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CONCENTRATING SOLAR TECHNOLOGIES

can meet a significant amount of your steam requirement for community cooking & process heat applications

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National Project Manager

UNDP-GEF Project on Concentrated Solar Heat

Ministry of New & Renewable Energy

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Inverse environmental and economic effects of fossil fuels has made it essential that alternate renewable sources of fuel for power generation and transportation be sought. A widely accepted alternate for these purposes is hydrogen. Prof. Y K Yadav, Dr Sachin Kumar and Raman Rao assess the biological methods to produce hydrogen.

In this article Tejas Shah, Sandeep Sharma and Dr Brahmanand Mohanty tell us about the Sri Aurobindo International Centre of Education in Puducherry, which is leading the way in becoming a net energy-positive educational institution in India.

Right to Education in itself will not be able to achieve its target if basic need—clean light source—is unavailable. In this case study, Prof. Chetan S Solanki, Prof. N C Narayanan, and Prof. Jayendran Venkateswaran discuss the ‘Million Solar Urja Lamp Programme’ initiative that intends to facilitate children’s education.

www.mnre.gov.in

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The information given in Akshay Urja magazine is very useful to me and my staff. I liked the article ‘The Essence of Suryakumbh’ in the June 2015 issue. It is a good effort for the Children’s corner section. I also liked the article ‘Unique Solar Engineers of Barefoot College’ in the same issue. Kindly publish some RE products, prices, and their availability that are useful for domestic purposes, such as solar panels, LED bulbs, solar lanterns, mobile chargers, etc. I appreciate your good effort. We have preserved all the newsletters of Akshay Urja received till date and kept in our library.

Anant B Tamhane
Engineer Consultant, Renewable Energy Nagpur, Maharashtra

I have gone through the recent issue of Akshay Urja magazine (June 2015) in which 1 MW Solar Power Plant at Shri Mata Vaishno Devi Katra Railway Station has been published. Thanking you for publishing the article. I communicate my appreciation for maintaining the excellent standard of the content and printing standard of this magazine. The magazine provides a global scenario of Solar Energy in India.

RK Chaudhary
Chief Electrical Engineer/USBRL Northern Railway, Jammu Tawi

I was at MNRE recently for some official work and came across the Akshay Urja publication. The magazine is very informative on entire spectrum including government’s policies, business scenario, state-of-the-art developments on technology front and also various state policies.

N Giriraj
Sr Deputy General Manager Bharat Electronics Limited Jalalahli Post, Bangalore

I must congratulate you and your colleagues for making Akshay Urja very interesting and meaningful for the readers.

Dr Dilip R Ranade
Bhelkenagar, Kothrud, Pune

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
Dear Readers,

India has voluntarily come out with its Intended Nationally Determined Contribution (INDC) for mitigating climate change. The country aims to slash carbon emission intensity by 33–35 per cent from 2005 levels over the next 15 years and generate 40 per cent of its power from non-fossil fuels by 2030. The announcement on October 2, 2015 from India is significant given that India has been making aggressive strides to enhance the use of renewable energy in its energy basket to move away from fossil fuels with a target of 175 GW renewable power by 2022. This target of 175 GW renewable power poses a challenge for the present grid capacity for evacuating 175 GW of renewable electricity. The Green Energy Corridors project under implementation by the state owned Power Grid Corporation of India Limited (PGCIL) to transmit clean energy is expected to play an important role for renewable power evacuation. It shall be a dedicated transmission network for mass chunks of power from rich renewable power states to the ones requiring higher energy demand. Introduction of dedicated transmission highways will be essential for transmitting gigawatts of power from renewable sources of energy through the enhanced grid capacity. An independent and stable transmission infrastructure will offer a great opportunity for the utilities.

Sri Aurobindo International Centre of Education has undertaken the initiative to demonstrate that within the prevailing policy environment of India, it is indeed feasible for the society to accelerate the energy transition, making ‘Sustainable Energy for All’ vision of the United Nations a reality by 2030. This institution’s experience serves as a good example for the millions of schools in India to not only meet their energy needs from the sun but also inspire their students to pursue a cleaner and greener path. The institution is leading the way in becoming a net energy-positive educational institution.

Our nation lost one of its most illustrious sons Dr A P J Abdul Kalam in July this year. Significantly, Dr Kalam described various renewable energy sources potentially available in India, including the solar power, wind power, biofuels, municipal waste, geothermal power, ocean tidal power, small and mini hydel power, nuclear power, and hydrogen power in one of his books. Otherwise in all his books, Dr Kalam advocated the renewable energy sources for achieving energy security in the country, expanding electrification in remotest corners or at the grassroots level, and also for reducing overdependence on fossil fuels. This pertinently reflects his foresight and prudence, as well as his dream for a developed India.

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 send us your views and suggestions.

Happy reading

ARUN K TRIPATHI
aktripathi@nic.in
Renewable Energy News

Tata Power Offers Rooftop Scheme

Tata Power Delhi is reaching out to its commercial and industrial consumers with a scheme to set up and maintain rooftop solar plants. The move would reduce tariff impact on consumers by 20 per cent during TOD (time of the day) peak period—1 p.m. to 5 p.m. It is expected to benefit over 50,000 consumers and save up to 400 MW in the next five years. The discom has signed a 25 kW rooftop solar project with Aakriti Furnishing in Kirti Nagar in Delhi. Rooftop solar installation is a one-time investment for 25 years as it is a renewable source of energy with a payback period of 4.5 years.

New Wind Atlas to Help Green Power Companies Stay in Black

The Government of India has launched the Indian Wind Resource Atlas with a tracking level of 100 metres that can also be used for measuring solar radiation, providing a tool for improving project efficiency and grid management. The new atlas is an online Geographic Information System (GIS) tool to identify regional and local wind energy potential in India. The atlas module can also be used for solar power projects to check parameters for selecting a site. The atlas will help policymakers at the Centre and states to deal with issues related to setting tariffs, transmission, grid frequency, etc., and providing better infrastructure for the investors.

Unveiling the atlas, Shri Piyush Goyal, Minister of State (IC) for Power, Coal, and New & Renewable Energy, sought to remove concerns that the government was overly focused on solar power projects. “The government has equal focus on various forms of renewable power and does not discriminate between solar, wind, or biogas in terms of providing support to these renewable sources,” he said. He also said the government reinstated provisions for accelerated depreciation to boost wind power sector in the first budget of the new government so that the industry can expand.

Suzlon Commissions 100.80 MW Wind Power Project for CLP in Rajasthan

The Suzlon Group, one of the leading wind turbine manufacturers, has announced that it has completed the commissioning of 100.80 MW wind power turnkey project for CLP India, one of the largest foreign investors and one of the largest wind power developers in the Indian power sector. The project will provide electricity to over 50,000 homes and curb approximately 0.21 million tonnes of CO₂ emissions annually. Suzlon will offer operations and maintenance for 20 years through an Integrated Service Package contract.

The project is located at Tejuva, Jaisalmer in Rajasthan which is the home to the country’s largest wind park with total capacity additions pegged at 1,500 MW out of which over 1,200 MW have already been commissioned. The project comprises 48 Wind Turbine Generators (WTGs) of Suzlon’s robust S97–2.1 MW wind turbines featuring Doubly Fed Induction Generator (DFIG) technology. All 48 turbines have a 90 metre hub height. The innovative S9X series product portfolio is designed to optimally harness the available wind resources and deliver higher energy, productivity, and improved serviceability.
**CPWD Commissions Solar Power Plant in Chennai**

The Central Public Works Department (CPWD) has commissioned a 100 kWp Grid Interactive Rooftop Solar Power Plant at Shastri Bhawan in Chennai. An official release said the 100 KWp solar plant was expected to generate 1.45 lakh units of electricity per year and would fully take care of the power requirements of the CPWD unit offices located in Shastri Bhawan. The payback period of the plant is around five years and the expected life of the plant is around 25–30 years. The plant is designed to withstand speedy wind with a velocity of more than 200 km per hour. There is scope for further expansion of the solar power generation.

For the benefit of other offices located at Shastri Bhawan, the available balance of the roof space will be utilized for solar power generation.

*Source: [http://news.webindia123.com](http://news.webindia123.com)*

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**Gurgaon gets its First Solar Power Plant of Delhi Metro**

Delhi Metro has inaugurated its first ever solar power plant in Gurgaon, Haryana at the HUDA City Centre metro station. It will provide power to escalators and elevators at the metro station. The first ever solar power plant at a parking lot with a generation capacity of 100 kWp was inaugurated by D S Mishra, Additional Secretary, Urban Development, Ministry of Urban Development. In total, DMRC has so far commissioned solar power plants with generation capacity of 2.8 MWp at Dwarka Sector 21, Anand Vihar, Pragati Maidan, Metro Enclave, Yamuna Bank station, Yamuna Bank depot, ITO as well as the Metro stations of Badarpur–Escorts Mujesar (Faridabad) corridor. DMRC is aiming to achieve solar power facilities with generation capacity up to 20 MWp by the end of 2017. It is trying to utilize the space available at its stations, depots, and residential areas to install solar power facilities. DMRC takes a number of initiatives to promote eco-friendly technologies and operations. It is a carbon neutral system and the average carbon dioxide (CO₂) saved per passenger per trip in the Delhi Metro is 144 g.

*Source: [www.iamin.in](http://www.iamin.in)*
The Government of India has pledged to reduce its greenhouse gas emissions intensity—the ratio between a country’s gross emissions to its gross domestic product at a particular point—by 33–35 per cent by 2030, compared to the 2005 levels. For this, India has to ensure that about 40 per cent of its electricity comes from non-fossil fuel sources or renewable energy sources. India will also increase its forest cover to create an additional carbon sink of 2.5–3 billion tonnes of carbon dioxide equivalent.

These targets (called the intended nationally determined contribution, or INDC) were presented to the United Nations Framework Convention on Climate Change (UNFCCC) for the global Paris summit. The government has said till 2030, these emission intensity-reduction targets and adaptation to climate change will require about $2.5 trillion, as well as an array of technologies.

It had committed to mobilize new funds from developed countries and said it would work to build an international architecture for diffusion of cutting-edge technologies, as well as collaborative research and development in this regard.

Source: www.business-standard.com

Tamil Nadu’s Largest Solar Plant Goes on Stream

A 40 MW solar plant has been commissioned near Sengottai in Virudhunagar district, making it the largest solar plant in Tamil Nadu to go on stream so far. The plant, which has come up at an investment of about ₹250 crore, was installed by Sterling and Wilson Pvt. Ltd. Sterling and Wilson took up the project as a Engineering, Procurement and Construction (EPC) contract. “We are glad to confirm that Malpani Group, under its flagship company Giriraj Enterprises, has successfully commissioned a 40 MW solar power plant in Tamil Nadu, which has always been a leader in the renewable energy,” Group Chairman Rajesh Malpani said. The plant has already started generating power and will generate about 2.5 lakh units of clean energy every day. “The plant has come up on nearly 250 acres and will evacuate power through the 110 kV sub-station at Erichinatham. This is Tamil Nadu’s highest capacity solar power plant as of now,” S Easwara Pillai, GM-Operations, Sterling and Wilson, said.

Source: www.thehindu.com

Delhi’s First Hydropower Plant to Generate Electricity from Sewage

Looking forward to green power generation, the Delhi Jal Board (DJB) has commissioned the first-ever hydropower plant in the national capital which will produce 20,000 kWh of electricity per year. The plant has been commissioned at Chilla area in East Delhi. This is the first plant in Delhi which will be run through hydraulic turbines propelled by treated effluent coming out of a Sewage Treatment Plant (STP). The treated effluent here falls through the height of 4.8 m which creates pressure and velocity leading to rotation of turbine, thereby, generating power. The generated electricity will be utilized at STP itself. “The use of fossil fuels leads to generation of carbon dioxide, which in turn leads to Green House Effect and Global Warming. However, no fossil fuel is being used in generation of power through hydropower at Chilla. Therefore, this technology is termed as a pollution-free technology,” DJB said in a statement.

Source: www.dnaindia.com

India Announces New Climate Change Targets

The Government of India has pledged to reduce its greenhouse gas emissions intensity—the ratio between a country’s gross emissions to its gross domestic product at a particular point—by 33–35 per cent by 2030, compared to the 2005 levels. For this, India has to ensure that about 40 per cent of its electricity comes from non-fossil fuel sources or renewable energy sources. India will also increase its forest cover to create an additional carbon sink of 2.5–3 billion tonnes of carbon dioxide equivalent.

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Source: www.business-standard.com
Germany to Fund €125 Million for Renewable Energy Corridor in India

Germany and India have signed two agreements to fund €125 million for the Green Energy Corridors’ project in Andhra Pradesh and Himachal Pradesh. Germany’s development bank, KfW, will fund €57 million for the project at Himachal Pradesh, and €68 million for the Andhra Pradesh project. The agreements were signed when Germany’s Chancellor Angela Merkel was on a state visit to India. Renewable Energy is one of the key areas of Indo–German partnership. With the financing of the transmission infrastructure of renewable energy projects, the Centre and State grids will be strengthened to evacuate more green energy. With the Green Energy Corridors, the intra-state network will feed the renewable energy to the respective state grids and the high capacity transmission corridors and inter-state network will connect major renewable energy pockets with the national grid.

Source: www.financialexpress.com

Solar Energy to Power Delhi Secretariat

The Delhi Secretariat will be the first in the country to be powered completely by solar and renewable energy. The Delhi government said that it will set up a 3 MW ground-based solar power plant at the Indraprastha power plant in association with the Ministry of New and Renewable Energy. “The solar power plant will supply power directly to the Delhi Secretariat for the next 25 years making it the first state secretariat to run completely on renewable and green energy making it an environment-friendly green building,” an official said, adding that work at the site had begun.

Source: www.thestatesman.com

DMRC Bags Top Award for Harnessing Solar Power in Metro Stations and Depots

Delhi Metro Rail Corporation (DMRC) has bagged the top spot for highest capacity installation of solar power plants in stations and depots across its vast network. Shri Piyush Goyal, Minister of State (IC) for Power, Coal, and New & Renewable Energy handed over the award to officials of DMRC at a ceremony held in Bengaluru on the first foundation day of the Association of Renewable Energy Agencies of States (AREAS) on August 27, 2015. As part of DMRC’s ‘solar mission’, it has installed several solar photovoltaic power plants that generate at around 2,794 (kilowatts peak) currently. The official statement from DMRC said that the company has signed a power purchase agreement for taking up solar power generation by another 7 MW. The power generated by these plants is used for DMRC’s operational requirements, which include station lighting and other loads.

Source: www.railnews.co.in
SolarWorld Sets New World Record for Solar-Cell Efficiency

SolarWorld AG has set a new world record for efficiency of industrially produced solar cells made using the so-called PERC-technology (passivated emitter and rear cell). The CalLab of the Fraunhofer Institute for Solar Energy Systems has confirmed that the global manufacturer of premium-quality products surpassed its own record by reaching a new height of 21.7 per cent in its solar cell efficiency. The cells, based on crystalline p-type silicon wafers, were manufactured using industrial production processes, meaning that they can be quickly placed into mass production.

“SolarWorld has been the first company to rely on PERC in its cell production. With this new record, we expand our technological lead even further. We can offer customers more electricity production on the same area and at the highest quality and durability,” says Dr.-Ing. E h Frank Asbeck, CEO of SolarWorld AG. Around 800 of the company’s cell capacity have already been changed to PERC. Thus, SolarWorld AG possesses the largest production capacity worldwide to manufacture this high-performance technology, which the company is going to expand. As a result of new coating processes on cells’ fronts and backs, the PERC technology achieves much higher efficiencies.

Source: www.renewableenergyfocus.com

ITM Power Opens M1 Wind Hydrogen Station in the UK

ITM Power has inaugurated its first publicly accessible hydrogen refuelling station at the Advanced Manufacturing Park, just off Junction 33 of the M1 motorway in South Yorkshire. The M1 motorway was highlighted as a key route for the early UK deployment of hydrogen refuelling, in the UK H2Mobility Phase 1 report in early 2013.

The M1 wind hydrogen station is funded by Innovate UK, and crucially has the support of Hyundai, Toyota, and Honda. The automakers showcased the Hyundai ix35 Fuel Cell, Toyota Mirai, and Honda FCX Clarity at the official opening of the station, alongside a UK-made Microcab H2EV micro car.

