatile Solids (%) (db)	79.41
Ash (%) (db)	20.38
Cellulose (%)	22.11
Hemicellulose (%)	16.61
Lignin (%)	9.60
C (%)	36.00
N (%)	1.811
P (%)	0.85
K (%)	2.10
CV (Cal/g)	3,772.69

Initially, a semi-continuous biogas digester having the volume of 200 L was developed with inclusion of agitation system where agitation process is carried out with biogas in a closed loop. Foot pump was used to create the pressure and bubbles were formed in a GI pipe which was kept vertical at the centre of the digester (Picture 1). The chopped and crushed water hyacinth is fed at 4 per cent total solid content in the daily fed reactor through the inlet and stirring with the recirculation of biogas through pipe is carried out with a foot pump three times a day with 10 minutes duration each time. Hydraulic retention time was 25 days. Biogas production was found to be 20–22 L d⁻¹, i.e., 262.5 L kg⁻¹ TS water hyacinth.



➤ **Picture 1:** Daily fed water hyacinth reactor

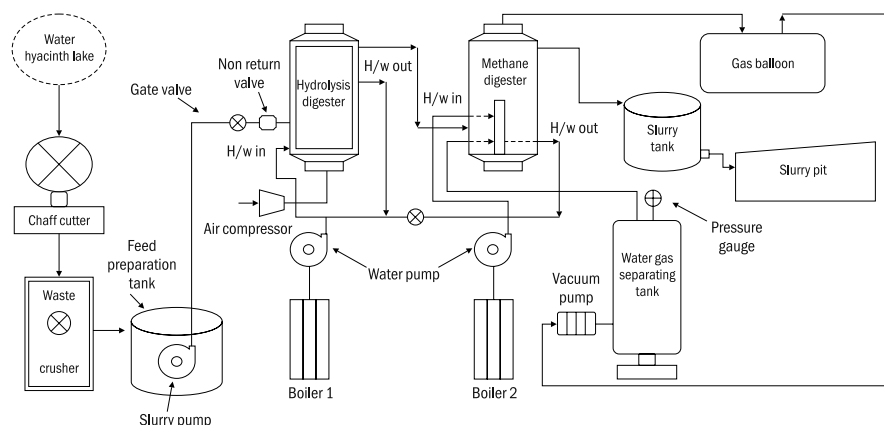


Figure 1: Biomethanation plant layout

⚡ Water Hyacinth Biomethanation Demonstration Plant

Based on the laboratory data, a high rate scale-up biomethanation demonstration plant with a feeding capacity of 1–1.20 tonne water hyacinth and water per day was developed and installed in the Institute premises with the financial support from the Ministry of New and Renewable Energy (MNRE), Government of India. All necessary components required for biomethanation of water hyacinth, that is, waste crusher, hydrolysis (3 m³ capacity) and methane digesters (15 m³ capacity), bubble gun for stirring and mixing the digester contents, geysers to maintain thermophilic conditions in both the digesters by hot water circulation, storage biogas balloon, water ring compressor pump for homogeneous mixing of the digester contents by re-circulating the biogas through the bubble gun were installed and commissioned. The plant layout comprising all components of biomethanation plant has been shown in Figure 1.

Fresh water hyacinth was chopped to 2–4 cm size and slurry was prepared with addition of water. Acclimatization of the culture with crushed water hyacinth has been initiated by feeding 100 kg of material and 900 L water. Once the process was stabilized, feeding was increased



up to 500 kg water hyacinth and 500 L water. The prepared slurry was pumped into the hydrolysis tank and compressed air passed from the bottom for mixing the contents of the hydrolysis digester. Mixing was done for 30 minutes three times a day. The hydrolysed material was fed into the methane digester. The mixing bubble gun (Picture 2) which was installed inside the methane digester

hot water at 50°C. The pictorial view of a demonstration plant is shown in Picture 3.

The average biogas production was observed as 245 L kg⁻¹ TS or about 20 L per kg of fresh material with 62 per cent methane content. The feeding was maintained at 1 to 1.2 T, thus, keeping the retention time from 12–15 days in the methane digester. The biogas produced was stored

after optimizing the prime movers and skipping the hydrolysis digester. It was observed that total revenue accrued from the project at the presently installed cost of ₹3,000,000 was ₹34,710. Since the cost of project can further be reduced by using only methane digester and escaping the hydrolysis digester and also optimizing the other equipment, the cost of biogas plant can be reduced to ₹1,500,000 and revenue generation will be ₹79,712. If a financial assistance of 30 per cent is provided on its project cost, the payback period may be reduced further.

The results revealed that the project is economically feasible and includes a desirable energy gain. The current approach to control water hyacinth does not represent a good social investment because of two major disadvantages: first, the biomass of water hyacinth is not used but is disposed of as waste; and second, the emissions from the thrown water hyacinth enter the atmosphere, thus, adding to greenhouse gas (GHG) emissions. Therefore, the proposed project is a good alternative to the current approach because the methane emission can be avoided and water hyacinth can be used as a substrate for high rate biomethanation system by mixing bubble gun technology at thermophilic temperatures for eradication of water hyacinth and other aquatic weeds. Municipalities and other government agencies involved in the disposal of water hyacinth may be benefitted. This biomethanation system may be used for different wastes, such as vegetable wastes, industrial effluents, etc., where slight modifications may be required as per the substrate.

*Acknowledgements: The financial support from the Ministry of New and Renewable Energy, Government of India, is duly acknowledged. **AU***

Dr Anil Kurchania (Email: bio@spreri.org), Er B Velmurugan, Dr Madhuri Narra, Er Bipin Vyas, and Mr Shakil U Saiyad, Sardar Patel Renewable Energy Research Institute (SPRERI), Vallabh Vidyanagar, Gujarat, India.



Picture 2: Mixing gun bubble generator with draft tube

re-circulated the compressed biogas (pressure 0.5 bar) for 15 minutes three times a day. Recirculation of biogas was designed to burst a bubble from the bubble gun every 60 seconds. Both the hydrolysis and methane digesters were operated at thermophilic conditions by circulating

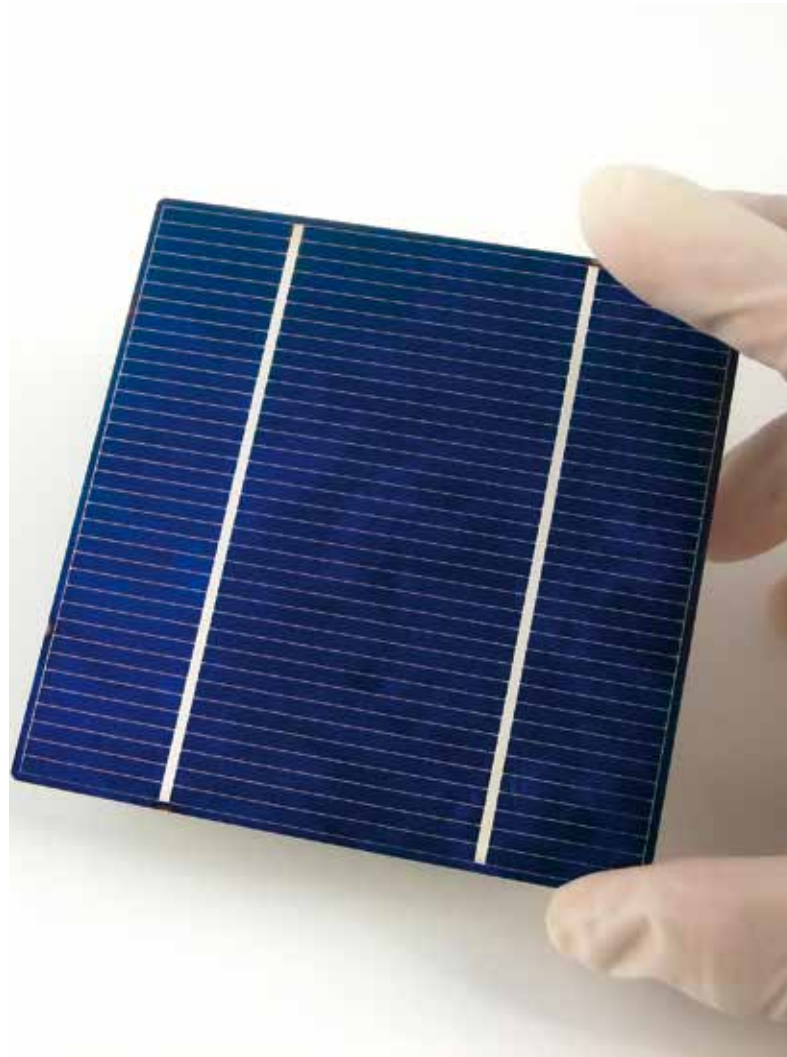
in a 25 m³ capacity biogas storage balloon, compressed by a vacuum pump and used for recirculation through the methane digester. Energy consumption was measured during the operation for the demonstration plant and it was about 21 kWh which can further be reduced to 11 kWh



Picture 3: Pictorial view of a demonstration plant

NEXT GENERATION SOLAR CELLS

The Future of Renewable Energy



Dr S S Verma highlights the journey of development of solar cells from their first to fourth generation, including the next generation solar cells and details the future scope of improvements as a potential source of alternative energy. He tells us that revolutionary techniques developed for the design and fabrication of solar cells could boost the efficiency of solar cells and accelerate the switch to renewable sources.

Solar cells, popularly known as PV cells, are actually electrical devices which help us to convert solar energy into direct current. When these cells are exposed to sunlight, they absorb photons and after completing the gap between two poles electric current starts to flow. These cells are helpful in controlling the voltage of electricity generated with reaction of positive and negative cells.

This field of technology came into practical use a few decades ago, when researchers were trying to find

an affordable and efficient means of producing energy through the use of renewable resources. However, solar power continues to be the most fruitful source of renewable energy. Due to the use of solar technology, small business owners can generate their own electricity for personal use at cheaper rates as compared to the local service provider. The International Energy Agency hopes to make solar cells the largest source of electricity in the world by 2050. Solar energy has, so far, faced strong

competition from hydroelectric and wind power, and only accounted for a small share of the total energy production. However, over time, solar power is emerging as perhaps, the greenest form of renewable energy and is in increasing demand across the world, with the global capacity for solar power generation now topping 100 GW. Significant progress has been made by the solar industry in bringing down the cost of solar electricity and in many parts of the world, it now competes with grid electricity in terms



⚡ Second-Generation (2G) Solar Cells

The second-generation (2G) solar cells were developed with the aim of reducing the high costs prevalent in 1G through the utilization of thin film technology; the idea being to save on bulk material cost with a significant reduction in the quality and quantity of the material used and the challenge of increasing the thin film absorption to compensate for the reduced thickness in the photoactive layers. This 2G thin film technology was based on PV materials identified during the development of 1G PVs and was extended to include amorphous or polycrystalline Si, CIGS, and CdTe. While the 2G PV family addresses the

cost issues associated with thick films, the performance of such 2G solar cells is known to be poor compared to their 1G counterpart. Therefore, the challenge was to improve the efficiency as much as possible within the inexpensive material envelope that encouraged the chemical vapour deposition of thin films and thermal crystallization, where appropriate. In the case of amorphous materials, to compensate for the significantly reduced active volume, an intrinsic layer was grown to produce p-i-n devices where photogenerated carriers could be swept to the doped materials by the built-in field. The key factor that worked in favour for 2G PV cells was the cost per watt delivery but the need for extended surface areas to compensate for the lower efficiency was an issue. This in turn pushed the development of the third-generation (3G) solar cells, including nanocrystalline films, PVs based on active quantum dots, tandem or stacked multilayers of

of cost, and since it requires fewer infrastructures, solar power can also be used in areas where conventional electricity is not an easy option.

Usually, when people are asked to imagine a solar panel, they will immediately think of the large, dark blue, silicon-based panels commonly seen in residential rooftop installations. However, recent innovations in alternative photovoltaic technologies have opened the possibility of solar panels with features such as flexibility, customized shape, and transparency. Flexible solar cells are lightweight due to the lack of heavy glass sheets and metal frames, thus, significantly reducing transportation and deployment costs. Requirements, limitations, and developments towards the conversion of solar power into electricity making use of solar cells have processed their (solar cells) development to present four generations with unique improvements related to their characteristics, such as solar spectrum, cost, safety, durability,

and efficiency, etc., and next generation of solar cells with more exotic properties are in the pipeline in the near future.

⚡ Types of Solar Cells

Today, four generations of solar cells are available, thus, enabling the use of different types of solar cells according to our needs and preferences. Some of the significant ones have been described in this article.

⚡ First-generation (1G) Solar Cells

Traditionally, the first-generation (1G) PV technology is known to comprise of photovoltaic technology based on thick crystalline films (mainly Si) which not only leads to high efficiency, but also high cost. These were the first generation PV cells and silicon continues to rule in the commercial market due to its dominant qualities. Typically, these cells are made with crystalline silicon wafer.

inorganics based on III–V materials such as GaAs/Ge/GaInP₂, or novel device concepts such as hot carrier cells where the aim was to obtain higher performance than their 2G counterparts, at a lower cost. These cells were known as Plasma Enhanced Chemical Vapor Deposition (PECVD). In this generation, four types of solar cells were introduced, including the amorphous silicon cells which can be deposited over large areas with the help of PECVD. Their band gap was about 1.7 eV and function was similar to c-Si. Polycrystalline silicon, made of pure silicon grains, works better than the previous designs because of their mobility. These can be easily moved over a large magnitude. Cadmium telluride (CdTe) cells are formed with cadmium and tellurium mixed with zinc cubic crystal structure. This material is cheaper than silicon but not as efficient as silicon. Copper indium gallium diselenide (CIGS) alloy cells are deposited on glass or stainless steel and are a complex model. Their band gap is about 1.38 eV.

