In order to meet its growing energy and power requirements, Kerala has decided to allow greater private investment in setting up power plants from hydel sources. In this article, G Anil presents a detailed description of the small hydro power project currently in operation in the state.
Affordability, availability, and access to energy are the key drivers for meeting the energy requirements of every individual and today renewable energy is playing a vital role to provide clean energy at affordable price and with ease of access in India. India has emerged as a promising market for the global community with its up-scaled target of 175 GW of renewable power including 100 GW alone from the solar. The conducive policy regime has been created and also the affordability of renewable energy in increasing day by day due to the economy of scale.

I am glad to mention that the country has exceeded its target of 4,460 MW with record capacity addition of 6,938 MW renewable power in the financial year (FY) 2015–16 and is ready to meet another challenging target of 16,660 MW in FY 2016–17 including 12,000 MW alone from solar power. Grid connected solar rooftop has emerged as major sector with a 40 GW target by 2022.

India has taken a leadership role by creating the International Solar Alliance (ISA) with its interim Headquarters in New Delhi and has also contributed `175 crore for ISA corpus fund and also for meeting expenditure for the initial five years. ISA is a part of Prime Minister’s vision to bring clean and affordable energy within the reach of all and create a sustainable world. It will be a new beginning for accelerating development and deployment of solar energy for achieving universal energy access and energy security of the present and future generations. ISA will be dedicated to promotion of solar energy for making solar energy a valuable source of affordable and reliable green and clean energy in 121 member countries.

I am happy to learn that Akshay Urja is being published regularly since January 2005. The present issue focusses on the opening of new possibilities in microgrid technology and efforts to enhance skilled manpower under the ‘Surya Mitra’ programme. Storage technologies, vital for off-grid applications, have also been comprehensively reviewed. We foresee a huge jump in installations in RE sector in India and look forward to your cooperation and suggestions in this noble effort.

Thank you.

Piyush Goyal
Minister of State with Independent Charge for Power, Coal, and New & Renewable Energy
Government of India

MESSAGE

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Thank you.

Upendra Tripathy
Secretary
Ministry of New and Renewable Energy, Government of India
The microgrid is a logical evolution of simple solar photovoltaic (PV) power systems and has made significant progress and now considered an affordable alternative for generating clean power for meeting the electricity needs for the developing and underdeveloped countries in an independent and sustainable manner. With the challenge of an estimated 1.3 billion people lacking electricity access, governments across the globe are implementing clean energy programme by installing versatile solar PV technology based power plants in far-flung islands and rural hamlets together with energy systems. The microgrid is a logical evolution of simple distribution networks and can accommodate a high density of various distributed generation sources. A typical microgrid power system consists of generators, wind turbines, solar PV arrays, and other renewable technologies, such as geothermal generation, main grid connection/interconnection switch, and energy-storage devices, such as flywheels and batteries for long and short-term storage. Rising cost and burdens of transmission and distribution (T&D) infrastructure, integration of renewable and storage technologies, power quality and reliability are some of the reasons for the growing interest in microgrids.

The Assam Energy Development Agency (AEDA) was constituted as the nodal agency for new and renewable sources of energy under the Ministry of Non-conventional Energy Sources, Government of India, for Assam in July 2002. In 2002, the primary objectives of the AEDA were to act as the State Nodal Agency of Ministry of Non-conventional Energy Sources in the areas of new and renewable sources of energy for the State—to initiate, promote, support, and coordinate all activities in the field of non-conventional energy sources as well as to thereby tap the potential to generate energy for various uses. 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.
RENEWABLE ENERGY NEWS

CPWD to Generate 42.50 MW Solar Power by September 2016

By September 2016, several government buildings across the country will be solar energy efficient with the Central Public Works Department (CPWD) setting up rooftop solar panels on them besides replacing conventional electrical fittings. The environment-friendly move will help the CPWD to generate 42.50 MW of solar energy across the country by September 2016 and in a total savings of ₹115 crore per year. The CPWD earlier signed a pact with the Solar Energy Corporation of India (SECI) for installation of grid connected rooftop solar photovoltaic panels in all government buildings maintained by CPWD across the country for generation of solar power. Consequently, SECI awarded works to 34 bidders for undertaking works in 16 States. Ten MW of solar power will be generated by May 2016 in Phase-I covering Delhi (3 MW), Uttar Pradesh (2 MW), North-East, and union territories (UTs) (2 MW) and 1 MW each in Andhra Pradesh, Karnataka, and Maharashtra. In Delhi, solar panels have already been installed for a total capacity of 1.50 MW over six government buildings—Nirman Bhawan, Shastri Bhawan, East Block and Sewa Bhawan (RK Puram), Pushpa Bhawan near Sheikh Sarai, and CGO Complex, Lodhi Road.

New Delhi Station Turns to ‘Waste Power’

Very soon, the waste generated at New Delhi Railway Station will not only be recycled but also be used to produce electricity to light up the station. The Delhi Division of Northern Railway is going to segregate waste at the station to make it biodegradable and recyclable. Biodegradable waste will be converted into electrical energy and manure. Electrical energy will be utilized by the Railways, most likely at the New Delhi Railway Station. “It is yet another green initiative by the Northern Railway’s Delhi Division and the bio–methanation plant at the New Delhi Railway station will be ready by June 2016,” said Delhi Divisional Railway Manager Mr Arun Arora. “The municipal solid waste (MSW) handling capacity of the plant at New Delhi will be 15 tonnes per day,” he added. The Railway Board has nominated RITES as the nodal agency for tendering for the waste-to-energy plant. Approximately, 2,000 units of electricity produced (three phase, 415V) in the waste-to-energy plant per day will be purchased by the Railways from the contractor. Nearly 15,000 m³ of land will be required for this project, as well as 50 kW of electric power supply and 12 kl water per day at chargeable basis for operation of the plant.

Government Plans to Make India 100 per cent Electric Vehicle Equipped Nation by 2030

The success of electric cars in India has been largely elusive due to the lack of infrastructure and the high cost of acquisition, which has made these cars a rare sight on our roads. However, in a recent statement, Minister of Power, Coal, and New & Renewable Energy, Shri Piyush Goyal said that the Indian government is aiming to make the country a 100 per cent electric vehicle nation by 2030. Elaborating on the proposal, Shri Goyal stated that the government is working on the viability of an electric car for zero down payment. The scheme will be self-financing as per the Minister and will not need any support from the government or any other kind of investment from other people. The aim is to make India, the first country of its size to have 100 per cent electric cars by 2030. Quite an ambitious target, the government is optimistic about achieving the large figure but also acknowledges that innovation and scale will be important elements in making this proposal a reality.

KSRTC to go Green, Run 1,800 Buses on Biodiesel

The Karnataka State Road Transport Corporation (KSRTC) has planned to run 1,800 of its 8,350 buses on biodiesel. The select buses will run on 20 per cent biodiesel and 80 per cent diesel. Currently, all KSRTC buses are running on diesel completely. The KSRTC has now decided to reduce the diesel component after a series of trials and tests it carried out with biodiesel has turned out successful. The talk of biodiesel has been there for long, but its implementation had not taken place as officials were unsure about the combination of fuel. The KSRTC has been plying a few buses on the biodiesel and diesel combination on a trial basis. “In terms of engine performance, vibrations, body imbalance, extra sound, etc., the buses performed well and did not show undue signs of stress of any kind. The fuel efficiency too worked out well. The new initiative will be taken up in 16 depots in the State on a pilot basis. Meanwhile, the Karnataka State transport corporation is also testing out a 100 per cent biodiesel bus, the first-of-its-kind in the State.

Hartek Power Connects 28 MW of Solar Projects to Grid in Punjab

India-based EPC provider Hartek Power has commissioned new substations required to connect 28 MW of solar power to the grid in Punjab. Hartek has connected two solar power projects—24 MW and 4 MW—to the grid for a solar developer in the Muktsar district of Punjab. The projects are the first to connect to the grid in Punjab under Phase 2 of the state’s renewable energy policy, the company said. We have now set our eyes on the 500-MW solar projects recently awarded by the State government under the Phase 3 auction,” Hartek Group Chairman and Managing Director Hartek Singh said in a statement. Hartek commissioned two 66/11 kV substations for the solar projects. The scope of work of the projects awarded in October included complete turnkey solutions and post-inverter works covering the design, supply, installation, and commissioning of the power plants as well as electrical and installation of substations.

Source: www.renewableenergyworld.com
Suzlon Wins another Order from IOCL for 48.30 MW Wind Project

The Suzlon Group, one of the leading global renewable energy solutions providers in the world has announced another turnkey order of 48.30 MW wind power project from Indian Oil Corporation Limited (IOCL). The project consists of 11 units of 579 120 m all-steel hybrid tower and 12 units of 579 90m tubular tower with rated capacity of 2.1 MW each. The project has the potential to provide power to 26,000 households and reduce 0.10 million tonnes of CO₂ emissions per annum. Located in the districts of Jaisalmer and Jodhpur, Rajasthan, the project is scheduled for completion by March 2017. Suzlon will provide comprehensive operation and maintenance for a initial period of 10 years.

Suzlon will fulfill this project with products from its S9X series, specially designed for the Indian terrain, and delivering higher energy yield. The 579 90m hub height wind turbine generator features the time tested Doubly Fed Induction Generator (DFIG) technology, which is designed to optimally harness available wind resources. It not only delivers higher energy yield, but also offers higher return on investment for customers. The 579 120m is the tallest all-steel hybrid tower (120 metre height) in the world and combines both lattice and tubular structures. The 579 120m prototype, set up in November 2014 at Kutch, Gujarat, achieved a plant load factor (PLF) of 35 per cent, successfully generating 6.42 million kWh over the first 12 months of operation.

RattanIndia Solar Wins 50 MW of Solar Project in Uttar Pradesh

Rattan India Group firm RattanIndia Solar Ltd has won solar project of 50 MW capacity at Allahabad in Uttar Pradesh. “The project was won at a tariff of Rs 4.43 per unit plus a viability gap funding of Rs 75 lakh per MW in reverse e-auction conducted by Solar Energy Corporation Limited (SECI). According to the statement, overall combined capacity of 440 MW was offered in this bid out of which 50 MW was for Allahabad. The land for the project will be provided by Uttar Pradesh. RattanIndia has solar projects of more than 240 MW spread across various states of India. All of our solar farms have fully acquired land. Majority of the solar power produced by our projects is being sold to Central government entities, such as NTPC and SECI—thus eliminating the risk of payments,” CEO of RattanIndia Solar, Anjali Rattan Nashier said.

Earlier, RattanIndia had won 70 MW of solar project in Rajasthan through NTPC and 40 MW of solar project in Maharashtra through SECI. The group is also implementing 10 MW of grid connected solar rooftop projects on CPWD buildings in Delhi and West Bengal, which includes important government buildings, such as The Supreme Court of India and Krishna Bhawan.

MIT Researchers Turn Waste Gas into Liquid Fuel

Turning the emissions of power stations, steel mills, and garbage dumps into liquid fuels has been demonstrated by MIT researchers using engineered microbes. The process has been successfully trialed at a pilot plant in China and a much bigger facility is now planned. Energy-dense liquids are vital to transport but are currently derived from oil, a fossil fuel, and transport produces about a quarter of the global carbon emissions driving climate change. Biofuels have been seen as a possible replacement, but current biofuels compete with food production and have been blamed for driving up food prices. Using waste gases to create low-carbon liquid fuels would be a major advance in the battle against global warming if they could be made at low cost and large scale. Another company expects to be using different microbes to produce fuel from steel plants in Belgium and China in 2017.

The Massachusetts Institute of Technology (MIT) process uses bacteria to convert the waste gases into acetic acid—vapor—then an engineered yeast to produce an oil. The patents for the process are owned by MIT and have been licensed to GTL Biofuel Inc.
Antigua and Barbuda Solar Power Plant Inaugurated
The Government of Caribbean island Antigua and Barbuda together with the UK-based clean energy provider PV Energy Limited officially inaugurated the 3 MWp solar power plant at the V.C. Bird International Airport of Antigua. The 900 kWp solar plant installation at the V.C. Bird International Airport, Antigua, developed and constructed by PV Energy Limited, plays a pivotal role in the clean energy strategy for Antigua and Barbuda. More than 12,000 top-tier polycrystalline photovoltaic panels generate up to 4.645 GWh per year and therefore save a substantial 3,019.50 tonnes of CO₂ emissions.