The site comprises a 225 kW wind turbine coupled directly to an ITM HGas PEM electrolyser, 220 kg of hydrogen storage, a hydrogen dispensing unit supplied by H2 Logic, and a 30 kW fuel cell system capable of providing backup power generation for nearby buildings.

Source: www.renewableenergyfocus.com

Wildlife Park Goes Green with Windhager Biomass System

The Wingham Wildlife Park, located in Kent, specified the wood pellet biomass boilers to replace its previous oil heating system due to its eco-friendly credentials as well as the money saving benefits from the Government RHI scheme. The fully automated 90 kW Windhager BioWIN Excel Kaskade system was installed by local installers, Grummant Heating and Plumbing Services, into a purpose built external cabin which also incorporates a separate wood pellet storage room. The boilers, which use a six probe suction feed system for the wood pellets from the pellet store to the boiler to produce a steady and comfortable amount of heat to the park’s offices and animal hospital rooms.

The wildlife park had planned to extend its previous oil heating system to heat the park’s indoor play area, which had been out of use during the colder winter months. Instead, the Windhager biomass system is now providing heat to the play area as well as the park’s offices and animal hospital rooms whilst still producing approximately £12,000 as savings a year.

Source: www.renewableenergyfocus.com
Eighty-Five per cent of British Power can be via Renewables by 2030, Says Greenpeace

Britain can produce 85 per cent of its power via renewable energy by 2030 provided it undergoes significant changes in energy production and use, according to a new study by Greenpeace. The study attempts to counter the argument that only fossil fuels and nuclear power can keep the lights on for the next few decades. It foresees wind leaping from today’s level of 13 GW of wind farms in operation—enough to power around 10 million homes—to a level of 77 GW in 2030, with solar rising from just more than 5 GW to 28 GW.

However, the renewables drive would need to be accompanied by a 60 per cent reduction in demand for domestic heating through a home insulation programme and other initiatives, according to the report by energy system analysts, DemandEnergy Equality. The plan, which would require a major change in government policies, envisages fossil fuels playing a role via combined gas-fired heat and power projects. Many homes and buildings would also need to move away from gas-fired boilers to their own ground source heat pumps or an electricity source.

Source: www.theguardian.com

SolarCity Unveils World’s Most Efficient Rooftop Solar Panel

SolarCity has built the world’s most efficient rooftop solar panel, with a module efficiency exceeding 22 per cent. The new SolarCity panel generates more power per square foot and harvests more energy over a year than any other rooftop panel in production, and will be the highest volume solar panel manufactured in the Western Hemisphere.

SolarCity will begin producing the first modules in small quantities very soon at its 100 MW pilot facility, but the majority of the new solar panels will ultimately be produced at SolarCity’s 1 GW facility in Buffalo, New York. SolarCity expects to be producing between 9,000–10,000 solar panels each day with similar efficiency when the Buffalo facility reaches full capacity.

SolarCity’s panel was measured with 22.04 per cent module-level efficiency by Renewable Energy Test Center, a third-party certification testing provider for photovoltaic and renewable energy products. SolarCity’s new panel created via a proprietary process that significantly reduces the manufacturing cost relative to other high-efficiency technologies is the same size as standard efficiency solar panels, but produces 30–40 per cent more power. SolarCity’s panel also performs better than other modules in high temperatures, which allows it to produce even more energy on an annual basis than other solar panels of comparable size.

Source: http://eqmaglive.com

Acciona Commissions 138 MW Wind Farm in South Africa

Spanish renewable energy company Acciona Energy has successfully commissioned their first South African wind energy project. Acciona Energy has commissioned the 138 MW Gouda wind farm in Drakenstein, which is about 100 km from Cape Town in South Africa. The wind farm consists of 46 3-MW turbines supplied by Acciona, and is expected to generate 423 GWh of electricity and offset greenhouse gas emissions equivalent to 406 million tonnes of carbon dioxide every year.

In addition to the Gouda wind farm, Acciona also operates the 94.3 MW solar PV power plant. Both projects were allocated to Acciona-led consortia during the second round of auctions under the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP). Acciona is working in partnership with Sener to set up the CSP project which will also have a molten salt storage system with 4.5 hours thermal storage capacity, and is expected to be commissioned in 2018. For both Sener and Acciona, this will be their second solar thermal project to be developed in South Africa, having worked together earlier on the Bokpoort plant (Upington), which is also a turnkey project employing Sener trough and a molten salt storage system. The Bokpoort plant is expected to be commissioned by the end of 2015.

Source: www.cleantechnica.com
Dr Om Prakash Nangia examines that for renewable power evacuation, the backbone shall be The ‘Green Energy Corridors’ project under implementation by the state-owned Power Grid Corporation of India Limited. It shall be a dedicated transmission network for mass chunks of power from rich renewable energy power states to the ones requiring higher energy demand. The author dwells on creating infrastructure highways across cities for transmission of PV power from utility-scale installations to the grid. Read on.
Power demand is increasing worldwide as it is vital for almost all activities of economic value. The renewable sources can produce electricity at close to or even below the cost of new fossil fuel-based power stations and mitigate global warming affordably. The cost of producing electricity from renewable sources such as wind and solar photovoltaic (PV) has been falling for a decade. Both these, low emission renewable energy (RE) technologies have grown very rapidly during the last several years and costs have dropped drastically by more than 70–75 per cent. The cost drivers of the different generating power technologies remain both technology- and market-oriented. The cost of installing PV systems across the world based on niche crystalline silicon (c-Si) technology is on the decline as a result of large volumes due to ever growing demand for providing access to electricity for the remote habitations in both the developing as well as the underdeveloped countries. Other important factors include sustained progress in technology, automation in manufacturing processes, ease and low cost of project financing, decreasing costs of balance of systems from 39 to 64 per cent during 2007–14, depending on market segment and geography.

In India, the current installed solar power capacity as per the latest data of the Ministry of New and Renewable Energy (MNRE) is around 4.26 GW (out of the total 100 GW target for solar power by 2022). The government is aiming for a ‘massive jump’ in its overall target of 175 GW by 2022 with a possibility of reaching 250 GW level by 2030 with more and more penetration of renewable energy. Government’s ambitious plans towards decarbonization will reduce strain on ecology and expected to abate over 170 million tonnes of CO₂, over its life cycle. By introducing large RE portfolio in the country’s energy mix, the country’s projections on its international commitment for the United Nations Climate Change Conference, COP21 (to be held at Paris in December 2015) shall be to achieve 30–35 per cent reduction in carbon intensity of its Gross Domestic Product (GDP) from 2005 levels by sourcing 20 per cent of installed electric power capacity from RE.

In many emerging economies including India, the grid constraints pose additional challenges. It is essential to have a stable grid to facilitate delivery of power on utility-scale. There is a shortfall at present in power evacuation infrastructure as the current grid capacity is totally inadequate in handling large inflow of renewable power. Introduction of dedicated transmission highways will be essential for transmitting gigawatts of power from renewable sources of energy through the enhanced grid capacity. An independent and stable transmission infrastructure will offer a great opportunity for the utilities. The current grid capacity is not designed for evacuating 175 GW of renewable energy that India is targeting. The ‘Green Energy Corridors’ project under implementation by the state owned The Power Grid Corporation of India Limited (PGCIL) to transmit clean energy will be the backbone for renewable power evacuation. It shall be a dedicated transmission network for mass chunks of power from rich renewable energy power states to the ones requiring higher energy demand.

The government has made plans to set up 25 mega solar parks with capacity of 20,000 MW involving investment of about ₹120,000 crore. Complimentary efforts shall be required to strengthen the grid through optimization so as to remove bottlenecks in power transmission between various producers and distribution companies. The new RE power evacuation scheme is likely to ensure reliability and resilience of the grid, which otherwise remains hampered due to shortfall in the transmission capacity. Also, the upgrading of the distribution infrastructure will be parallel essential for the smart cities project planned by the Government. Together with a politically favourable climate, India’s high solar irradiation levels and competitive costs and compliance of the climate change requirements, the development of new transmission highways across cities shall help achieve its upscaled RE capacity targets by 2022 including 100 GW of solar power.
Techno-Economic Potential of Crystalline Silicon-Based Solar Power

Earth receives solar energy equivalent to roughly 10,000 times the world energy demand. India is a tropical country, endowed with sunshine with a huge untapped solar energy. The potential for harnessing solar power is extremely high. The solar market all over is showing a lot of promise, growing very fast with a big push.

Silicon in its purest form is the base material and its availability as raw silicon material in the earth’s crust is in abundance. Crystalline silicon (c-Si) is dominant among other solar materials. It is mature with semi-conducting properties for manufacturing high efficiency cells and modules in making it a workhorse photo-voltaic (PV) technology. Solar cells based on c-Si account for about 85 per cent of the PV installations. The Compound Annual Growth Rate (CAGR) of the global cumulative PV installations between 2000 and 2014 is 44 per cent. The global PV production by technology (1980–2014) is shown in Figure 1.

Based on the solar cell developments over the years, the average efficiency of commercial c-Si PV modules has increased from 12 to 16 per cent. The laboratory scale module efficiencies are around 23 per cent with corresponding cell efficiencies between 20.8 per cent for multi-crystalline and 25.6 per cent for mono-crystalline silicon. Another significant development during the last 10 years for both mono- and multi-crystalline silicon based solar cells technology, is the lowering of material consumption in wafer (sawn from ingots) for the cells from 16 g/Wp to less than 6 g/Wp, leading to thinner and lower wafer costs. The c-Si solar cell development during 1990–2014 is shown in Figure 2.

One of the most important advantages of the technology using c-Si material is the energy payback period and reliability of performance for a period of over 25 years, as compared to thin films (micro-crystalline silicon layers, a-Si:H, CdTe, CuInSe2) based modules (with relatively lower efficiencies), are prone to light induced degradation over a period of time and considered hazardous in manufacturing and waste disposal. The other prominent technologies for concentrated photovoltaic (CPV) and concentrated solar power (CSP) have a few technical, operational, and maintenance issues and yet to establish their commercial competitiveness. The typical energy payback time with c-Si PV modules is shown in Figure 3.

The Government of India is making accelerated efforts to bring the country among the top five solar power producing nations with increased energy availability so as to improve the quality of life of the people through access of cheap and clean electricity in about 80,000 un-electrified villages in India. In India, the cost of solar power per unit has come down drastically to about 1.5 times that of coal-based power in 2014. The decreasing costs of silicon solar mainly in utility scale solar relate to technological maturity and scalability. With the advancement of technology and market competitiveness, the ‘green power’ is expected to reach grid parity by 2017–18 as per official estimates. To bring down the costs further, the government is also considering a dollar and yen denominated tariff plan under which it is likely to get green power at less than ₹4.50 per unit.

An extraordinary feature of the large solar potential will be on the employment front. With the increasing importance of low carbon resources producing cheaper clean energy fuels, there is a tremendous increase in utility-scale projects resulting in greater employment in several countries including India. With the availability of large trained workforce, the government has plans to create job opportunities (skilled and unskilled) for about 50,000 unemployed youth by engaging them as solar entrepreneurs to set up 20,000 MW of capacity.

Revised Solar Mission Targets vis-à-vis Utility Scale PV Installations

Through energy reforms, the country is preparing for the new market and new business opportunities in the RE sector. Strong growth in solar PV installations is expected with increasing global as well as domestic demands for green electricity. In view of lowering trends in module costs and increasing volumes, forecast of over 30 per cent year to year growth in PV is inevitable. The growth of solar installed
capacity phenomenally in India shows an increase from 3.7 MW in 2005 to around 4.26 MW in 2015. Since the country is riding on a high economic development wave that challenges its ability to harness the potential of renewable energy, India is all set for a massive jump to achieve 100 GW of solar power target in the next seven years. With clean energy initiatives, the solar power in India is becoming an inexpensive energy option competing neck-to-neck with the conventional fossil fuel-based power.

In line with India’s RE expansion plans, the scaled up target for solar power is 100 GW by 2022, out of the total 175 GW RE power target with a possibility of enhancement to 250 GW by 2030.

The revised solar power target will mainly comprise 60 GW through Large and Medium Scale Grid Connected Solar Power Projects and 40 GW through Decentralized Solar Power Generation in the form of Grid Connected Rooftop Projects. With this ambitious target, India will become one of the largest green power producers in the world. The total investment in setting up 100 GW will be around ₹600,000 crore. To achieve such a massive target with the help of setting up of green energy corridors, which are essential for interstate transmission, the government is pushing to initiate many supporting interventions like waving of fees for interstate RE power transmission. Other similar proposals, such as incorporating changes in land use regulations and tenancy laws to facilitate aggregation and leasing and identification of land by farmers/developers for solar projects and identification of large government complexes/buildings for rooftop projects are also in the offing.

For the 60 GW grid connect solar project’s target of MNRE (out of total 100 GW) up to 2022 the following is the broad break-up under different segments:
- 20 GW : Allocation for states under their policies
- 10 GW : Allocation to Central Public Sector Undertakings
- 10 GW : Scheme for unemployed youth and farmers
- 10 GW : Part of the ongoing programmes
- 5 GW : Allocation to private sector/large IPP’s
- 5 GW : Solar Energy Corporation of India (PSU under MNRE)

With ambitious targets fixed by the government for RE power generation, the solar manufacturing sector will get a boost. However, grid capacity for the transmission of gigawatts of power from utility-scale installations essentially requires a major renovation and modernization by creating a dedicated network through new energy corridors.

**Development of RE Power Transmission Infrastructure Highways across Cities**

**Green Energy Corridors—Key to Evacuate Gigawatts of PV Power**

Renewable energy sources are playing an increasingly important role in India. Use of solar energy is growing exponentially and resulting in decrease in cost of installation of utility-scale projects recently to a level of about 50 per cent. The boom in the solar sector in the country calls for setting up of new capacity transmission highways (green energy corridors) at the national level. Electric power transmission relates to transportation highways for large amount of electricity produced by utility-scale plants over long distances. The infrastructure of these highways include transmission towers (very tall metal structures), which are meant to keep the high voltage power lines separated from each other and other objects in the vicinity. Since the grid encounters hindrance in absorbing the RE (solar and wind) power because of climatic unpredictabilities and varying voltages, operation of the dedicated energy corridors in a dynamic mode, will get rid of choking conditions encountered otherwise in the transmission of power.

The high cost energy corridor project being undertaken for building the new infrastructure will go a long way to make a robust network for power transmission and overcome variations in RE power. The corridors shall become the backbone for evacuation of gigawatts of sun power with high reliability of the grid across the
country. Some of the essential basic requirements to be taken care of during planning and designing for the infrastructure energy corridors connected to utility-scale plants are: setting aside land away from densely populated areas for erecting transmission lines and high voltage towers; environmental impact assessment and mitigation measures; soil, air and water testing at site and corrective measures taken if necessitated; provision of a dedicated area for an electric sub-station, and clearing of vegetation with permanent access roads. The sub-station should be fully equipped with essential maintenance facilities and security measures, such as fencing, lighting, fire control, and first-aid equipments, etc.

For ensuring increased use of sustainable renewable energy supply in India, the governments of Germany and India have recently signed a technical and financial cooperation document. Under this agreement for strengthening the RE power evacuation network in India, a concessional loan of €1 billion has been committed by Germany through Kreditanstalt für Wiederaufbau (KfW) along with technical assistance for forecasting, balancing, and network management for the interstate and intrastate projects in India. In order to carry out the gigantic task for providing transmission infrastructure for integration of large scale renewable capacity during the 12th Plan and beyond, the government has entrusted the project to the state owned PGCIL. The company has made extensive plans for its execution on a country-wide basis as depicted in Figure 4. PGCIL has taken the challenge with the construction of ‘green energy corridors’ at an estimated cost of ₹43,000 crore, which will facilitate to synchronize reliable flow of clean PV electricity through the interstate grid without any hindrance. The project will make the transmission system dynamic and increase its efficiency by introducing smart grid innovations into the network and provide energy security to the country on a long-term basis.

**Challenges and Remedies in Integration of Large-Scale Renewable Power**

The broad challenges currently encountered by the grid leading to choking conditions during transmission are as follows:
- Intermittency
- Variability/Unpredictability
- RE plants connected at remote locations with weak transmission network.