⚡ Third-Generation (3G) Solar Cells

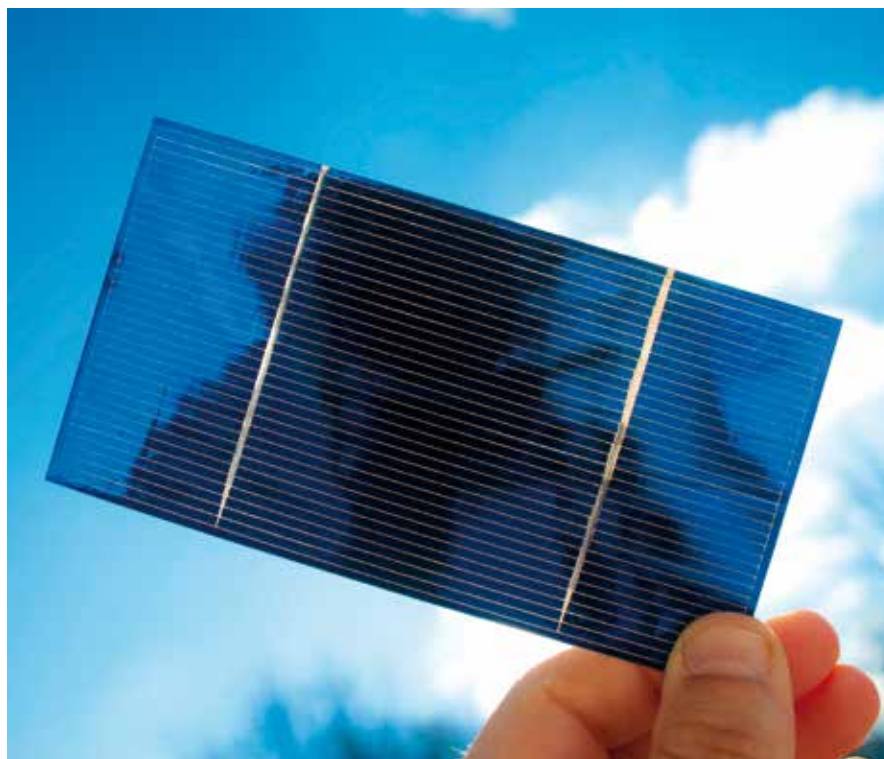
Thereafter began a true race to design materials at the nanoscale and scale-up to the macroscopic areas. For the first time, significant attention was paid to the charge and energy transfer processes and the respective routes to optimize charge collection, thereby enhancing the energy capture within the solar spectrum. With the introduction of organic materials exhibiting photovoltaic properties, their potential for low cost and high optical absorption placed them as a 3G technology. In addition to organic (or polymer) solar cells, another candidate that grew to dominate 3G PV technologies is dye or semiconductor sensitized solar cells (DSSCs). Despite the reasonable success of 3G cells, significant improvements in device performances

are required if this technology is to be competitive with the previous PV generations in terms of cost per watt. This generation was very different from the previous one due to the use of innovative semiconductors. The various types of solar cells introduced in this generation, include Nanocrystal solar cells, Photoelectrochemical (PEC) cells, Grätzel Cell, Dye-sensitized hybrid solar cells, and Polymer solar cells. Nanocrystal solar cells were based on silicon substrate with coating of nano crystals. A thin film of nano crystals is used along with it which was obtained by the process of spin coating. They create a higher potential for solar cells. PECs were second on the list and consisted of a semiconducting photoanode. It works best with electrons and can also separate non-salacity of semiconductors. Grätzel cells were dye sensitized and used photoelectrons to increase power efficiently. Dyes were made of metal organic complex and its molecules are hit by increasing heat. The polymer solar cells were the last invention of this generation; they were lightweight, inexpensive, flexible,

and disposable at any molecular level. They have little negative impact on the environment. In turn, these 3G cells offer significant cost improvements on first and second generation solar cells—based on crystalline and polycrystalline silicon—which are still responsible for over 90 per cent of the solar power being generated today.

⚡ Fourth-generation (4G) Solar Cells

The fourth generation (4G) of PV technology which combines the low cost/flexibility of polymer thin films with the stability of novel inorganic nanostructures was introduced with the aim of improving the optoelectronic properties of the low-cost thin film PVs. These device architectures are meant to maintain the inexpensive nature of a solution-processable PV device structure; but incorporate inorganic components to improve on energy harvesting cross-sections, the charge dissociation, and charge transport within the PV cells. While the





previously introduced mesoscopic solar cells may be considered as a 4G technology due to the incorporation of an inorganic component (usually titania), especially when combined with a polymer or organic layer as a solid-state DSSC, this inorganic component is a requirement for the functionality of the cell and does not introduce additional benefits as for the inorganics-in-organics architectures. Till date, the most effective polymer solar cells (PSCs) have been based on the bulk heterojunction (BHJ) concept. The 4G solar cells are a hybrid that combine the low cost and flexibility of conducting polymer films (organic materials) with the lifetime stability of novel nanostructures (inorganic materials). This inorganics-in-organics technology improves the harvesting of solar energy and its conversion into electricity, offering better efficiency than the current 3G solar cells while maintaining their low cost base. These new generation materials for solar cells have been truly engineered at the nanoscale. They are designed to maximize the harvesting of solar radiation, and thereby efficiently generate electricity. It is believed that 4G solar cells will be the technology for future photovoltaic energy sources.

This generation brings most successful types of solar cells for mankind and those were hybrid-nanocrystal cells. For generation of these cells polymers and nanoparticles were mixed to make on layer which can help electrons and protons to move for producing better voltage and good quality of direct current.

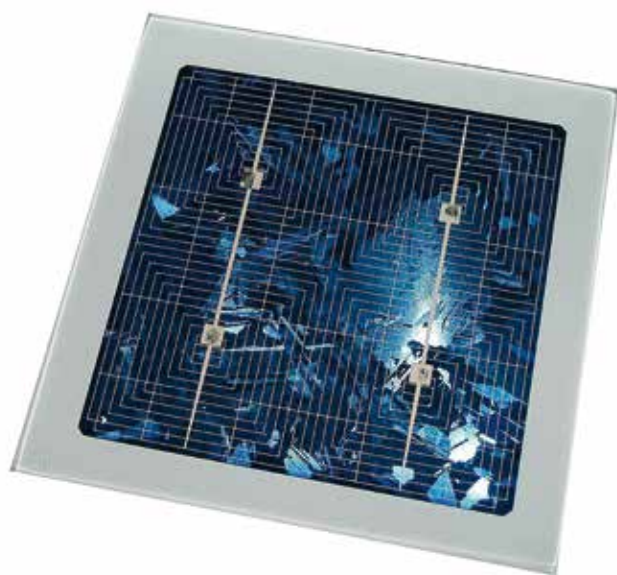
⚡ Next Generation Solar Cells

So far, most of the solar cells are entirely made of inorganic semiconductors, usually silicon, but these materials are not as energy efficient as organic semiconductors. The new method lies in the groundwork for building a new generation of solar cells made up of both organic and inorganic material. In silicon solar cells, every single particle of light (photon) can excite one electron only, but with a new material (naturally present in green leaves), the same quantity of light releases not one but two electrons, doubling the energy capacity of the semiconductor. This improves the energy efficiency ratio to up to 95 per cent, a figure impossible to reach with conventional, inorganic semiconductors. The process 'clears

the way for hybrid solar cells which could far surpass current efficiency limits'. The next-generation solar cells could be infinitely more useful, thanks to a newly discovered nanotube structure capable of transporting electrical charges 100 million times higher than previously measured. Most solar cells

THE FOURTH GENERATION (4G) OF PV TECHNOLOGY WHICH COMBINES THE LOW COST/FLEXIBILITY OF POLYMER THIN FILMS WITH THE STABILITY OF NOVEL INORGANIC NANOSTRUCTURES WAS INTRODUCED WITH THE AIM OF IMPROVING THE OPTOELECTRONIC PROPERTIES OF THE LOW-COST THIN FILM PVs. THESE DEVICE ARCHITECTURES ARE MEANT TO MAINTAIN THE INEXPENSIVE NATURE OF A SOLUTION-PROCESSABLE PV DEVICE STRUCTURE; BUT INCORPORATE INORGANIC COMPONENTS TO IMPROVE ON ENERGY HARVESTING CROSS-SECTIONS, THE CHARGE DISSOCIATION, AND CHARGE TRANSPORT WITHIN THE PV CELLS.

currently use silicon to absorb light, however inefficiencies in the material have led scientists to develop carbon nanotubes that can be implemented to enhance the light absorption capabilities of current cells. However, until now the nanotubes have been randomly placed within the solar cells in suboptimal structures as they are difficult to arrange. Scientists are able to manipulate the carbon nanotubes using controlled, nano-scale dimensions inside a polymer matrix. This method allowed rearranging the nanotubes into complex networks that reduced the cost of nanotubes needed. Extremely small amounts of nanotubes can be used—less than 1 per cent—and still produce



THE NEXT-GENERATION SOLAR CELLS COULD BE INFINITELY MORE USEFUL, THANKS TO A NEWLY DISCOVERED NANOTUBE STRUCTURE CAPABLE OF TRANSPORTING ELECTRICAL CHARGES 100 MILLION TIMES HIGHER THAN PREVIOUSLY MEASURED. MOST SOLAR CELLS CURRENTLY USE SILICON TO ABSORB LIGHT, HOWEVER INEFFICIENCIES IN THE MATERIAL HAVE LED SCIENTISTS TO DEVELOP CARBON NANOTUBES THAT CAN BE IMPLEMENTED TO ENHANCE THE LIGHT ABSORPTION CAPABILITIES OF CURRENT CELLS. HOWEVER, UNTIL NOW THE NANOTUBES HAVE BEEN RANDOMLY PLACED WITHIN THE SOLAR CELLS IN SUBOPTIMAL STRUCTURES AS THEY ARE DIFFICULT TO ARRANGE.

efficient devices leading to lower material cost. Solar cells made of these materials are solution processable, implying that do not require expensive equipment and yet increase the conductivity within the cell. The resulting nano networks possess exceptional ability to transport charges up to 100 million times higher than previously measured carbon nanotube random networks produced by conventional methods.

However, photovoltaic cells continue to depend on light to produce electricity, and so, generate a negligible amount of power when there are clouds overhead. But, researchers wondered whether it would be possible to create all-weather solar cells. Rain helps solar cells operate efficiently by washing away dust and dirt that block the sun's rays. Solar cells could someday generate electricity even during rain showers with the help of graphene. Raindrops contain salts that split up into positive and negative ions. In order to manipulate that bit

of chemistry, researchers turned to graphene, the one-atom-thick sheet of carbon. Graphene's electrons can attract the positively charged ions, such as sodium, calcium, and ammonium, resulting in separated layers of positive and negative ions that act much like a capacitor to store energy. With that in mind, scientists added graphene to a dye-sensitized solar cell, a kind of inexpensive thin-film solar cell, thereafter placed these on a flexible, transparent backing of indium tin oxide and plastic. The resulting flexible solar cell demonstrated a solar-to-electric conversion efficiency of up to 6.53 per cent, and generated hundreds of microvolts from slightly salty water that was used to simulate rainwater. Therefore, future solar cells may produce electricity in all-weather conditions with high efficiency, desired geometry and long life span.

Acknowledgements: The use of information retrieved through various references/sources of internet in this article is highly acknowledged. **AU**

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AKSHAY URJA WELCOMES ARTICLES ON RE

The need to have a sustainable energy supply necessitates the exploration of available energy sources, and among these, renewable resources are at the forefront. It is now an established fact that RE (renewable energy) can be an integral part of sustainable development because of its inexhaustible nature and environment-friendly features. RE can play an important role in resolving the energy crisis in urban areas to a great extent.

Today RE is an established sector with a variety of systems and devices available for meeting the energy demand of urban inhabitants, but there is a need to create mass awareness about their adoption. *Akshay Urja* is an attempt to fulfil this need through the dissemination of 20,000 copies (bilingual) in India and abroad. The magazine 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 in high resolution files on a CD or through email. *Akshay Urja* will pay an honorarium of ₹2,500 to the authors for each published article of 1,500 words and above. The publication material in two copies, along with a soft copy on CD/DVD/email may be sent to:

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SKILLING MANPOWER

The New Ecosystem

The gradual evolution of India as a knowledge-based economy has resulted in an abundance of qualified manpower. However, there is a great scope to further develop and empower this manpower in order to ensure the country's global competitiveness. **Dr P Saxena** provides an overview of the various steps taken by the government and key stakeholders towards skilled manpower.