Statoil Launches Batwind Battery Storage for Offshore Wind Energy
A new battery storage solution for offshore wind energy will be piloted in the world’s first floating wind farm, the Hywind pilot park off the coast of Peterhead in Aberdeenshire, Scotland. Batwind will be developed in cooperation with Scottish universities and suppliers, under a new memorandum of understanding (MoU) signed in Edinburgh on March 18, 2016 between Statoil, the Scottish Government, the Offshore Renewable Energy Catapult and Scottish Enterprise. Battery storage has the potential to mitigate intermittency and optimize output. This can improve efficiency and lower costs for offshore wind. The pilot in Scotland will provide a technological and commercial foundation for the implementation of Batwind in full-scale offshore wind farms, opening new commercial opportunities in a growing market. Statoil will install a 1 MW battery based storage pilot system in late 2018. This equates the battery capacity of more than two million iPhones. The pilot will be part of Hywind Scotland, an innovative offshore wind park with five floating wind turbines located 25 km offshore Peterhead. The wind park is currently under construction and start of electricity production is expected in late 2017.

Doubling Renewables by 2030 will Boost Global GDP by up to USD 1.3 Trillion
Doubling the share of renewables in the global energy mix by 2030 can save up to $2 trillion annually by 2030—15 times more than the costs—according to a new report by the International Renewable Energy Agency (IRENA). IRENA’s Roadmap for a Renewable Energy Future, released at the Berlin Energy Transition Dialogue, recommends options to boost the share of renewable energy in the global energy mix from just over 18 per cent today, to as much as 36 per cent by 2030. “Achieving a doubling is not only feasible, it is cheaper than not doing so,” said IRENA Director-General Adnan Z Amin. “IRENA shows this is not only the most economic pathway, but also the most socially and environmentally conscious. It would create more jobs, save millions of lives from reduced air pollution and set us on a pathway to limit global temperature rise to 2°C as agreed in Paris.”

This second edition of IRENA’s global roadmap broadens its analysis to cover 40 countries, representing 80 per cent of global energy use. According to the report, great strides have been made to increase renewables in the power sector, which is on track to generate roughly 45 per cent of the world’s electricity by 2030 (up from 23 per cent today). If a doubling is achieved, this would grow to more than 50 per cent. There is also great potential to increase renewables in transport, buildings, and industry, but these sectors are currently lagging behind.

India and France Launch $1 Trillion Potential Solar Programme for Developing Countries
Shri Piyush Goyal, Union Minister of State (IC) for Power, Coal & New and Renewable Energy and Ms Ségolène Royal, French Minister of Environment, Energy and the Sea, in charge of International Relations on Climate and President of COP21 co-chaired a Ministerial Side Event on International Solar Alliance (ISA) at the New York on April 22, 2016. Shri Goyal and Ms Ségolène Royal announced the solar finance programme that aims to lower the cost of finance and facilitate the flow of more than $1 trillion investment to members of the ISA. The Interim Administrative Cell of ISA and the United Nations Development Programme (UNDP) declared their intention to promote solar energy globally. Ministers and representatives from over 25 countries, including Bangladesh, Brazil, Ethiopia, Namibia, Uganda, Nigeria, Peru, Djibouti, Surinam, Zambia, Bolivia, Seychelles, Sri Lanka, Maldives, India, the USA and France participated in the ISA side event. In order to accelerate massive deployment of solar energy at various scales in their countries, Ministers agreed to take concerted action through targeted programmes launched on a voluntary basis, to better harmonize and aggregate the demand for:

- Solar finance, so as to lower the cost of finance and facilitate the flow of more than US $1,000 billion investment in solar assets in member countries;
- Mature solar technologies that are currently deployed only at small scale and need to be scaled up;
- Future solar technologies and capacity building, through strategic and collaborative solar R&D, to improve the efficiency and integration of solar power as well as increase the number of solar applications available.

A common buyers’ market for solar finance, so as to lower the cost of finance and facilitate the flow of more than $1 trillion investment to members of the ISA. The Interim Administrative Cell of ISA and the United Nations Development Programme (UNDP) declared their intention to promote solar energy globally. Ministers and representatives from over 25 countries, including Bangladesh, Brazil, Ethiopia, Namibia, Uganda, Nigeria, Peru, Djibouti, Surinam, Zambia, Bolivia, Seychelles, Sri Lanka, Maldives, India, the USA and France participated in the ISA side event. In order to accelerate massive deployment of solar energy at various scales in their countries, Ministers agreed to take concerted action through targeted programmes launched on a voluntary basis, to better harmonize and aggregate the demand for:

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While announcing the programmes, Shri Piyush Goyal expressed his confidence that these programmes will serve the interests of the farming communities in the prospective ISA member countries and ensure that there is sufficient flow of affordable finance for solar projects. He further stated that the ISA will provide a vibrant platform to bring together countries with rich solar potential to aggregate demand for solar energy globally, thereby reducing prices; promoting collaborative solar R&D and capacity; and facilitating the deployment of existing solar technologies at scale.
MICROGRIDS

Opening New Possibilities for the Electricity Grid

The concept of microgrid is getting more favourable as scope of harnessing power from the new renewable energy resources is increasing day by day. In this article, Pankaj Verma and Dr Prasenjit Basak aim at familiarizing the reader with the new concept of microgrid. Various microgrid topologies, its control and operation, and the new trend in the distributed energy resources (DERs), such as vehicle to grid (V2G) technology, have been presented in this article. Many technical and economic challenges against adoption of this new technology have also been explored.

As the reserves of nonrenewable sources of energy are falling down in the nature we need to look for some other alternatives in place of these sources. Some of the renewable sources of energy are wind, solar, small hydro, etc., but these sources are distributed, hence if we could find a way to combine all these energy sources then loads with high power demand can be served easily. The configuration in which various distributed sources are combined to serve together is simply a microgrid.

Technically, a microgrid is a localized grouping of electricity sources and loads that normally operate connected to the centralized grid, but can disconnect and function autonomously as physical and/or economic conditions dictate. The microgrid is a logical evolution of simple distribution networks and can accommodate a high density of various distributed generation sources. A typical microgrid power system consists of generators, wind turbines, solar photovoltaic (PV) arrays, and other renewable technologies, such as geothermal generation, main grid connection/interconnection switch, and energy-storage devices, such as flywheels and batteries for long and short-term storage. The typical range of microgrid rating is 500 kW–15 MW.

Why Microgrids?

Some of the various reasons for interest in microgrids include:

- Rising cost and burdens of transmission and distribution (T&D) infrastructure: Building new T&D infrastructure has become difficult in some areas due to permission issues, public resistance, and the difficulty, cost, or both of upgrading or building new infrastructures.
- Integration of renewable and storage technologies: The greatest obstacle to the integration of renewables has been the risk to grid stability. Some renewable energy sources, most notably wind and solar, are intermittent by nature, which increase the voltage and frequency fluctuations on the grids. The risk is greatest when there is a high penetration of renewables. However, technology advancements in grid stabilization and energy storage have addressed these concerns in microgrids. Nowadays, the challenge of renewable energy generation peaking not matching up with the demand peaks can be resolved using energy-storage modules. An energy-storage module is a packaged solution that stores energy for use at a later time. The energy is usually stored in batteries for specific energy demands or to effectively optimize cost. The modules can be stored as electrical energy and supplied to the designated loads as a primary or supplementary source. Moreover, it provides a stable and continuous power supply, regardless of the supply source status. Voltage and frequency can also be improved by using storage modules.
- Power quality and reliability: The need for high reliability and good power quality has increased as more customers install microprocessors-based devices and sensitive end-use machines.
- Public policy: In a full reversal from the past, public policy today is favouring distributed generation that offers improved efficiency, lower emissions, enhanced power system security, and other benefits of national interest. Policies supporting this include tax credits, renewable portfolio standards, emission restrictions, grants, and so on.
- More knowledgeable energy users: Energy users are becoming more aware of alternative power approaches and are more willing to consider on-site generation options than in the past. Many are interested in combined heat and power (CHP) as well as reliability enhancements.

Microgrid Topology

Microgrids can operate in parallel with or isolated from the utility grid during emergency conditions or planned events. This type of distribution grid structure offers potential for improvement in power supply efficiency and reliability of power supply in comparison with the traditional and passive distribution grids. But what is an optimal topology for this kind of distribution network? The well-known approaches include a radial, a normally open-loop, or a meshed structure for the distribution systems, which constitute the possible solution for microgrid optimal topology as shown in Figure 1.

The factors determining the selection of optimal microgrid network topology include:

- Size, type, and location of distributed energy resources (DERs) and loads
- Power quality and reliability targets (the minimum power quality that a microgrid has to provide to its customers affects the selection of an optimal network structure)
- Economic constraints/available budget
- Investment cost (primary equipment, protection and control, communication)
- Operating and maintenance costs, including cost of power losses and energy not supplied due to interruptions
- Technical constraints (e.g., protection system, voltage profile, and physical equipment dimensions)
- Voltage level (usually medium-voltage networks are open-loop networks and low-voltage networks are radial, with normally open-loop topologies in some exceptional cases).

A schematic structure of a radial microgrid consisting of fuel cells and photovoltaic generators as the DERs is shown in Figure 2.

The PCC (point of common coupling) is the point where the microgrid is coupled to the main utility grid using the STS (static transfer switch).

Microgrid Control and Operation

Microgrid control

Microgrids are comprised of different components, such as:

- Distributed generators, such as microturbines, fuel cells, PV, diesel generators, etc.
- Energy-storage devices, such as batteries, flywheels, supercapacitors
- Flexible loads, such as heating, ventilation, air-conditioning, and lighting
- Reconfigurable feeders, tap-changing transformers, and reactive power compensation.

These components can be controlled in a continuous or discrete way in order to keep a microgrid running in utility-connected or islanded operating modes, as well as to guarantee a seamless transition between two modes. Typical control tasks include:

- Spinning reserve management to cope with the emergency conditions

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**Figure 1: Traditional distribution network topology**

**Figure 2: Radial microgrid structure**
Microgrid operation

A microgrid can operate in either the grid-connected or islanded mode, and may experience mode transition. In the grid-connected operation mode, the microgrid is connected to the main grid through the point of common coupling and operates in parallel with the main grid to deliver power to the load. From the distribution system perspective, a grid-connected microgrid can be treated as an individual controllable entity, acting like a generator to the supply power or a load to consume power. On the other hand, the microgrid operating in the islanded mode is independent of or isolated from the main grid, due to either disturbance in the main grid or its geographical isolation, such as a remote island. In the islanded mode, the microgrid operation, such as the voltage and frequency control and regulation, is implemented in a stand-alone system. The transition between the two modes can occur during the operation. For example, when a fault occurs in the main grid, the microgrid is resynchronized and connected back to the main grid via the common coupling point. Some types of microgrids, such as institutional/campus, industrial/commercial, community/utility, and military base microgrids, operate in the grid-connected mode most of the time, and only switch to the islanded mode when disturbance happens to the main grid. Some other types of microgrids, that is, remote off-grid and weakly grid-connected microgrids (such as military forward installations and remote mining industrial sites), operate in the islanded mode all the time, or very often.

Vehicle to Grid Technology

The microgrid may consist of many types of distributed energy resources but the latest trend in the DERs are the electric vehicles which can feed power from the battery packs to the grid or can pull power back from the grid to recharge the battery packs according to the requirements. When the electric vehicles feed power to the grid it is known as vehicle-to-grid (V2G) interaction, while the reverse flow of power for the purpose of charging the batteries is known as grid-to-vehicle (G2V) interaction.

The scheme of the power system with V2G is shown as Figure 3. The power from thermal power plant or wind power station is transmitted to the consumption areas via transmission systems and distribution systems. When electric vehicles are connected to the grid power, they can receive signals of the grid operator and power is fed into the electric grid by two modes—one is vehicles joined to the distribution systems in homes, the other is that vehicles are aggregated and joined to the transmission systems in aggregations. The application of V2G will be beneficial to both grid operators and vehicle owners. In addition, it will bring advantages to the environment in the future.

Benefit to the grid operator

The stored battery energy can be used to serve a portion of the local demand on a feeder thus contributing to peak shaving. Secondary advantages of peak shaving include reducing transmission congestion, line losses, delay transmission investments and reduce stressed operation of a power system. In a deregulated market, load serving entities purchase electric energy through long-term contracts with generation companies and short-run spot electricity markets. Peak shaving applications of electric vehicles reduces the cost of electricity during peak periods. Moreover, the price of services from electric vehicle is more competitive than conventional generations and electric vehicles offer the power system with a flexible controllable load.

Benefit to the vehicle owner

Energy is stored in electric vehicles during the night—when the price is low—and is withdrawn during peak-time—when the price is high, electric vehicles act like pumped-storage units. So, vehicle owners can gain revenue from the difference of prices and compensate part of the initial investment.