The following are the important remedial measures recommended by the PGCIL, which are essentially to eliminate bottlenecks and overcome the challenges, which are to be taken up through an institutional arrangement:
- Technical standard requirements (grid code, connectivity standards, real-time monitoring—through synchrophasor technology system on pooling stations and interconnection with centralized control centre)
- Precise forecasting of renewable generation and demand
- Demand side management, demand response, and storage for load balancing
- Strong grid interconnections including quick ramp up reserve plants like gas-fired in case of no generation from RE plants due to intermittency or some other breakdowns
- Close coordination with respective load despatch centres (LDCs) for RE generation and control for smooth grid operation

![Figure 4: Perspective transmission plan for RE capacity by 2030](Source: PGCIL Report)
Establishment of Renewable Energy Management Centres equipped with advanced forecasting tools and a foolproof communication set-up
Training and capacity building at all generating locations and centres.

2 Envisaged Gains from the New Transmission Infrastructure Network

Seamless supply of the interstate renewable power generated from the ultramega solar projects from states rich in such resources to the deficient ones
Increased grid flexibility to integrate large quantities of variable (distributed and utility-scale) renewable energy
Introduction of latest and innovative new smart grid applications in the country to bring efficiency through demand response and demand side management, control of power system and quality, reduction in AT&C losses, conservation and sustainability
Achieving economic growth and energy security with balancing of the grid power transmission and integration of RE sources
Enable States in meeting of Renewable Purchase Obligation (RPO) targets and successfully achieving 3 per cent target for solar power
Aim to reduce the precious foreign exchange outflow by affecting a 10 per cent cut in crude oil and natural gas energy imports (80 per cent and 18 per cent, respectively) by 2022 and by about 50 per cent by 2030
Reduce carbon emissions, through a strategic switch from carbon-based energy to renewable energy.

2 Conclusions

No single electric power generation technology, either fossil fuels or clean energy fuels, can be relied upon to meet the twin objectives of economic development and climate change mitigation. Depending mainly on renewable sources for energy will need a major shift in the way power evacuation over long distances is to be planned and carried out.

A combination of several technological innovations based on equipment designs, ease of fuel supply and their rates, infrastructure construction, geographical locations, and payback period should invariably be considered while finalizing the generation source. To meet the country’s exponentially growing power requirement, the Indian government is taking series of initiatives for improvement of energy access with transitions to renewable to achieve country’s revised RE target of 175 GW including 100 GW especially for solar power by 2022. The cost of conventional power from coal and gas has been rising exponentially because of the high cost of extraction, transportation, and infrastructure construction. On the other hand, the reducing costs of PV modules, technical innovations leading to decline in the costs of Balance of Systems (BOS), structural hardware and installation techniques as a whole are providing a competitive and dominating push towards a mature and high growth solar regime. Solar and other renewable sources of clean power with zero fuel cost and zero emissions can be considered India’s milestone for establishing a major achievement on electricity front in future. The green practices being followed in India to tackle energy challenges through harnessing renewable sources of energy will result in holistic benefits to the country in terms of energy security, mitigation of greenhouse gas emissions, and socio-economic development and creation of additional jobs.

The main challenge lies in India’s ability to meet its clean energy targets and in evacuation of gigawatts of RE power from utility-scale plants to the grid. This will require meticulous planning and large investments. The Green Energy Corridors initiative being undertaken by the Government at high costs shall be integrated with national grid across cities to act as the backbone for establishing a robust infrastructure, using transmission highways for uninterrupted transfer of solar power from the utility-scale plants. By

Dr Om Prakash Nangia, Senior Consultant in Solar Energy, Director at New Era Solar Solutions Pvt. Ltd, New Delhi. Email: om.p.nangia@gmail.com, nangiaom@newera-solar.com
Inverse environmental and economic effects of fossil fuels has made it essential that alternate renewable sources of fuel for power generation and transportation be sought. A widely accepted alternate for these purposes is hydrogen. **Prof. Y K Yadav, Dr Sachin Kumar** and **Raman Rao** assess the biological methods to produce hydrogen.

A ample use of fossil fuels all over the country in transportation and power/heat generation is creating not only the environmental problems but also the economic imbalance due to their uneven distribution. Therefore, researchers around the country are focusing on finding alternate energy resources that are environment-friendly and renewable in nature. Hydrogen is one such attractive energy source that has the highest energy yield (142 KJ/g) among any known fuel. It can be easily
transported through conventional means and has been accepted globally as environmentally safe energy resource due to carbon neutral combustion.

Need of Biohydrogen

Presently, most of the hydrogen is produced from fossil fuels, which accounts about 98 per cent of its total production. Conventional physiochemical methods for H₂ production are based on steam reforming of natural gas (40 per cent); coal gasification (18 per cent); and pyrolysis or gasification of biomass, which produces a mixture of gases (H₂, CH₄, CO, CO₂, and N₂). All these methods require high temperature (>850°C) and, therefore, are energy intensive and expensive. Water can also be used as a renewable resource for hydrogen production and methods are based on photolysis, electrolysis, and thermo-chemical methods. However, electricity costs account for 80 per cent. Although, all these methods have the potential for effective H₂ production but require a source of energy, which is derived from fossil fuels that make these processes economically impractical and unsafe/toxic to the environment. Therefore, among the various technologies, which are used for hydrogen production, biological hydrogen production perhaps exhibits the substantial prospective to replace the fossil fuels as these technologies are less energy intensive and more environment-friendly as compared to conventional processes.

Application of Hydrogen Gas

- For power generation transportation with zero pollution (Figure 1)
- For the production of NH₃ and CH₄
- For electricity generation in Microbial Fuel Cell (MFC) (Picture 1)

Bioprocess for Hydrogen Gas Production

Biological production of hydrogen is carried out using microorganisms in an aqueous environment at particular temperature and pH. However, the yield of hydrogen production is low as compared to other conventional methods but there is reduced emission of greenhouse gases (GHGs) by 57–73 per cent using biological methods. Among different hydrogen production methods, biological methods are of great importance as they are less energy intensive. Advantages and disadvantages of hydrogen production methods are outlined in Table 1. Various operational parameters required for biohydrogen production along with bioreactor configuration are described in Table 2.

Table 1: Advantages and disadvantages of hydrogen production methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasification</td>
<td>Higher hydrogen yield</td>
<td>Solar collector plates are needed</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>Liquid fuels, solid charcoals, and gaseous compounds are formed</td>
<td>Activity of catalyst will be reduced</td>
</tr>
<tr>
<td>Direct biophotolysis</td>
<td>Direct sunlight and water are used for producing hydrogen</td>
<td>Inhibitory effect of hydrogen and low hydrogen productivity</td>
</tr>
<tr>
<td>Indirect biophotolysis</td>
<td>Hydrogen can be produced from blue-green algae</td>
<td>Inhibitory effect of hydrogen on the activity of nitrogenase</td>
</tr>
<tr>
<td>Dark fermentation</td>
<td>Light requirement is not mandatory and various substrates can be used as carbon source</td>
<td>Yield is comparatively low and inhibitory effect of oxygen towards hydrogen</td>
</tr>
<tr>
<td>Photo fermentation</td>
<td>Photosynthetic bacteria does not have PSII, as a result oxygen inhibition effect on hydrogen production is eliminated. Can use different organic biomass</td>
<td>Nitrogenase activity is inhibited by the presence of oxygen and photochemical efficiency is quite low</td>
</tr>
<tr>
<td>Two-stage fermentation</td>
<td>Comparatively high yield of H₂ and organic acids produced during dark fermentation can be efficiently used to produce further hydrogen</td>
<td>Pre-treatment of dark fermentation's effluents, pH adjustment and optimization of nutrient media composition is required</td>
</tr>
</tbody>
</table>
Table 2: Processes, operational parameters, and types of bioreactor used for biohydrogen production

<table>
<thead>
<tr>
<th>Process</th>
<th>Operational parameters</th>
<th>Bioreactor configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biophotolysis</td>
<td>pH, temperature, hydraulic retention time, pretreatment, organic loading rate (OLR), etc.</td>
<td>flat-plate photobioreactor</td>
</tr>
<tr>
<td>Dark fermentation</td>
<td>-do-</td>
<td>Batch/CSTR/membrane reactor/baffled bioreactor</td>
</tr>
<tr>
<td>Photo fermentation</td>
<td>-do-</td>
<td>Batch/continuous/photobioreactor</td>
</tr>
<tr>
<td>Two-stage dark/photo fermentation</td>
<td>-do-</td>
<td>Batch/continuous/membrane reactor/baffled/photobioreactor/anaerobic reactor</td>
</tr>
</tbody>
</table>

Major bioprocess used for hydrogen gas production is outlined in Figure 2.

**Biophotolysis of water by algae**

In direct biophotolysis, the photosystem (PSI and PSII) of algae (Anabaena sp. and Chlamydomonas reinhardti) convert the solar energy into chemical energy, which is required to break down the water molecule to produce biohydrogen (Equation 1) as shown in Figure 3.

- The oxygen content should be maintained below 0.1 per cent to increase the hydrogen yield as hydrogenase enzyme is inhibited in the presence of oxygen.

\[ 2H_2O \rightarrow 2H_2 + O_2 \] (1)

During indirect biophotolysis, hydrogenase and nitrogenase both enzymes produce the hydrogen as shown in Equations 2 and 3:

\[ 12H_2O + 6CO_2 \rightarrow C_6H_12O_6 + 6O_2 \] (2)

\[ C_6H_12O_6 \rightarrow 12H_2 + 6CO_2 \] (3)

**Dark fermentation**

In dark fermentative process, the microorganisms act on the preferred substrate/feedstock and undergo anaerobic fermentation in the absence of light to produce molecular hydrogen and carbon dioxide as shown in Figure 4.

- These microbes are either obligate or facultative anaerobes. End products are soluble metabolites depending upon the mechanism used. Use of waste water as feedstock for dark fermentative biohydrogen production is drawing more attention since the last few years. Among different feedstock, carbohydrates are preferred feedstock for dark fermentation that produces hydrogen along with acetic acid and butyric acid as shown in Equations 4 and 5.

\[ C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2 \] (4)

\[ C_6H_{12}O_6 + 2H_2O \rightarrow CH_3CH_2COOH + 2CO_2 + 4H_2 \] (5)

**Photofermentative hydrogen production**

In this method, non-sulphur purple photosynthetic bacteria (Rhodobacter sphaeroids, R. capsulatus, etc.) capture the light energy and convert organic acids into hydrogen and carbon dioxide in the absence of oxygen (Equation 6) as shown in Figure 5.

\[ CH_3COOH + 2H_2O \rightarrow 2CO_2 + 4H_2 \] (6)

**Figure 2: Bioprocessing for hydrogen production**

**Figure 3: Biophotolysis of water by algae**

**Figure 4: Dark fermentation**

**Figure 5: Photofermentative hydrogen production**

The main enzyme responsible for photofermentation by photosynthetic bacteria is ATP-dependent nitrogenase and optimum temperature and pH required for photofermentation is in the range of 30–35°C and pH of 7.0, respectively. However, low light conversion
efficiencies (3–10 per cent), inhibition of nitrogenase enzyme to the presence of nitrogen content, and oxygen concentration are some hurdles in photofermentation that can be overcome by metabolic remodeling and by using co-cultures having different light utilization characteristics.

### Two-stage dark/photofermentative hydrogen production

This process is more beneficial as compared to dark and photofermentation alone. In this method, the organic acid produced during the dark fermentation can be further used to produce hydrogen by converting them into hydrogen and CO$_2$ by using photoheterotrophic bacteria. The yield of hydrogen production using dark fermentation is low; therefore, the organic acids are produced, dark fermentation can be converted into further hydrogen by using photosynthetic bacteria as shown in Figure 6.

A maximum theoretical yield of 12 mol H$_2$/mol of hexose sugar can be obtained using sequential dark and photofermentation.

The general reaction of two-stage fermentation system can be described as follows:

- **Stage 1**: Dark fermentation (selective anaerobes):
  \[ C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_2COOH + 2CO_2 + 4H_2 \]
- **Stage 2**: Photo fermentation (photosynthetic bacteria):
  \[ CH_2COOH + 2H_2O \rightarrow 2CO_2 + 4H_2 \]

### Biological Hydrogen Production Status in India

At present, hydrogen gas in India is produced in chemical and fertilizer industries. Significant work has been done till now in the field of biohydrogen production in India. However, the scope of hydrogen energy at present is limited to research, development, and demonstration stage. The main aim of research for producing biohydrogen is directed towards the development of new and improved strategies, use of various feedstocks to produce biohydrogen with higher yield, higher production rate, and optimization of reactor designs.

![Figure 6: Two-stage dark/photofermentation system](image-url)
on industrial-scale, cost-effective methods have been developed. Dark fermentation has proved significant among other biological methods of producing biohydrogen. Many studies have been conducted using dark fermentative bacteria (Clostridium sp. and other facultative anaerobes such as Enterobacter aerogenes, etc.) to produce biohydrogen. Initially, research was mainly focused on using pure bacterial culture on glucose as a substrate. With the advancement in time, other feedstocks, such as xylose, sucrose, and waste materials are used for biohydrogen production. However, the emphasis has shifted from laboratory-based pure substrate to cheap and easily available waste materials to produce biohydrogen. The Ministry of New and Renewable Energy (MNRE) has supported various research and development (R&D) projects with broad vision of cost effectiveness as well as commercial production of biohydrogen. As a result of these efforts, laboratory-level prototypes of hydrogen-fuelled motorcycles and water/methanol electrolysers for hydrogen production have been developed successfully. The MNRE has successfully demonstrated first demonstration project of hydrogen dispensing station through Indian Oil Corporation Ltd. and Society of Indian Automobile Manufacturer at Dwarka, New Delhi. It has an electrolyser with 5 Nm³/h hydrogen production capacity. The hydrogen so produced is being blended with CNG to use in demonstration and test vehicles. Other bodies, such as the Ministry of Science and Technology, CSIR Laboratories, IITs, Defence Research and Development Organization (DRDO), Oil and Gas companies, and other private sector companies are extensively participating in the R&D work related to biohydrogen production.

**Conclusion**

The biological methods to produce hydrogen are more advantageous as compared to other methods as it can utilize the organic waste water effectively to produce hydrogen thereby reducing the production cost. Exploitation of industrial effluents as substrate for biohydrogen production with concurrent waste water treatment is an attractive and effective way of trapping clean energy from renewable resources in a sustainable approach. This provides dual environmental benefits in the direction of waste water treatment along with sustainable bio-energy (H₂) production. However, biological hydrogen production in India is still in the stage of infancy as these processes are performed mainly at laboratory-scale by using different feedstocks and microorganisms. Therefore, in order to make the process feasible at commercial scale, further research and development is required in the field of biohydrogen production. Fermentation method of producing hydrogen has been proven to be more viable as compared to chemical method. But this method has drawbacks of low hydrogen yield and low production rate. However, this problem can be overcome by using two-stage hybrid systems (dark fermentation followed by photofermentation). The organic acids produced during the dark fermentation can be used as feedstock for photofermentation to enhance the biohydrogen yield. This process, however, needs some modification in the bioreactor design. Genetic modification in the particular bacterial strain in order to destroy the hydrogen-consuming bacteria and use of cell immobilization technique are other methods to enhance the biohydrogen yield. If we become successful in realizing the potential of hydrogen gas, it will aid in sustainable growth of our economy by reducing the emission of GHGs.