Today, India is one of the youngest nations in the world with more than 62 per cent of its population in the working age group (15–59 years) and more than 54 per cent of its total population below 25 years of age. Its population pyramid is expected to bulge across the 15–59 age group over the next decade. It is further estimated that the average age of the population in India by 2020 will be 29 years as against 40 years in USA, 46 years in Europe, and 47 years in Japan. In fact, during the next 20 years, the labour force in the industrialized world is expected to decline by 4 per cent, while it will increase by 32 per cent in India. This poses a formidable challenge and a huge opportunity. In order to reap this demographic dividend, which is expected to last for next 25 years, India needs to equip its workforce with employable skills and knowledge so that they can contribute substantively to the economic growth of the country.

⚡ National Policy for Skill Development and Entrepreneurship 2015

Recognizing the imperative need for skill development, the National Policy for Skill Development and Entrepreneurship 2015 was announced on July 15, 2015. The primary objective of this policy is to

meet the challenge of skilling at scale with speed, standard (quality), and sustainability. It aims to provide an umbrella framework to all skilling activities being carried out within the country, align them to common standards, and link skilling with the demand centres. In addition to laying down the objectives and expected outcomes, the policy also identifies the overall institutional framework which will act as a vehicle to achieve the expected outcomes.

As per the policy, skill development is the shared responsibility of the key stakeholders, namely the government, the entire spectrum of the corporate sector, community-based organizations, those outstanding, highly qualified, and dedicated individuals who have been working in the skilling and entrepreneurship space for many years, industry and trade organizations, and other stakeholders. The policy links skills development to improved employability and productivity in paving the way forward for inclusive growth in the country. The skill strategy is complemented by specific efforts to promote entrepreneurship in order to create ample opportunities for the skilled workforce.

The core objective of the policy is to empower the individual by enabling her/him to realize their complete potential through a process of lifelong learning where competencies are

accumulated via instruments, such as credible certifications, credit accumulation, and transfer, etc. As individuals grow, the society and nation also benefit from their productivity and growth.

Skill development and entrepreneurship are complementary to each other. The key stakeholders include central ministries/ departments, state governments, and industries/employers. There is a need to ensure alignment of the efforts of all stakeholders, in the skill and entrepreneurship landscape, towards a common goal. While the Ministry of Skill Development and Entrepreneurship, Government of India, will coordinate and converge all efforts in this space, the relevant central ministries/departments, state governments, and industries/employers are expected to fulfill the roles and responsibilities pertaining to their domain.

⚡ Sector Skill Councils (SSCs)—An Important Arm of Execution

In order to ensure that skill development efforts, by all stakeholders in the system, are in accordance with actual needs of the industries, Sector Skill Councils (SSCs) have been set up. SSCs are autonomous, industry-led and industry-governed bodies which will help link the requirements of industry



with appropriately trained manpower. The SSCs are set up for the purpose of developing sector-specific competencies/skills, assurance of quality through accreditation of the skills acquired by trainees, curriculum development for skills training, qualification framework, setting requisite standards and benchmarks, recruitment and placement of trained and skilled workforce, as well as data collection, management, and provider of well-trained workforce to the industry.

The SSCs are national-level organizations with a government–industry interface and formed in partnership with stakeholders from industry, labour as well as the academia. The Agriculture Skill Council of India, Automotive Skills Development Council, Gems & Jewellery Skill Council of India, Power Sector Skill Council, and so on, are just a few examples of the numerous SSCs presently in operation. The initial funding, in these Councils, is by the government and it becomes self-funded as it grows over a period of time. Formed as a Society or a Sec 25 Company with its own Governing Council, CEO, and a secretariat, the SSC is a separate entity. Specifically,



SSCs complement the vocational institutes and existing education system for an interface with the industry.

Skill Council in the Renewable Energy Sector

It is realized that multi-fold scaling up of renewable energy generation capacity requires commensurate development of skilled workforce for manufacturing, project work, and asset maintenance. The renewable energy sector alone is likely to have two million green jobs in the next

10 years. A strong urgent need of a broad-based, industry-led skill development activity to up-skill and/or re-skill manpower is felt.

The Ministry of Skill Development and Entrepreneurship jointly with the Ministry of New and Renewable Energy has set up the 'Skill Council for Green Jobs'. The main promoters of the Council are the Confederation of Indian Industry (CII) and Ministry of New and Renewable Energy. The Council began its operations from October 1, 2015. In this short time, it has affiliated over 70 training partners, across the country, to impart quality training in its domain of activities. It has also developed the National Occupational Standards and Qualification Packs in the solar domain. Most recently, it has come out with three participant handbooks on solar rooftop installations. It is in the process of developing the National Occupational Standards for solar designers; ground-mounted SPV power plants, solar proposal evaluators, and so on. Simultaneously, it has also identified wastewater treatment as its priority area to meet skilled manpower requirements of the Swachh Bharat Mission.

A 'green job' is defined as one that helps bring about and maintain a transition to environmentally sustainable forms of production and consumption. It cut across all the





sectors, be it energy, materials, water conservation, waste management, pollution control, etc. The green skill can be divided into two categories—developing green skills for the existing

A 'GREEN JOB' IS DEFINED AS ONE THAT HELPS BRING ABOUT AND MAINTAIN A TRANSITION TO ENVIRONMENTALLY SUSTAINABLE FORMS OF PRODUCTION AND CONSUMPTION. IT CUT ACROSS ALL THE SECTORS, BE IT ENERGY, MATERIALS, WATER CONSERVATION, WASTE MANAGEMENT, POLLUTION CONTROL, ETC. THE GREEN SKILL CAN BE DIVIDED INTO TWO CATEGORIES—DEVELOPING GREEN SKILLS FOR THE EXISTING WORKFORCE AND SKILLING WORKFORCE FOR GREEN JOBS.

workforce and skilling workforce for green jobs. While the Skill Council for Green Jobs proposes to target both these categories, the immediate focus would be skilling the workforce towards green jobs for renewable energy, energy efficiency, and waste treatment.

Marking the first anniversary of the Skill India Mission on July 15, 2016, the Ministry of Skill Development and Entrepreneurship announced the launch of new initiatives—Pradhan Mantri Kaushal Vikas Yojana (PMKVY) 2.0, India International Skill Centres, India Skills Online, and a Labour Management Information System (LMIS)—thereby, reinforcing the Ministry's commitment to the youth of India. Skill India is seeing great traction and is all geared to meet its philosophy of speed, scale, and standards, ensuring there are ample opportunities for everyone to acquire skills. The Union Cabinet has approved ₹22,000 crore worth of outlay for programmes, such as Apprenticeship Protsahan Yojana and PMKVY 2.0, to be implemented over the next few years. Given the realities of the rapidly changing economic landscape in the country, entrepreneurship opportunities have emerged as an important source of meeting the growing aspirations of the youth. An all-inclusive approach, which is competent, quality conscious, market savvy, innovative, and comprises globally competitive entrepreneurs, to strengthen the entrepreneurship development scenario in the country, needs to be carefully mentored and encouraged. Skills need to be an integral part of employment and economic growth strategies to spur employability and productivity. Coordination with other national macroeconomic paradigms and growth strategies is, therefore, critical. For a skills strategy to be successful, it should be complemented by commensurate creation of jobs in the primary, secondary and tertiary sectors. **AU**



"Today, the world and India need a skilled workforce. If we have to promote the development of our country then our mission has to be 'skill development' and 'Skilled India'. Millions and millions of Indian youth should acquire the skills which could contribute towards making India a modern country. I also want to create a pool of young people who are able to create jobs and the ones who are not capable of creating jobs and do not have the opportunities, they must be in a position to face their counterparts in any corner of the world while keeping their heads high by virtue of their hard work and their dexterity of hands and win the hearts of people around the world through their skills. We want to go for the capacity building of such young people. My brothers and sisters, having taken a resolve to enhance the skill development at a highly rapid pace, I want to accomplish this."

**Hon'ble Prime Minister of India,
Shri Narendra Modi**

Dr P Saxena, Chief Executive Officer, Skill Council for Green Jobs, Chanakyapuri, New Delhi, India. Email: ceogreenjobs@gmail.com.

Developed 1 m³ FRP biogas plant

FRP BIOGAS PLANT

for Efficient Kitchen Waste Management

Availability of sufficient energy, food, and waste disposal facilities are highly essential for the development of the community.

Disposal of kitchen waste is a great problem for community kitchens as the undisposed waste raises problems for public health as well as ecological system. A research work was undertaken to improve the anaerobic digestion of family-size biogas plants based on kitchen waste integrated with phase separation compartments.

Dr Deepak Sharma, Er Kapil Samar, and **Er Amol Shurpatne** of Biogas Development and Training Centre describe performance evaluation of fibre glass reinforced plastic (FRP) technology based one cubic metre capacity biogas plant.

There is worldwide awakening for protection of environment and safe disposal of food/ kitchen waste. In Denmark, it is mandatory that restaurants, public institutions, and other catering centres collect their food waste for recycling. Kitchen waste is available from mess and canteens of industrial establishments, hotels, hostels, religious institutions, etc., where food is prepared for a number of people at a time, in community-type kitchen. All these produce a large quantity of kitchen waste every day, which is generally accumulated near the kitchen. This waste degrades aerobically and, after sometime, emits foul odour and makes the environment near kitchen polluted. Kitchen waste mainly consists of the following:

- Uncooked food waste, such as potato peelings, onion peelings, melon peelings, banana peelings, cabbage, leaves and stem, rotten vegetables, pumpkin peelings, etc.
- Remains of dressed vegetables, such as green pea, green gram, etc.
- Cooked food, such as rice, pieces of chapattis, vegetable waste, tea leaves, etc.

Technology has now been developed for completely prefabricated and portable high-density polyethylene (HDPE), fibre glass reinforced plastic (FRP), rubberized nylon fabric, and RCC-based biogas plants that are being made in factories and assembled on site for installation. The prefabricated biogas plants could be suitable for rural as well as urban areas and would better meet the criteria for judging a technology ready for mass-scale diffusion.

Methodology

Family-size biogas plant was developed to create better conditions for anaerobic digestion of kitchen waste by separating the three main processes of hydrolysis, acid phase, and methane phase with the help of

making compartments inside the digester by providing two partitions having certain heights. These compartments were made of FRP material and their volumes were decided considering the number of days for which the slurry inside the digester was to be kept. The days required for acid phase and methane phase were determined by evaluating laboratory results, where variations of pH along with other parameters were mainly evaluated. The volume of slurry kept for acid phase was further divided into hydrolysis, acid formation, and methane formation phases decided on the basis of past research work. Fresh slurry fed in the digester from inlet pipe is retained in the first compartment for a certain period to create hydrolysis process. Afterwards, the slurry passes into the second compartment by crossing the first partition and is retained there for the acid phase. After a certain time period, the slurry passes into third compartment crossing the second partition. Flow of slurry from one compartment to another also helps to better mix the slurry inside the digester (Figure 1).



digester with inlet and outlet tanks. The gas dome was made from a special three-layer reinforced fabric namely high-tenacity rubberized nylon fabric coated with hypalon on the outer and neoprene on the inner surface. FRP digester was fabricated in two segments, and they were assembled with a vertical joint at the site. Flanges with holes were provided at the joint and the segments were assembled by bolts, keeping a rubber seal having thickness of 5 mm between the flanges to make the digester leak proof. Digester was fabricated in parts to make its transportation easier and more economical. Construction of FRP digesters is simple and can be done at local level whereas HDPE/LDPE digesters require the fabrication at one central place with the help of costly moulds and then have to be transported

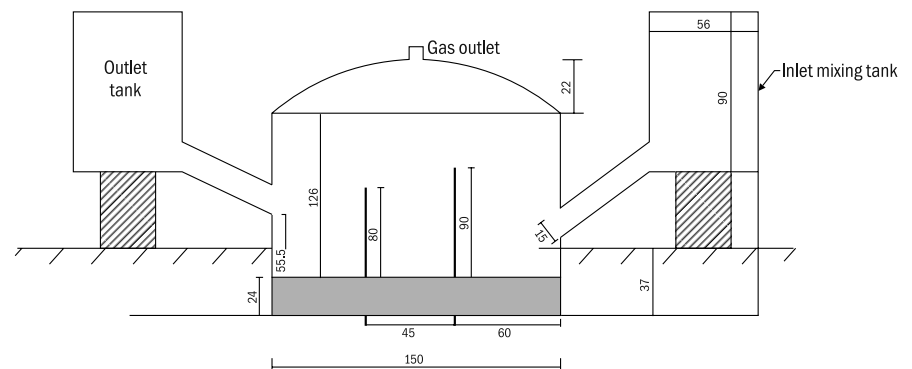


Figure 1: Schematic diagram of family-size FRP biogas plant integrated with phase separation

The pilot plant was fabricated by FRP and consisted of cylindrical

to site. Technical specifications of the developed model are given in Table 1.