Benefit to the environment

Electric vehicles release almost no air pollutants at the place where they are operated. In addition, it is generally easier to build pollution control systems into centralized power stations than retrofit enormous numbers of cars. Another advantage is that electric vehicles typically have less noise pollution than internal combustion engine vehicles, whether it is in idle or in motion. Electric vehicles emit no tailpipe CO2 or pollutants, such as NOx, NMHC, CO, and PM at the point of use.

Technical Challenges

Some of the technical challenges that must be overcome to achieve stable, economic and secure microgrid operational status must deal with several aspects.

- Intermittent renewable generation: One of the major incentives to deploy microgrids is to facilitate the integration of renewable generation in the distribution system. The power output of renewable generation (such as solar and wind) is significantly influenced by the season and weather, and these are characterized as intermittent power resources. That is, the power output of these resources can vary abruptly and frequently and impose challenges on maintaining microgrid stability, especially in the islanded mode.
- Low grid inertia: A microgrid may include both conventional and modern DERs. Conventional distributed generators, such as diesel generators, usually synchronous generators that directly connect to the grid. Modern distribution grids use the most renewable resources and energy-storage devices that are connected to the grid indirectly through PE interface. These DERs either have a low inertia or are inertialess, and bring dynamic problems to microgrid operation.
- Coordination among distributed energy resources: A microgrid may have various types of DERs, such as vehicle-to-grid (V2G) interaction, renewable generation (such as solar and wind), energy storage devices, and so on. These DERs usually have different operation characteristics in their generation capacity, startup/shutdown time, ramping rate, operation cost/efficiency, energy storage charging/discharging rate, and intertemporal control limitations. The microgrid operation should consider the characteristics of different components and provide appropriate control strategies.

Conclusion

The microgrid is the cluster of various DERs which is subjected to combine the power from various DERs using various control and operation strategies so as to achieve a higher power level with no compromise with the power quality. The microgrids may have many configurations and are connected according to the geographical location and power demand of the areas. Microgrids can play a significant role in eliminating the energy crisis state in our country but some plans and strategies need to be framed first so as to overcome technical and economic challenges arising with the adoption of the microgrid technology.
Apart from the above, the Ministry has also been supporting broad based research, design, development, and demonstration programme for the development of motor, controller, charger, chassis, battery, and battery management system, etc., as per the research and development guidelines of the Ministry. Now, the Ministry of Heavy Industries and Public Enterprises, Government of India, has taken up an initiative and formulated the guidelines for implementation of BOVs on a large scale. Therefore, MNRE has discontinued the scheme. The Ministry of Heavy Industries and Public Enterprises, Department of Heavy Industry has set up a National Council for Electric Mobility (NCEM) and a National Board for Electric Mobility (NBEM) for mission mode approach to expand electric mobility and manufacture of electric vehicles (including hybrid) and their components. MNRE is a permanent member in the NCEM as well as in the NBEM.

- **Improving BOVs/Hybrid Electric Vehicles/Plug-in Hybrid Electric Vehicle**

  Critical Challenges for Large-scale Deployment of Electric Vehicles (EVs) in Power Systems: The most critical challenge is with respect to the battery, which has low energy density, high gross weight, low life cycle and also takes too much time for charging, i.e., 6 to 8 hours continuously. A suitable battery is not available in the Indian market. Lithium-ion battery is most suitable for electric vehicles; however, the cost is three to four times higher than the lead-acid traction batteries. Lithium is not available in India and is therefore dependent on China, Bolivia, Columbia, and Brazil respectively, instead of importing fossil fuel from the Gulf countries, technologies, practices, and policies hold the greatest promise for managing EV charging along with proper assignment of charging costs, while protecting consumer privacy. A proper charging facility should be developed point-to-point. A mechanism should be in place which allows consumers to recharge the batteries without having to wait.

- **Facilitation for International Harmonization regarding international standards for integration of EVs with electricity networks:** The Government of India is closely working with the Bureau of Indian Standards and with other organizations to develop a mechanism for standardization of components, i.e., motor, controller, charger, chassis, battery and battery management system, etc., keeping in view International harmonization.

- **Constructive roles in organized EV charging:** International seminars/symposia/conferences should be organized for electricians/mechanics/fitters who will be directly involved in day-to-day operation and maintenance. These vehicles should also be charged from renewable energy, where conventional power is not available.

- **Experience of Clean Energy Ministerial (CEM) countries where direct load control has been deployed:** However, as far as the CEM experience is concerned, it has been seen that due to fluctuation in voltage, the life of battery reduces and users are losing confidence day by day in purchasing BOVs. Due to fluctuating voltage, in some cases chargers have also been burnt. It has also been seen in Bharat Heavy Electrical Vehicles and Chatelec Company, Pimpri-Chinchwad, Pune that a number of chargers were burnt during the charging of the buses (16-seater capacity) at night. This issue has been discussed a number of times with the manufacturers, wherein they have informed that fluctuation in voltage may result in such mishaps.

- **Emerging business models at the EV power system interface, their benefits, cost and risks allocated, and how policy can be formulated for better incentives:** The cost of the electric vehicle...
## Table 1: List of BOV manufacturers

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Company</th>
<th>Nature of Business</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/s Mahindra Reva Electric Vehicles Pvt. Ltd</td>
<td>4-Wheeler Manufacturer</td>
<td>Bengaluru</td>
</tr>
<tr>
<td>2</td>
<td>M/s Hero Electric Vehicles Pvt. Ltd</td>
<td>2-Wheeler (Low &amp; High speed) Manufacturer</td>
<td>Delhi</td>
</tr>
<tr>
<td>3</td>
<td>M/s Electromob (I) Ltd</td>
<td>2-Wheeler (Low &amp; High speed) Manufacturer</td>
<td>Gujarat</td>
</tr>
<tr>
<td>4</td>
<td>M/s Avon Cycles Ltd</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Ludhiana</td>
</tr>
<tr>
<td>5</td>
<td>M/s Lectrix Motors Ltd</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Delhi</td>
</tr>
<tr>
<td>6</td>
<td>M/s BSA Motors Pvt. Ltd</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Chennai</td>
</tr>
<tr>
<td>7</td>
<td>M/s Lohia Auto Industries</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Noida (UP)</td>
</tr>
<tr>
<td>8</td>
<td>M/s Green Electric Vehicles</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Chennai</td>
</tr>
<tr>
<td>9</td>
<td>M/s Ultra Motors</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Delhi</td>
</tr>
<tr>
<td>10</td>
<td>M/s Ajanta(Oreva)</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Gujarat</td>
</tr>
<tr>
<td>11</td>
<td>M/s Ampare Vehicles Pvt. Ltd</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Coimbatore</td>
</tr>
<tr>
<td>12</td>
<td>M/s Nortech Ferrow Alloys</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Delhi</td>
</tr>
<tr>
<td>13</td>
<td>M/s Ashish Wheels Ltd</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>West Bengal</td>
</tr>
<tr>
<td>14</td>
<td>M/s Xs Bikes</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Himachal Pradesh</td>
</tr>
<tr>
<td>15</td>
<td>M/s Doon</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Uttarakhand</td>
</tr>
<tr>
<td>16</td>
<td>M/s Argentum</td>
<td>2-Wheeler (Low speed) Manufacturer</td>
<td>Noida (UP)</td>
</tr>
</tbody>
</table>

It is comparatively lower than the conventional vehicles because of low production. MNRE has been providing Central Financial Assistance as an incentive to the Ministry to meet out the high cost of the vehicles. The Government of India is also considering waiving road tax, VAT, Octroi, etc.  

### Unique challenges and opportunities arise in emerging economies for EV integration
- There is a need to develop high energy density battery, i.e., lithium-ion battery for integration of electric vehicles on mass level.
- **Energy criteria and mobility schemes may be developed for urban planning and sustainable cities:** Electric mobility is fully dependent on sustainable power production, which will build up confidence between industries and users of electric vehicles at mass level. A public transport system should be developed with the help of a city planner taking help from the Ministry of Urban Development, Ministry of Highways and Road Transportation, and the Ministry of Heavy Industries and Public Enterprises, Government of India.

Table 1 gives a list of the manufacturers that have been listed in the Ministry after the proviso of Regulation 5 of ‘RE Tariff Regulations, 2012.’

The Central Electricity Regulatory Commission (CERC) annually reviews the benchmark capital cost norm for solar PV power projects as per the proviso of Regulation 5 of ‘RE Tariff Regulations, 2012.’

- On March 23, 2016, the CERC determined the benchmark Capital Cost for ground-mounted solar PV power for the financial year 2016–17 at ₹330.02 lakh/MW. The component-wise breakup for the benchmark is given in Table 1 for the year 2016–17. In comparison to last year’s cost breakup, all component costs have been brought down. This year’s cost is ~13 per cent lower than last year’s benchmark of ₹605.85 lakh/MW, which itself was a step down by ~12 per cent from the 2014–15 benchmark cost of ₹69.109 lakh/MW. The tariff for solar PV is devised as per the ‘Tariff Structure’ defined in the proviso 9 of the regulation.

### Benchmark Capital Cost for Solar to a New Low

The benchmark capital cost norm for solar PV power projects for the year 2016–17 is ₹530.02 lakh/MW.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost for 2016–17 (lakh/MW)</th>
<th>Percentage of Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV modules</td>
<td>328.39</td>
<td>61.96%</td>
</tr>
<tr>
<td>Land cost</td>
<td>25.00</td>
<td>4.7%</td>
</tr>
<tr>
<td>Civil and general</td>
<td>35.00</td>
<td>6.6%</td>
</tr>
<tr>
<td>Mounting structure</td>
<td>35.00</td>
<td>6.6%</td>
</tr>
<tr>
<td>Inverters</td>
<td>35.00</td>
<td>6.6%</td>
</tr>
<tr>
<td>Evacuation cost</td>
<td>44.00</td>
<td>8.3%</td>
</tr>
<tr>
<td>Preliminary and operational expenses, etc.**</td>
<td>37.63</td>
<td>5.21%</td>
</tr>
<tr>
<td>Total capital cost</td>
<td>530.02</td>
<td>100%</td>
</tr>
</tbody>
</table>

* Cables earthing arrangements, step up outdoor type transformer, breaker, current transformers, potential transformers, auxiliary transformers control cables, isolators, lightning arrestors, protection relays, and Time of Day (ToD) metres/tariff metres, peripheral lighting, telemetry system for real time monitoring.

** (i) Insurance Cost: 0.5 per cent; (ii) Contingency: 0.5 per cent; (iii) Interest during construction (IDC): 5 per cent; (iv) Financing cost: 1 per cent; (v) Project management cost: 0.5 per cent; and (vi) Pre-operative Cost: 0.5 per cent.

### CERC Endorses Capital Cost for Solar to a New Low

The tariff for renewable energy technologies shall be single part tariff consisting of the following fixed cost components:

1. **Return on equity:** (a) Interest on loan capital; (b) Depreciation; (c) Interest on working capital; (d) Operation and maintenance expenses. The interest cost for the year 2016–17 as mentioned in the tariff order was determined as ₹6.8/kWh, which is an almost 20 per cent drop from ₹7.04/kWh in 2015–16.

These cost reductions indicate increased viability of solar PV power in near future and bring a positive note to the growth of the solar PV sector in the country.

Information compiled by Mr. Avinash Jain, Research Associate, RETA, TERI, New Delhi. Email: abhinav.jain@teri.res.in. Mr Abhinav Jain, Research Associate, RETA, TERI, New Delhi.

### Table 1: The component-wise breakup for the benchmark for the year 2016–17

<table>
<thead>
<tr>
<th>Component</th>
<th>2016–17 LCOE</th>
<th>5.68/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levelized benefit from AD</td>
<td>0.59/kWh</td>
<td></td>
</tr>
<tr>
<td>Net levelized Tariff after adjusting AD</td>
<td>5.09/kWh</td>
<td></td>
</tr>
</tbody>
</table>
With increased dependence on emission free technologies, the distributed grid is changing. One of the main challenges is to optimize grid efficiency and its stability vis-à-vis variable generation of green power. With a view to enhance deployment ability and provide continuity of service of renewable and low carbon technologies, the key to an innovative solution lies in provision of energy storage (ES) in RE power applications. A recent report from the World Energy Council, E-storage—shifting from cost to value, mentions that the current methods of evaluating energy storage are not accurate due to a limited focus on the cost of investing and thus hindering the progress on its large deployment. The report also estimates that energy storage costs will fall by as much as 70 per cent over the next 15 years due to the adoption of new technologies.