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**MINISTRY OF NEW AND RENEWABLE ENERGY (MNRE) HAS SUPPORTED VARIOUS RESEARCH AND DEVELOPMENT (R&D) PROJECTS WITH BROAD VISION OF COST EFFECTIVENESS AS WELL AS COMMERCIAL PRODUCTION OF BIOHYDROGEN.**

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Prof. Y K Yadav, Director General, SSS-NIBE; Dr Sachin Kumar, Assistant Director/Scientist, and Mr Raman Rao, Senior Research Fellow, are affiliated with Sardar Swaran Singh National Institute of Bio-Energy (Formerly Sardar Swaran Singh National Institute of Renewable Energy), Kapurthala, Punjab, India. E-mail: sachin.biotech@gmail.com
नवीन और नवीकरणीय ऊर्जा मंत्रालय में हिंदी दिवस/हिंदी प्रवाह दिवस वितरण समारोह

यह वर्ष की भाषा इस वर्ष भी नवीन और नवीकरणीय ऊर्जा मंत्रालय में 14-28 सितंबर, 2015 के दौरान हिंदी प्रवाह का आयोजन किया गया। राजनीतिक हिंदी में काम करने के लिए वातावरण तैयार करने हेतु मंत्रालय के अधिकारियों और कर्मचारियों के लिए विभिन्न प्रतियोगिताओं जैसे हिंदी निबंध, प्रश्नोत्तरी, हिंदी टंकन एवं भाषा प्रतियोगिता आदि का आयोजन किया गया। इन प्रतियोगिताओं के लिए पुरस्कार वितरण समारोह का आयोजन दिनांक 14.10.2015 को किया गया। इस अवसर पर श्री उपेन्द्र विश्वास, सचिव, नवीन और नवीकरणीय ऊर्जा मंत्रालय के कर क्मों से पुरस्कार विजेताओं को नकद उपस्थापन और प्रशासक पत्र दिए गए। पुरस्कार विजेताओं का विवरण निम्नलिखित है:

### 1. हिंदी निबंध प्रतियोगिता

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<th>पत्रनाम</th>
<th>पुरस्कार</th>
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<td>अनुभव अधिकारी</td>
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### 2. भाषा प्रतियोगिता

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### 3. प्रश्नोत्तरी प्रतियोगिता

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<td>3</td>
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<td>4</td>
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<td>साहायक</td>
<td>तृतीय</td>
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### 4. शुभलेखन प्रतियोगिता

1. श्री ब्रज कुमार शिखर | एम.टी.एम | प्रथम |
2. श्री सुंदर सिंह गोयनी | एम.टी.एम | द्वितीय |
3. श्री समर सिंह | एम.टी.एम | तृतीय |

### 5. प्रश्नोत्तरी प्रतियोगिता

1. श्री लिहित गुप्ता | साहायक | प्रथम |
2. श्रीमती अर्नथा रानी मिश्रा, प्रवर श्रेणी लिपिक | प्रथम |
3. श्रीमती सुजा लता लोहित | साहायक | द्वितीय |
4. श्री उमेश कुमार, प्रवर श्रेणी लिपिक | तृतीय |
5. श्री लिहित गुप्ता, एम.टी.एम | तृतीय |

समारोह के आरंभ में श्रीमती बीणा धननार, अनुभव पार्थिक ने सचिव महादेव और उपस्मित सपीता अभिकारियों/कर्मचारियों के स्वागत किया और राजनीतिक हिंदी के प्रश्न के श्रेणी में मंत्रालय द्वारा किए, गए प्रवास और प्रश्न के संबंध में वातावरण। पुरस्कार वितरण से पूर्व मानवीय गृहमंत्री, श्री राजनाथ सिंह और नवीन और नवीकरणीय ऊर्जा मंत्री, श्री पीयूष गोविल द्वारा हिंदी दिवस पर जारी संदेश फाइल रुप में सुनाया गया।

इस अवसर पर सचिव महादेव ने हिंदी दिवस के महत्त्व पर प्रकाश की डाला और हमें यह भी बताया कि 14 सितंबर के दिन हिंदी भाषा के लिए ही नहीं, अर्थात् अन्य भाषाओं के लिए भी एक ऐतिहासिक दिन है। उन्होंने अन्य अभिकारियों और कर्मचारियों से राजनीतिक विभाग द्वारा वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने की दिशा में पूरी गणितीय से प्रवास करने का आयोजन किया और पुरस्कार विजेताओं को भाग लिया। अंत में डा. एस. के. माधवनाथ, वैज्ञानिक एवं प्रमाण (राजनीति) ने उपस्मित अधिकारियों/कर्मचारियों का आयोजन व्यक्त किया।

[म]
Energy is universally recognized as one of the most important inputs for economic growth and human development. India’s economic growth is driving its energy consumption. India is the world’s fourth largest economy, with Gross Domestic Product (GDP) adjusted for inflation and purchasing power. India is also the world’s fourth largest energy consumer.

As Indian economy continues to grow, so will its energy consumption. The country’s primary energy consumption more than doubled between 1990 and 2011. As the demand continues to grow, in keeping with the GDP growth, the energy sector is struggling to deliver a secure supply of energy amid growing energy imports, greater energy security concerns, and environmental consequences of fossil fuel use. India’s energy demand, which was nearly 700 Mtoe in 2010, is expected to exceed 1,500 Mtoe by 2030. In the business-as-usual scenario, India’s dependence on energy imports is expected to increase from 30 per cent in 2010 to 51 per cent, making it one of the most important energy importing countries in the world. This calls for an effective and dynamic energy policy framework in order to address a number of challenges that India faces. There is a need for a paradigm shift in the thinking process through behavioural and lifestyle changes in addition to the innovative policies that are being adopted by the government to create sustainable infrastructure, smart cities, and grids.

Sri Aurobindo International Centre of Education (SAICE) (Picture 1) has undertaken the initiative to demonstrate that, within the prevailing policy environment of India, it is indeed feasible for society to accelerate the energy transition, making the ‘Sustainable Energy for All’ vision of the United Nations (energy that is accessible, cleaner and more efficient) a reality by 2030.

**Institution’s Growth Over the Years**

**Phase 1: From 2012 to 2014**

A pilot research initiative was undertaken by the Sri Aurobindo International Centre of Education (SAICE) during 2012–14 to demonstrate the feasibility of an electricity consumer achieving net-energy positive status by adopting measures to lower the energy demand through energy efficiency and conservation, and producing electricity using solar energy.

The SAICE buildings are considered as Puducherry’s heritage and these buildings were designed to function with the least amount of energy by incorporating bio-climatic architectural features that are well-suited to the local hot and humid climate. While the buildings are well protected from the sun, the high ceilings and wide windows allow for adequate daylight and natural ventilation.

In the beginning of the project, the energy consumption profile of the school was monitored to derive the pattern of electricity use over a fairly long period of time. Based on life cycle analysis, the energy efficiency measures that were found to be more attractive than purchasing grid electricity were retained. Inefficient lamps, fans, air conditioners, and computers were substituted by more energy-efficient alternatives to lower the energy demand by more than 25 per cent without compromising on the quality and service (Figure 1).

Following the demand management measures, it was decided to install a solar power plant that could produce sufficient electricity to meet all the energy needs of SAICE.
Sri Aurobindo International Centre of Education: A Leading Net Energy-Positive Institution

Centre of Education

In this article Tejas Shah, Sandeepan Sharma, and Dr Brahmanand Mohanty tell us about the Sri Aurobindo International Centre of Education in Puducherry, which is leading the way in becoming a net energy-positive educational institution in India.

The students at SAICE were encouraged to participate in the installation of the rooftop solar power plant (Picture 2). This allowed them to acquire a better understanding of the working principles of a grid-tie solar power generation system and practical exposure to various aspects of the solar system to be taken into consideration in order to ensure its proper functioning over a long period of time.

By the time the 17 kWp solar power plant was commissioned in September 2014, the status of SAICE had evolved from being an electricity consumer to a net-electricity producer. As shown in Figure 2, SAICE was able to meet all its electricity needs and even export an excess of 700 kWh into the power grid during the first month of operation.

This research initiative was supported and recognized by the Government of Puducherry as well as the Power Grid Corporation of India Limited (PGCIL) as part of the pioneering Smart Grid Pilot project being implemented for the first time in India. Smart Grid facilitates efficient, reliable, and intelligent two-way electricity delivery system through integration of renewable energy sources, smart transmission, and distribution. Smart Grid technology brings efficiency and sustainability in meeting the growing electricity demand.

The net-meter installed by PGCIL keeps track of the bi-directional electricity flow. This is a huge step towards making the power grid smart. The power supply system that is traditionally dependent on mega-size fossil-fuel based thermal power plants now has an option to integrate a large number of clean and benign (solar and wind) power generators distributed across the network and closer to the points of use, thus reducing the dependence on environmentally-polluting fossil fuels, eliminating the power transmission and distribution losses, and helping to avoid electricity outages by bridging the demand-supply gap.

Phase 2: Initiated in 2015

The experience and knowledge gained from the pilot research activity provided useful insights and contributed to the formulation of the grid-connected rooftop solar regulation by the Joint Electricity Regulatory Commission (JERC) for Goa and Union Territories of India, including...
Puducherry, in the later part of December 2014. This policy includes feed-in tariff (production and sale of solar electricity to the power grid) and net metering (production and exchange of electricity with the power grid). An innovative feature of the new regulation is the group net-metering option that allows a consumer having more than one electricity connection to generate excess solar electricity at a given connection point in order to offset the electricity consumed at other connection points. Sri Aurobindo Ashram, being the owner of many buildings, has the option to use the excess electricity generated by SAICE to lower the electricity consumption of other Ashram buildings (e.g., Ashram Press or Guest House) by an equivalent amount.

The SAICE took up a new phase of research, in conjunction with the local government and electricity department, in January 2015 for putting the concept of group net metering into practice, in consultation with the local government and the power utility. This phase involved the enhancement of the grid-tied solar power plant so as to achieve a cumulative solar power generation capacity of 50 kWp. The solar power plant is expected to generate an average of 6,500 kWh of electricity per month, which is more than three times the present electricity consumption of the school. The excess electricity produced by the school will compensate for the electricity consumption of other Ashram buildings. In the initial phase, 17 kWp of solar power plant was installed in September 2014. After the solar policy was adopted, another 33 kWp of solar plant was commissioned on March 31, 2015 to take the total capacity to 50 kWp. A wide-angle photo of the solar panels installed on SAICE rooftop is shown in Picture 3.

Data gathered from the remotely monitored smart electric meter has been analysed for a typical day and plotted in Figure 3. The main operation of the school is during the daytime and there are limited activities beyond sunshine hours. The electricity produced by the solar plant not only takes care of all the needs of SAICE during the day but also exports 161 kWh of electricity to the power grid.

![Picture 3: A wide-angle photo of the solar panels installed on SAICE rooftop (Photo Courtesy: Kasper)](image)

Space air conditioning happens to be one of the major electricity consumers in buildings. There is a trend of installing air conditioning in new residential and commercial buildings located in hot and dry as well as warm and humid climates. While the air conditioning load becomes more important on sunny days, such days are also more favourable for the production of electricity from rooftop solar power plants. A number of studies report that the constructed floor area in India is likely to increase by around four times in the next couple of decades. Suitable policies adopted for these new constructions can help reduce their energy intensity and encourage them to adopt rooftop solar systems to partially/wholly meet their electricity needs.

To illustrate the above point, the energy performance of SAICE in April 2015 is presented in Figure 4. The remotely monitored smart electric meter allows tracking the hour-wise and day-wise imports and exports of electricity between SAICE and the local power utility. The excess electricity exported to the power grid after meeting all the electricity needs of SAICE was around 5,000 kWh. In such circumstances, regulations favouring feed-in-tariff

![Figure 3: Graphical presentation of the net metering performance of SAICE on June 16, 2015](image)
can encourage school buildings with large unutilized rooftops to not only meet their own energy needs but also earn revenue by selling excess generated electricity to the power grid. The money earned can be used judiciously for upkeep of the school infrastructure.

Conclusions Based on the Preliminary Assessment

The rooftop solar plants commissioned so far on the rooftop of the SAICE buildings will silently produce electricity for at least two decades, leading to win-win solutions at all levels:

- Apart from eliminating the need for hefty electricity bills every month, these installations will protect other Ashram buildings from all future electricity price hikes over the entire lifetime of the rooftop solar power plants.
- The power utility will gain by meeting its Renewable Portfolio Obligation (RPO), avoiding transmission and distribution losses, reducing the load on distribution transformers, and bridging the demand-supply gap, especially during the peak electricity demand periods in the daytime.
- Burning of large amounts of fossil fuels can be avoided, thus helping to extend the availability of fossil fuels and reducing the adverse environmental impact of fossil fuel burning.
- The country will gain higher energy independence and be better protected from unpredictable hikes in the price of fossil fuels due to geo-political reasons.
- The global environment will improve by switching from high greenhouse gas emitting fuels to a clean and perennial source of energy.

The main message of this research initiative is that those who have access to energy and can well-afford it have the responsibility to adopt demand- and supply-side measures, both technical and non-technical, that can contribute to making the scarce energy resources available for all those who do not have access or have poor access to them. Such grass-roots initiatives backed up with strong institutional support and leadership commitments at the national level can make the goal of energy independence a reality in the foreseeable future.

Salient feature of the rooftop solar power system installed at SAICE:

- Installed capacity of rooftop solar power plants at the SAICE up to March 2015: 50 kWp
- The amount of solar electricity generation estimated over 2 decades: 1,500 MWh
- The avoidance of coal to be burnt in thermal power plants (including the transmission and distribution losses): 1.1 million tonnes of coal
- Avoided carbon dioxide emissions from the coal fired power plants: Over 1,000 tonnes

Mr Tejas Shah (teacher), Mr Sandeepan Sharma (student), and Dr Brahmanand Mohanty (alumnus), Sri Aurobindo International Centre of Education, Puducherry, India. Email: tejasyshah@gmail.com and mohantyb@gmail.com
Enriched Biogas Slurry
A Potential Source of Nutrients for Organic Farming

Dr S Hazarika, Er M J Barooah, Dr P K Dutta, and P Rajkhowa
explore the unrealized nutritive potential of biogas spent slurry for organic farming. Through case studies conducted in Assam, they describe the usefulness and significance of developing this resource.

The slurry emanating from the biogas plant is referred to as biogas plant spent slurry (BSS). It is rich in nitrogen (N), phosphorous (P), potassium (K), and several micronutrients. The content of these plant nutrients varies, depending on the type and nature of feedstocks used for production of biogas. The average nutrient and organic matter content of BSS is given in Table 1. The digested slurry discharged from the conventional biogas plants normally contains 92–94 per cent moisture whereas in the case of solid state biogas plants, the moisture content varies between 88–90 per cent. BSS is one of the potential sources of nutrients for organic farming but it is practically difficult to supply the entire nutrient demand of crops with BSS because of its bulky nature. To reduce bulkiness, enrichment of BSS with nutrients using organic (e.g., biofertilizers) and mineral sources (e.g., rock phosphate) is an attractive option for its use in organic farming practices.

Organic farming has emerged as a major thrust area in agriculture over the years. Assam and the North-East are mostly organic by default and out of 85,346 ha under organic cultivation in the North-East, Assam has an area of 2,828 ha. The Government of India through Ministry of Development of North Eastern Region (DoNER) has launched a ‘Scheme for Organic Farming in the North Eastern Region’ with an initial outlay of ₹ 100 crore for the year 2014–15. Conscious organic farming has suddenly picked up across the state of Assam, especially among those cultivating ginger, turmeric, oranges, black pepper, and pineapples. On an experimental basis, the State Department of Agriculture, Assam, has taken up organic cultivation of scented rice (var. Joha, Keteki Joha, etc.) across 92 ha in three districts, involving 162 farmers. Moreover, the Agricultural and Processed Food Products Export Development Authority (APEDA) has plans to export indigenous varieties of rice, produced with organic farming methods in the Northeastern region of the country to the foreign markets. As per the

Table 1: Average nutrient content of biogas plant spent slurry (BSS)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Average Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1.8%</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>1.0%</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.90%</td>
</tr>
<tr>
<td>Mn</td>
<td>188 ppm</td>
</tr>
<tr>
<td>Zn</td>
<td>144 ppm</td>
</tr>
<tr>
<td>Fe</td>
<td>3,550 ppm</td>
</tr>
<tr>
<td>Cu</td>
<td>28 ppm</td>
</tr>
<tr>
<td>C/N ratio</td>
<td>10–15</td>
</tr>
<tr>
<td>Organic matter</td>
<td>65%</td>
</tr>
</tbody>
</table>
statistics provided by National Biogas and Manure Management Programme (NBMMP), more than 85,000 numbers of family type biogas plants have so far been installed in Assam and there is ample scope to involve these biogas plant owners in organic farming practices in the years to come. Realizing the importance of enriched BSS as a source of nutrients for organic farming, packages have been developed for rice and mustard crops and tested in the farmers’ fields. To create awareness and popularize the technology among the farmers, a field day was organized at the demonstration site.