**Table 1:** Technical specification of the FRP biogas plant

Sr. No.	Descriptions	Unit	Specification
FRP biogas plant			
1	Capacity of plant	m ³	1
2	Total volume of biogas plant	m ³	2.4
3	Slurry volume in digester	m ³	1.6
4	Gas storage volume with balloon	m ³	0.8
5	Diameter of digester	m	1.50
6	Depth of digester	m	1.26
Design parameters			
1	Hydrostatic pressure	Pa	10,591.18
2	Earth pressure	Pa	756
3	Hoop stress (σ_h)	MPa	2.21
4	Longitudinal stress (σ_L)	MPa	1.10
5	Circumferential strain		6.32×10^{-4}
6	Longitudinal strain (ϵ_L)		7.71×10^{-5}
7	Thickness of FRP plant	mm	6
8	Thickness of balloon	mm	0.6
C) Height of partition walls			
1	First wall (nearer to inlet side)	cm	90
2	Second wall (nearer to outlet side)	cm	80
D) Other parameters			
1	Feed rate	kg/day	25
2	Retention period	day	40
3	Quantity of kitchen waste	kg/day	12.5
4	Quantity of cattle dung	kg/day	12.5
5	Dilution ratio		1:1 (kitchen waste + cattle dung : water)
C) Height of partition walls			
1	First wall (nearer to inlet side)	cm	90
2	Second wall (nearer to outlet side)	cm	80
D) Other parameters			
1	Feed rate	kg/day	25
2	Retention period	Day	40
3	Quantity of kitchen waste	kg/day	12.5
4	Quantity of cattle dung	kg/day	12.5
5	Dilution ratio		1:1 (kitchen waste + cattle dung : water)

Results

Biogas volume generated through developed 1 m³ biogas plant was observed daily with the help of dry biogas flow meter. Biogas production varied from 637 to 896 L/day in FRP biogas plant. Average biogas production from FRP plant was

786.05 L/day. The average methane and carbon dioxide content were observed as 57.43 and 39.2 per cent, respectively (Figure 2).

Total solids, total volatile solids, pH, and organic carbon content were observed at the interval of every 20 days. These parameters were observed after stabilization of methanogenic

activities in the plant whereby the plant started generating near constant production of the biogas.

It can be observed that the average total solid content of the inlet charge was 9.37 per cent in the mixture of cattle dung and kitchen waste that reduced to 7.5 per cent for the digested slurry. Similarly, the average total volatile solid were calculated as 79.36 per cent of total solids for the inlet charge of the plant, which reduced to 64.35 per cent after digestion. The average Nitrogen, Phosphorous, and Potassium (N,P,K) content in the fresh slurry was observed as 1.19, 0.77, and 0.54 per cent, respectively, whereas the average N,P,K content in digested slurry was observed as 1.41, 0.90, and 0.64 per cent, respectively. Average increase of 16 per cent in N,P,K value in the digested slurry was also observed.

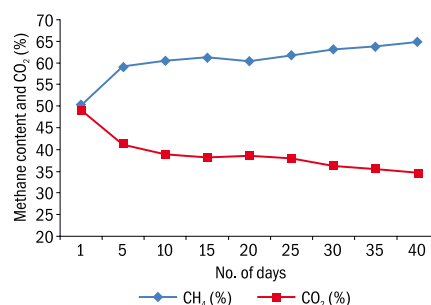


Figure 2: Methane and carbon dioxide content of biogas in digestion period

Conclusion

In consideration of the atmospheric pollution and disposable solution of kitchen waste, the developed FRP biogas plant provides feasible solution to public. The feasibility of phase separation and duration of digestion stages was assessed. Family-size FRP biogas plant integrated with phase separation of 1 m³ capacity performed satisfactorily. Average biogas production from FRP plant was 786.05 L/day. **AU**

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SOLAR ENERGY EDUCATION IN INDIA

for Sustainable Skill Development



A major obstacle to the development of solar energy is the presence of a large void in education process. This void can be filled by putting efforts to improve overall understanding and knowledge of reliable and environmentally sound solar energy. It is essential for young students to learn about energy and energy sources, a changing environment, and a sense of interdependence of systems on earth.

Umakant Sahoo of NISE talks about the various initiatives by NISE made in this direction.

Solar energy as an education subject normally involves physical science and engineering, but sometimes depending on the student category, also economics and social science. It is necessary to introduce solar energy concept from the very early stage of education. For primary level, the courses demonstrate the principle of solar energy and conversion of solar energy to electricity through solar cell and heat through solar thermal technologies. In addition, during night time and cloudy days, no energy is available from the sun. Therefore, the concept of energy storage is introduced for electricity and process heat applications. A number of organizations are engaged in developing curriculum/teaching materials for renewable energies especially at ITI levels.

For a student in secondary school, the content of the course is based on the concept of simple, either stand-alone or hybrid energy systems. However, the types and sizes of various components are given, that is, the effects of series and parallel connections of solar cells, modules, batteries, charge controllers, measuring equipment, energy converters, system protection, and various characteristics of electrical appliances are considered. Also, different types and sizes of solar thermal technologies are used for various process heat applications, that is, flat plate collector, evacuated tubular collector, parabolic trough collector, Scheffler, and solar dish. It was found that approximately 60 per cent of the responded institutes are either engaged in developing curriculum for ITI or developing teaching resource materials in the area of solar energy.

⚡ University Education

At the university level, the proposed solar energy topics could be included with applied science or engineering courses. Solar energy courses can be



a part of the regular undergraduate and postgraduate programmes. This could be done by incorporation of solar energy concepts in routine science and engineering subjects with the help of thermal power; heat and mass transfer; thermodynamics for instance in solar collectors, solar cookers, solar distillation system, solar chimney, solar thermal, and power systems; etc. It has been found through the survey that 45 per cent responded organizations are conducting courses on solar energy at undergraduate/postgraduate level as a part of full-fledged engineering course.

It appears through the survey that only 60 out of 1,346 technical institutions in India offer postgraduate courses in Energy Management with electives on Renewable Energy (Solar Energy). And, only one engineering college named AMITY University have taken the special branch on engineering course of solar energy.

⚡ The Role of National Institute of Solar Energy (NISE)

It has been found that only 20 per cent of organizations are running short training courses and conducting workshops on solar energy. The National Institute of Solar Energy (NISE) is one of the institutions that provide scientific, technical, and practical training for people working in the area of solar energy and conducting training programmes for government officials of different departments in order to educate them about various aspects of solar energy. The Energy and Research Institute (TERI) also conducts training programmes on renewable energy and solar energy. Some of the IITs and NITs are also conducting training programmes related to solar energy and its applications. Recently, rapid development of solar energy applications, including



⚡ Suryamitra training programme

electrical power generation, hot water production, building heating and cooling, and industrial process heat have created the need for training and education of the workforce and future researchers in skill development programme. This proposal aims to develop the needed educational material incorporating the latest advances and field deployed commercial systems, providing field experience for students. The courses were initially developed by a group of faculty members at NISE and offered at various institutions.

⚡ Objectives of the programme

- Train students for fundamental understanding of solar energy and its application
 - Provide hands-on experience on design and development and research in solar-based energy conversion systems at the facilities of various institutions
 - Creation of manpower specialized in the applications of solar energy.
- These focussed trainings will assist in building capacity of solar energy professionals in India to achieve solar deployment targets for 2022.

⚡ Public Awareness Programme

Lack of public awareness about solar energy is a significant obstacle that limits the utilization of this important and freely available energy source. There are some methods that could be used to disseminate information amongst large number of people in shortest time, such as newspaper, television, radio, exhibition, etc. Seminar, workshops, and conferences in universities on the subject of solar energy are a good tool for gathering interested people. These discussions will provide the environment to effectively present seminars about solar energy and to discuss and exchange ideas among the specialization. It is recommended to include solar energy subjects in the current curriculum at every level of education. Degree courses on solar energy are required to be arranged for creation of appropriate technical manpower in the field of solar for sustainable development. In addition, a well-organized solar energy information network is required to be established. Organizing relevant workshops and seminars could also

play a significant role in increasing the public awareness about utilizing solar energy.

⚡ Progress of Solar Energy Skill Development in India

This area could require more concentration especially in the trade of electricians, plumbers, installation of solar water heating systems, operation of solar thermal, solar photovoltaic plant, etc., so that trained tradesmen can easily install, operate, maintain, and look after solar equipment. 'Skilling India' is the dream project of the Hon'ble Prime Minister of India for creating job opportunities for the unemployed youth in the various service and manufacturing sectors throughout the country. It is a flagship programme of the PMO targeting to create 500 million skilled manpower by 2020.

The National Institute of Solar Energy (NISE) has been assigned with the responsibility to execute various skill development programmes throughout the country in the field of solar energy technology. NISE has innovative, result-oriented skill development division to cater to the need of 'Make in India' programme. At present, various programmes are

being conducted at NISE and at its partner institutes across India.

⚡ Skill Development Activities at NISE

NISE is conducting solar energy training for the past two decades for national and international participants. NISE regularly invites people from solar and renewable energy industry and interacts with them to identify the skill gaps in the new recruits of the renewable energy industry. A dedicated training programme on renewable energy technologies for the senior defence, BSF officers, and chartered engineers are also regularly being conducted 2–3 times in a year. NISE has excellent laboratory facilities (viz., RE Skill Development Training Laboratory, Solar PV Electronics Skill Development Laboratory, PVSyst/PVSOL laboratory) to offer training to trainers and to the participants of training courses in NISE campus. About 30 skill development programmes were conducted at NISE campus during 2015–16. NISE proposes to conduct 50 training programmes in FY 2016–17 that includes in-house training programmes at NISE as well as programmes at other locations spread all over India.

⚡ Suryamitra Programme

NISE is organizing 'Suryamitra' skill development programme, in collaboration with State Nodal Agencies, at various locations across the country. The duration of this skill development programme is 90 days. It is a residential programme and it is free of any cost, which includes boarding and lodging. Suryamitra Skill Development Programmes are sponsored by the Ministry of New and Renewable Energy (MNRE), Government of India. More than 100 academics and R&D institutions/organizations are partnering with NISE to train 50,000 Suryamitras (i.e., 50,000 ITI/diploma holders) in the three years (FY 2015–16 to FY 2017–18). NISE is also offering Suryamitra course from its campus. The Government of India is contemplating increasing the number of trained Suryamitras to 100,000 by 2019–20. More than 350 academicians and R&D institutions/organizations are expected to participate in this programme to achieve the target of 100,000 Suryamitras. NISE is the National Coordinator for administering the programme.

⚡ Solar Energy Training Network (SETNET)

NISE has established the Solar Energy Training Network (SETNET) institutions across India to build skills and capacities to ensure the availability of qualified solar energy professionals to meet the national solar deployment targets. The objective of SETNET is to ensure availability of skilled manpower to meet the solar deployment target for 2022. Through a competitive process, NISE has identified 35 SETNET partners across the country that are empanelled by NISE to provide the skill development courses. Several programmes are being launched across India. ^{AU}

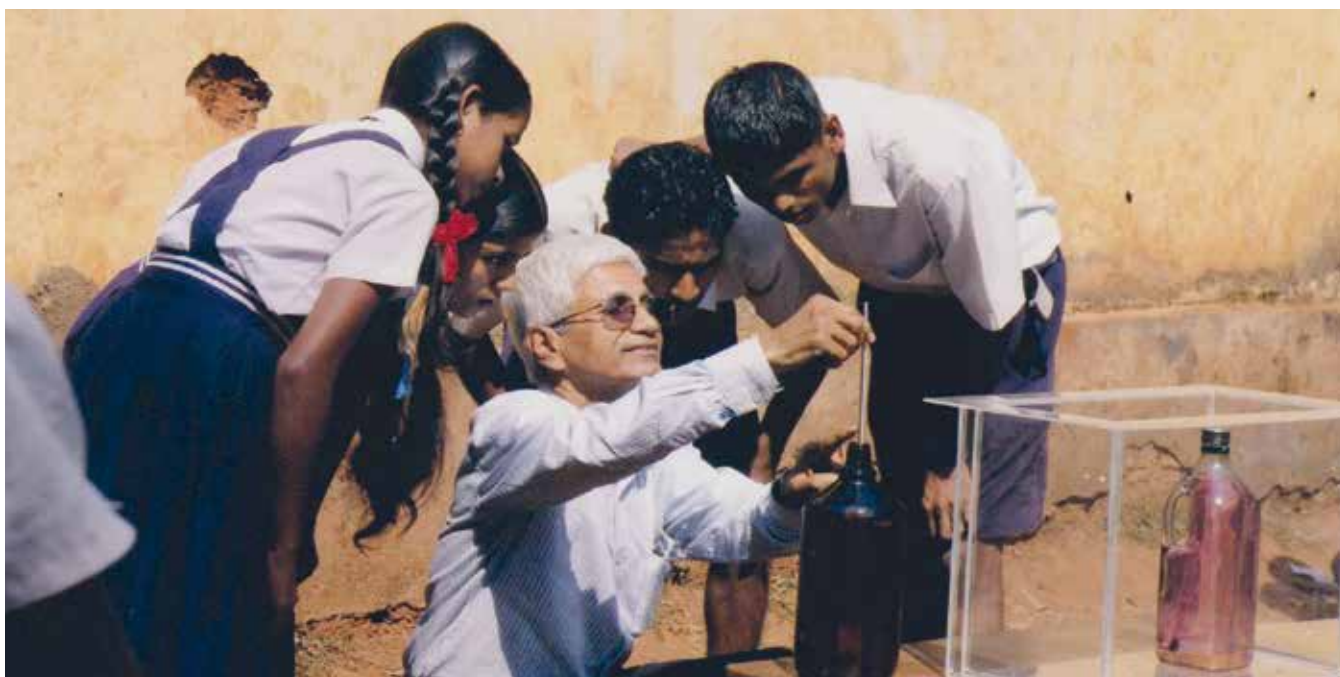
Shri Umakant Sahoo, Research Scientist (Solar Thermal), National Institute of Solar Energy, Ministry of New and Renewable Energy, Government of India.



