January–March 2017

ENERGY FUTURE

The Complete Energy Magazine
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COVER STORY

SOLAR ENERGY IN INDIA

Challenges with Policies for Off-Grid Installations

PHOTOVOLTAICS FOR RURAL ELECTRIFICATION AND DIGITAL SUSTAINABILITY

An Integrated Approach is the Way Ahead

ENERGY PERSPECTIVES FOR SUSTAINABLE FOOD PROCESSING

VIEW POINT

Tapping the Sun to Meet India's Solar Target

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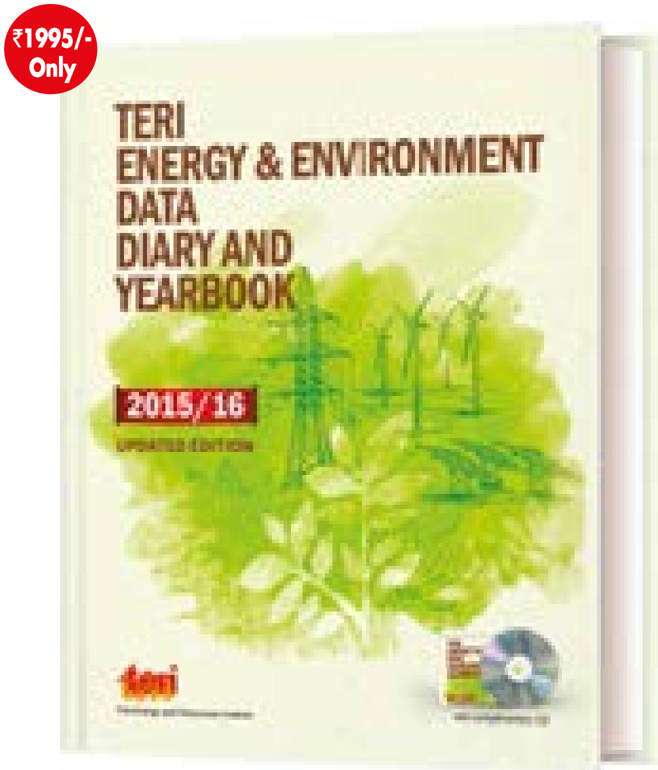
The Most Comprehensive Annual Data Diary and Yearbook on India's Energy Sector and Its Impact on Environment



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Key features

- Exhaustive compilation of data from energy supply and demand sectors
- Recent data along with data from the past years covered in the form of structured and easy-to-understand tables
- Recent advances made in the energy sectors
- Self-explanatory figures and graphs showing the latest trends in various sectors
- The "Green Focus" at the end of every chapter highlights a topical issue
- A complimentary CD that contains all the chapters and additional tables

Topics covered

Energy, environment, and sustainable development • **Energy supply:** Coal and lignite, Petroleum and natural gas, Power, Renewable energy • **Energy demand:** Agriculture, Industry, Transport, Household energy • **Local and global environment:** Environment, Climate change

For sample chapters and Sankey diagram, please visit: www.teriin.org/projects/teddy

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From the editor's desk...

The last couple of years have been remarkably good for renewable energy despite historically low oil prices as well as decreasing coal prices globally. As per *Renewables 2016: Global Status Report* of REN 21, the year 2015 witnessed an addition of about 147 GW of renewable power capacity, the largest annual increase ever. And, it is not only renewable electricity but renewable heat capacity too increased by around 38 GW. It further reports that 'The solar PV market was up 25% over 2014 to a record 50 GW, lifting the global total to 227 GW. The annual market in 2015 was nearly 10 times the world's cumulative solar PV capacity of a decade earlier.' As far as solar water heating is concerned, the cumulative capacity was around 435 GW in 2015. And under the recently ratified Paris Agreement, renewable energy is not only the cornerstone of Nationally Determined Contributions (NDC) of most of the countries, but several countries are also aspiring to have 100% of their energy demands being met through renewables.

Over the years, cost of renewables, particularly solar photovoltaic has come down drastically and with expected reduction in energy storage, i.e., battery costs, by 2025, there is strong likelihood of despatchable solar energy becoming cheaper than conventional grid electricity. Bloomberg's *New Energy Outlook 2016* forecasts that solar PV costs would fall by as much as 60% by 2040. Given the focus on clean energy as new normal and race to make variable renewable electricity truly despatchable in nature, natural gas could play a significant role. On the one hand it may become a 'transition fuel' and on the other hand it could help balance the grid with quick ramping up or down in synchronization with solar and wind energy generation. One thing is clear, energy sector is all slated to become much cleaner—and more efficient sooner rather than later. *Energy Future* seems to be heading towards a stage when today's 'non-conventional' becomes conventional!