**Nutrient Package**

Nutrient packages were developed in the Department of Agricultural Engineering, Assam Agricultural University using enriched biogas slurry as a source of nutrients for cultivation of rice and mustard crops using organic farming practices. Under this package, 50 per cent of the recommended dose (RD) of nitrogen (N) for rice and mustard crops is replaced by BSS nitrogen and remaining 50 per cent is substituted by biofertilizer (BF). The BSS is enriched with rock phosphate and Phosphate Solubilizing Bacteria (PSB) so that the quantity of BSS required to replace 50 per cent RD of N can meet the plant nutrient demand for phosphorus (P). The quantity of BSS and other additives used in the package is shown in Table 2. A 2 m³ biogas plant discharges about 50 kg wet slurry per day and to obtain 1 metric tonne of fresh slurry, a time period of 20 days will be required. Since the quantity of BSS required for a hectare of land is quite large (Table 2), a farmer has to plan well in advance to collect and store the BSS. It can be stored safely in pits covered with shed.

<table>
<thead>
<tr>
<th>Crops</th>
<th>RD of fertilizer N (kg/ha)</th>
<th>Quantity of fresh BSS* to replace 50% RD of N (t/ha)</th>
<th>Quantity of BF to replace 50% of RD of N (kg/ha)</th>
<th>Quantity of RP (kg/ha)</th>
<th>Quantity of PSB (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBP</td>
<td>SSBP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mustard</td>
<td>40 (88 kg urea)</td>
<td>20</td>
<td>10</td>
<td>0.5–1.0 (Azotobacter for seed treatment)</td>
<td>110</td>
</tr>
<tr>
<td>Rice</td>
<td>40 (88 kg urea)</td>
<td>20</td>
<td>10</td>
<td>3.5 (Azospirillum for root deep treatment)</td>
<td>110</td>
</tr>
</tbody>
</table>

* considering N content of 2% on dry weight basis, total solid (TS) content of conventional biogas plant (CBP) 5% and TS content of solid state biogas plant (SSBP) 10%, phosphorous @ 2% P₂O₅ on dry weight basis of slurry using rock phosphate (RP) containing 18% P₂O₅. BF: biofertilizer

**Package for rice**

The package for organic cultivation of rice, using enriched BSS, involves the following steps:

- Enrichment of slurry with *Azospirillum* biofertilizer
- Coating of roots of rice seedlings with *Azospirillum* inoculated slurry
- Enrichment of slurry with rock phosphate and PSB and its application into the field
- Transplanting of rice seedlings following recommended practices.

**Enrichment of BSS with *Azospirillum***

A suitable quantity of fresh slurry is enriched with *Azospirillum* which is an efficient N fixing micro-organism and a proven biofertilizer (@ 3.5 kg/ha) for rice in Assam. The amount of slurry depends on the number of seedlings to be inoculated with *Azospirillum* for transplanting which in turn is contingent on the area of land to be transplanted.

**ORGANIC FARMING HAS EMERGED AS A MAJOR THRUST AREA IN AGRICULTURE OVER THE YEARS. ASSAM AND THE NORTH-EAST ARE MOSTLY ORGANIC BY DEFAULT AND OUT OF 85,346 HA UNDER ORGANIC CULTIVATION IN THE NORTH-EAST, ASSAM HAS AN AREA OF 2,828 HA.**

**NUTRIENT PACKAGES WERE DEVELOPED IN THE DEPARTMENT OF AGRICULTURAL ENGINEERING, ASSAM AGRICULTURAL UNIVERSITY USING ENRICHED BIOGAS SLURRY AS A SOURCE OF NUTRIENTS FOR CULTIVATION OF RICE AND MUSTARD CROPS USING ORGANIC FARMING PRACTICES.**
Inoculation of seedling roots with enriched slurry

The slurry is placed over a plastic sheet (Pictures 1 and 2) with its four sides raised and the *Azospirillum* biofertilizer is mixed uniformly with the slurry. The roots of the 25-day old rice seedlings are dipped into the enriched slurry to form a uniform coating surrounding the roots. After coating the roots, seedlings are brought out of the slurry and kept overnight so that roots are inoculated with *Azospirillum*. New batches of seedlings can be treated with the same enriched slurry till it is exhausted. The rice seedlings with inoculated roots are transplanted in the field during morning hours. The leftover slurry after root treatment is applied uniformly in the field.

Enrichment of BSS with P

For enrichment of the slurry with P, rock phosphate and PSB are mixed thoroughly with the slurry (Pictures 3a and 3b) at least 10 days prior to application and turning is done intermittently. Enriched slurry is applied to the field and mixed uniformly with the soil on the day of final preparation of land. The quantity of slurry, rock phosphate, and PSB required for enrichment are presented in Table 2.

**Package for mustard**

The amount of slurry required to supply 50 per cent RD of N to mustard crop is worked out based on nutrient and moisture content. The slurry is enriched with rock phosphate and PSB following the same procedure as described for rice. The enriched slurry is applied into the field and mixed thoroughly with soil seven days prior to the sowing of seeds. Prior to the sowing, seeds are coated with *Azotobacter* biofertilizer which is a very efficient free living N fixing microorganism and is found promising under Assam conditions. Initially, seeds are coated with a sugar solution that acts as a sticker and then the biofertilizer is mixed uniformly with the seeds (Pictures 4a and 4b). The seeds inoculated with *Azotobacter* are sown in the field following recommended methods.

The usefulness of these packages were demonstrated in the farmers’ fields (Pictures 5 and 6) of two villages, viz., Katonipar and Nahotia, Jorhat, Assam where five solid state biogas plants were installed under All India Coordinated Research Project on Renewable Sources of Energy (AICRP on RES) for their popularization. The details of the crop, variety, yield, and location of the demonstration sites are shown in Table 3. The crops are grown under rainfed conditions. There was no incidence of diseases and pests in rice and mustard crops. However, Nahotia village being endemic area for mustard saw fly, prophylactic measure was taken using liquid formulation of *Beauveria bassiana* (Brand name: Helcon-L). It was applied at the rate of 1 litre per 200 litres of water, at an interval of 15 days. The biofertilizers used for enrichment of BSS was obtained from the Biofertilizer Production Unit, Department of Soil Science, Assam Agricultural University, Jorhat, Assam.
Enriched Biogas Slurry: A Potential Source of Nutrients for Organic Farming

Table 3: Details of crop variety, yield, and location of the demonstration site

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Demonstration site</th>
<th>Soil type</th>
<th>Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Control plot</td>
</tr>
<tr>
<td>Rice</td>
<td>Keteki Joha (scented variety)</td>
<td>Katonipar village, Jorhat</td>
<td>Alluvial with clay loam texture</td>
<td>29**</td>
</tr>
<tr>
<td>Mustard</td>
<td>TS-36</td>
<td>Nahotia, Jorhat</td>
<td>Alluvial with sandy loam texture</td>
<td>11.9</td>
</tr>
</tbody>
</table>

* with recommended dose of inorganic fertilizer; ** var. Keteki Joha is inherently having low yield potential

To create awareness and popularize the nutrient package among the farmers, a field day was organized at Nahotia, Dhekorgorah Block, Jorhat, Assam which witnessed the participation of 50 farmers from nearby villages (Pictures 7, 8 and 9). The biogas plant owners of the locality were convinced through technology demonstration and showed interest to take up organic cultivation of crops using biogas plant slurry as a source of nutrients.

Conclusion

Organic farming has emerged as a major thrust area in the northeastern region of the country. This region is mostly organic by default, however, conscious organic farming has suddenly picked up across the state of Assam and other parts of the North-east. In order to make organic farming a success, availability of organic sources of nutrients is a matter of concern. Among the organic sources of nutrients, biogas plant spent slurry can be a potential source of nutrients for organic agriculture since it contains appreciable quantities of both macro- as well as micro-nutrients and organic matter as compared to other organic sources of nutrients such as FYM, compost, etc. Moreover, it can suitably be combined with other organic sources of nutrients such as biofertilizers and organic manures. More than 85,000 numbers of family type biogas plants have so far been installed in Assam and there is large scope to popularize biogas technology in the region since availability of animal dung as a source of feedstock of biogas plant is abundantly available (~15 million tonnes). Therefore, there is ample opportunity for the biogas plant owners to offer a large share of the nutrient requirement for successful organic agriculture in the region.

Acknowledgement: The fund received from National Project on Organic Farming, GoI, to carry out the demonstration is duly acknowledged.

* * *

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To completely utilize the abundant solar energy in India, there was a need to enhance the output of solar drying system by extending the drying operation beyond solar hours. Therefore, Sardar Patel Renewable Energy Research Institute (SPRERI) has designed the solar–biomass hybrid drying system. Dr M Shyam, J P Makwana, and Samir Vahora discuss the benefits of this unique drying system, while dwelling on the technical aspects.

India is blessed with abundant solar energy. Solar drying systems are now being used for agro-industrial applications. SPRERI forced-flow cabinet-type solar dryer has been in regular operation in an industry named M/s Jayveer Food Industry located at Chanashma in district Patan, Gujarat, since 2010. The solar drying system comprises flat plate solar collectors connecting air ducts and a blower for supply of hot air to three drying cabinets. A batch of fresh produce (approximate Moisture Content is 90 per cent) loaded into the dryer in the morning got dried only partially by the end of the first solar
day, and the drying operation, in general, continued for the second day to achieve the desired result from the product. The quality of the product, which was left overnight in drying cabinet under ambient conditions, was affected due to microbial growth. Besides, moisture condensation also takes place in the drying cabinet. The industry was also interested in enhancing the output by extending the drying operation beyond solar hours. A SPRERI biomass combustor-cum-air heater was successfully retrofitted with the solar drying system for completing batch drying operation by the same day. The solar–biomass drying system is in operation in the industry for more than a year now.

Solar Drying System

The system comprises 49 flat plate solar collecting modules, each of 2 m² area with air ducting and a blower for supply of hot air to the drying cabinets (Figure 1). The solar modules, which are placed on the roof, have been installed at an angle of 12° with the horizontal to maximize the solar energy absorption. Flat plate solar collecting modules have been arranged in seven rows with four rows on left side and three rows on right side of the common duct. A blower of 3,000 m³/h air flow capacity equipped with 3.7-kW electric motor has been placed between the solar modules and the drying cabinets. The ambient air is drawn through the solar modules, gets heated up, passes through an insulated common duct of 300 mm × 300 mm section and is pushed by the blower into three drying cabinets. The drying cabinets have been installed inside the building. Each drying cabinet has 34 trays, arranged in two columns for loading the product. The warm humid air discharged from the cabinets may be partially re-circulated, if it has adequate moisture holding capacity.

Biomass Combustor-cum-Air Heater

SPRERI natural convection-type biomass combustor-cum-air heater has fuelwood burning capacity of 10–16 kg/h. It does not emit fly ash/smoke and has provision of control of the air temperature and flow rate. The combustion chamber is thermally insulated from inside; the flue gases pass through stainless steel pipes while the air flows through the shell. It has provisions for regulating the fuel feeding and air flow rates and ash removal. Thermal efficiency of the combustor had been reported to be 73 per cent for air flow rate of 1,110 m³/h and hot air temperature of 89°C. The thermal efficiency will be higher for higher air flow rates and lower hot air temperatures used for drying of the farm produce.

THE THERMAL EFFICIENCY OF THE COMBUSTOR-CUM-AIR HEATER WAS FOUND TO BE ABOUT 78 PER CENT FOR THE AIR FLOW RATE OF 2,600 M³/H AND HOT AIR TEMPERATURE OF 54–58°C. THE SYSTEM IS BEING USED IN THE INDUSTRY FOR DRYING GREEN CHILLIES, SPINACH, CORIANDER LEAVES, ETC.
Retrofitting of Biomass Combustor

The combustor-cum-hot air generator was retrofitted between the blower and the drying cabinets (Figure 1 and Picture 1). The air flow rate through the combustor was, however, found significantly reduced primarily because of very high pressure drop. The industry did not agree for replacement of the blower to match the increased pressure drop conditions. The problem was, however, overcome to a large extent by the use of larger diameter pipe and fittings for retrofitting the combustor-cum-hot air generator and the air flow rates for solar alone and combustor alone modes of operations were found to be 2,800 and 2,600 m$^3$/h, respectively. The drying system was operated in the following three modes for air heating and the drying operation:

- Heating the air by solar energy alone when adequate sunshine is available (solar alone).
- Heating the air by biomass energy alone during sunshine hours (solar–biomass).
- Hybrid mode, i.e., solar alone/biomass alone/solar plus biomass mode of operation depending upon the solar radiation to heat the air to the desired temperature.

Operation and Performance

Initially, the dryer was operated under no load condition and air temperatures at different locations inside the drying cabinets, air flow rate, blower speed, and solar radiation were measured for solar alone, solar–biomass, and hybrid modes of operation. The temperature of the hot air before the drying cabinet was found in the range of 55–65°C in solar alone mode during summer months and in biomass alone mode of operation. However, during rainy and winter seasons, hybrid mode of operation, i.e., solar heating of the air followed by biomass heating was practiced to achieve the desired hot air temperature of 55–65°C. The thermal efficiency of the combustor-cum-air heater was found to be about 78 per cent for the air flow rate of 2,600 m$^3$/h and hot air temperature of 54–58°C. The system is being used in the industry for drying green chillies, spinach, coriander leaves, etc.

Data was collected for drying fresh green chillies and spinach leaves in solar alone, solar–biomass, and hybrid modes of operations. On an average, 102 kg of green spinach leaves were dried from an initial moisture content of 78 per cent to a final moisture content of 93.4 per cent and 106 kg of green chillies were dried from initial moisture content of 93.4 per cent to an average final moisture content of 5 per cent. The produce was spread in a thin layer on the 34 drying trays that were stacked in two columns in each of the three drying cabinets (Picture 2). The solar-heated air entered from one side of each of the three drying cabinets, passed over the trays and left the cabinets from the opposite side. The batch got dried in two days in solar alone mode of operation. The moisture condensation in the drying cabinet after midnight hours affected the product quality. This problem was not encountered in solar–biomass and hybrid modes of operation because the batch drying was completed by the same day. Average fuel consumption in combustor alone and hybrid modes of operations were 8–10 kg/h and 3–5 kg/h, respectively. The drying time, average air temperatures, and operational cost for the three different modes of operation are summarized in Table 1.

The drying time in hours for solar–biomass and hybrid modes of operation were lower by 13–17 per cent and 25–27 per cent than the solar alone mode. The batch loaded in the morning got dried by the same late evening in solar-combustor and hybrid modes of operation as against two days in solar alone mode. Samples of the fresh and dried products of spinach and coriander leaves and green chillies are shown in Pictures 3 to 5. Dried green chillies were ground and the powder was supplied to upper end restaurants/exported (Picture 6).
Cost Economics

Major items of recurring costs for drying one batch each of 106-kg green chillies and 102 kg green spinach leaves in solar alone, solar–biomass, and hybrid modes of operation are also given in Table 1. Cost of the fuelwood and the electricity used were taken as ₹ 5/kg and ₹ 8/unit, respectively. Four unskilled workers (wages at the rate of ₹ 200/day) were engaged for pre-treatment of the produce and carrying out the drying operation. Operating cost of the biomass combustor per hour for drying green spinach leaves and green chillies have been worked out to be ₹ 150/hour and ₹ 137/hour, respectively. The cost computations clearly reveal that solar–biomass and hybrid modes of drying saved ₹ 270–₹ 665 per batch compared to solar alone mode of operation, primarily because of major reduction in cost of the manpower. The batch drying operation was completed in one day in solar–biomass and hybrid modes as against two days in solar alone mode.

Conclusion

The industry is regularly using the dryer in solar–biomass or hybrid modes of operation for drying products such as fresh fenugreek, spinach, coriander and mint leaves, green chillies, fresh tomatoes, etc. Besides lower cost of operation, the output capacity of the industry increased by approximately 100 per cent. The product quality is also superior.