⚡ SETNET Team with 35 SETNET Partners at NISE

Household Unit for SOLAR WATER DISINFECTION

Millions of people, especially children below 5 years of age in the developing and underdeveloped countries die because of infected water. **Dr Pramod V Pathak** says that considering the socio-economic conditions of poor labourers and workers in our country, who can hardly afford electrically operated water purification gadgets for the family level size, it posed a great challenge to develop a solar gadget for these people that would help disinfect water.



▲ **Picture 1:** Author giving demonstration of temperature measurement to the students after solar exposure

Solar water disinfection has been explored and many types of small and big gadgets have been developed. It is the UV-A ray component that kills bacteria of different types. Although glass is considered to be impervious to the UV rays, but it was confirmed that ordinary soda-lime-silica type (window or plate glass) can transmit

more than 90 per cent of the incident radiation in the UV-A component and visible regions of the sunlight. It was also noted that even the visible spectrum of the light also contributes to disinfection. A UNESCO report suggests that if water filled in PET bottle is subjected to sunlight for 16–20 hours, it will disinfect water. However, the temperature reached

on exposure is of the order of 40–42°C depending on the ambient temperature. It does not specify the extent of disinfection. It was noted that exposure to sunlight at temperatures above 50°C for about 2 hours results in disinfection. However, data on extent of disinfection was not available. Other set ups include a continuous flow type unit where water

flows through a serpentine path in sunlight which results in disinfection. A large scale pilot plant can disinfect about 500 L water per day. However, there is no unit which will meet daily requirement of disinfected water for a family of 4–5 members, i.e. about 8–10 L water per day.

⚡ Design of Experiments

As the additives in PET bottles leach into water at higher temperature causing harm, it was found that prolonged use of hot water in PET bottle would be harmful. PET bottles were used as container was not considered for experimental purpose. Based on this information that UV-A component penetrates ordinary glass, it was decided to use the glass bottles of different sizes with small narrow neck for storing water. In one UNESCO report it was pointed out that large mouth vessels are susceptible for spoiling water as the kids and even elders too are inclined to insert dirty hands from the large open top. In order to achieve higher temperature above 50°C it was decided to use box made of acrylic transparent sheet of 3 mm thickness

as acrylic transmits visible, UV as well as infrared components of the sunlight. A fish tank-type acrylic box of base 22 cm X 44 cm and 38 cm height was fabricated for initial trials. It had a lid of acrylic plate fitting tight on the top. Provision was made for inserting thermometer inside the box. This box was accommodating three bottles of about 2 L volume each.

Initially, thermal treatment experiments were conducted. All the three bottles were filled with ordinary untreated water and were inserted in the acrylic box in the morning around 8.30–9.00 a.m. For the first few trials hourly check of the temperature rise was measured. It was found that on an average it took about 2–2.30 hours to reach temperature above 50°C. The box was allowed to remain till 3.30 p.m. in the sunlight. It ensured exposure to the sunlight above 50°C for more than 2 hours. By 2.30–3.00 p.m., temperature of water in bottles would rise to as high as 55–60°C. It was like a glass house effect.

In order to confirm consistency in temperature rise, several experiments were conducted in summer and winter months. It was found that except on days when it rained,

temperatures higher than 50–55°C were invariably achieved. In order to simulate the cold weather conditions, frozen water at 0°C was used in for a few batches. It was found that in all these cases temperatures above 50°C was attained.

In order to achieve higher temperature a double-walled box was fabricated. With inner box dimensions same as above. The double-walled box gives water temperature of the order of 7–10 degrees higher than the single-walled box. It would rise to 65–70°C.

It was observed that within the same acrylic box, temperature of water inside the bottle changed with colour of the bottle. This prompted the author to design a simple experiment to verify and quantify the colour and energy absorption correlation for physics laboratory. Some experiments were carried out with copper jars suitable for refrigerators. Copper jars showed faster temperature rise and gave higher temperatures. Profile of the temperature for different coloured glass bottles and copper container is given in Table 1.

Table 1: Double-walled acrylic box with glass bottles of different colours

Time (hrs)	Box temperature (°C)	Transparent bottle (°C)	Brown bottle (°C)	Green bottle (°C)
9.00	33	31	32	33
14.15	57	55	58	55

The overall pattern of temperature rise as it emerges is given in Table 2. Coloured bottle temperature pattern: Blue > Green > Brown > transparent

Table 2: Double-walled acrylic box with copper jar and transparent bottle filled with water

Time (hrs)	Temp inside box (°C)	Copper jar water temperature (°C)	Transparent bottle water temperature (°C)
10.00	48	39	38
15.00	69	97	86

Simulation of cold weather conditions is shown in Table 3.

Table 3: Double-walled acrylic box with cold water in bottles

Time hrs	Box temperature (°C)	Transparent bottle(°C)	Brown bottle(°C)
9.30	-	1	1
14.30	52	53 < T	T > 53

Biological Testing

Once the temperature profile of water in bottles was confirmed that water temperature rises to higher than 50–55°C and remains there for more than two hours, the next step was to conduct biological testing. For this purpose, the usual method of biological testing was carried out with the *E. coli* strain. Freshly grown *E. coli* strain on the previous day was injected in the sterilized water in the morning and initial count was measured. The initial morning coliform count used to be in the range of 10^5 – 10^7 per cc. The bottles were put in the box in

sun at 8.30–9.00 a.m. and removed from the box after 2.30 p.m. The final count of *E. coli* was measured. It was found that in all the cases where the temperature of water in bottle rose to higher than 50°C the bacterial count dropped down to below detection level (BDL) indicating that highly infected water turned into potable water. These experiments were carried out in single-wall box and the double-walled boxes with bottles of different colours. In all the cases, initial *E. coli* concentration in the range of 10^5 – 10^7 dropped down to BDL. Table 4 gives the biological testing data.

The above type of experiments were performed many times to confirm consistency of results and total disinfection. It was noted that in some cases the green coloured bottles were not that effective. So, the green coloured bottles should not be used.

Application of the Device

This is a simple device. It can be manufactured locally. The fabricator for all the different designs was a mini-scale entrepreneur. Bottles were purchased from the local market. The locally fabricated acrylic boxes worked well for more than two years and the set-up cost was in the range of ₹1,200–1,500. These develop loosening of joints but the joints can be easily repaired locally. However, the boxes are moulded, these will be single piece moulds. Their life will be longer. Also, the production in bulk can reduce the price. It is also possible to design the foldable boxes to be

Table 4: Exposing different coloured bottles with *E. coli* inoculated water from morning 9.30 a.m. to 2.30 p.m. in the afternoon

Bottle Description	Initial <i>E. coli</i> concentration/mL	Final <i>E. coli</i> concentration/mL
Transparent bottle	8×10^5	BDL
Brown bottle	3.2×10^6	BDL
Green bottle	36×10^5	BDL
Copper jar	5.2×10^5	BDL
Green bottle	5.2×10^5	BDL



 **Picture 2:** Conducting solar water disinfection with different bottles in double-walled acrylic boxes

assembled at the user end to reduce the transport volume. The acrylic boxes are easy to fabricate and repair. These are simple to handle. If the casting of acrylic boxes is done and these are moulded as single piece box, then these would have longer life and will be sturdy to handle. Some major observations about this renewable energy product are as follows:

- An acrylic box can be used for

speedier solar water disinfection

- Glass bottles with narrow neck can be used for storing water for disinfection
- The device can be used in the cold climate such that water at near 0°C could be disinfected.
- An optimum size box with 4–5 glass bottles with 2 L capacity can be placed at a time in the box to get 8–10 L of disinfected water enough

for a family with 4–5 members so that 2 L water per head could be provided.

- Even if different coloured bottles or copper containers are used, the end result is total disinfection of water.
- The device is simple to operate and runs on solar energy only. **AU**

Dr Pramod V Pathak, Member Secretary, Goa Energy Development Agency, Ds&T Compound, Saligaon, Goa, India.

MNRE BIDS ADIEU TO SHRI UPENDRA TRIPATHY

Shri Upendra Tripathy, who made a mark in administration in different positions during his service period, retired from services as the Secretary of the New and Renewable Energy, Government of India, on October 31, 2016.

Some of the highlights of his remarkable career include bringing the National Solar Mission on a fast track and the launch of the International Solar Alliance during the COP21 Summit in Paris. Some other milestones that were achieved during his tenure include: Decision on 1,00,000 MW as enhanced target from renewables which was further enhanced to 175 GW by the Government; RE-INVEST 2015 and its continuation as a biannual event; Renaming of three R&D Institutes (NISE, NIWE, and NIBE) as National Institutes; Green Flagging of World Renewable Energy Museum; Idea of a Renewable Energy University; Establishment of Association for Renewable Energy Agencies of States (AREAS);

Launching of Off-shore Wind Policy and Repowering Policy; Development of 34 Solar Parks across India; Bringing Renewable Energy Investments upto ₹15 crore under Priority Sector Lending; A special scheme for 1,00,000 solar pumps for farmers; Launch for creation of 50,000 'Suryamitras' Special emphasis on Grid Connected Solar Rooftop scheme; Enhancement in Ministry's budget from ₹1,500 crore to ₹9,000 crore by 2016–17.

The entire family of MNRE and the *Akshay Urja* team bid adieu and wish good luck to Shri Upendra Tripathy in all his future endeavours!



RE Tweet from the Minister



Piyush Goyal @PiyushGoyal · 22h

Bid farewell to Shri Upendra Tripathy, Secretary, MNRE. I thank him for the great work over past many years & my best wishes for his future

123 403



🔸 The Hon'ble Minister Shri Piyush Goyal and Shri Upendra Tripathy along with the latter's family members.

INTEGRATED HYBRID SYSTEM

For Sustainable Development of Remote Isolated Communities



In many countries, less than 5 per cent of the rural population has access to electricity. In India also, a lot of people do not have access to electricity in remote areas. **Radhey Shyam Meena** reports one such novel initiative wherein electricity requirement is fulfilled by renewable energy. In this study, an integrated hybrid system is used to generate electricity from the combination of solar and wind energy. This article presents a review on both the wind power and photovoltaic (PV) power generation techniques.

An urgent need for power around the world is seeing more and more power facilities running on the fast track. In the case of developing countries like India, these installations can provide a boost to grid power or bring off-grid power to people who have none. In developed nations, they can enhance energy security and support the transition to a

renewable-based power mix. India with potential for renewable energy (RE) requires supporting policies, renewable purchase obligations, and it is good to note that other incentives have already been set up for reducing carbon footprint for mitigation of greenhouse gas (GHG) emissions and to empower rural areas of the country. The Ministry of New and Renewable Energy is already active to fulfill and

to meet the target of installation of 175 GW renewable energy capacities in India by 2022. Until recently, the most widely adopted procurement strategy for attracting renewable energy involved feed-in tariffs (FiT). This article presents a novel integrated hybrid system of solar and wind energy for off-grid power generation in non-interconnected areas or remote isolated communities.

Proposed System

Hybrid systems based on microgrid provide ways to use renewable energy in an efficient way. A key challenge in the deployment of renewable sources is their intermittent nature. In the present work, the dynamic component models, a simulation model for the proposed hybrid energy system has been developed. The overall power management strategy for coordinating the power flows among the different energy sources is presented in this work. Simulation studies have been carried out to verify the system performance under different scenarios using a load profile and weather data. The results show that the overall power management strategy is effective and the power flows among the different energy sources and the load demand is balanced satisfactorily. Therefore, this system can tolerate the rapid changes in load and environmental conditions, and suppress the effects of these fluctuations on the equipment side voltage.

Fuel cell system

The proton exchange membrane fuel cell (PEMFC) is one of the most promising and certainly the best

known of the fuel cell types satisfying the above requirements.

Electrolyzer system

Water can be decomposed into its elementary components by passing electric current between two electrodes separated by an aqueous electrolyte.

Ultra-capacitor system

Ultra-capacitors are essentially used in power applications requiring short duration peak power. An ultra-capacitor is an energy storage device. Its construction is similar to that of a battery. This subsection, presents the model of the ultra-capacitor bank to perform load sharing with the fuel cell system. When they simultaneously operate with the wind turbine and solar cell, fuel cell systems exhibit good power supply capability during steady state operation. The response of fuel cells during instantaneous and short-term peak power demand periods is relatively poor. In these periods, the ultra-capacitor bank can assist the fuel cell system to achieve good performance reducing the cost and size of the fuel cell system. Ultra-capacitor modules are connected in parallel with the fuel cell

to reduce its voltage variation due to sudden load changes. Ultra-capacitor has transfer function base model.

Typical Information about the Project

With ever-increasing concerns on energy issues, the development of renewable energy sources is becoming more and more attractive. Then, a new stand-alone wind–PV hybrid generation system is proposed for application to remote and isolated areas. For the wind power generation branch, a doubly excited permanent magnet brushless machine is used to capture the maximum wind power by using online flux control. For the PV power generation branch, a single-ended primary inductance converter is adopted to harness the maximum solar power by tuning the duty cycle. The simulation results confirm that the proposed hybrid generation system can provide high efficiency with the use of maximum power point tracking (MPPT).

This system has 75 W solar cells, a 400 W wind turbine, a 500 W proton exchange membrane fuel cell, ultra-capacitors, electrolyzer, and a power conditioner. It is used to step up ultracapacitor voltage to DC 200 V and invert to 120 Vrms, 60 Hz AC.