**Solar PV Outlook**

The state-of-the-art solar photovoltaic (PV) power systems have made significant progress and are now considered an affordable alternative for generating clean power for meeting the electricity needs of the developing and underdeveloped countries in an independent and sustainable manner. To face/tackle the challenge of an estimated 1.3 billion people lacking electricity access, governments across the globe are implementing clean energy programme by installing versatile solar PV technology based power plants in far-flung islands and rural hamlets together with energy systems. With this abundant renewable resource having excellent solar irradiation levels in regions nearer to the equator, harnessing of resourceful and untapped solar potential, remains high (including in India: the annual global horizontal solar radiation data is shown in Figure 1).

With consistent drop in panels cost per watt and other consumables, the levelized cost of energy (LCOE) of solar PV would be decreasing to competitive levels with all conventional power generation technologies by 2030. Solar has a promising future to challenge the intermittency with new storage innovations and market developments. With energy demands globally set to increase on year to year basis, these innovations in ES are likely to shift increasingly towards renewable technologies where the costs are continuously showing downward trend. With the biggest demands in economically emerging countries such as India, solar PV is going to be the primary energy and the major investment option.

In the long run, the increasing preference for solar power plus storage, by virtue of uninterrupted usage and affordability, would greatly help in decarbonizing the power generation technologies to help protect the nature, leading to revival of global economy and reducing carbon footprint.

**Energy Storage (ES)**

During the past two decades, the commercially matured renewable technologies (solar, wind) have made remarkable progress by making strong inroads in the global energy mix for deployment across all sectors, viz., industrial, commercial, institutional, and residential through cost competitiveness. This is bound to increase overall bankability on clean power at affordable rates in the foreseeable future. It is a known fact that both solar and wind technologies, though infinite sources, are variable in nature and lack dispatch ability in keeping the electric grid stable. The continuous and independent deployment of green power systems is not highly viable with these renewable sources unless there is a provision for energy storage, which permits storage of the surplus clean solar and wind power instead of exporting it. The ES systems have consistently been held against investment but safe, cost-effective and rapidly evolving storage technologies could change the economics of bringing the clean power into the power generation stream. The energy storage demand is primarily driven by a changing utility landscape requiring more storage.
WIND SYSTEM OUTPUT.
OF SOLAR PV AND
ALLOW OPTIMUM USAGE
BATTERIES, WHICH
ELECTRICAL ENERGY
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SECURITY OF THE
OF CLEAN POWER,
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DELIVERY OF

have a few practical challenges, such as higher cost, energy density lower than lithium-
South Wales, Australia during the 1980s). The capacity based redox flow storage systems
multi hours of storage under different environmental conditions (–20° to +40°C), are
islands for long duration storage with zero degradation. The vanadium batteries with
only vanadium ions (having unique properties with four iconic states), ideally suited for
power solutions for utilities. Vanadium (chemical element V) redox flow batteries using
batteries. Due to their long-life time and deep cycling ability to store large energy
Lithium-ion type. The improved storage development benefits the application of few
batteries. Normal, the return on investments on solar PV systems improves with storage.
supply shifts, the integration of storage systems in households with PV panels.

The IRENA report (2015) on battery storage for renewables divides the application
areas into island (for converting power supplies from diesel sets to renewable) and
off-grid systems. In order to integrate renewable, the distributed solar plus storage
products consumers with a viable alternative to the grid, the smoothing of energy
energy storage shifts, the integration of storage systems in households with PV panels.

The highly popular batteries for storage systems are Vanadium Redox flow and Lithium-ion type. The improved storage development benefits the application of few
batteries. Due to their long-life time and deep cycling ability to store large energy
capacities, flow batteries are predicted to gain in market share especially in the area of
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South Wales, Australia during the 1980s). The capacity based redox flow storage systems
have a few practical challenges, such as Higher cost, energy density lower than lithium-
ion technologies (which are with power based solutions), and the space requirement
for installation due to large electrolytes tanks is more.

The lithium-ion battery has been the technology of choice over the past year. In the
coming years, the trend for combination of storage and influx of new solar systems
will gain popularity with economical viability for both off-grid and utilities services
using lithium-ion batteries. Affordability shall be the key element in the outlook for
energy storage technology. A recent report from Deutsche Bank estimated that the
cost of lithium-ion batteries could fall by 20–30 per cent a year, bringing commercial
or utility-scale batteries to the point of mass adoption before 2020. The bank report
states that lithium-ion battery costs fell roughly 50 per cent, to about $500/KWh,
between year-end 2014 and year-end 2015. In the wider market, consulting firm
IHS expects continuing declines in lithium-ion battery prices. They fell 53 per cent
between 2012 and 2015, and falling by half again by 2019 with economies of scale.
Lithium-ion batteries (Figure 2) are lighter, more efficient, higher depth of discharge
limit (> 75 per cent), require integrated controller that manages charge and can
discharge more stored energy with longer expected life times.
The practicability of the smart storage systems using batteries with renewable
power generation is becoming highly visible internationally and is experiencing technical
challenges in battery storage which are being met by large
research grants and investments.

These systems while complimenting the intermittent energy generation as well as
realizing peak demand shifting pattern have smart technological features such as:
(i) peak shaving, (ii) remote energy management, and (iii) grid services features. As
costs for energy storage continue to decline, the applications, such as peak shaving
and grid balancing continue to get recognition commercially by providing economical
energy storage solutions. With large requirements of distributed batteries in energy
storage systems, the need will grow for advanced batteries with better density at
economical costs. According to GTM research, the solar-plus-storage is estimated to
explode from a $ 45 million industry in 2015 to a $ 3.1 billion industry in 2020.

Smart Storage Technology: A Game Changer for Variable Green Power

Storage Battery Technologies

The technology developers, independent renewable power producers, and the utility
industry together have been engaged on innovative solutions for quite some time which
have been systematically cater to 24x7 deploy ability of the solar power. Currently, out of
the all major renewable sources, viz., solar, wind, hydro, biomass, the most matured
solar technology is showing an exponential rise globally, but its intermittent nature,
greatly depends on energy storage facility for grid integration, reliability and frequency
regulation. Batteries can offer storage at economical costs. Fast responding batteries or
flywheels (as quick acting load control systems) are deployed for ramping to full
power virtually instantaneously and making the grid stabilized. The various types of
batteries used for energy storage are: lead-acid batteries (made up of plates of lead
and lead oxide that sit in a bath of electrolyte solution); ‘deep-cycle batteries’ (similar to
type of lead-acid battery that uses a thicker lead plate and requires less maintenance;
these are used in off-grid situations for backup power and grid energy storage); flow
batteries (using a variety of different chemical combinations, a typical flow battery
is made up of two tanks of liquids that are pumped past a membrane held between
two electrodes and when the chemicals combine with the electrodes they produce
electricity). Flow batteries are generally used in larger stationary applications, such
as the grid for balancing or off-grid for power supply. At the same time, the industry
is experiencing technical challenges in battery storage which are being met by large
research grants and investments.

The highly popular batteries for storage systems are Vanadium Redox flow and Lithium-ion type. The improved storage development benefits the application of few
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Applications

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off-grid systems. In order to integrate renewable, the distributed solar plus storage
products consumers with a viable alternative to the grid, the smoothing of energy
energy storage shifts, the integration of storage systems in households with PV panels.

Normally, the return on investments on solar PV systems improves with storage.
Integrated solar plus storage economical products, being marketed with designs
for residential and commercial services, as backup, or standalone applications are
getting popular for quick installations. Stationary energy storage continues to show
strong growth in the number of projects. These include output power stabilization
for renewable power systems and for a variety of grid functions monitoring and
improvements such as:
- Grid management asset
- Fast response frequency regulation
- Integrate more RE power in to the grid
- Primary control reserve
- Load balancing to the grid
- Valuable backup source during grid outages.
THE LITHIUM-ION BATTERY HAS BEEN THE TECHNOLOGY OF CHOICE OVER THE PAST YEAR. IN THE COMING YEARS, THE TRENDS FOR COMBINATION OF STORAGE AND INFUX OF NEW SOLAR SYSTEMS WILL GAIN POPULARITY WITH ECONOMICAL VIABILITY FOR BOTH OFF-GRID AND UTILITIES SERVICES USING LITHIUM-ION BATTERIES. AFFORDABILITY SHALL BE THE KEY ELEMENT IN THE OUTLOOK FOR ENERGY STORAGE TECHNOLOGY.

Some of the largest storage energy plants set up internationally with RE (mainly solar; wind) during 2015 have been listed below:

- 2X31.5 MW with lithium-ion installation for wind energy (Picture 2) by Inverenergy (at Grand Ridge Wind Energy farm, Chicago, USA)
- 40 MW with Lithium-ion battery system (by Toshiba at Tohuka Electric Power Substation, Nishi Sendai, Japan)
- 28 MW with Lithium-ion array (at Korea Electric Power Corporation, Seoul)
- The US Department of Energy has announced in 2016 funding of $18 million for six new energy storage (Figure 3) demonstration projects across the country.

These projects to be carried out with utility companies as partners, will enable the development and demonstration of integrated, scalable, and cost-effective solar technologies that incorporate energy storage to power American homes after the sun sets or when clouds are overhead.

- Sonnen Co. (Germany) is providing solar PV plus battery storage with digital controls (Picture 3) to create microgrids that allows sharing of renewable power among users.
- Tesla Motor’s new innovation has led to continuous fall of prices. Its new product “Powerwall”, a rechargeable lithium-ion battery for residential/electric vehicles (Picture 3) to create microgrids that allows sharing of renewable power among users.
- Water management processes
- Pumping stations
- Gas and oil sites
- Gas and oil sites

Other significant applications where the combined solar plus energy storage will be of important use are as follows:

- Mines
- Gas and oil sites
- Pumping stations
- Water management processes
- Weather tracking stations.

Invariably, the trend towards remote power applications is driven by the fact that utility power often is unavailable or is available as a delayed resource, and that service is not Invariably, the trend towards remote power applications is driven by the fact that utility power often is unavailable or is available as a delayed resource, and that service is not.

The Mining sector in Australia plays an important role since mines are not grid-connected due to remote locations and utilize electricity generated at sites often through diesel generators. In 2014, the Australian Renewable Energy Agency (ARENA) and ASCOM estimated the total off-grid generation capacity at mines is estimated at 3.9 GW with an annual electricity consumption of 12 TWh. Typically 20–30 per cent of the operating costs of mines are related to energy. A large part of on-site power is generated by diesel generators. Diesel energy is expensive due to transportation to remote places. At the same time, several health hazards causing disease to the workers are serious in nature with the use of gensets. Mines normally run 24X7 with a constant load, which means that intermittent sources of energy, such as solar and wind installations cannot fully power the mines without storage. PV is typically used for solar-diesel hybrid power plants. The share of variable PV can be increased to 100 per cent by integrating storage into the PV-diesel hybrid system. This is important as the price for solar power has come down mainly driven by falling component prices of modules and inverters. If the PV plant generates peak energy, the diesel gensets can be switched off and the mining operations are fully powered by solar. If clouds pass over the PV array, the power drop can be compensated by storage.

A memorandum of understanding (MoU) on clean energy storage development project has been signed between Canada and India under the protocol of the governments of the two countries. The development work shall be on “grid simulation and testing to be conducted in Ontario by Ryerson University while the onsite integration and deployment will be managed by Anna University on the Tamil Nadu Generation & Distribution Company grid.” It is likely to provide improved reliability of the grid and enhancement of renewable energy production on the electricity distribution system, while ensuring environmental and climate change mitigation benefits.

- Balance of Systems (BOS)

The BOS component supply for the grid-scale energy storage projects is ready for renewable power industry. With the widespread use in home storage and utilities, the battery costs (with better density and advanced innovations) and that of BOS (energy storage by SW magnitude) will cut down. The report predicts the BOS costs in storage (Figure 4) during the next five years should see a 40 per cent decline to values lower than $400/kW.

Solar plus storage applications tend to occur behind the metre, while utility mandates are most often front-of-metre applications. About the future of energy storage and how the grid will be shaped by behind-the-metre and front-of-the-metre installations, the current incentives for behind-the-metre installation, e.g., those installed by end-users at their homes are greater than for front-of-the-metre installations, e.g., large-scale utility installations. In the short term, these incentives will drive growth of behind-the-metre applications faster than front-of-the-metre, which are used for utility purchases of power from large-scale energy storage projects. The trend for behind-the-metre storage increased significantly during 2015 and is likely to show strong growth for 2016.