Amit Kumar
Senior Director, Social Transformation, TERI
&
Dean (Distance & Short-term Education), TERI University

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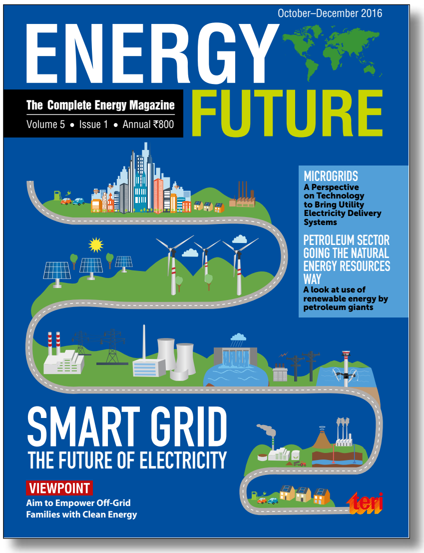

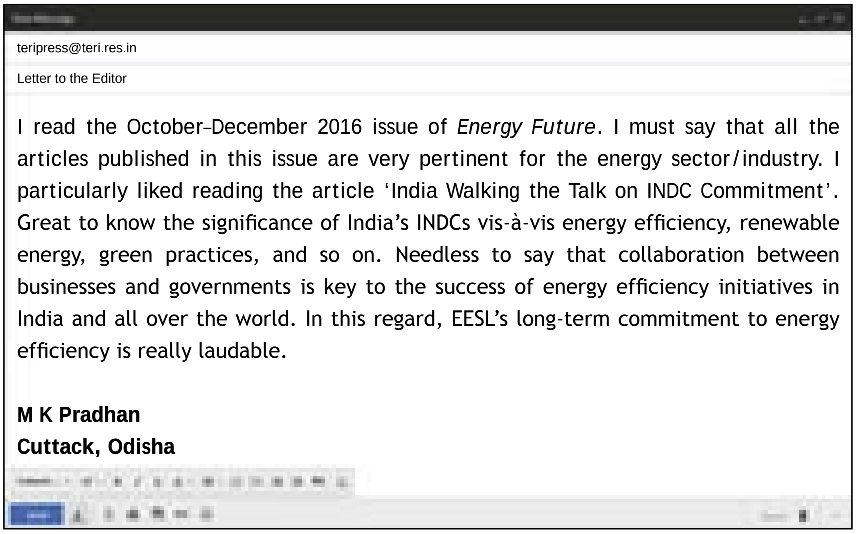
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Letter to the Editor

I read the October–December 2016 issue of *Energy Future*. I must say that all the articles published in this issue are very pertinent for the energy sector/industry. I particularly liked reading the article 'India Walking the Talk on INDC Commitment'. Great to know the significance of India's INDCs vis-à-vis energy efficiency, renewable energy, green practices, and so on. Needless to say that collaboration between businesses and governments is key to the success of energy efficiency initiatives in India and all over the world. In this regard, EESL's long-term commitment to energy efficiency is really laudable.

M K Pradhan
Cuttack, Odisha

"The latest issue of Energy Future makes for a gripping reading. I mean the Cover Story on smart grids is such an elaborate and informative article that I have kept it as a ready reference material on smart grids. Similarly, it was a pleasant revelation of sorts to know that petroleum sector is now going the natural energy resources way. Good to note that the Indian petroleum sector may enhance its utilization of renewable energy manifold as there is no other viable alternative but to have a judicious energy mix so as to reap the maximum possible dividends regardless of the traditionally held beliefs about a certain technology area.

Akshar Godhania
Ahmedabad, Gujarat"

"I liked reading the Case Study published in the October–December 2016 issue of *Energy Future* on 'Floating Solar Power Plant'. This I think is a really novel solution/initiative to develop solar plants in spite of the scarcity of adequate land space. I also recently read in the media that a company has come up with a smart way to build and deploy solar power plants without gobbling up precious agricultural land in space-challenged Japan—by building the plants on freshwater dams and lakes. The situation is ditto for India. Nevertheless, there are encouraging signs in India with the successful initiative at Rajarhat Newtown in Kolkata.