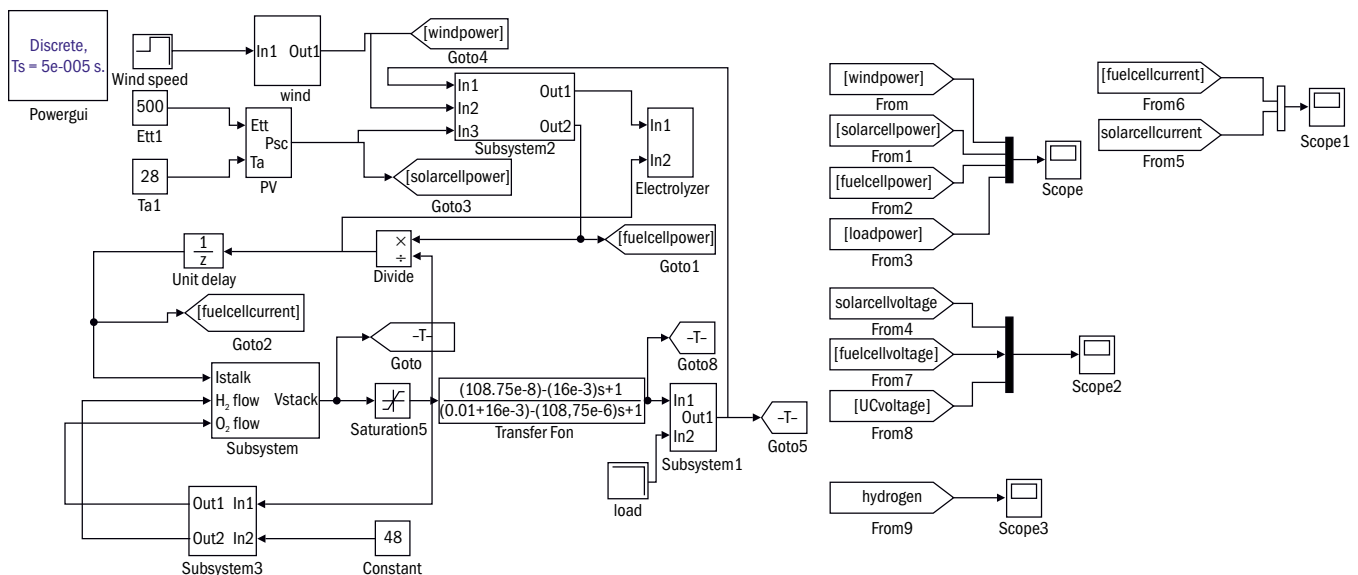


Figure 1: The layout of the project

When wind speed is 12.5 m/s, then wind turbine produces maximum power 400 W. Solar cell has maximum power is 75 W. Capacitance $C=108.75 \mu\text{F}$, series resistance $R_c=16 \text{ m}\Omega$, and stray resistance $R_s=0.01 \Omega$. Figure 1 gives the layout of the project.

Hybrid System Simulation Result

Simulation results with step changes in load demand, wind speed, radiation, and ambient temperature are analysed. The initial wind speed is 10 m/s. Wind speed increases, at $t=10$ s from 10–12 m/s and decreases to 8 m/s at $t=16$ s. The solar cell initially supplies power at the radiation 500 W/m^2 and temperature 25°C . At 15 s, the radiation increases to 600 W/m^2 and temperature also increases to 28°C . Solar power, wind power, and fuel cell power variation with time are shown in Figure 2. The load demand changes from 360 W to 225 W at 10 s. The power tracking performance of the hybrid topology with respect to load demand change and environmental variations is shown in Figure 2.

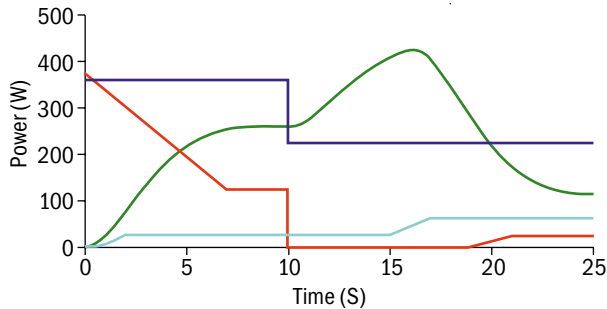


Figure 2: Power tracking performance of the hybrid topology with respect to load demand change and environmental variations

Fuel cell current variation at $t=0$ s to $t=10$ s is due to start-up transients and load demand, as the solar cells and wind turbines contribution are limited and fixed. During $t=10$ s to $t=16$ s, the fuel cell current decreases to zero because load demand is reduced and the wind turbine increases output power. After $t=16$ s, variation in fuel cell

current is due to changes in power demand from the fuel cell with varying availability of wind energy. When wind speed is decreased to 8 m/s at $t=16$ s then the contribution of the fuel cell starts at $t=19.1$ s. With changes in load and environmental conditions, there are variations in the fuel cell current as shown in Figure 3.

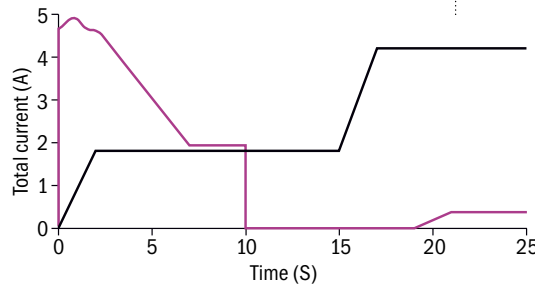


Figure 3: Variation in solar cell and fuel cell current with time

The use of an ultra-capacitor in parallel with the fuel cell reduces the stack's output. With variations of the ultra-capacitor voltage between 49 and 62 V, the power converter unit regulates the load voltage. The controller in the boost converter adjusts the duty ratio so as to attain a fixed 200 V DC in the inverter's input. The inverter, on the other hand, delivers 120 Vrms to the load. Figure 4 shows variation in UC voltage with time.

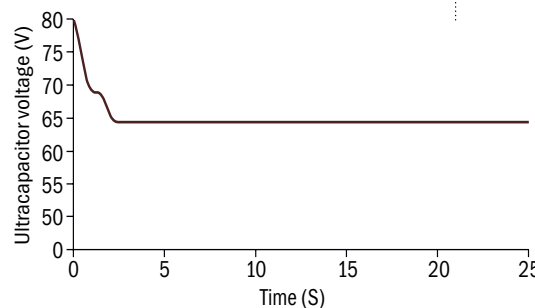


Figure 4: Variation in UC voltage with time

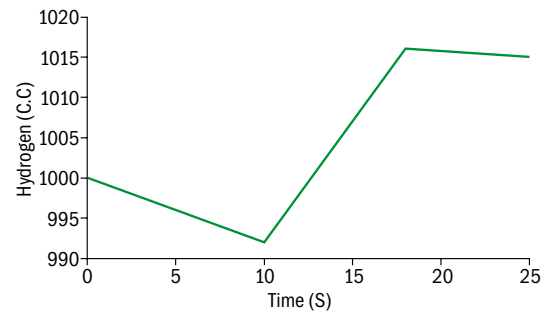


Figure 5: Hydrogen variation in storage tank with time

Hydrogen is used as a fuel in fuel cell. The electrolyzer electrolyzes water to produce hydrogen by the excess power of the system and stores it from $t=10$ s to $t=19.1$ s. The variation of hydrogen in storage tank is shown in Figure 5. The system can circulate supply load demand and renewable energy will not be wasted.

Conclusion

To overcome the deficiency of the solar cell and wind system, the appropriate way is by integrating them with the fuel cell (FC) and ultra-capacitor (UC) system, which has been explored in this work. PID controller is also used to control the fuel cell voltage by varying the H_2 and O_2 flow rates. Modelling of various components of this isolated system is presented in this work. The voltage variation at the output is found to be within the acceptable range. The output fluctuations of the wind turbine varying with wind speed and the solar cell varying with both environmental temperature and sun radiation are reduced using a fuel cell. Therefore, this system can tolerate the rapid changes in load and environmental conditions, and suppress the effects of these fluctuations on the equipment side voltage. The proposed system can be used for off-grid power generation in non-interconnected areas or remote isolated communities. It reduces the dependence on



India needs access to electricity with the use of solar energy



Indian villages need access to energy

one single source and increases the reliability. Hence an attempt is made in this work to improve the efficiency of the system as compared with their individual mode of generation.

In this work, the fuel cell is an accessory generator in this system and supplies insufficient power. Supply and load demand are to keep balance but when supply is bigger than the load demand then the electrolyzer model electrolyzes water to produce hydrogen and store it for further usage, so this system can circulate supply load demand and energy will not be wasted.

Therefore, this system can tolerate the rapid changes in load and

THE PROPOSED SYSTEM CAN BE USED FOR OFF-GRID POWER GENERATION IN NON-INTERCONNECTED AREAS OR REMOTE ISOLATED COMMUNITIES. IT REDUCES THE DEPENDENCE ON ONE SINGLE SOURCE AND INCREASES THE RELIABILITY. HENCE AN ATTEMPT IS MADE IN THIS WORK TO IMPROVE THE EFFICIENCY OF THE SYSTEM AS COMPARED WITH THEIR INDIVIDUAL MODE OF GENERATION.

environmental conditions, and reduce the effects of these fluctuations on the equipment side voltage. The proposed system can be used for off-grid power generation in noninterconnected areas or remote isolated communities.

⚡ The Way Forward

The hybrid system modelled in this work is efficient, durable, and cheaper as compared to the hybrid system with that of using battery. The parameters of the proposed model in this work can be further improved or advanced control method can be used.

A computer measurement and control bus may also be added to the system. Computer controlled relays will allow all the major elements of the system to be switched in and out of the system through computer programmes. These provisions will help in the better study of more complex issues such as power faults, caused by sudden over voltages like lightning. In future, the effort to improve the stability and dynamics of grid connected Wind-PV generator may also be made. **AU**

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Light in a remote village in Barpeta Distt. of Assam



Need to utilize wind energy for rural India



नवीन और नवीकरणीय ऊर्जा मंत्रालय में हिन्दी पखवाड़ा-2016 का आयोजन

प्रत्येक वर्ष की भांति इस वर्ष भी नवीन और नवीकरणीय ऊर्जा मंत्रालय में दिनांक 14 से 30 सितम्बर, 2016 तक हिन्दी पखवाड़ा आयोजित किया गया। सर्वप्रथम 14 सितम्बर, 2016 को माननीय गृह मंत्री एवं माननीय नवीन और नवीकरणीय ऊर्जा मंत्री का संदेश जारी किया गया। पखवाड़े के दौरान मंत्रालय के अधिकारियों एवं कर्मचारियों के लिए विभिन्न प्रतियोगिताओं का आयोजन किया गया जिसमें उन्होंने अत्यंत उत्साह के साथ भाग लिया। इस वर्ष हिन्दी पखवाड़े के दौरान आयोजित प्रतियोगिताओं के लिए पुरस्कारों की राशि में वृद्धि की गई। इसके साथ ही प्रत्येक प्रतियोगिता में दो प्रोत्साहन पुरस्कार भी देने का निर्णय लिया गया।

हिन्दी पखवाड़े के दौरान आयोजित प्रतियोगिताओं के विजेताओं को पुरस्कार वितरण हेतु दिनांक 16.10.2016 को पुरस्कार वितरण समारोह आयोजित किया गया। इस समारोह के दौरान मंत्रालय के सचिव, श्री उपेन्द्र त्रिपाठी ने पुरस्कार विजेताओं को प्रशस्ति पत्र और नकद पुरस्कार प्रदान किए। अपने संबोधन में सचिव महोदय ने कहा कि हिन्दी में कार्य करना हमारा संवैधानिक दायित्व है और जहां तक संभव हो हमें अपना कार्य हिन्दी में करने का प्रयास करना चाहिए। पुरस्कार वितरण समारोह में आर्थिक सलाहकार श्रीमती सुतपा मजुमदार, निदेशक, प्रशासन श्री गिरीश कुमार, उप सचिव एवं प्रभारी (रा.भा.), श्रीमती अलका जोशी सहित मंत्रालय के वरिष्ठ अधिकारी एवं कर्मचारी उपस्थित थे।

CHINTAN ON IREDA'S FUTURE GROWTH

The Indian Renewable Energy Development Agency (IREDA) organized the Chintan 3 Programme on September 2, 2016, at Scope Complex in New Delhi for sharing of information, generating new ideas, and open discussion. The event was followed by some cultural activities. The Chintan 3 Programme began with the inauguration ceremony with the lighting of traditional lamp by senior officials of MNRE, IREDA, and NISE. Shri Upendra Tripathy, Secretary, MNRE addressed the participants and called upon everyone to strive to accomplish the goals set by the government. A book titled *Environmental Studies: Multiple Choice Questions* published by TERI Press and written by Dr A K Tripathi, Advisor, MNRE, was released at the function. Shri K S Popli, CMD, IREDA, made a presentation on IREDA's Future growth plans as part of the Chintan 3 which was followed by discussions by many participants.