- Solar and Storage Futuristic Trends

For the rapid growth of the green power industry, Green Tech Media analyst and the PA consulting group experts have predicted “a decentralized, digital and dynamic grid system, with dropping cost of sensors, power electronics and renewable technologies like solar” for the next generation utilities. International consultancy firm KPMG’s report (2015) predicts major changes in power generation industry, with “Solar prices in India falling substantially (lower than coal) by 2020, helping the technology shall become a major part of the country’s energy mix, and that over the next decade solar will scale up significantly, reaching a 12.5 per cent market penetration by 2025.” Further the ‘significant evolution’ expected in storage technologies, will make self-consumption of solar power generated particularly in residential settings more attractive. The bigger contribution may come from the solar rooftop business. This will be supported by a rise in storage technologies, and together they could change the energy landscape.

A MEMORANDUM OF UNDERSTANDING ON CLEAN ENERGY STORAGE DEVELOPMENT PROJECT HAS BEEN SIGNED BETWEEN CANADA AND INDIA UNDER THE PROTOCOL OF THE GOVERNMENTS OF THE TWO COUNTRIES.
Environment Affects Solar Power Generation

Installing solar panels on rooftops, canal tops, and barren lands has been a regular practice nowadays. But, majority of the installations are not well maintained and are left unattended under the open sky. Solar panels require minimum maintenance but they are not completely maintenance free. Before installing the panels a through survey of the site considering the environmental factors affecting the performance of the solar panels must be carried out with the ultimate goal of maximizing the power collection capacity as well as the efficiency of the system. Avipsa Dey discusses some of these factors in this article.
So on a hot day, when panel temperatures may reach 45°C, a panel with a temperature coefficient of −0.5 per cent would result in a maximum power output reduction of 10 per cent. Conversely, if it is a sunny winter’s morning, the panels will actually be more efficient. It seems ironic but it is the fact that the more sunshine we get, the hotter the panels become and this in turn counteracts the benefit of the sun. The knowledge regarding temperature will help to improve the efficiency of solar panels that operate in non-optimal conditions. To maintain a favourable temperature of the panels, cooling systems are kept which may pass a cool liquid behind the panels to pull away heat and keep the panels cool. This is similar to how our body might sweat as a way to stay cool during the run at 47°C temperature.

**Effect of Shading and Clouding**

Solar modules or cells are designed to convert solar radiation (sunlight) into electricity which will then either be sold to a grid or used to charge batteries in an off-grid system. A solar panel performs best, giving the maximum output when it is directed perpendicular to the solar rays and getting the direct radiations. When a panel is blocked by a shadow either by a cloud, a chimney, tree branch, or neighbouring buildings, etc., it can reduce the performance of system as the panel is no more exposed to direct radiations and gets diffused radiations. Since the shadows are almost never evenly spread over every module in the array, mismatching outputs between modules in a string and strings in the array are induced. From the two different types of shades applied, two different effects occur.

‘Soft shading’ can be described as simply lowering the intensity of the irradiance levels, without causing any form of visible separation of shaded and unshaded regions. A great example of soft shading would be due to clouds evenly blocking out some, but not all of the sunlight. Soft shade applied on some modules in a string and not evenly to others will cause an effect called ‘current mismatch’, where the current output of each module is varied. Since the laws of electricity dictate that all components connected in series must have the same current, what typically results is the string settling on the output of the lowest-performing module, reducing the output of the entire string to that of the most heavily-shaded cell in the string. This same effect occurs independently for all strings in an array, as strings are connected in parallel. However, despite being independent to each string, current imbalance in one string can still negatively affect other strings.

Hard shading is created when a physical object, such as a telephone pole, or tree is physically obstructing the sunlight, creating obvious visible regions of lit and unlit cells on the array. Hard shade, on the other hand, causes the output voltage of the shaded modules to drop. However, when two or more strings connected in parallel have shade unevenly applied to them, an effect called ‘voltage mismatch’ occurs. Voltage mismatch is the condition in which two parallel strings are giving different voltage output when measured independently. Hence, before installing we should have the knowledge and expertise in choosing the best areas of the roof to add or maximize return on investment. The areas with constant shade obstructions must be avoided. Some shadow may affect the panel in the morning, however, but may not affect the same panel for the rest of the day—resulting in overall good performance.

**Effects of Dust and Pollution**

Dust accumulation is the crucial factor which decreases the practical efficiency of PV panels and tend to make PV systems an unattractive alternative energy source, particularly for the larger domestic markets (as the dust collected blocks the direct rays to strike the solar panels). Dust is a term generally applied to minute solid particles with diameters less than 500 μm. It is a lesser acknowledged factor that significantly influences the performance of the PV installations and occurs in the atmosphere from various sources, such as dust lifted up by wind, pedestrian and vehicular movement, volcanic eruptions, and pollution. Dust would also refer to the minute pollens of fungi, bacteria, vegetation, and microfibres from fabrics, such as clothes, carpets, linen, etc., that are omnipresent and easily scattered in the atmosphere and consequently settle as dust. The characteristics of dust settling on PV systems are dictated by two primary factors that influence each other viz., the property of dust and the local environment. The local environment comprises site-specific factors influenced by the nature of prevailing (human) activities, built environment characteristics (surface finishes, orientation, and height of installation), environmental features (vegetation type and weather conditions). The property of dust (chemical, biological and electrostatic property, size, shape, and weight) is as important as its accumulation/aggregation. Likewise, the surface finish of the settling surface of PV also matters. A sticky surface (furry, rough, adhesive residues, electrostatic buildup) is more prone to accumulate dust as it is less sticky and smoother one. It is also a well-known fact that dust promotes dust, i.e., with the initial onset of dust, it would tend to attract or promote further settlement; the surface becomes more vulnerable to dust collection. The effect of gravity, horizontal surfaces usually tend to accumulate more dust than inclined ones. This however is dependent on the prevalent wind movements. Generally, a low-speed wind pattern promotes dust settlement while a high-speed wind regime would, on the contrary, dispel dust settlement and clears it. However, the geometry of the PV system in relation to the direction of wind movements can either increase/decrease the prospects of dust settlement at specific locations of the PV system. After installing PV panels it is highly recommended to clean them on regular intervals of time for maximizing the power collection capacity and minimizing the losses.

Solar panels work best in certain weather conditions, but since the weather is constantly changing and as engineers are installing solar panels at various parts of the world in different climate regions, most panels do not operate under ideal conditions. That is why it is important for engineers to understand how panels react to different weather conditions before installing them. Thus, emphasis must be laid on a detailed study of the site considering the environmental factors as a need of the hour for captivating the maximum power output from these doped silicon panels along with the recommended measures, for a brighter and shinier future of the world.  

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**RE Feature**  
**Environment Affects Solar Power Generation**  

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Akshay Urja  
April 2016
The increased focus of the Government of India on renewable energy has been instrumental in the launching of various schemes for the creation of a skilled workforce in this sector. In this context, the Suryamitra Training Programme, is aimed at imparting training and thus, creating a workforce of skilled solar technicians. In this case study, Rajiv Kumar provides an overview of the Suryamitra Training Programme and its features.

**Suryamitra Programme: A Life Changing Journey from Unskilled to Skilled Solar Technician**

The increased focus of the Government of India on renewable energy has been instrumental in the launching of various schemes for the creation of a skilled workforce in this sector. In this context, the Suryamitra Training Programme, is aimed at imparting training and thus, creating a workforce of skilled solar technicians. In this case study, Rajiv Kumar provides an overview of the Suryamitra Training Programme and its features.
RE Feature

The instruction manual, containing the directions on safety, required tools, time management, and group dynamics, was given by the faculty to each group. The process of practical is very similar to the actual process. Practical class of four hours before lunch and three hours post lunch was also conducted. Assessment of each trainee during the practical was done by the faculty. Records of assessment are maintained for future reference and final assessment.

5. Lunch: From 1:00 to 2:00 pm, lunch is arranged in the trainee’s accommodation. Lunch contains 1 dal (legumes), 1 subzi (vegetable), roti (bread), and chawal (Rice). The menu of lunch changes from time to time.

6. Theory Session: After the practical session, a one hour theory class is conducted in a well-furnished classroom, equipped with modern classroom facilities, such as projector. The first lecture in each batch is about safety as we consider safety of each trainee to be the first priority. In each class, a demo with the help of exact tools and instruments is shown, which are used in the industry to perform the task. Most part of the lecture contains videos and PowerPoint presentations of the actual process which is performed in the industry. The schedule of training is provided in Table 1.

Assessment of Trainee

Assessment of each trainee is done by the process described as follows:

1. Daily Assessment: Daily assessment of each trainee is done by the faculty during the practical. In daily assessment, the knowledge of trainees, regarding safety and the respective process is checked. Moreover, his contribution to the group is also checked.

2. Periodic Test: Periodic tests of theory and practical in the interval of one month are taken up to assess the performance of the trainees.

3. Final Assessment: Final assessment of the trainee is carried out by the Ministry of Skill Development and Entrepreneurship (MSDE), Government of India, through an external agency. Before completion of the training, intimation to the MSDE is given through their online portal. Registration of each student is done on the online portal to generate the profile ID. Subsequently, MSDE appoints an external agency to conduct the final test. The profile ID is shared with the external agency. The external agency comes to the campus to take the test. The test paper is designed by them. The trainees have to write their responses within a limited time of one hour. Following the test, a viva and practical is performed by the trainee that is examined by the external agency. After the final assessment, results are declared by the external agency. The successful student is awarded a certificate under National Council for Vocation Training and is blessed with the vast opportunities of employment in Solar Power Project in India and abroad.

Recreation Activity

To rejuvenate the trainees, a volleyball ground is built near the accommodation and a cricket ground is located inside the training campus. Moreover, various tournaments are organized in the training campus from time to time.

Placement

Based on the requirements from the site, the alumni are called for placement and interested students are placed at the site. Preference is given based on the merit. After placement, the performance of trainees is analyzed with the help of a special feedback process.

Some highlights of the of the Suryamitra training programme are provided in Table 2.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>Date/No. of Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MNRE’s approval of the programme</td>
<td>Jan 2014</td>
</tr>
<tr>
<td>2.</td>
<td>Commencement of first batch</td>
<td>Jan 24, 2014</td>
</tr>
<tr>
<td>3.</td>
<td>Compilation of first batch</td>
<td>Apr 2014</td>
</tr>
<tr>
<td>4.</td>
<td>Total no. of students completed their training in FY 2014–15</td>
<td>103</td>
</tr>
<tr>
<td>5.</td>
<td>Total no. of students completed their training in FY 2015–16</td>
<td>155</td>
</tr>
<tr>
<td>6.</td>
<td>Total no. of students pursuing their training at CSTI Pilikhuwa</td>
<td>54</td>
</tr>
<tr>
<td>7.</td>
<td>Total no. of students placed after completion of training</td>
<td>150</td>
</tr>
</tbody>
</table>

* Till February 2014

RENTERABLE ENERGY IN ASSAM

A STATE WITH TREMENDOUS POTENTIAL

The Government of India launched the National Solar Mission (NSM) in January 2010 to accelerate development and promotion of solar energy technologies in the country. This article provides an overview of the areas of implementation of the NSM in Assam.

The Assam Energy Development Agency (AEDA) was constituted as the nodal agency for new and renewable sources of energy under the Ministry of Non-conventional Energy Sources, Gol, for the state of Assam in July 2002. In 2002, the primary objectives of the AEDA were to act as the State Nodal Agency of Ministry of Non-conventional Energy Sources in the areas of new and renewable sources of energy for the State—to initiate, promote, support, and coordinate all activities in the field of non-conventional energy sources as well as to thereby tap the potential to generate energy for various uses either industrial or domestic and especially for the rural, hilly, and border areas not connected with the conventional grid; and to disseminate information about the recent technological advancement and already available technology in the field of non-conventional and renewable sources of energy.

AEDA recognizes the great potential in renewable sources of energy in meeting the energy needs of people in a socially and environmentally sound manner. It calls for concerted efforts by governments, local institutions, NGOs, the private sector as well as the international community towards the promotion of new and renewable sources of energy. The Government of India has taken a conscious and keen interest in harnessing the country’s abundant potential of new and renewable sources of energy in partnership with stakeholders since long by taking policy initiatives through the Ministry of New and Renewable Energy (MNRE). And significant growth has already taken place during last decade due to this.
India. A 100-kWp SPV power plant was installed at Dibrugarh University, Dibrugarh, Assam, to meet the University’s power requirement by harnessing solar energy.