Dr M Shyam, Mr J P Makwana, and Mr Samir Vahora Sardar Patel Renewable Energy Research Institute (SPRERI), Gujarat, India. Email: director@spreri.org
The eleventh President of India, Bharat Ratna Dr A P J Abdul Kalam (1931–2015) spoke eloquently about India’s aspiration to become a developed nation by 2020. He presided over the ‘Technology Vision 2020’ exercise for India at the Technology Information Forecasting and Assessment Council (TIFAC), an autonomous organization under Ministry of Science and Technology, Government of India. TIFAC’s ‘Technology Vision 2020’ had an objective of ‘Transforming the nation into a developed country, wherein five areas in combination have been identified, based on India’s core competence, natural resources and talented manpower for integrated action to double the growth rate of Gross Domestic Product (GDP) and realize the Vision of Developed India’. Amongst these five areas, ‘Infrastructure with reliable and quality electric power including solar farming for all parts of the country, providing urban amenities in rural areas and interlinking of rivers’, in particular, takes deep interest in strengthening renewable energy sources.


In all of his books, Dr Kalam advocated renewable energy sources for achieving energy security in the country, expanding electrification at the grassroots level, and reducing overdependence on fossil fuels. In his book, *Governance for Growth in India* (2014), Dr Kalam envisaged a ‘New India’ emphasizing on sustainable energy sources and said that, “Power generation through renewable energy has to be increased from 5 per cent to 28 per cent. Dependence on fossil fuels as a primary energy source needs to be brought to 50 per cent from the present 75 per cent.”

In his book, *The Scientific Indian: A Twenty-First Century Guide to the World Around Us* (2010), Dr Kalam described various potential renewable energy sources available in India, including solar power, wind power, biofuels, municipal waste, geothermal power, ocean tidal power, small and mini hydel power, nuclear and hydrogen power. He also prescribed an action plan for power system loss reduction. The action plan when implemented will help in improving energy efficiency, transmitting and distributing the power with minimum loss, and close monitoring of the losses.

He further suggested the need for an ‘Energy Independence Vision’ by 2030. He summarily narrated his ideas, “A major objective of India’s Energy Independence Vision 2030 would be to bring down our dependence on non-renewable sources of energy and increase the use of renewable ones. Apart from the extensive use of solar power, this mission would involve the expansion of wind energy farms. Micro-hydroelectric power units should be set up along streams and small rivers. There should be a thrust on using municipal waste to generate electricity. All thermal power stations
Dr APJ Abdul Kalam’s Vision for Renewable Energy in India

should substitute 20 per cent of their annual electricity output with electricity from renewable energy systems. Lastly, all steel plants and heavy industries should be mandated to use their waste heat to generate electricity to meet their own needs. We need to embark on launching a national solar energy policy, which promotes solar energy systems and products manufacturing in the country, and exclusive R&D for nano science and technology for solar energy systems."

He further laid emphasis on power from municipal waste, for electricity generation as well as for effective solid waste management in cities and towns. He also indicated his concerns about biomass presently wasted in rural areas. He envisaged that, “Once these technologies are perfected, much of the agricultural produce and biomass currently wasted in villages could also go to electricity-generating plants. What a boon this would be for rural India, since the agricultural waste would feed the grids and produce power for local consumption. As of now, much of the agricultural waste is just burnt as its disposal is costly.” As a satellite and rocket engineer, Dr Kalam had thorough knowledge about the use of solar energy in space satellites as the major source of energy. Later, he emphasized on harvesting solar energy from space. Dr Kalam and Mark Hopkins of the National Space Society (NSS) in the USA agreed to start an international space solar power feasibility study, in 2013, under the framework of Kalam–NSS Space-based Solar Power Initiative beginning in 2013. Dr Kalam described the concept of Space Solar Power in his book, A Manifesto for Change: A Sequel to India 2020 (2014) wherein he stated that, "At a time when the world is witnessing a rapid depletion of fossil fuels, it is essential to explore the possibility of harvesting solar energy from space.

I definitely foresee the emergence of technological coherence soon in the space solar power mission, which will benefit the nation and the world in a big way.” In a speech at NSS’s International Space Development Conference in 2013 (ISDC 2013) at San Diego, California, he described the rationale for harvesting solar energy from space, “Civilization on earth will run out of fossil fuels in this century. Oil reserves are on the verge of depletion, followed by gas and finally coal. However, solar energy is clean and inexhaustible. What better vision can there be for the future of space exploration, than participating in a global mission for perennial supply of renewable energy from space?”

Dr Kalam’s ideas and vision have been and will continue to be the guiding force towards achieving the targeted growth in renewable energy sector in India. His Technology Vision for 2020 has also been instrumental in initiating an array of renewable energy initiatives and missions across the country for a better energy future.
With a large young and school-going population, India needs to provide its young citizens adequate means towards education. In this regard, Right to Education in itself will not be able to achieve its target if basic need—clean light source—is unavailable. In this case study, Prof. Chetan S Solanki, Prof. N C Narayanan, and Prof. Jayendran Venkateswaran discuss the ‘Million Solar Urja Lamp Programme’ initiative that intends to facilitate children’s education.

With 356 million, 10–24 year olds, India has the largest young population in the world, according to a report issued by the United Nations. Education is thus essential for the future of the country. However, according to the Census of India, 2011, 7.8 crore families in the country use kerosene as a primary source of lighting. Figure 1 shows that kerosene is used by more than 30 per cent households in several large states of India. Many school-going students who study during evening hours are affected by either lack of access to alternate source of lighting or by erratic electricity supply. Alongside Right to Education, therefore, it is desirable to provide the ‘Right to Light’ as well.

**The Solar Lamp**

The light level required for study purposes is about 150 Lux at the reading area (Rajendra Prasad Eye Institute, New Delhi). Thus, to provide light for four hours every evening requires only 0.7 kWh of electricity per year. Note that 1 unit is equal to 1 kWh. Now, a 0.5 Watt LED provides up to 250 Lux of light. A solar power lamp with LED light can provide 150 Lux of light at the table in low intensity and up to 250 Lux of light in

![Figure 1: Percentage of households with kerosene as main source of light: State-wise distribution (Source: Census 2011)](image-url)
high intensity mode using a 1 W solar panel, at a cost of ₹400–₹600 per lamp. The Ni-MH batteries can be used for 700 cycles.

Solar Lamp Programme

A sustainable adoption of solar energy products has not yet happened in India, due to clear mismatch between the requirements and the scope of past solar lamp programmes. Solar lamps that are of low cost are typically required in remote, rural areas; they should be locally available along with access to timely and low-cost after-sales service. However, at present the lamps are produced in large urban cities, which results in high cost of lamp (due to higher overheads), minimal availability at local level (due to lack of distribution channels), and after-sales service is time consuming and expensive due to distance the end user has to cover to reach out the repair shop. Hence, to directly and completely address this problem, any solar lamp programme must involve local people in all aspects of assembly, distribution, and after-sales service. This will ensure that the lamps are of low cost, sufficiently available in local market and thereby, promoting market penetration of solar products into remote areas. This kind of mechanism will also ensure timely and low-cost after-sales service as locally available trained manpower will be repairing the lamps.

Further, a countrywide large-scale solar lamp programme must address, simultaneously, the issues of Scale, Speed, and Skill. IIT Bombay has developed one such model, the Million Solar Urja Lamp (SoUL) Programme that focusses on the localization of solar energy. In this model, the assembly, distribution, and maintenance of the solar lamps are done by the locals. In order to achieve scale, the model is designed such that it can be replicated in parallel in multiple blocks, across districts and states. To achieve speed, the assembly and distribution for any block is designed to be completed in 90 days. In order to target skill development, rural residents are trained in the assembling, distribution, and repair of these lamps in their local areas.

The Million SoUL Programme (MSP)

Objectives and concepts

The objective of the Million SoUL programme is to provide high-quality and affordable clear light for study purposes to a million students in the fastest possible way. The specific goals are:

- Provide one SoUL to every student to increase their study hours
- Involve local people in lamp assembly, distribution, and repairs
- Generate sustainable employment in rural areas
- Generate local capabilities for sale, repair, and maintenance of several solar products
- To design a model that can be replicated in a larger domain.

The target is 1,000,000 school students of classes 5 to 12 in rural areas. In order to achieve the objectives, the Million SoUL Programme has been structured based on the following concepts:

- Right to Light: Every student residing in rural areas has the opportunity to get a SoUL, thus reducing the dependency on kerosene and help build a better future.
- Localization Model: The assembly of lamps, their distribution, repair, and maintenance are carried out by the local people who are trained by IIT Bombay; thus ensuring low costs, better availability, and better after sales services.
- Saturation Model: In order to make a visible impact, every school student in a particular region (a block in a district) gets an opportunity to own the lamp. On an average, a block has 17,600 school children studying in 5th to 12th standard.

The endeavour of this project is to reach out to at least 75 per cent of these children in each block; in a way saturating the block with solar lamps. This allows for better logistics management, lower costs, and sustainable job creation.

Doability Model: In the initial phase, the project targets blocks with less geographical or social constraints. This is essential to demonstrate the large-scale implementation in quick time.

Overview of the Programme

The MSP has drawn on IIT Bombay’s technical expertise in solar lamp technology, operations management, concurrent evaluation, and impact analysis. IIT Bombay is the central coordinating agency for this programme and has partnered with several Non-Government Organizations (NGOs) to help execute the project at diverse regions of the country. These NGOs or institutional partners are chosen based on several criteria including their field presence, organization size and reach, prior work in solar-related areas, etc. An assembly-cum-distribution centre is established at the premises of the partner NGO. Each centre typically serves one to three blocks. The locals are hired from various village clusters of the selected block and are trained (by IIT Bombay) to test and assemble quality lamps, to campaign and then distribute the lamps to the target beneficiaries (school students). The NGOs are also mentored by IIT Bombay on various management aspects. The components for assembling the lamps are sourced from four vendors and supplied directly to the assembly centres. At the centres, the components are assembled into SoULs. The quality of the lamp is ensured through rigorous testing, both before and after assembly. The SoULS are then sold at subsidized price of ₹120 to students.
through their schools, with the aim to saturate each block by selling one lamp per school child. This act of purchasing of the lamp by students is essential in order to build/create a sense of ownership and better usage. This further leads to self-reliance and sustainable development. Basic information about every beneficiary is recorded. Further, SoUL Repair/Resource Centres (SRCs) are set up in each block to ensure long-term use of the lamps and sustainability of this initiative. This service facility is provided for free to students for one year (until December 2015) and is located such that there is atleast one repair centre at less than 10 km radius from any village.

The funding and expenditure for the project is illustrated in Figure 2.

**Current status of MSP**

The MSP is currently operational in selected blocks and districts in the four states of Madhya Pradesh, Maharashtra, Rajasthan, and Odisha, as shown in the map (Figure 3). The green dots in the maps indicate the assembly-cum-distribution centres, and the dark blue areas indicate the blocks currently covered. As of...
April 2015, the total Solar Urja lamps distributed is 735,281. The overall summary of activities is shown in Table 1.

Table 1: Summary of the activities of the MSP

<table>
<thead>
<tr>
<th>Lamps distributed</th>
<th>735,281 (as of April 30, 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local manpower trained and employed</td>
<td>780</td>
</tr>
<tr>
<td>Number of SoUL Repair Centres set-up</td>
<td>260</td>
</tr>
<tr>
<td>Presence in villages (approx. number)</td>
<td>8,449</td>
</tr>
<tr>
<td>Number of blocks covered</td>
<td>71</td>
</tr>
<tr>
<td>Number of saturated blocks</td>
<td>35</td>
</tr>
<tr>
<td>Number of assembly-cum-distribution centres</td>
<td>36</td>
</tr>
<tr>
<td>Number of districts with SoUL presence</td>
<td>22</td>
</tr>
<tr>
<td>NGO partners</td>
<td>13</td>
</tr>
<tr>
<td>Number of suppliers for SoUL kits</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: State-wise summary of the activities of the MSP

<table>
<thead>
<tr>
<th>State</th>
<th>Madhya Pradesh</th>
<th>Rajasthan</th>
<th>Maharashtra</th>
<th>Odisha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamps distributed</td>
<td>383,412</td>
<td>180,082</td>
<td>115,236</td>
<td>56,551</td>
</tr>
<tr>
<td>Manpower trained</td>
<td>427</td>
<td>196</td>
<td>76</td>
<td>81</td>
</tr>
<tr>
<td>Number of SRC set up</td>
<td>137</td>
<td>64</td>
<td>38</td>
<td>21</td>
</tr>
<tr>
<td>Number of villages (approx.)</td>
<td>3,730</td>
<td>2,726</td>
<td>1,054</td>
<td>939</td>
</tr>
<tr>
<td>Number of blocks</td>
<td>31</td>
<td>14</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Number of saturated blocks</td>
<td>23</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Number of districts</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Assembly centres</td>
<td>19</td>
<td>9</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>NGO partners</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The state-wise summary of activities is shown in Table 2.

The progress of the distribution of lamps is illustrated in Figure 4. The first lamp was distributed on February 13, 2014. The initial phase of the project, from February to June 2014, saw the set up and streamlining of the operations. The next six months, July 2014 to December 2014, was the active period (which also coincided with the school working calendar), during which a total of about 6 lakh lamps were distributed.

Concurrent Evaluation and Preliminary Findings

The objectives of concurrent evaluation are as follows:
- Evaluate performance of the SoUL
- Assess the socio-economic impact of MSP on beneficiaries (at individual level, at household level, and at community level)
- Evaluate market potential created by the programme for solar photovoltaic products/technology in rural India
- Assess the implementation model of MSP for scalability and replicability.

The multidimensional objectives of the concurrent evaluation are achieved through mixed method approaches of ‘qualitative’ and ‘quantitative’ methods of data collection. The qualitative research method primarily uses methods such as focus group discussions, key informant interviews, and observation. The quantitative research employs household survey methodology. A total of 21 of 71 blocks have been chosen, by using ‘stratified random sampling’ method, where concurrent evaluation is then carried out. The treatment sample is taken as 1.5 per cent of the total student beneficiaries. Also, additional 10...
per cent of the treatment sample is considered as the control sample, i.e., the households with students of classes 5 to 12 who did not purchase the lamp. Data for the evaluation is collected in two rounds. The first round of data collection was conducted in November 2014 to April 2015 and the second round, in which the same households will be surveyed again, is planned from June 2015 to November 2015.

**Preliminary findings**

Detailed analysis of the data is under progress. However, the preliminary findings so far, based on four blocks in Madhya Pradesh, are summarized below. The treatment sample households were 2,526, and the control sample households were 333.

*The socio-economic background:* A total of 96 per cent of the surveyed households follow Hindu religion. All four blocks have predominantly tribal population, with 59 per cent of the sampled households belonging to scheduled tribes, 29 per cent other backward classes, and 7.78 per cent scheduled castes. Around 52 per cent of all surveyed households are BPL cardholders, while 35 per cent are APL cardholders. There are 26 per cent non-electrified households in the sample. The primary occupation of 88 per cent of the surveyed households is agriculture or labour.

**Lighting devices used for study at night**

- In the treatment households, there are 5,068 children; of these 5,050 are enrolled in schools, and amongst these, 95 per cent reported to study at night.
- Of the students who study at night (in the treatment sample), 21 per cent used ‘Only SoUL’. Of the ‘Only SoUL’ users, 65 per cent children belonged to non-electrified households.
- Of the total school-going children, 82.02 per cent studied with SoUL or SoUL as well as other devices, such as 47.38 per cent children who used SoUL and electricity.
- The erratic power supply was the main reason stated for using SoUL in electrified households.
- In the treatment sample, replacement of kerosene-based lighting device with SoUL was noted and higher SoUL usage in non-electrified households was also evident. In the control sample, 25 per cent children used ‘only kerosene based device’ for study purpose, as against 5 per cent in the treatment sample.

**Kerosene: Purchase and usage**

The average per month kerosene purchase is about 3.8 litres.