Shri Ashok Vajpayee, noted Hindi Litterateur and Chief Guest presented a selection of his well-known poems as part of the Hindi Fortnight celebrations. He was also presented a memento by Shri Upendra Tripathy, Secretary, MNRE for having graced the occasion. Family members of the staff of MNRE, IREDA, SECI, and NISE were also present on the occasion. The last programme of the evening was a humorous Hindi play titled 'Taj Mahal ka Tender', which was directed by noted Director Shri Gajraj Nagar of Ras Theatre Group. **AU**

RENEWABLE ENERGY INDIA (REI) EXPO 2016

Key industry and policymakers congregated at Asia's Largest Energy Trade Expo, Renewable Energy India (REI) 2016 on September 7–9, 2016 at Greater Noida. The expo was inaugurated by the Chief Guest, Shri Upendra Tripathi, Secretary, Ministry of New and Renewable Energy (MNRE), Government of India and other key dignitaries, such as Mr Justin Wu, Head of APAC, Bloomberg New Energy Finance, Hong Kong; Hon'ble Mr James Gordon Carr, Minister of Natural Resources, Government of Canada; Mr Hans-Josef Fell, President of the Energy Watch Group (EWG) and Former Member of German Parliament; Mr Munehiko Tsuchiya, Executive Director, NEDO, Japan; HE Ambassador Tomasz Łukaszuk, Embassy of Poland in India and Mr Yogesh Mudras, Managing Director, UBM India amidst an august industry gathering.



The show brought together internationally renowned exhibitors, consultants, business experts, and key government officials under one common platform, to discuss global best practices and seek solutions to some of the most pressing challenges in the power and energy sector. REI in its 10th anniversary saw participation from countries, such as host India, Japan, Switzerland, USA, Korea, Taiwan, China, Australia, Italy, Canada, Malaysia, Netherlands, Israel, Germany, Spain, Singapore, Belgium, and was supported by the Ministry of New and Renewable Energy, Government of India (MNRE), Indian Renewable Energy Development Agency Ltd (IREDA), Solar Energy Corporation of India Limited (SECI), National Institute of Wind Energy (NIWE) and International collaboration through Indo German Energy Forum (IGEF), and Bloomberg New Energy Finance(BNEF). **AU**

SUSPENDED BOX SOLAR OVEN

to Boost Rural Entrepreneurship


Conventional box type solar cookers cannot follow the sun properly except during solar noon. Moreover, use of single reflector is not so suitable to boost up the energy collection. Box type cookers with multiple reflectors generally known as solar ovens are equipped with adjustable leg at back for changing the inclination with respect to the ground. But these ovens also cannot follow the sun in morning and afternoon as adjustment of these ovens with the ground is limited. It is due to the fact that after certain degrees of inclination the oven will be turned over in front for the weight of reflectors and also for the rotation of line of action of oven box weight towards front. Another problem with existing solar ovens with the typical adjustable back stand is that, when oven inclination is to be changed then at first oven is to be lifted against its weight before readjustment in its stand. By the use of fiberglass body and aluminium reflectors this handling problem is however partly solved but material cost is thus increased.

The solar oven model (Picture 1) discussed below (follows the sun at right angle almost throughout the day which is especially beneficial in summer for solar cooking as during summer, intensity of solar radiation is still sufficient to cook utilizing solar energy when sun is low in the sky. The oven is provided with one large cooking pot.

Constructional Details

The presently proposed suspended box type solar oven consists of two boxes, a black painted aluminium inner box kept inside an outer box.



 **Picture 1:** Suspended box solar oven

The outer box is made of GI sheet. The space between the two boxes is filled up with loose packed glass wool insulation. Length, width, and depth of the oven box are 44 cm, 44 cm, and 36 cm, respectively. The upside of the oven box has double transparent glass covers keeping a gap of 20 mm in between. Neoprene rubber is used as cover gasket to seal the closed cover and inner box. The supporting frame of the glass cover is hinged with oven box and cooking pot can be withdrawn or handled by opening the glass cover.

The oven box is suspended from inverted 'T' shape main frame and can be easily adjusted from 5° to even up to 80° with respect to the ground by simply swinging the oven

box and, thereafter, positioning of rectangular support frame in desired slot. Slots are formed by series of long studs provided in the mainframe base. Location of pivot points from where the oven is suspended is just few centimetres above the centre of gravity point of the oven box so that changing of inclination of oven box required a light force. (approximate CG point is detected by trial keeping oven box sidewall parallel to the ground with open reflectors). The sketch of proposed oven is shown in Figure 1.

In this oven, only one cooking pot is used mainly for cooking rice. The tilting cooking tray is square and ends of the tray are folded upwards. The cooking pot is kept on

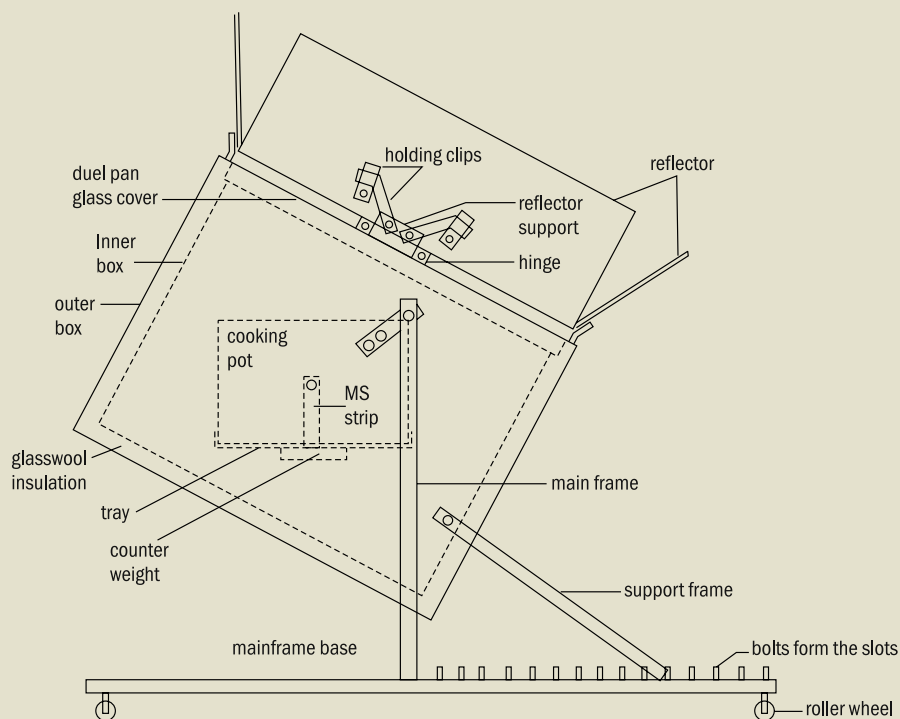


Figure 1: Diagram of suspended box solar oven

this cooking tray. In this new oven, cooking tray along with cooking pot is suspended through MS strips from pivots fixed in the sidewalls of the inner box and these pivots are aligned with the horizontal axis of the cooking pot. For the stability of the pot a counter-weight of about one and a half kg is attached at the bottom of cooking tray. During changing of oven inclination, the tray along with pot rotates at its horizontal axis and maintains constant horizontal position to avoid spilling over of food items. Cooking pot and interior of the oven are painted black by automobile muffler paint to increase absorption of solar radiation.

The oven has four foldable mirror reflectors. Size of the reflectors is equal to the glass cover and these are hinged with oven box at four sides of the glass cover. The reflectors when open are held fixed at an angle of 115° with the oven face by the help of reflector supports and holding clips provided at the backside of the reflectors. Reflectors can be folded for keeping on the top of the oven box cover when not in use.

During reorientation of the oven, apart from changing of inclination of the oven box, the whole oven can be rotated at the ground at desired position with the help of caster wheels attached at the bottom of the supporting frame, but the position of reflectors remain unchanged throughout the working period. To get the best performance, reorientation in every 30 minutes interval is suggested.

Merits

- The new oven can follow the sun at right angle almost throughout the day
- Easy reorientation system to follow the sun
- Indigenous design of pot holding arrangement to keep the pot always in central position inside cooker box (i.e., not typical suspended pot holding system) for better utilization of all the reflectors at all inclinations of the oven.

Test Results

At first after construction of the solar

oven, some routine tests, such as inner box leakage test, leakage test of upper and lower sides of cover plate, cover gasket leakage test, etc., are carried out in line with IS code. Other performance tests were also carried out. Reorientation is done in every 30-minute interval.

Test date, time, and location: April 6, 2015 to April 15, 2015, from 9:30 a.m. to 12:30 p.m., Jalpaiguri (26.32° N latitude, 88.46° E longitude), West Bengal

- Average ambient temperature: 27°C
- Average intensity of solar radiation during test period: 0.53 kW per m^2
- Peak temperature of empty cooking pot: 170°C

Test date, time, and location: April 16, 2015 to April 25, 2015, from 10:30 a.m. to 12:50 p.m., Jalpaiguri, WB

- Average ambient temperature: 28°C
- Initial temperature of water: 26°C
- Average intensity of solar radiation during test period: 0.55 kW per m^2
- Time taken for boiling of 2 L of water: 110 minutes.

Cooking Performance

Average time taken for cooking 1.5 kg (after preparation) of rice is 100 minutes

Project Economics

- Minimum economic unit is 30 ovens per month
- Total Investment is ₹250,000 working capital for two months
- At an estimated cost of ₹3,000 per cooker one can earn a profit of ₹10,000 per month. **AU**

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LEARN TO MAKE A LIGHTWEIGHT SOLAR OVEN

Hello kids! A 'solar cooker' is a device which uses the energy of direct sunlight to heat, cook or pasteurize food or drink. Many solar cookers currently in use are relatively inexpensive, low-tech devices, although some are as powerful or as expensive as traditional stoves, and advanced, large-scale solar cookers can cook for hundreds of people around the world. Solar ovens or solar cookers are increasingly used to reduce reliance on firewood and other fuels. Even if you have electricity, a solar oven can be an effective, energy-saving addition to your cooking tools. Now, let us learn how to make a lightweight solar oven at our homes with the simple steps mentioned below.

⚡ Step 1

Place a cardboard box inside a larger cardboard box. Make sure there is at least an inch of clearance between the sides, and fill the gap with shredded newspaper, which will act as an insulator.

⚡ Step 2

Line the inside of the smaller box with black construction paper, to absorb heat. Next, cut the flaps from flat cardboard sheets in the shape of slightly flared squares. Since you will be attaching these to the walls of your box, the width of each narrow end of each square should equal the width of the side you will be attaching it to; the width of each flared end should be several inches wider than the width of the narrow end.

⚡ Step 3

Cover each piece of cardboard with reflective material such as foil. Make sure it sits tightly around the reflector, and smooth out any wrinkles or folds. Secure the material with rubber cement or tape on one side of each cardboard piece.

⚡ Step 4

Attach each reflector to the top of one side of the box. You can glue, staple, or thread them as necessary, allowing them to flop over for now.



⚡ Step 5

Prop each reflector up at around a 45° angle. The easiest, most secure way to do this is to connect the reflectors together at the flared top corners (for example, by piercing adjacent corners and tying them together with thread, then untying them for disassembly). You can also stick rods in the ground underneath the reflectors, stack something underneath each reflector, or use any other method that will hold them securely in place. If it's a windy day, make sure your reflectors would not blow over.

Note: If using rods, glue the reflectors to the rods to add more stability.

⚡ Step 6

Position the oven in full sun, place food in the smaller box, and wait for it to cook. It is best to cook the food in jars or on a small, dark baking pan. You may need to reposition your box several times during cooking to catch the sun. Happy cooking with solar energy! **AU**

Source: <http://www.wikihow.com/>

SURYAMITRA MOBILE APP

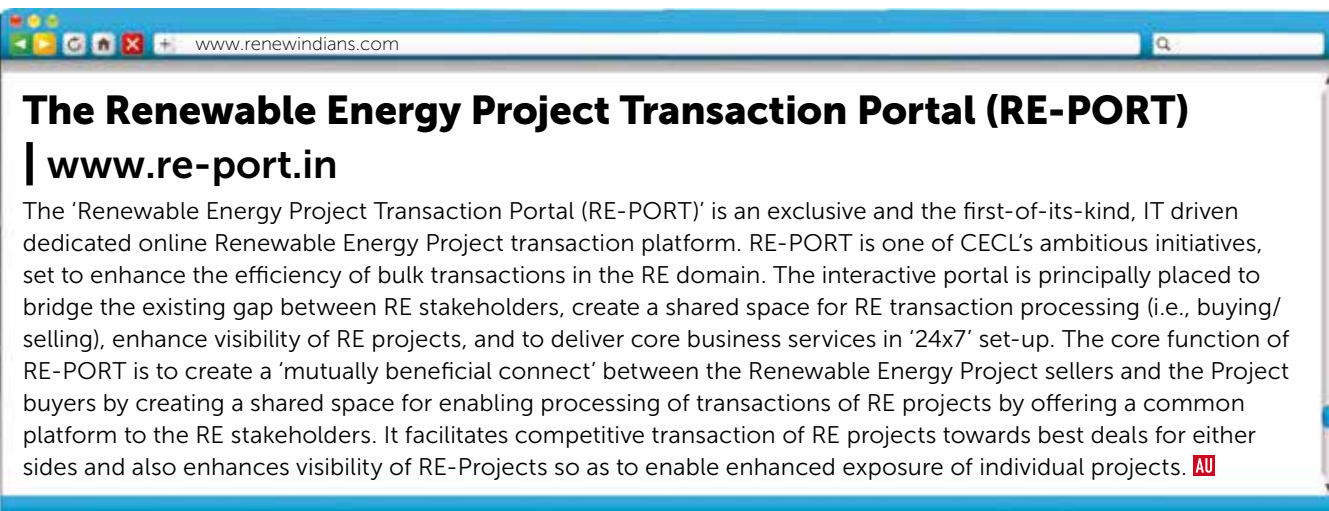
Suryamitra Skill Development Programme is a flagship programme under the Hon'ble Prime Minister's 'Make in India' initiative. This Programme is a comprehensive skill development programme which produces skilled manpower to serve solar photovoltaic (SPV) power plants, SPV rooftop, act as installer, operation/repair, and maintenance. The duration of Suryamitra programme is 3 months/600 hours. Suryamitra Programme is sponsored by the Ministry of New and Renewable Energy (MNRE), Government of India. The National Institute of Solar Energy (NISE) is implementing the programme across India in all States and UTs with world class training partners. As part of Suryamitra programme, NISE has developed a GPS-based mobile Application (known as Suryamitra Mobile APP) which allows the services of trained 'Suryamitras' to the various end users of solar applications across India at their doorsteps.