- **Srikishan Sarda College**: The college is situated in the Hailakandi district in Assam—a remote region. Installation of 100 kWp SPV Power Plant at Srikishan Sarda College, Hailakandi, Assam, facilitated teaching—learning process of the college with uninterrupted power supply, especially the practical classes of Science stream.

- **Common Service Centre (CSC), AMTRON**: The main objectives of CSC are:
  - CSCs are envisioned as the front-end delivery points for the government, private, and social sector services for benefit of rural populations in the remotest corners of the country through a combination of IT as well as non-IT services.
  - The aim of the Scheme is not merely to roll out IT infrastructure but to build a network of 100,000+ rural businesses across India. To that effect, the CSC Scheme has been designed to create a value proposition for all stakeholders and alignment of their economic interests.
  - The CSC Scheme is envisaged to be a bottom–up change in rural India.

- **Jorhat Government HS School**: The Jorhat Government Boys’ HS and MP School is situated in Sonarua Path, near Head Post Office, Jorhat. The electricity generated by 1 kWp SPV power plant is used directly for running electrical appliances within the school premises.

- **DC Offices and BDO Offices**: Solar Power Plant of 5 KWp capacity has been installed at each of the seven Deputy Commissioner’s Office in Assam and 1 kWp capacity has been installed at 75 BDO offices in Assam. The DC and BDO offices are carrying out there official works smoothly without any power interruption.

- **AEDA Office, Bigyan Bhawan**: The Assam Energy Development Agency (AEDA) is the state nodal agency of the MNRE, GoI, which implements renewable energy projects in Assam. AEDA has installed a 10-kWp SPV power plant for demonstration, which runs all electrical system from solar energy in the office.

- **Langpi Dehangi Rural Bank, Ulukunchi Karbi Anglong**: A 4-kWp SPV Power Plant was installed in the Ulukunchi Branch of the bank to carry out their day-to-day transactions for smooth functioning of the bank’s operations.

- **Kasturba Gandhi Balika Vidyalaya, Birisinghura Char, Dhubri**: The School administrators of Kasturba Gandhi Balika Vidyalaya, Birisinghura Char, Dhubri, used the large roof of the school building for placing the solar panels of 5-kWp Solar Power Plant. The SPV Power Plant is now generating clean solar electricity that has not only cut energy costs but makes a lasting impression on students.

- **Langpi Dehangi Rural Bank, Volkson Branch, Karbi Anglong**: After installation of the 4-kWp SPV Power Plant in the bank, the day-to-day transactions are running smoothly benefiting both the bank employees and customers.

### Implementation of the NSM in Assam

The Government of India (GoI) launched the National Solar Mission (NSM) in January 2010 to accelerate development and promotion of solar energy technologies in the country. India has high potential for generating solar power as availability of solar radiation in various parts of the country is quite good. Solar photovoltaic (PV) systems represent an attractive option due to low cost and ability to install in various sizes (KW to MW level). The MNRE has brought out various schemes for promoting solar power projects in different capacity ranges. This includes utility scale megawatt size projects as well as off-grid applications up to 100 KW.

To meet the NSM objectives, large area rooftop installations are considered as one of the potential route. In this type of systems, the generated solar power may be self-consumed. These projects are envisaged to mitigate diesel consumption, which is consumed while operating diesel generator backup. MNRE has brought out pilot scheme to promote solar PV systems with a view to demonstrate of off-grid connected and roof top solar power plants to facilitate reduction in consumption of diesel for power generation and dependency on grid power.

To establish the effectiveness of these solar systems in different locations of Assam.

### Areas of Implementation

- **Dibrugarh University**: The University is situated at Rajabheta at a distance of about 5 km to the south of Dibrugarh in north-eastern Assam. A 10-kWp SPV power plant was installed at Dibrugarh University, Dibrugarh, Assam, to meet the University’s power requirement by harnessing solar energy.

- **BDO office Boko Kamrup**

- **DC Office Diphu Karbi Anglong**

- **Langpi Dehangi Rural Bank Ulukunchi Karbi Anglong**

- **Samaria Satra Boko Kamrup**
Renewable Energy in Assam: A State with Tremendous Potential

A 5-kWp Solar Power Plant was also installed on roof of Kasturba Gandhi Balika Vidyalaya, Amri Block, Ulukunchi, Karbi Anglong, to facilitate generation of clean solar electricity for the school.

**Gaon Panchayat Offices in Jorhat:**
To facilitate carrying out the official works smoothly, 1-kWp SPV Power Plant were installed in 15 Gaon Panchayat offices in Jorhat region of Assam.

** Gaon Panchayat Offices in Kamrup:**
Installation of the ten 0.5-kWp and three 1-kWp SPV power plants in Gaon Panchayat offices has enabled them to carry out their official work smoothly.

**Chamaria Satra:**
Satras are monasteries established by Srimanta Sankaradeva (1449–1567 AD) and his followers in Assam and surrounding regions. Installation of 5-kWp SPV Power Plant has provided uninterrupted electricity supply for proper illumination. It also powers different gadgets primarily used for security for the inhabitants as well as numerous priceless treasures housed in Satara premises such as scriptures, artifacts, handis, and so on.

**Public Health Engineering Department (PHE), Dibrugarh:**
In four different areas of Dibrugarh district, 10-kWp SPV Power Plants were installed under Piped Water Supply Scheme (PWSS) to provide affordable and sustainable power to the water supply systems enabling villagers to receive continuous water supply.

**Special Area Demonstration Programme**
The Special Area Demonstration Project Scheme of the MNRE has been introduced with an objective of demonstrating application of various renewable energy systems in a project mode at places of national and international importance, including world heritage sites, heritage monuments, religious locations, and places of public interest, to create greater awareness of renewable and to supplement the energy requirement at such locations.

**Areas of Implementation**
- **Assam Raj Bhawan:**
  Raj Bhavan Assam is the residence-cum-secretariat of the Governor of Assam. The MNRE, GoI, had sanctioned the project ‘Installation of Renewable Energy Systems at Assam Raj Bhawan, Guwahati (Assam) under Special Area Demonstration Project Scheme. The objective of demonstrating application of various Renewable Energy systems in a project mode with 100 per cent funding from the Ministry is to create greater awareness of renewable energy and to supplement the energy requirement in the Assam Raj Bhawan Complex.
  Under the Project, different Renewable Energy Systems have been installed and commissioned at Assam Raj Bhawan Complex as per sanction and guideline provided by the Ministry. The Renewable Energy Systems are as follows:
    **30-kW SPV Power Plant:**
    A 30-kWp Grid Interactive SPV Power Plant has been installed successfully by AEDA through M/S Sunshine Power Product Pvt Ltd, Kolkata. Now the plant is capable for generating power and trial run have already been done. "Net Metering" facility with this power plant has already been initiated with concern authority of Government of Assam. It is expected to connect "Net Meter" with the power plant within a short period. The electricity bill of Raj Bhawan will reflect in payable amount direct reduction due to utilization of solar power.
    **6-kW Solar–Wind Hybrid Aero Generator:**
    A 6-kW solar–wind hybrid system with battery bank (3kWp Solar PV Power plant & 3 kWp Aero Generator) was installed in the Raj Bhawan Complex. The battery bank is being charged from the power generated from the solar power plant as well as Aero Generator. A power conditioning unit is also connected with the bank battery by which conversion of DC current to AC current are being done. Street lights installed under the project would be connected as lighting load with this system.

**SPV Demonstration Programme
**

**CSC, AMTRON:**
The main objectives of the CSC are:
- To develop a platform that can enable government, private, and social sector organizations to integrate their social and commercial goals for the benefit of rural populations in the remotest corners of the country through a combination of IT as well as non-IT services.
- To roll out IT infrastructure as well as to build a network of 100,000+ rural businesses across India. To that effect, the CSC Scheme has been designed to create a value proposition for all stakeholders and alignment of their economic interests.
- The CSC Scheme is envisaged to be a bottom–up model for delivery of content, services, information, and knowledge, that can allow like-minded public and private enterprises—through a collaborative framework—to integrate their goals of profit as well as social objectives, into a sustainable business model for achieving rapid socio-economic change in rural India.
- Five 0.5 kWp SPV Power Plants have been installed in each CSC of AMTRON at different locations of Assam. The service centres of AMTRON are using the power pack for providing Xerox, DTP, Internet, and photo print.

Under SPV Demonstration Programme, 1-kWp SPV power plant was installed at Rongjyangphong Mini PHC in Karbi Anglong District. The doctors can perform surgeries under the electric light and also can refrigerate injections and vaccines. Under SPV Demonstration Programme, 1-kWp SPV power plant was installed at Putsari Mini PHC in Karbi Anglong District. This has enabled doctors to perform surgeries under the electric light and also can refrigerate injections and vaccines.
A BOON FOR TURMERIC DRYING
FORCED CIRCULATION SOLAR DRYER FROM PUNJAB AGRICULTURAL UNIVERSITY

The production of green turmeric has shown significant improvement in Punjab but for its use, it has to be processed, i.e., dried, polished, and graded. As turmeric is an essential part of Indian cuisine, sustained growth in demand is expected for the product. As a part to diversify agriculture huge potential under turmeric cultivation has been envisaged. As per a simple economic estimate, one acre farm yields 80-90 quintals. For the last few years, the wholesale market price of raw turmeric is Rs 12-12 per kg whereas after processing about 5 kg of fresh turmeric yields 1 kg of dried turmeric powder and the branded turmeric powder is available at approx. Rs 200-250/kg and the unbranded is available at Rs 150/kg. At present, major portion of the produce is dried locally by spreading it on cemented floor in open exposed to solar radiation. The land area required for drying turmeric in open is large due to thin layer drying. The open sun drying has major drawbacks of slow drying and high land cost.

Polishing losses are also more for turmeric dried in open. The open sun drying is large due to thin layer drying. The open sun drying has major drawbacks of slow drying and high land cost.

To overcome the drawbacks of turmeric drying in open sun, a large forced circulation solar dryer called ‘PAU Forced Circulation Solar Dryer’ for turmeric has been designed in the School of Energy Studies for Agriculture at Punjab Agricultural University (PAU), Ludhiana as shown in Picture 1. The PAU Forced Circulation Solar Dryer has two main components, viz., greenhouse and solar air heating arrangement. The greenhouse contains tray-rack for initial drying and drying chamber for final drying of turmeric. The solar air heating arrangement has solar air heaters, connecting pipes, electric air blower, etc. The solar air heater was also designed at PAU and utilizes evacuated tubes. This solar air heater heats air efficiently to higher temperature as compared to the conventional solar air heaters. Air temperature up to 65°C can be attained in the greenhouse during turmeric drying months. The dryer needs electric energy input for electric air blower. This dryer also has control on the relative humidity of air in greenhouse for maximum utilization of the drying capacity of hot air. This dryer can be operated in batch as well as semi-continuous loading mode for better utilization of the dryer capacity. It is suggested to follow the semi-continuous mode for loading turmeric in solar dryer.

In semi-continuous mode after 3-4 drying days, fresh product can be added daily due to shrinkage of drying product in solar dryer. The first lot of dried product is removed after 8-10 drying days, thereafter the dried product can be removed daily. In semi-continuous mode this solar dryer has drying efficiency of 23-29 per cent. The drying time is reduced to almost half as compared to open sun drying. The quality parameters, viz., volatile oil content, curcumin content, colour, polishing loss, and polishing time of turmeric dried in this dryer was found to be better as compared to open sun.

The salient features of the dryer are:
- Better quality parameters of the product dried in this solar dryer as compared to open sun drying due to lesser exposure time to solar radiation.
- Product dried in solar dryer is free from dust, birds excreta, dead insects, etc.
- Lesser area required as compared to open sun drying.
- In comparison to open sun, no attention required during off-sunshine hours and in case of rain, storm, etc.
- Higher shelf life of dried product due to lower final moisture content because higher temperature air from array of solar air heaters is used for final drying.
- Heat of air in the greenhouse is better utilized by removing air only when it has high relative humidity by using automatic humidity controlled exhaust fans.
- Faster and efficient drying due to drying at higher temperature and in semi-continuous mode.