Chaitali Dasgupta
Kolkata, West Bengal"

"I am pursuing a PG course on Energy Studies and I look forward to read the magazine after every three months. It was wonderful to note that you have started incorporating articles on Petroleum, Oil, and Natural Gas sectors also. It was understandable that lately there was so much emphasis on India's renewable energy installation target (clearly put in its INDCs) that you also published quite a few articles on the renewable energy aspect. But, now with prominent articles on other sectors would make *Energy Future* a complete 'energy' magazine in all respects. Kudos and best wishes to your editorial team.

Niharika Dubey
Lucknow, Uttar Pradesh"

Thank you very much for your encouragement. The editorial team of Energy Future will ensure that the magazine caters to your information and knowledge needs. We welcome your suggestions and comments to further improve our content and presentation.

Email: teripress@teri.res.in

Editor
Energy Future

Errata

In the previous issue (Volume 5, Issue 1, October–December 2016), the affiliation of the authors for one of the articles was missing. The article 'Torrefection: Option for cleaner cooking solution' was written by Paltu Acharjee, Fellow, and Avishek Goel, Research Associate, Renewable Energy Technology Applications, TERI. Email: paltu.acharjee@teri.res.in

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RENEW LEADS THE PACK IN BAGGING ROOFTOP SOLAR PROJECTS

Having bagged 49 MW of projects across different states and under different models of financing, ReNew Power is the biggest winner among the hundreds of solar developers who have been allotted parts of the Solar Corporation of India's (SECI) mega tender of 500 MW of solar rooftop projects. SECI floated the tender in April 2016 to give a fillip to rooftop solar projects in the country, whose development has been relatively slow so far. Of the 8727.62 MW of grid-connected installed solar capacity in the country, rooftop solar is barely around 500 MW.

Of the 500 MW, 400 MW were allotted to large projects in the range of 25–500 kW and 100 MW to small ones below 25 kW. The 400 MW of large projects were divided between 200 MW to be built under the Capex model, where the rooftop owner also owns the solar plant and the remaining 200 MW under the Resco model, where the developer builds and owns the plants while the property owner is paid a tariff for the power produced. The Resco model has proved the least popular; among the larger players, only ReNew Power has shown enthusiasm for the Resco model, with 26.9 MW of its 36.1 MW won in this category. Among states, in both categories, the northern ones have attracted the maximum response. EF

Source: http://economictimes.indiatimes.com

OIL FIRMS PLAN TO SET UP SEVEN 2G ETHANOL UNITS FOR ₹4000 CRORE

State-run fuel retailers Indian Oil Corp. Ltd (IOCL), Bharat Petroleum Corp. Ltd (BPCL), and Hindustan Petroleum Corp. Ltd (HPCL) will set up around seven so-called second generation (2G) ethanol plants across the country. The plants will be set up at a cost of ₹4000 crore and will help enhance ethanol availability for blending with petrol.

2G ethanol is produced using non-edible agricultural waste left over after harvesting. Currently, technology is available to convert cellulose into sugar, which can later be fermented to form ethanol. These plants will come up at locations close to farm lands, in order to reduce costs.

In September 2016, IOCL tied up with Pune-based Praj Industries Ltd to build three 2G bio-ethanol plants with technology developed by Praj. The country is targeting a more than seven-fold expansion in its biofuel market in the next six years, Minister of State for Petroleum & Natural Gas Shri Dharmendra Pradhan said on August 10, 2016.

Union minister Shri Nitin Gadkari had said the government will soon come up with a new policy on non-conventional resources as it plans to take up ethanol blending in petrol to 22.5% and in diesel to 15%. He added that this could reduce India's annual crude oil imports bill of ₹7 trillion. EF

Source: http://www.livemint.com

MORE THAN 20 COUNTRIES SIGN INTERNATIONAL SOLAR ALLIANCE

The International Solar Alliance (ISA), brainchild of Indian Prime Minister Shri Narendra Modi, moved to a next level when more than 20 countries, including India, France, and Brazil, signed its framework agreement on side-lines of the UN climate conference (COP22) in Marrakech, Morocco.

More countries are expected to join it formally in coming weeks. The ISA will enter into force once 15 countries ratify it after completing their respective domestic processes. It will help these countries to bargain their positions as a group to get low-cost finance and technology to boost solar energy.