- A total of 12.48 per cent households in treatment and 9.31 per cent households in control sample reported that they do not purchase kerosene at all. For both the sample households, the main source of kerosene purchase is Public Distribution System (PDS), with just 5.74 per cent households in treatment and 8.11 per cent households in control purchasing kerosene from the market as well.
- The average per month expenditure on kerosene purchased from PDS was approximately ₹ 65, in both the samples.
- Kerosene is primarily used for lighting purpose (98 per cent households in treatment and 99 per cent in control); and negligible quantity is used for cooking as kerosene is used mainly for igniting the fire.
- It is found that SoUL has replaced the use of kerosene-based device for study purposes. However, kerosene continues to be used for lighting in other rooms (in multiple room houses) or as a backup against erratic electricity supply.

**Expenditure on lighting:** The monthly expense on lighting is computed by considering the total amount spent per month on electrical devices, electricity bill, and kerosene purchase. The monthly expense for lighting is found to be lower by a significant amount of ₹ 70–₹ 75 for treatment sample (households with SoULs) than the control sample (households without SoUL).

**Need for solar PV Products:** A total of 48.02 per cent households from the treatment sample and 51.96 per cent households from the control sample expressed the need for solar-based lighting solutions. Additionally, 12.15 per cent in treatment and 8 per cent in control sample expressed the need for solar cookers.

**Preference for source of lighting:** About 70 per cent of the treatment households preferred solar products as their first source of lighting, followed by electricity.

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Prof. Chetan S Solanki, Associate Professor, Department Energy Science and Engineering, IIT Bombay; Prof. N C Narayanan, Professor, Center for Technological Alternatives for Rural Areas, IIT Bombay; and Prof. Jayendran Venkateswaran, Associate Professor, Industrial Engineering and Operations Research, IIT Bombay. Email: chetanss@iitb.ac.in
On the event of completion of one year, the First Foundation Day ceremony of the Association of Renewable Energy Agencies (AREAS) was held at KEB Engineers Association Auditorium on August 27, 2015 in Bengaluru. The three-day event was hosted by Karnataka Renewable Energy Development Limited (KREDL). On this occasion, best performing SNAs/States/Organizations were given awards for excellent work in the field of renewable energy in different categories. Total 110 awards were announced for 40 award categories including grid connected renewable capacity addition, off-grid applications, innovation, R&D, financing renewable, promotion of renewable by municipal bodies and PSUs. Shri Piyush Goyal, Hon’ble Union Minister of State (I/C) for Power, Coal and New and Renewable Energy presented the awards. Amongst the states, Maharashtra got the highest number of awards (15), followed by Rajasthan (11), Gujarat (9), Tamil Nadu (9), and Karnataka (7).

In his inaugural speech, Shri Piyush Goyal highlighted the importance of renewable energy for environment safety and energy security. Mentioning the ambitious targets set for renewable energy by the Government of India, he stated that AREAS has a very colossal task ahead to contribute in achieving these targets with spirit of collaboration and shared responsibilities and efforts. He also mentioned that support and cooperation of regulatory bodies is important for promotion of renewable energy. He also emphasized that cost can be brought down by the economies of scale.

Shri D K Shivakumar, Hon’ble Energy Minister, Karnataka; Shri M K Shankaralinge Gowda, Chairman, KERC; and Shri Upendra Tripathy, Secretary, MNRE also addressed the gathering. On this occasion, AREAS also organized a one-day workshop wherein issues of policies, energy storage, hybrid technologies, and future roadmap of AREAS were discussed.

During the valedictory session of the workshop, Secretary, MNRE released the AREAS Directory 2015 that contains the contact details of power sector and renewable energy organizations of the central as well as state level. The detailed list of all the award winners is presented in the table given below.

<table>
<thead>
<tr>
<th>SL No.</th>
<th>Award Category</th>
<th>State Nodal Agencies(SNAs) / States / Organizations</th>
</tr>
</thead>
</table>
| 1     | Awards to top three States/SNAs for achieving highest cumulative grid connected renewable power capacity (including all technologies) in the country by the end of March 31, 2015. | 1st Award – Tamil Nadu/TEDA  
2nd Award – Maharashtra/MEDA  
3rd Award – Gujarat/GEDA |
| 2     | Awards to top three States/SNAs for achieving highest cumulative grid connected Solar power capacity in the country by the end of March 31, 2015. | 1st Award – Gujarat/GEDA  
2nd Award – Rajasthan/RREC  
3rd Award – Madhya Pradesh/MPUVN |
| 3     | Awards to top three States/SNAs for achieving highest cumulative grid connected Solar rooftop power capacity in the country by the end of March 31, 2015. | 1st Award – Gujarat/GEDA  
2nd Award – Punjab/PEDA  
3rd Award – Telangana/TeNREDCC |
| 4     | Awards to top three States/SNAs for achieving highest cumulative grid connected Wind power capacity in the country by the end of March 31, 2015. | 1st Award – Tamil Nadu/TENGEDCO  
2nd Award – Maharashtra/MEDA  
3rd Award – Gujarat /GEDA |
5 Awards to top three States/SNAs for achieving highest cumulative grid connected Biomass power capacity in the country by the end of March 31, 2015.  
1st Award – Maharashtra/MEDA  
2nd Award – Uttar Pradesh/UPNEDA  
3rd Award – Karnataka/KREDL

6 Awards to top three States/SNAs for achieving highest cumulative grid connected small Hydropower capacity in the country by the end of March 31, 2015.  
1st Award – Karnataka/KREDL  
2nd Award – Himachal Pradesh/HIMURJA  
3rd Award – Maharashtra/MEDA

7 Award to top three States/SNAs from North-East for achieving highest cumulative grid connected renewable power capacity (including all technologies) amongst NE states by the end of March 31, 2015.  
1st Award – Arunachal Pradesh/APEDA  
2nd Award – Sikkim/SREDA  
3rd Award – Mizoram/zedA

8 Award to top three UTs/SNAs for achieving highest cumulative grid connected renewable power capacity (including all technologies) amongst UTs by the end of March 31, 2015.  
1st Award – Andaman & Nicobar/energy Department, Andaman & Nicobar  
2nd Award – Chandigarh/CREST  
3rd Award – Lakshadweep/ledA

<table>
<thead>
<tr>
<th>Grid Connected Renewable Power—Capacity Addition during 2014–15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Awards to top three States/SNAs for achieving highest capacity addition in grid connected renewable power (including all technologies) in the country during the financial year 2014–15</strong></td>
</tr>
</tbody>
</table>
| 1st Award – Rajasthan/RREC  
2nd Award – Madhya Pradesh/MPUVN  
3rd Award – Maharashtra/MEDA |

| **Awards to top three States/SNAs for achieving highest capacity addition in grid connected Solar power in the country during the financial year 2014–15** |
| 1st Award – Rajasthan/RREC  
2nd Award – Madhya Pradesh/MPUVN  
3rd Award – Punjab/PEDA |

| **Awards to top three States/SNAs for achieving highest capacity addition in grid connected Solar rooftop power in the country during the financial year 2014–15** |
| 1st Award – Rajasthan/RREC  
2nd Award – Madhya Pradesh/MPUVN  
3rd Award – Maharashtra/MEDA |

| **Awards to top three States/SNAs for achieving highest capacity addition in grid connected Wind power in the country during the financial year 2014–15** |
| 1st Award – Rajasthan/RREC  
2nd Award – Madhya Pradesh/MPUVN  
3rd Award – Maharashtra/MEDA |

| **Awards to top three States/SNAs for achieving highest capacity addition in grid connected Biomass power in the country during the financial year 2014–15** |
| 1st Award – Uttar Pradesh/UPNEDA  
2nd Award – Maharashtra/MEDA  
3rd Award – Tamil Nadu/TEDA |

| **Awards to top three States/SNAs for achieving highest capacity addition in grid connected Small hydro power in the country during the financial year 2014–15** |
| 1st Award – Karnataka/KREDL  
2nd Award – Himachal Pradesh/HIMURJA  
3rd Award – Uttarakhand/URED |

<table>
<thead>
<tr>
<th>Off-Grid Renewable Applications—Cumulative up to March 31, 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Awards to top three States/SNAs for deployment of highest cumulative numbers of Solar Home Lighting Systems in the country by the end of March 31, 2015.</strong></td>
</tr>
</tbody>
</table>
| 1st Award – Uttar Pradesh/UPNEDA  
2nd Award – Rajasthan/RREC  
3rd Award – Tamil Nadu/TEDA |

| **Awards to top three States/SNAs for deployment of highest cumulative numbers of Solar Street Lighting Systems in the country by the end of March 31, 2015.** |
| 1st Award – Uttar Pradesh/UPNEDA  
2nd Award – Tamil Nadu/TEDA  
3rd Award – Maharashtra/MEDA |

| **Awards to top three States/SNAs for deployment of highest cumulative numbers of Solar Lanterns in the country by the end of March 31, 2015.** |
| 1st Award – Jharkhand/JREDA  
2nd Award – Maharashtra/MEDA  
3rd Award – Uttarakhand/URED |

| **Awards to top three States/SNAs for deployment of highest cumulative numbers of Solar Water pumps in the country by the end of March 31, 2015.** |
| 1st Award – Rajasthan/RREC  
2nd Award – Punjab/PEDA  
3rd Award – Uttar Pradesh/UPNEDA |

| **Awards to top three States/SNAs for deployment of highest cumulative kWp of off-grid Solar Power Plants in the country by the end of March 31, 2015.** |
| 1st Award – Chhattisgarh/CREDA  
2nd Award – Gujarat/GEDA  
3rd Award – Rajasthan/RREC |

| **Awards to top three States/SNAs for deployment of highest cumulative kW of Aero Generators in the country by the end of March 31, 2015.** |
| 1st Award – Maharashtra/MEDA  
2nd Award – Goa/GEDA Goa  
3rd Award – Meghalaya/MNREDA |

| **Awards to top three States/SNAs for deployment of highest cumulative sq mtr of Solar Water Heaters collector area in the country by the end of March 31, 2015.** |
| 1st Award – Karnataka/KREDL  
2nd Award – Gujarat/GEDA  
3rd Award – Maharashtra/MEDA |

| **Awards to top three States/SNAs for deployment of highest cumulative Concentrated Solar Thermal (CST) applications in the country by the end of March 31, 2015.** |
| 1st Award – Maharashtra/MEDA  
2nd Award – Karnataka/KREDL  
3rd Award – Gujarat/GEDA |

<table>
<thead>
<tr>
<th>Off-Grid Renewable Applications—Deployment during 2014–15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Awards to top three States/SNAs for implementation of National Biogas and Manure Management Programme in the country during 2014–15.</strong></td>
</tr>
</tbody>
</table>
| 1st Award – Andhra Pradesh/NEDCAP  
2nd Award – Maharashtra/ROD & WC Dept., GoM  
3rd Award – Assam/SNO FDA, Social Forestry, Assam |
<table>
<thead>
<tr>
<th>No.</th>
<th>Awards</th>
<th>Details</th>
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</table>
| 24  | Awards to top two States/SNAs for highest capacity addition of Off-grid Biomass Gasifiers for Rural applications in the country during 2014–15. | 1st Award – Bihar/BREDA  
2nd Award – Rajasthan/RREC |
| 25  | Awards to top two States/SNAs for highest capacity addition of Off-grid Biomass non-bagasse based plants in the country during 2014–15. | 1st Award – Haryana/HAREDA  
2nd Award – Tamil Nadu/TEDA |
| 26  | Awards to top two States/SNAs for highest capacity addition of Off-grid Waste to Energy plants in the country during 2014–15. | 1st Award – Andhra Pradesh/NEDCAP  
2nd Award – Punjab/PEDA |
| 27  | Award to top ranking agency for achieving targets of installing Watermill development scheme | Energy Management Centre, Kerala |
| 28  | Awards to top ranking SNA for achieving targets under Unnat Chulha Abhiyan. | JAKEDA, Jammu & Kashmir |
| 29  | Awards to top three State Transmission Utilities for creating highest transmission capacity for renewables as on March 31, 2015. | 1st Award – TANTRANSCO, Tamil Nadu  
2nd Award – RRVPNRL, Rajasthan  
3rd Award – KPTCL, Karnataka |
| 30  | Awards to top three State for achieving highest non-solar RPO compliance during 2014–15. | 1st Award – Himachal Pradesh  
2nd Award – Karnataka  
3rd Award – Tamil Nadu |
| 31  | Awards to top three States for achieving highest solar RPO compliance during 2014–15. | 1st Award – Rajasthan  
2nd Award – Gujarat  
3rd Award – Madhya Pradesh |
| 32  | Awards to top ranking States amongst the NE-States for achieving highest overall RPO targets and Renewable power generation during 2014–15. | Nagaland |
| 33  | Awards to top ranking UT amongst the UTs for achieving highest overall RPO targets and Renewable power generation during 2014–15. | Lakshadweep |
| 34  | Awards to top three green buildings of SNAs for installing renewable power applications. | 1st Award – CREDA, Chhattisgarh  
2nd Award – CREST, Chandigarh  
3rd Award – HAREDA, Haryana |
| 35  | Awards to top two green buildings of SNAs NE- States for installing renewable power applications. | 1st Award – ZEDA, Mizoram  
2nd Award – AEDA, Assam |
| 36  | Awards to top three municipal bodies for installing & promoting renewable energy. | 1st Award – Surat Municipal Corporation, Gujarat  
2nd Award – Pune Municipal Corporation, Maharashtra  
3rd Award – Thane Municipal Corporation, Maharashtra |
| 37  | Awards to top three institutions for R&D in renewable energy. | 1st Award – IIT Bombay  
2nd Award – IISC Bengaluru  
3rd Award – IIT Delhi jointly with Mahindra & Mahindra |
| 38  | Awards to top three financial institutions for highest lending to renewable energy projects in the country during 2014–15. | 1st Award – IREDA  
2nd Award – L&T Infrastructure Finance Co. Ltd.  
3rd Award – Axis Bank |
| 39  | Awards to top three PSUs for installing highest cumulative capacity of grid connected solar rooftop by the end of March 31, 2015. | 1st Award – DMRC  
2nd Award – AAI  
3rd Award – NTPC |
| 40  | Special awards for innovation in renewable energy | Awards to State of Andhra Pradesh (NEDCAP), Assam (AEDA), Kerala (ANERT), Tamil Nadu (TEDA), and Uttar Pradesh (UPNEDA) |

Shri Jeevan Kumar Jethani, Scientist-D, Ministry of New and Renewable Energy (MNRE), Government of India, New Delhi. Email: jethani.jk@nic.in
The National Institute of Solar Energy (NISE) is organizing ‘Suryamitra’ skill development programmes in collaboration with State Nodal Agencies (SNAs), at various locations across the country. The duration of this skill development programme is 600 hours (approximately 90 days). This is a residential programme and it is free which includes boarding and lodging. Suryamitra Skill Development Programmes are sponsored by the Ministry of New and Renewable Energy (MNRE), Government of India. The Indian Government has set an ambitious target towards achieving 100 GW solar power capacity under the Jawaharlal Nehru National Solar Mission (JNNSM) by 2022. It is estimated that to achieve this target and to create employment, MNRE and NISE will have to create at least one million skilled solar workforce, therefore, the MNRE has initiated a ‘Suryamitra’ SPV installer skill development programme. Some of the features of this programme are as follows:

- The NISE has been assigned with the responsibility to execute the Suryamitra programme throughout the country.
- This is a 600 hours/3 months course.
- Suryamitras (the trained personnel), after getting the training, are required to participate in installation and maintenance of 100 GW of solar power plants proposed under the flagship schemes of the MNRE.
- In addition to this, these Suryamitras will propagate solar energy across all sectors.

The main objective of this programme is to train people who have at least passed 10+2, ITI/diploma holders, as field technicians to execute the JNNSM programme across the country and to provide them decent employment.

The NISE has identified a network of institutions through SNAs to conduct training programmes, arranging funds for them, and also monitor them for proper execution. Separately, NISE is also organizing Suryamitra programme in its own campus, so as to set an example.
Two-Days Training Programme on GRID-CONNECTED ROOFTOP SOLAR PV SYSTEMS for State Nodal Agencies, DISCOMs, and State Electricity Regulatory Commissions

The Energy and Resources Institute (TERI) organized a two-day training programme (first in the series) on ‘Grid-connected Rooftop Solar PV Systems for State Nodal Agencies, DISCOMs and State Regulatory Commissions’ on October 6–7, 2015 at TERI University, Vasant Kunj, New Delhi. The training programme was designed in such a way that it enabled the target groups (exclusively for the SNAs, DISCOMs and SERCs) to understand technical, financial, and regulatory aspects, including grid-interconnection, metering arrangements, and remote monitoring mechanism of rooftop solar PV systems. Practitioners and renowned industry experts from TERI, MNRE, SECI, CEA, ISGF, IIT Delhi, TPDDL, DMRC, NPC, SunAlpha, Jakson, CMCC, and SMA presented their views and shared experiences on implementing rooftop PV systems.