This dryer can be made to any desired capacity. A solar dryer of about 700 kg turmeric loading capacity has been designed. The designed dryer has greenhouse floor area of 6.60 m x 3.5 m and 3 m height. The greenhouse has north wall vertical and insulated with 5 cm thick thermocole insulation. For circulation of air inside the greenhouse the two air circulators are fitted inside the greenhouse. Besides exhaust fan controlled with humidity controller has been provided in one side wall of the greenhouse to maintain required humidity level. The greenhouse is covered with 200 micron UV stabilized transparent plastic sheet. Inside the greenhouse the tray racks are provided on north and south side for initial drying of product. The tray racks have 58 trays each of size 80 cm x 80 cm x 2.5 cm with wire mesh base. The drying chamber has opening at bottom for hot air inlet from solar air heater and opening at top for air outlet in greenhouse. The drying chamber has eight trays. Solar air heater with aperture area of 2 m² has been provided outside the greenhouse for heating air. The solar air heater works in recirculation mode with greenhouse and sucks in air from greenhouse for heating. The above designed solar dryer has been installed at two user locations, namely: (i) Farm Produce Promotion Society (FAPRO) Village Ghugial, District Hoshiarpur, and (ii) S Tejinder Singh, Village Kang Khurd, District Kapurthala. FAPRO is a consortium of around 300 farmers. The farmers bring their produce under the umbrella of FAPRO. The processing, packaging and then selling are done by the society. The FAPRO processes turmeric from February to June each year. They have a concrete floor of about 50 m x 50 m, on which turmeric is spread for drying in open sun (Picture 2). The solar dryer was installed at FAPRO in May 2015 and its photograph is shown in Picture 1. About 3 tonnes of turmeric was dried in this dryer from May to June 2015. The society is quite satisfied with the quality of dried turmeric. Picture 3 shows another installation of this solar dryer at the farm of Shri Tejinder Singh. Both the dryers are working satisfactorily.

On an average 50 kg of dried turmeric is removed per day by operating solar dryer in semi-continuous mode. The quality of turmeric dried in this dryer is good and comparable to branded turmeric available in the market but the total cost for dried turmeric including cost of fresh turmeric and post harvest operations is much lower. The cost of drying operation in this solar dryer is Rs 1.12 kg of dried product. The approximate cost of other post-harvest operations, viz., washing, boiling, polishing, grinding, and packaging is Rs 16 per kg approximately. This makes total cost for obtaining 1 kg of turmeric powder to Rs 80 approximately. The payback period in terms of number of drying days to recover the initial investment in comparison to branded turmeric are about 30 and those in comparison to unbranded turmeric are 50 days.
In order to meet its growing energy and power requirements, Kerala, also referred to as God's own country, has decided to allow greater private investment in setting up power plants from hydel sources. Along with active participation of the local people, the Energy Management Centre, Thiruvananthapuram, has been instrumental in setting up environment-friendly systems of development of power. In this article, G Anil presents a detailed description of the small hydro power project currently in operation in the state.

Kerala, with a population of 33 million, faces numerous challenges to meet its energy requirements in a sustainable manner. The current production of electricity is far too insufficient to meet the growing demand of the consumers. The state has enormous renewable energy potential and more than 3,000 MW of exploitable hydropower capacity. Renewable Energy Technologies (RETs) have neither attracted the requisite level of investment nor tangible policy commitment. Although some resources have been allocated for developing, adapting, and disseminating RETs in rural areas, the total impact is still insignificant and very marginal.

The aims and objectives of establishing the UNIDO project at the Energy Management Centre (EMC) is to further strengthen the Small Hydro Power related activities of the Centre. With the establishment of the UNIDO Centre, several renewable energy-related awareness building and training programmes would be conducted in order to promote and accelerate sustainable development. It will facilitate the design of cost-effective RETs, using locally manufactured equipment, materials, and labour and organizing consultancy services on comprehensive aspects of renewable energy systems and small hydro power development.

The first off-grid 110 kW micro hydel project and connected Community Development Centres in Mankulam Panchayat (Local Body) in Idukki District in Kerala was commissioned during 2004. The Hon’ble Minister for Power, Government of Kerala, Mr. Aaryadan Muhammed inaugurated the project on October 28, 2004, at 1600 hrs at Mankulam. The Community Development Centre was inaugurated by Mr A J J Rvenderie, Managing Director, UNIDO, VIENNA, Austria.

The UNIDO Regional Centre (RC) for Small Hydro Power (UNIDORC) at the Energy Management Centre (EMC), Trivandrum, initiated such an endeavour in Mankulam, the only unelectrified Panchayat and an agriculture resource-rich village in the Idukki district of Kerala, devoid of communication facilities. This was done in association with the local self-government of this Panchayat.

More than six waterfalls are available in this panchayat, all of them with power generation potential. During 2001, with the objective of generating power for the lighting needs of the local community, the Panchayat initiated implementation of a 110 kW micro hydropower scheme at Pampurrykayam, with a catchment area of 8 sq. km. After construction of the penstock line by around 2002, this project was held up due to various reasons, including lack of finance for purchase of the turbine sets.

It was in this context that the UNIDO RC at EMC identified this scheme as the potential power source for its community development initiatives in this Panchayat. The RC stepped in and brought two turbine generators of 55 kW, each from China, through UNIDO’s International Centre—the ICSHP. The Panchayat and EMC raised resources and created a 4 km stretch of 11 kV line and the RC completed the distribution network to provide power to about 250 families and other 50 establishments, including the upcoming telephone exchange, in the first phase. Limit switches are provided to help optimize the power usage within 150 watts to 175 watts, which is sufficient to provide the basic lighting and entertainment services to the local community. Picture 1 shows the front view of power house—Mankulam MHP. The total cost of this project is about ₹4.7 million and the power generation cost works out to be ₹1.63 per unit, without transmission and distribution network ($2.5 million). In addition, the RC has provided 10 computers, VSAT Internet link, and computer publications to help create a computer education centre as part of the CDC programme. UNIDO supported the establishment of five CDCs in the Panchayat. The RC will also be involved in facilitating creation of cottage/tiny industrial units in this Panchayat as its second phase, followed by further expansion of the electrical system.

In fact, this symbiotic association between a worldwide organization, UNIDO, and the local self-government made possible through the Regional Centre at EMC, Trivandrum, has given a great model to the developing world. Also, this CDC programme driven by
environmentally benign power utilizing local resources has rekindled the once forgotten and still relevant concept of self-sufficiency of our rural villages, as envisioned by Mahatma Gandhi, the Father of the Nation. The Panchayat also has the rare distinction of generating power for its own use. The project commissioned in 2004, however, lasted only for two years. Once the utility’s (Kerala State Electricity Board Limited or KSEBL) power supply reached this region, the project lost its relevance and the distribution network, along with transformers, was surrendered to the KSEB by the Panchayat. The power house was idle for almost six years since 2004.

The Energy Management Centre (EMC), under the Department of Power, Government of Kerala, technically supported the Mankulam Power, Government of Kerala, near Munnar in Idukki District, Kerala, India. Mr Aryadan Muhammed dedicated the project on May 10, 2012, at 1200 hrs at Mankulam, thus, becoming the first local body in India to sell power to the state utility—KSEB—through a Power Purchase Agreement (PPA). The plant is synchronized to the 11kV grid of KSEB through a step up transformer. The cost involved for the overhauling and grid connectivity is ~₹15 lakh. The powerhouse has two turgo impulse turbines, which can each generate 55 kW of power daily. It is located near the Pambumkyam waterfalls, just a kilometre away from Mankulam town.

This panchayat, however, lacks connectivity and lags behind in development. It has around 3,250 families, including those living in seven tribal villages. One-third of the population is made up of tribal people. The plant has a net head of 70 m and a discharge of 0.1 cumecs each. The local people have been trained to run the plant, thus, generating employment opportunities, in addition to the voltage improvements in the locality, and thereby reducing losses to the utility. The revenue thus generated by the Panchayat would be utilized for the developmental activities of the Panchayat.

The overall production estimated from the two generators is around 5.5 lakh units/year. The power purchase agreement (PPA) was signed by the Panchayat with the state utility—KSEBL, with the approval of the Kerala State Electricity Regulatory Commission (KSERC). With the Energy Regulatory Commission fixing the rate at ₹4.8/unit, the Panchayat is set to earn a gross revenue of around ₹26.4 lakh annually, minus the costs incurred for maintenance charge of ~4 per cent. The Panchayat is also planning to develop the area as a tourist spot by directing the water from the powerhouse into an area proposed for a lake. Picture 2 shows Mankulam Power house—inside view.

**IMPACT OF THIS UNIQUE PROJECT**

- Dera, as it is generally known, is a mini-township with 7,000 residents. Annually, 50 lakh people visit the place, which creates awareness about solar power green energy among the general public.
- The Government of India has set a target of 40,000 MW to be achieved by 2022 and this project is a role model, which shall encourage replication of such large rooftops on buildings/sheds.
- This project is a major catalyst for encouraging replication in other large buildings, rooftops in the country.

Features of this project are summarized in the table below:

<table>
<thead>
<tr>
<th>Project capacity</th>
<th>19.52 MWp (7.52 + 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Beas (District Amritsar)</td>
</tr>
<tr>
<td>Area covered</td>
<td>82 acres of rooftop</td>
</tr>
<tr>
<td>EPC company</td>
<td>L&amp;T and Tata Power Solar</td>
</tr>
<tr>
<td>Capital cost</td>
<td>156 crore</td>
</tr>
<tr>
<td>Project commissioning</td>
<td>April 2014 (7.52 MW) and December 2015 (12 MW)</td>
</tr>
<tr>
<td>Roof type</td>
<td>11.5 MWp installed on single roof of ACC sheets and remaining 8 MW installed on multiple roofs</td>
</tr>
<tr>
<td>Modules type</td>
<td>Poly/multicrystalline</td>
</tr>
<tr>
<td>Module wattage</td>
<td>250 Wp</td>
</tr>
<tr>
<td>Inverter rating</td>
<td>500 KW/850 KW (central type)</td>
</tr>
<tr>
<td>Grid evacuation voltage</td>
<td>132 kV</td>
</tr>
<tr>
<td>No. of solar PV modules</td>
<td>78,102</td>
</tr>
<tr>
<td>132 kV substation</td>
<td>11 kV/132 kV</td>
</tr>
<tr>
<td>Grid connectivity</td>
<td>To PSTCL 132 KV S/S</td>
</tr>
</tbody>
</table>

**WORLD’S LARGEST 11.5 MWp SINGLE ROOFTOP SOLAR POWER PROJECT**

The world’s largest 11.5 MWp single rooftop solar power project has been commissioned at Dera Beas, District Amritsar in two phases—7.52 MWp in April 2014 and 12 MWp in December 2015. This project is India largest in campus with a total capacity of 19.5 MWp. The project has been set up in record period of six months. It is evacuating power through 132 kV transmission system and is feeding power to 132 kV PSTCL grid substation Beas. The project abates 26,135 tonnes CO₂ annually.
**Workshop on**

Promotion of Solar Technologies in Himachal Pradesh under Solar City Programme

The growing need of energy and increasing environmental concern is a challenge to the mankind, hence, other alternatives of conventional resources of energy have to be explored, said Chief Minister of Himachal Pradesh Shri Virbhadra Singh after inaugurating workshop on 'Promotion of Solar Technologies in Himachal Pradesh under Solar City Programme' organized by HIMURJA and Ministry of New and Renewable Energy (MNRE), Government of India (GoI), at Hotel Holiday Home on March 5, 2016. Final master plans for development of Shimla and Hamirpur as Solar cities were approved by the MNRE.

The Chief Minister said that our country is facing an acute energy scarcity which is hampering its industrial growth and economic progress. Setting up of new power plants is inevitably dependent on import of highly volatile fossil fuels. He said that amid the growing demand for sustainable energy, the solar power technologies are on the verge of large scale global deployment for being clean renewable resource with zero emission and having tremendous potential of energy. He said that with recent developments in the field, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. He also said that final master plans for development of Shimla and Hamirpur cities, as solar cities, have been approved by MNRE, GoI. The Ministry has conveyed the sanction of 15 kWp Solar Power Plant at Panchayat Bhawan, Shimla, 20 kWp Solar Plants each at Ridge Shimla and at Old Bus Stand.

**Solar Rooftop Policy Coalition Unveils the “Scaling Up Private Investment in Rooftop Solar”**

A report titled "Scaling Up Private Investment in Rooftop Solar" was launched on March 17, 2016 by Shri Piyush Goyal, Minister of State with Independent Charge for Power, Coal, and New & Renewable Energy. The product of an in-depth study by the Solar Rooftop Policy Coalition—which consists of The Nand and Jeet Khemka Foundation, The UK Department for International Development, The Climate Group and The Shakti Sustainable Energy Foundation—the report looks at ways to increase private investment in rooftop solar in India. Authors focus on how solar on the roofs of business, institutions, and homes can be scaled up to the Government’s target of installing 40 GW of rooftop solar capacity by 2022. Rooftop solar will contribute to India’s energy security and is an important part of achieving the Government’s overall target of 175 GW of renewable energy by 2022.