This Suryamitra application is available in Google Play Store/App store for Android and iOS with the name of 'Suryamitra', which can be downloaded free of cost. All the citizens, business establishments, educational institutions, government departments, and PSUs, may please avail the services of Suryamitras for SPV power plant installations, operation/repair and maintenance through the Suryamitra application for the quality services. Therefore, all are encouraged to download Suryamitra APP from Google Play Store and use it for quality Solar Photovoltaic installation, repair, and maintenance at your doorstep.

Your feedback is most welcome at NISE. You could reach us by sending an e-mail to suryamitra.nise@gmail.com.





The Renewable Energy Project Transaction Portal (RE-PORT)
| www.re-port.in

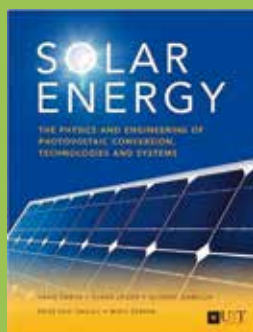
The 'Renewable Energy Project Transaction Portal (RE-PORT)' is an exclusive and the first-of-its-kind, IT driven dedicated online Renewable Energy Project transaction platform. RE-PORT is one of CECL's ambitious initiatives, set to enhance the efficiency of bulk transactions in the RE domain. The interactive portal is principally placed to bridge the existing gap between RE stakeholders, create a shared space for RE transaction processing (i.e., buying/selling), enhance visibility of RE projects, and to deliver core business services in '24x7' set-up. The core function of RE-PORT is to create a 'mutually beneficial connect' between the Renewable Energy Project sellers and the Project buyers by creating a shared space for enabling processing of transactions of RE projects by offering a common platform to the RE stakeholders. It facilitates competitive transaction of RE projects towards best deals for either sides and also enhances visibility of RE-Projects so as to enable enhanced exposure of individual projects. **AU**

Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems

Olindo Isabella, Klaus Jäger, Arno Smets, René van Swaaij, and Miro Zeman; UIT Cambridge Ltd, 488 pages

This comprehensive textbook takes you through everything you need to know about solar energy from the physics of photovoltaic (PV) cells through to the design of PV systems for real-life applications.

Solar Energy is an invaluable reference for researchers, industrial engineers, and designers working in solar energy generation. The book is also ideal for university and third-level physics or engineering courses on solar photovoltaics, with exercises to check students' understanding and reinforce learning. It is the perfect companion to the *Massive Open Online Course (MOOC) on Solar Energy* (DelftX, ET.3034TU) presented by co-author Arno Smets. To buy online visit www.amazon.com. **AU**



Frequently Asked Questions on Biogas Technology

Dr Deepak Sharma and Er Kapil K Samar (Editors);
Biogas Development and Training Centre

This book consists of frequently asked questions (FAQs) on biogas technology, all supposed to be commonly asked by entrepreneurs, farmers, and new technocrats. It is conveniently arranged by application including waste generation, biogas, bio-manure, and government schemes. The book is a perfect first-stop reference for any scientist, engineer, technical staff or student looking for information on biomethanation technology. **AU**

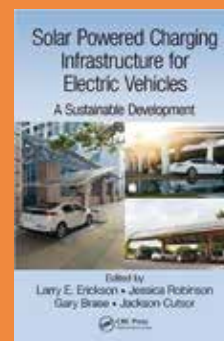


Solar Powered Charging Infrastructure for Electric Vehicles: A Sustainable Development

Larry E Erickson, Jessica Robinson, Gary Brase, and Jackson Cutsor (Editors);
CRC Press, 182 pages

Solar Powered Charging Infrastructure for Electric Vehicles: A Sustainable Development aims to share information on pathways from our present situation to a world with a more sustainable transportation system with EVs, SPCSS, a modernized smart power grid with energy storage, reduced greenhouse gas emissions, and better urban air quality. Covering 200 million parking spaces with solar panels can generate about one-fourth of the electricity that was generated in 2014 in the United States. Millions of EVs with 20 to 50 kWh of battery storage can help with the transition to wind and solar power generation through owners responding to time-of-use prices.

Written for all audiences, high school and college teachers and students, those in industry and government, and those involved in community issues will benefit by learning more about the topics addressed in the book. Those working with electrical power and transportation, who will be in the middle of the transition, will want to learn about all of the challenges and developments that are addressed here. To buy online visit www.amazon.com. **AU**



National

November 10–12, 2016 | Bhubaneswar, India

International Conference on Recent Advancement in Air-conditioning and Refrigeration

Website: <http://cvrce.edu.in>

November 11–13, 2016 | Kottayam, Kerala, India

International Conference on Advanced Materials for Power Engineering

Website: <http://www.power.macromol.in>

December 16–17, 2016 | Kolkata, India

RACON 2016

Website: <http://racon.co.in>

December 17–18, 2016 | Gangtok, India

International Conference on Emerging Trends and Advances in Electrical Engineering and Renewable Energy

Website: <http://www.etaeere.in>

December 22–23, 2016 | Vijayawada, India

Smart Electric Grid

Website: <http://10times.com/smart-electric-grid>

January 10–12, 2017 | New Delhi, India

Windergy India 2017

Website: <http://windergy.in>

International

November 7–18, 2016 | Marrakech, Morocco

UNFCCC COP22

Website: <http://unfccc.int>

November 9–10, 2016 | Chicago, Illinois, USA

Solar Power PV Conference & Expo

Website: <http://www.enfsolar.com>

November 14–16, 2016 | Long Beach, CA, USA

Renewable Energy from Waste Conference and Exhibition

Website: <http://www.rewconference.com>

November 15–17, 2016 | Barcelona, Spain

Smart City Expo World Congress

Website: <http://www.smartcityexpo.com>

December 5–6, 2016 | Toronto, Canada

Solar Canada Annual National Conference and Exposition

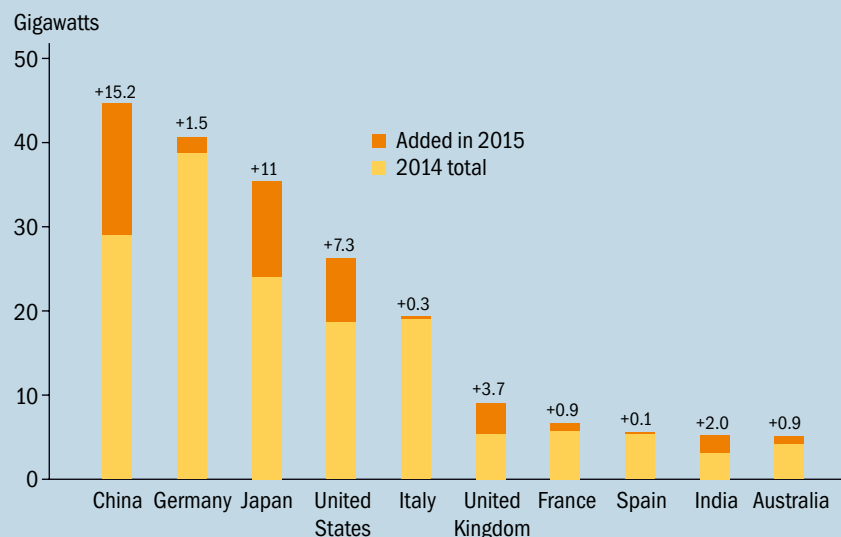
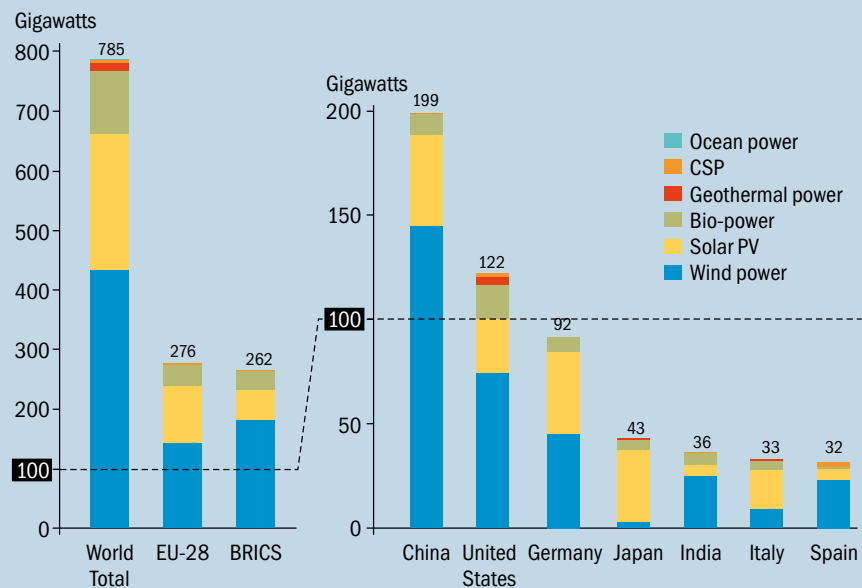
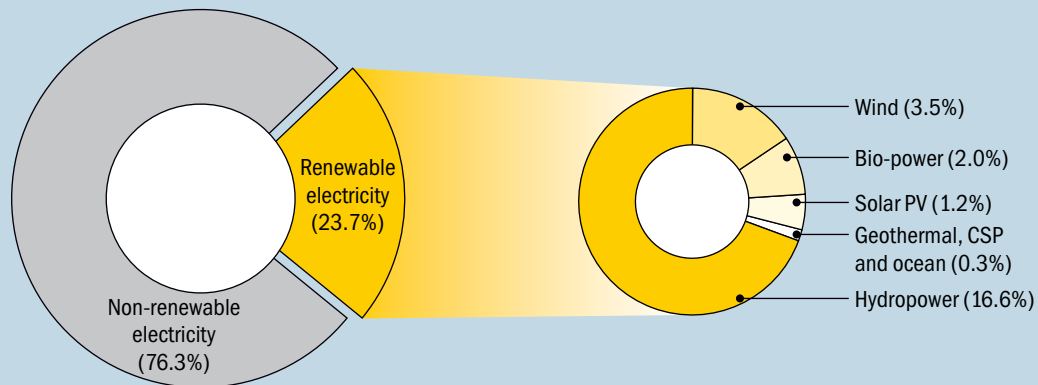
Website: <http://solarcanadainconference.ca>

December 13–15, 2016 | Orlando, USA

Renewable Energy World Conference & Expo North America

Website: <http://www.rewintl.com>

RENEWABLE ENERGY AT A GLANCE: GLOBAL



Source: REN21 Renewables 2016 Global Status Report

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INCENTIVES

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CONTACT

- Solar Energy Corporation of India (website www.seci.gov.in, Phone Number: 011-71989200, Email: corporate@seci.gov.in)
- Empaneled Channel Partners/New Entrepreneurs (list available at MNRE website www.mnre.gov.in)
- State Nodal Agencies for respective States (<http://www.mnre.gov.in/related-links/>)
- Indian Renewable Energy Development Agency (www.ireda.gov.in, Phone Number: 011-26717428, Email: abhilakh@ireda.gov.in)



MINISTRY OF NEW AND RENEWABLE ENERGY

Government of India | website : www.mnre.gov.in | Solar Energy Helpline No. 1800 233 4477
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Government of India
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15-17 FEBRUARY 2017, GANDHINAGAR, GUJARAT, INDIA

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15th-17th February



LET US MAKE THE SUN BRIGHTER AT RE-INVEST 2017

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International
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in 2015
attracted:

3000
Participants
41
Countries

119
Exhibitors of
technology and
innovation in
renewable energy

Commitments from:
Developers
283 GW
of Renewable
power installation

Manufacturers
62 GW
Banks & Financial Institutions
76 GW Financing

458
Green energy
commitments by
global and domestic
companies

Venue

Mahatma Mandir Convention and Exhibition Centre,
Gandhinagar, Gujarat, India
Date: 15-17 February, 2017
Timings: 10 AM to 6 PM

RE-INVEST Secretariat
Ministry of New and Renewable Energy
Tele: 011 2436 2360; E-mail: ss.madan@nic.in
<http://re-invest.in> ; www.mnre.gov.in

ISA Interim Secretariat
NISE Campus, Gwalpahari,
Gurugram, Haryana
www.intsolaralliance.org

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