Officials (53–55) from various State Nodal Agencies (SNAs)/Solar City Cells under MNRE, Electrical Distribution Companies (DISCOMs), and State Electricity Regulatory Commissions (SERCs) attended this training programme. The event was concluded with a valedictory session and distribution of certificates to the participants, along-with the site visit to 48 kWp Rooftop Solar PV power plant at TERI University and TERI’s Solar Lighting Laboratory (SLLab).

The First National Level Workshop for the application/integration of Concentrating Solar Thermal (CST) technologies to save cost and promote renewable energy in the Dairy sector in India was organized jointly by the Ministry of New and Renewable Energy (MNRE) and the United Nations Industrial Development Organization (UNIDO) on October 12, 2015, at India Habitat Centre, New Delhi. The Workshop was chaired by the Secretary, MNRE Shri Upendra Tripathy and was inaugurated by the Secretary, Department of Animal Husbandry, Dairying and Fisheries (DAHDF), Ministry of Agriculture. National Project Manager, UNIDO, moderated the proceedings.

In her inaugural address, the UNIDO Representative and Director, Regional Office South Asia, mentioned that the workshop is very timely and aptly placed as it targets the dairy sector, which has an impact on almost every individual of the nation. The welcome address by the Secretary, MNRE strongly conveyed the message that renewable energy (RE) technologies in the world have come a long way and are moving fast, although the poor people of the country are still facing the most severe ill effects of the conventional fuels. Reliability of RE technologies is consistently improving with higher efficiency systems and better storage options are now available. With such progress being made, industries should now feel comfortable adopting such technologies. He extended the support of the MNRE, UNIDO, and Public Sector Units (PSUs) to Dairy Representatives to enable them to select the most suited project developers/technology providers for the solar installations in their industrial set-up.

The workshop was a highly interactive one and addressed many queries from the dairy sector in going for the CST technologies. UNIDO and MNRE would be organizing more such interactive-workshops targeting different industrial sectors to strengthen the outreach and enabling each sector to go for an informed transition towards these technologies.
The rural people of our country mainly depend on agriculture as India is an agrarian economy. There exists a huge mass of unemployed youth who face difficulty in making their ends meet. Rural youth can find self-employment opportunities by fabricating low-cost renewable energy technologies and energy efficient devices. It is necessary to encourage the unemployed rural youth to go through the venture as entrepreneurs, especially on a wide source of simple and low-cost renewable energy technologies that have a vast potentiality of income generation. This article describes two of the few simple renewable energy technologies and energy efficient devices. The technology has been developed by Appropriate Rural Technology Institute (ARTI). Other such technologies would be published in the forthcoming issues. It is strongly believed that, if mass production of these devices is taken up, it would create an atmosphere of sustainable development in India.

### Energy from Biomass

Biomass, notably wood and cows or animal dung, is the major source of fuel in most third-world countries. Forest debris, agricultural residue, municipal refuse, food waste, and a host of other unnecessary organic waste and residue constitute biomass that could be an enormous prospective energy source.

#### Compact Digester for Producing Biogas from Food Waste

The compact plants are made from cut-down high-density polythene (HDPE) water tanks. The standard plant uses two tanks, with volumes of typically 0.75 m³ and 1 m³.
The smaller tank is the gas holder and is inverted over the larger one which holds the mixture of decomposing feedstock and water (slurry). An inlet is provided for adding feedstock, and an overflow for removing the digested residue. A pipe takes the biogas to the kitchen, where it is used with a biogas stove. The gas holder gradually rises as gas is produced, and sinks down again as the gas is used for cooking (Figure 1 and Picture 1). Weights can be placed on the top of the gas holder to increase the gas pressure. Cost of fabrication of one unit is approximately ₹15,000.

The feed can be waste flour, vegetable residue, waste food, fruit peels, and rotten fruits. Feedstock with large lumps can be broken up with a food blender. Hand and pedal powered food blenders are being developed, for times when electricity is not available. Oil cake, left over from oil-pressing, is another useful feedstock. The feeding of the plant is built up over a few weeks until it provides a steady supply of gas, typically 250 g of gas per day from 1 kg (dry matter) of feed.

### Gasifier Stove

The downdraft gasifier is operated in batch mode, appropriate for cooking meals. The gasifier is filled with briquette fuel/wood pallets up to 4 inch of the top. In the stove, primary air is supplied through a small fan below the grate. Secondary air stream is passed through annular passage in between combustion chamber and surrounded outer cylinder and mixed with effluent gas near the top of the combustion chamber through two rows of circumferential holes (Picture 2).

### Specifications

- Internal diameter: 8"
- Height of stove top from grate: 14"
- Distance of lower set of secondary air ports from grate: 10" 
- Gap in between upper set of secondary air port from stove top: 2"
- Outer wall diameter: 9.8", i.e., cross-sectional area of secondary air space is maintained 50 per cent of primary air coming through grate
- Gap in between pot bottom and pot stand height: 2", i.e., circumferential area of gap is equal to cross sectional area of inner diameter of stove
- Fan power: 0.22 W
- Cost of fabrication: ₹1,500.

Mr Sankha Subhra Datta is a Senior Section Engineer (Mechanical) in the Diesel Locomotive Shed, N F Railway, Siliguri Junction, West Bengal, India. E-mail: subhradatta611@gmail.com

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Akshay Urja (bilingual) is widely circulated to all stakeholders of renewable energy. We invite advertisements (in colour) from interested organizations, manufacturers, institutions, etc. The advertisement tariffs are as follows:

<table>
<thead>
<tr>
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<td>Inside front cover (₹)</td>
<td>50,000</td>
<td>150,000</td>
<td>142,500</td>
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TERI PRESS | TERI, Darbari Seth Block, IHC Complex | Lodhi Road, New Delhi -110 003
Tel. +91 11 2468 2100, 4150 4900 | Fax: +91 11 2468 2144, 2468 2145 | Email: teripress@teri.res.in | Web: www.teriin.org
Whooshy gods
People have worshipped the wind for thousands of years. The wind god is called Aeolus by the Greeks, Zu by the Sumerains, and Pavan or Vayu by the Indians. Yu Ch’iang is the Chinese god of the sea wind. Shu is the Egyptian god of wind, while Raja Angin is the Malayan wind-god.

Gimme more blades!
People often wonder why there aren’t more blades on wind turbines. The right number of blades for a wind turbine depends on the nature of the work turbine does. Turbines for generating electricity need to operate at high speeds, but do not need much turning force, so they have two or three blades. Wind pumps operate with plenty of force but not with much speed and, therefore, have many blades.

Once upon a time
Windmills were first used in Persia 2,800 years ago. The concept of windmills reached Europe through the crusaders. Windmills first appeared in England in AD 1137.

Hail wind!
Once there were over 9,000 windmills in Holland, but today there are only about 1,000 left. But that doesn’t stop the country from celebrating its windmills. On National Windmill Day, over 600 windmills are opened to visitors for free!

How clean is it?
A wind turbine produces enough clean electricity in six months to balance all of the greenhouse gases emitted during its manufacture and it produces clean electricity for another 20–25 years.
**Facts**

**Wind Power!**
The blades on a modern wind turbine sweep 48 tonnes of air every second, that’s the same weight as 10 elephants or five double-decker buses!

**Double Advantage**
Panasonic has invented a device that combines solar and wind power generation in one unit. ‘Seagull’ is a mast with blades rotating along its length and solar panels on top. During the day, the panels generate power, which is stored in a battery. At night, the wind turbines generate electricity and also ensure power supply on cloudy days. The ‘Seagull’ illuminates Tokyo’s streets at night.

**Whooooo**
The strongest gust of wind was recorded on April 12, 1934 at Mount Washington, in the United States. The wind blew at a speed of 370 kilometres per hour. That’s faster than most Formula one racing cars!
Introducing Renewable Energy

The book is about renewable energy that you can harness for a small-scale ‘micro power’ project. It is designed to give the reader a view of what renewable energy is, how it works and what it can be used for. The book includes step-by-step instructions for two renewable energy projects, one solar PV and one wind project. However, it is not intended as a detailed ‘how to’ guide for installing all types of renewable energy system. The book is an introductory guide on the subject that will give you enough grounding for you to extend your knowledge with more specialized information later on. Although this book focusses on small scale renewable energy systems, it also covers larger scale systems at a high level as well.

Solar Energy Storage, 1st Edition
Bent Sorensen | Academic Press | 394 pages

In this book, expert contributing authors explain current and emergent storage technologies for solar, thermal, and photovoltaic applications. The book sheds light on the economic status of solar storage facilities, including case studies of the particular challenges that solar energy systems present to remote locations. It includes information on: chemical storage mechanisms, mechanical storage tactics, pumped hydro, thermal storage, and storage strategies for systems of all sizes—from centralized utilities to distributed generation. The book would prove to be useful for energy and power engineers, scientists, and researchers working with renewable technologies.

Recent Advances in Thermochemical Conversion of Biomass
Ashok Pandey, Thallada Bhaskar, Michael Stöcker, and Rajeev Sukumaran | ELSEVIER | 504 pages

This book provides general information and data on one of the most promising renewable energy sources—biomass—for its thermochemical conversion. This book provides date-based scientific information on the most advanced and innovative processing of biomass as well as the process development elements on thermochemical processing of biomass for the production of biofuels and bio-products on (biomass-based biorefinery). The conversion of biomass to biofuels and other value-added products on the principle biorefinery offers potential from technological perspectives as alternate energy. The book covers intensive R&D and technological developments done during the last few years in the area of renewable energy utilizing biomass as feedstock and will be highly beneficial for the researchers, scientists, and engineers working in the area of biomass-biofuels-biorefinery.
**Forthcoming Events**

**National**

**November 18–20, 2015 | Mumbai, India**
**Intersolar India**  
Website: www.intersolar.in

**December 1–2, 2015 | Bhubaneswar (SNA), India**
**Training Programme on Grid-Connected Rooftop SPV Systems for SNAs and ERCs**  
Website: www.teriin.org

**December 2–4, 2015 | Ahmedabad, India**
**ENERASIA 2015**  
Website: enerasia.in

**December 7–9, 2015 | Mumbai, India**
**Three-days Training Programme on Grid-Connected Rooftop SPV Systems for Channel Partners, New Entrepreneurs, Manufacturers**  
Website: www.teriin.org

**December 8–9, 2015 | New Delhi, India**
**3rd International Conference & Exhibition on Energy Storage & Microgrids in India**  
Website: http://www.esiexpo.in

**December 16, 2015 | Hyderabad, India**
**Stakeholder’s Workshop to Expedite Solar Deployment for RPO Compliance in Southern States**  
Website: www.teriin.org

**International**

**November 05, 2015 | London, UK**
**Renewable Energy Crowdfunding Conference**  
Website: www.recrowdfunding.eu

**November 8–12, 2015 | Daegu, Korea**
**ISES Solar World Congress**  
Website: www.swc2015.org

**November 24–25, 2015 | London, UK**
**International Tidal Energy Summit 2015**  
Website: http://www.tidaltoday.com/tidal-conference

**December 03–05, 2015 | Dhaka, Bangladesh**
**10th SOLAR Bangladesh 2015 International Expo**  
Website: http://cems-solarexpo.com

**December 06–08, 2015 | Abu Dhabi, UAE**
**The 2nd International Conference on Renewable Energy Technologies (ICRET 2015)**  
Website: http://icret.org
**RENEWABLE ENERGY AT A GLANCE: GLOBAL**

### Solar PV Global Capacity

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<td>2012</td>
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<td>2013</td>
<td>138</td>
</tr>
<tr>
<td>2014</td>
<td>177</td>
</tr>
</tbody>
</table>

- **40 GW Added in 2014**

### Concentrating Solar Thermal Power Global Capacity

- **Spain (2.2 GW) 53%**
- **United States (1.6 GW) 38%**
- **India (0.22 GW) 5%**
- **United Arab Emirates (0.1 GW) 2%**
- **Rest of World (0.09 GW) 2%**

- **925 MW Added in 2014**

### Wind Power Global Capacity

<table>
<thead>
<tr>
<th>Year</th>
<th>Gigawatts</th>
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<td>2013</td>
<td>319</td>
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<tr>
<td>2014</td>
<td>370</td>
</tr>
</tbody>
</table>

- **51 GW Added in 2014**

### Hydropower Global Capacity

- **China (280 GW) 27%**
- **United States 7.5%**
- **Canada (77 GW) 7.3%**
- **Russia (48 GW) 4.5%**
- **India (45 GW) 4.3%**
- **Rest of World (437 GW) 41%**

Source: Renewables 2015 Global Status Report
**WHAT RE-INVEST 2015 ACHIEVED SO FAR?**

- **Increased** participation in Tenders generated.
- **Generated** confidence among foreign investors.
- **Helped** States bring out their renewable energy policies.
- **Brought** States and developers together.
- **Developed** confidence amongst financial institutions to lend to the renewable energy sector.
- **Generated** awareness on India’s commitment to Renewable energy.
- **Increased** collaboration between various stakeholders.
- **Reduced** perceived risks in the renewable energy sector.
- **Increased** awareness about policies and programmes of the Government of India and State Governments.
- ** Expedited** capacity addition of grid connected; rooftop and off grid solar projects.
- **Inclusion** of cost of rooftop solar system as part of home loan and consequently ensuring eligibility for tax benefits as under home loans.
- **Achievement** of priority sector lending status for renewable energy (RE) resulting in which banks can provide loans of INR 15 crore to RE generators, non-conventional energy based public utilities and upto INR 10 lakh per borrower for individual households.
- **Utilization** of 25 years old NTPC coal power based stations for bundling with solar capacity.
- **Announcement** of new loan scheme to promote rooftop solar photovoltaic power projects by the Indian Renewable Energy Development Agency. The scheme will provide loans at interest rates between 9.9 and 10.75 per cent to system aggregators and developers.
- **Issue** of tax free bonds of INR 6000 crore for renewable energy by CPSEs in FY 2015-16.

For more information, please contact:
RE-INVEST Helpdesk at IREDA
Phone: +91 11 24682206 - 10
Email: investors@ireda.gov.in

RE-INVEST Secretariat
Ministry of New and Renewable Energy
Phone: +91 11 2436 2360 Email: re-invest.mnre@nic.in
http://www.RE-INVEST.in; www.mnre.gov.in

https://www.facebook.com/REInvest2015
https://twitter.com/Retnvest2015

Photo © Dhiraj Singh/UNDP India
Install Grid Connected Rooftop Solar Systems on your roof in residential, commercial, industrial and institutional buildings and make your roof your own power house. Meet your electricity requirement and the excess electricity can be fed to the local grid.

40,000 MW Grid Connected Solar Rooftop Systems targeted by 2022

How to Install Solar Rooftop Systems?
Visit MNRE website www.mnre.gov.in, calculate your requirement at "Solar Rooftop Calculator" and fill-up "Installation Interest Form" or scan QR code on your mobile to reach the link at Solar Rooftop Calculator:

Incentives:
- Upto 30% Government subsidy for non-commercial and non-industrial categories for using domestic solar panels
- Accelerated depreciation benefits for industrial and commercial buildings
- Custom Duty Concessions and Excise Duty Exemptions
- 10 years tax holiday
- Avail bank loan as a part of home loan/home improvement loan
- System Aggregators can avail loan from IREDA at concessional interest rate (9.9% to 10.75%)
- Avail loans under Priority Sector Lending upto ₹ 10 lakhs for individuals

Benefits:
- Reduce your electricity bill and save money
- Payback period: 5-6 years
- Sell your own green power and earn money
- Make mother Earth a better place to live

Contact:
- Solar Energy Corporation of India (website www.seci.gov.in, Phone Number: 011-7189200, Email: corporative@sec.gov.in)
- Empanelled Channel Partners (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: 011-26717429, Email: abhi@ireda.gov.in)