Sir David King, UK Foreign Secretary’s Special Representative on Climate Change said: “India can be the game changer in the global transition to renewable energy, driving sustainable economic growth. India has achieved great things in ground-mounted solar and this report can help repeat this success in rooftop solar.” Uday Khemka, Managing Trustee, the Nand and Jeet Khemka Foundation said: “This is a really exciting time for rooftop solar which has huge potential for growth. Implementing the recommendations of this report, including addressing risks faced by investors, will contribute to sustained scale up of the rooftop solar sector and accelerated progress towards the Government’s 40 GW target for rooftop solar by 2022.”

**CAPACITY BUILDING FOR SOLAR ROOFTOP SYSTEMS IN BENGALURU AND BHOPAL**

The Energy and Resources Institute (TERI) under its Management Development Programme (MDP) organized a three-day training programme (fourth in the series) on ‘Grid-Connected Rooftop Solar PV Systems’ for channel partners, project developers, manufacturers, and new entrepreneurs from February 16–18, 2016 at TERI SRC, Bengaluru, Karnataka. The training programme was designed to enable the target groups to understand the technical, financial, and regulatory aspects of rooftop solar PV systems, including their quality standards, project management, grid-interconnection, metering arrangements, and remote monitoring mechanism.

The training programme, various practitioners and renowned industry experts from TERI, MNRE, NITI KREDL, BESC, Tata Power Solar, and Mytrah Energy shared their views and experiences on implementing solar systems. A total of 46 participants attended the training programme. The event concluded with a valedictory session and distribution of certificates to the participants. Overall, the programme was a success and was highly appreciated by the participants as well as the speakers. During the programme, the participants highlighted some issues and put forward some suggestions including: (i) More actions for remote monitoring option for solar rooftop PV Projects; (ii) Promoting the hybrid systems for overall applications (where grid is not available or is available infrequently); (iii) Support/assistance for indigenous manufacturers; (iv) ‘Make in India’ campaign for solar rooftop PV market in India; and (v) Provide electricity regulations and government orders regarding solar on SPIN website for new entrepreneurs.

TERI, on behalf of the MNRE, also organized a three-day training programme (fourth in the series) on Grid-Connected Rooftop Solar PV Systems for channel partners, project developers, manufacturers, and entrepreneurs from March 16–18, 2016 at Bhopal, Madhya Pradesh. During the programme, various practitioners and renowned industry experts from TERI, MNRE, SECIL, Madhya Pradesh Urja Vikas Nigam Limited, Bhopal Municipal Corporation, MP Madhya Krishi Vidyut Vitaran Company Limited, State Bank of India, Enerparc, and Sunkalp Energy shared their views and experiences on implementing solar rooftop PV systems. A total of 23 participants attended the training programme. The event concluded with a valedictory session and distribution of certificates to the participants. This was followed by a site visit to Grid-connected rooftop solar PV Power Plants under MP Madhya Krishi Vidyut Vitaran Company Limited.
Low-Cost Energy Saving Devices: To Boost Rural Entrepreneurship

The rural people of our country mainly depend on agriculture as India is an agrarian economy. Thus, there exists a huge mass of unemployed youth who are facing constraints to continue their existence. Rural youth can find self-employment opportunity by fabricating low-cost renewable energy technologies and energy efficient devices. In the third part of this series of articles, the author describes two simple renewable energy technologies and energy saving devices, i.e., evaporated cooler and insulated food cabinet. It is strongly believed that, if we put maximum production of these devices is taken, it would create an atmosphere of sustainable development in India.

**Energy Saving Devices**

Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. There are many motivations to improve energy efficiency. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Reducing energy use is also seen as a solution to the problem of reducing greenhouse gas emissions.

**Evaporated Cooler**

The cooler (Figure 1) operates on the principle of evaporative cooling. Thus the system decreases the temperature and increases the relative humidity in the interior of the cooler.

The door, back wall, top and bottom sides of the cooler box are fabricated by Gi sheet with 12 mm thick ply board outside layer used as insulation while two sides of the cooler box are made of layers of jute. Water from overhead PVC water tank keeps both side jute pads wet by a drip system through perforated PVC pipes. The system uses a small fan of 22 W power, which draws air through jute pads.

When suction fan draws warm air from outside through the wetted pads, water evaporates and draws energy from surroundings which produce considerable cooling effect and increases humidity inside of storage chamber.

**Insulated Food Cabinet**

The food cabinet consists of two one-side open aluminium inner boxes kept inside of a one side open Gi outer box and two-inch thick glass wool insulation is provided in between the gap of two boxes in all sides and bottom. Lower inner box is supported at its bottom by two wooden blocks. Door is provided at the open side of the inner boxes (Figure 1).

**Test Result**

Each bottom pot is filled with 2 l of hot water and each top pot is filled with 1.5 l of hot water and then pot lids are closed. Cabinet doors are closed after placing pots inside. Temperature of the hot water is measured 98°C during filling.

**Conclusion**

There are so many other designs of low cost renewable energy technologies and energy saving devices available. Techno-economic viability of such entrepreneurship on low cost renewable energy technologies will surely get social acceptance in our country.

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

*Pasteurization is a process involving heating liquids rapidly to kill harmful organisms. Interestingly, the liquid does not have to be heated to boiling point for pasteurization to occur.*

**Task**
You need to work in a small group to build a solar pasteurizer. It must be made from recycled materials and water should be heated to a temperature of 70°C for 15 minutes to be considered a successful pasteurizer.

**Material Required**
- Clear plastic drinking bottle (at least 1 or 1.5 litres)
- An aluminium can (375 ml)
- Black paint
- Thermometer
- Cardboard box (or a large piece of thick cardboard) and a 3 cm square piece of cardboard
- Aluminium foil
- Scissors and/or craft knife
- Water

**Constructing the Solar Pasteurizer**

**Step 1**
Paint the can black and set aside to dry.

**Step 2**
Cut the top off the drink bottle. Ensure that the bottle is cut at the widest point to allow the aluminium can to be fitted inside it.

**Step 3**
Cut three or more tabs (slits) in the top section of the bottle.

**Step 4**
Pierce a hole in the centre of the 3 cm square piece of cardboard and insert a thermometer through the hole—the cardboard should sit firmly around the thermometer.

**Step 5**
- Fill the can with water and place the thermometer into the can—the cardboard should rest on the top of the can and the thermometer should stick out enough to be read easily.
- Place the can inside the bottle and put the top section back on the bottle using the tabs (slits) to hold it in place.

**Step 6**
- Place the solar pasteurizer in a sunny position and record the temperature at regular intervals (on Table 1).
- If the pasteurizer is not reaching the required temperature (70°C for 15 minutes) follow the additional steps below.

**Step 7**
- Make a solar reflector out of the cardboard box (or thick cardboard).
- Cover the reflector in aluminium foil.
- If you do not want to make the reflector you can simply cover one side of the bottle with foil.

**Step 8**
Locate the reflector and pasteurizer in full sun. For maximum effectiveness make sure the shadow of the pasteurizer appears in the centre of the back panel. Rotate the reflector gently to keep the shadow in this position.

**Step 9**
Record the temperature at regular intervals (on Table 2).

<p>| Table 1: Solar pasteurizer with no reflector |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Temp. in °C</th>
</tr>
</thead>
</table>

<p>| Table 2: Solar pasteurizer with reflector (or aluminium foil) |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Temp. in °C</th>
</tr>
</thead>
</table>

Source: originenergy.com.au/energysavers

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**Children’s Corner**

See… A green building refers to a structure that is environmentally responsible and resource-efficient throughout a building’s life cycle. A green building design minimizes the balance between materials and the renewable environment. Energy-efficient lighting, solar rooftops, waste management are important components of a green building.

Yes, surely my house is a green building... Please tell me what actually is a green building?

I have built my house with all the modern amenities and services but I wonder… if I should have invested in a green building... What about you? Is your home a green building?
Urban DC Microgrid: Intelligent Control and Power Flow Optimization
1st Edition
Manuela Sechilariu and Fabrice Locment
Butterworth-Heinemann | 306 pages
Urban DC Microgrid: Intelligent Control and Power Flow Optimization focuses on microgrids for urban areas, particularly associated with building-integrated photovoltaic and renewable sources. This book describes the most important problems of DC microgrid application, with grid-connected and off-grid operating modes, aiming to supply DC building distribution networks. The book considers direct current (DC) microgrid to supply DC building distribution networks for positive energy buildings; dynamic interactions with the utility grid based on communication with the smart grid; supervisory control systems; and energy management. The global power system is exposed and the DC microgrid system is presented and analysed with results and discussion, highlighting both the advantages and limitations of the concept. Coverage at the system level of microgrid control as well as the various technical aspects of the power system components make this a book interesting to academic researchers, industrial energy researchers, electrical power, and power system professionals.

Harness the Sun: America’s Quest for a Solar-Powered Future
Philip Warburg
Beacon Press | 256 pages
In Harness the Sun, Philip Warburg takes readers on a far-flung journey that explores America’s solar revolution. Beginning with his solar-powered home in New England, he introduces readers to the pioneers who are spearheading their move towards a clean energy economy. The readers meet the CEOs who are propelling solar power to prominence and the intrepid construction workers who scale our rooftops installing panels. The readers encounter the engineers who are building giant utility-scale projects in prime solar states, such as Nevada, Arizona, and California, and the biologists who make sure wildlife is protected at those sites. Warburg shows how solar energy has won surprising support across the political spectrum. Prominent conservatives embrace solar power as an emblem of market freedom, while environmental advocates see it as a way to reduce America’s greenhouse gas emissions. Yet solar energy has its downsides and detractors too. Harness the Sun offers a grounded, persuasive vision of America’s energy future: It is a future fuelled by clean, renewable sources of power, with solar at centre stage.

GlobalData Power | http://power.globaldata.com/
GlobalData Power is the interactive research platform designed for executives and analysts active in, or supplying services to, the power and renewable energy industries. The database covers detailed information on all power technologies, such as thermal, wind, solar, hydro, nuclear, and other renewable technologies. Subscribers receive access to unique power databases, analysis on the latest news and deals, company profiles, expert opinion, and research reports. These are fully integrated with innovative desktop tools for easy search, browse, and data access. The platform enables one to rapidly find data, track companies, build custom presentations, and extract information into Word, PDF, Excel, and PowerPoint formats.

May 11–13, 2016 | New Delhi, India
2nd Smart Cities India 2016 Expo
Website: http://www.smartcitiesindia.com/

May 12–14, 2016 | Mumbai, India
LED Expo Mumbai 2016
Website: http://www.ledindia.com/

May 18–20, 2016 | New Delhi, India
Renewable Energy World India
Website: http://www.power-genindia.com/

May 18–20, 2016 | New Delhi, India
Power-Gen India & Central Asia
Website: http://10times.com/power-gen-conference

May 20–21, 2016 | Bengaluru, India
International Conference on Power, Circuit and Information Technologies
Website: http://10times.com/icpcit

May 3–5, 2016 | Milan, Italy
Exhibition and Conference: 17th Solarexpo
Website: www.solarexpo.com

May 4–6, 2016 | Sunnyside Tahoe City, USA
Utility Energy Forum
Website: http://www.utilityforum.org

May 14–15, 2016 | Mississauga, Canada
Energy Smart Show
Website: https://energysmartshow.com

May 23–26, 2016 | La, USA
AWEA WINDPOWER 2016
Website: http://www.awea.org/

May 24–26, 2016 | Shanghai, China
The 10th China (Shanghai) International Wind Energy Exhibition and Conference
Website: http://www.chinawind.biz

June 2–3, 2016 | Tokyo, Japan
Solar Asset Management Asia (Japan) 2016
Website: http://www.solarassetmanagement.asia
RENEWABLE ENERGY AT A GLANCE: INDIA

Source: MNRE

As on 31/03/2015
As on 31/03/2016

Wind Power

3,743.97
6,762.85

Solar Power

4,055.36
4,773.90

Small Hydro Power

4,418.55
2,831.33

Bio Power

115.08
115.08

Waste to Power

Total

35,776.96
42,726.77

Water mills/ micro hydel

17.21
18.71

SPV systems

234.25
453.86

Aero-generators/ hybrid systems

2.53
2.69

Biomass gasifiers (industrial)

152.05
164.24

Biomass gasifiers (rural)

17.95
18.15

Biomass (non-bagasse) cogeneration

154.47
160.16

Waste to energy

Total

1,174.50
1,329.74

Family biogas plants (nos. in lakh)

48.18
48.55

Solar water heating-collector areas (million m²)

8.82
8.90

Source: MNRE