The Alliance is expected to achieve the objective of the Paris Agreement, which emphasizes on moving towards renewable energy. The Alliance has been envisioned as a dedicated platform that

will contribute towards the common goal of increasing utilization and promotion of solar energy and solar applications to help the world transition to a low-carbon and greener society. EF

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

COAL BETTER THAN RENEWABLES FOR INDIA: WCA CEO BENJAMIN SPORTON

India's goal of reducing carbon emissions and supplying affordable electricity to nearly 237 million people with no access to power is best served by coal-based power plants using the latest technology, rather than renewable energy projects, which are less reliable and have huge additional costs, a top official at a global organization of coal miners said. Benjamin Sporton, chief executive of London-based World Coal Association, said high-end coal-based power plants using advanced technology will be as environmentally friendly as a renewable power project of similar investments, and yet produce about four times more power. Considering that solar and wind power projects are intermittent due to weather conditions, these sources of energy need systems to manage this unpredictability, which will add to the actual cost of power generation.

India has set a renewable energy capacity target of 175 GW by 2022, but has maintained that coal will continue to play a leading role in the energy basket as it is abundantly available in the country. As per WCA estimates based on planned and under-construction projects in India, coal-based power generation in the country will rise significantly in absolute terms by 290 GW in 20 years, although its share in the energy basket will decline slightly. At present, about 60% of the country's over 307 GW of power generation capacity is based on coal. EF

Source: http://www.livemint.com

ABB INDIA, IIT MADRAS TO DEVELOP MULTI-VILLAGE MICROGRID MODELS

To strengthen UAY (Uchhatar Avishkar Yojana) scheme, ABB India and IIT Madras will collaborate to develop a power management system to optimize the operation of multiple microgrids, with and without grid connection, while managing electricity supply to villages.

This system will also enable the integration of individual solar photovoltaic (PV) rooftops to a village microgrid. The government is looking at a generation capacity of 40 GW in the next five years through grid-connected rooftop solar PV and small scale solar PV plants. Such clusters have the capability of generating and using renewable energy locally from one kilowatt to a few hundred kilowatts. It is imperative to network such locally distributed nano or microgrids for optimal usage of renewable power across users, keeping in mind the dynamic demand/supply situation. Such interconnection and interleaving of microgrids with the existing distribution system and infrastructure will provide economic benefits for the people, in terms of reduced outages and lower cost of power. EF

Source: http://economictimes.indiatimes.com/

GOVERNMENT PLANS TO BOOST SETTING UP OF BIOMASS POWER PLANTS

There is a renewed interest in biomass power plants, which can not only generate electricity but also help dispose of agriculture waste, burning of which in Punjab and Haryana is partly blamed for the alarming levels of pollution Delhi is experiencing.

The government already provides financial assistance of ₹20 lakhs per MW for setting up biomass power plants, and ₹15 lakhs per MW for cogeneration projects by sugar mills. Such plants cost around ₹4.5–6 crore per MW, while generation expense is around ₹3.25–4.00 per kWh. They are also entitled to concessional import and excise duties while acquiring equipment, as well as a tax holiday for 10 years.

Unlike sun and wind energy, this segment has been languishing in India. At the end of 2015/16, the country's total biomass power installed capacity (along with cogeneration units) was 4831.33 MW, with another 1150 MW under construction. Capacity addition has in fact slowed in the past three years, from 465.6 MW in 2012/13 to 412.5 MW in 2013/14, 405 MW in 2014/15 and 400 MW in 2015-16.

The main reason for biomass power's stagnation is that for many years the feed-in tariff offered by the states for biomass power was too low. Thus, banks and financial institutions were wary of lending for biomass projects. Another big hurdle has been the absence of a regular supply chain, since agricultural waste is readily available only during the two or three post-harvest months after which it becomes increasingly expensive. EF

Source: http://economictimes.indiatimes.com/

ENERGY PUSH: BATHINDA GETS SOLAR POWER PLANT

Deputy Chief Minister Sukhbir Singh Badal inaugurated a 100-MW solar power plant at Sardargarh village in November 2016. He said this was the country's biggest horizontal single axis tracker plant at a single location and would be instrumental in changing the face of the state.

Set up by the Adani group, the plant costing ₹640 crore would prove to be a game changer for not only 232 farmers, who have given their land on lease for the project but would also act as a perfect example for other regions to follow, he added.

"Solar energy is the future of Punjab. The investment in the solar power sector has increased from a meagre ₹82 crore in 2012 to ₹10 000 crore today. Our focus is to bridge the gap between rural and urban areas of Punjab in the next five years," he claimed.

In the next five years, all 12 000 villages of the state would be provided with sewerage facilities, solar lights and concrete streets at a cost of ₹35 000 crore, he added. EF

Source: http://www.tribuneindia.com

LED TUBE LIGHTS WILL NOW TAKE SAVING OF POWER TO THE NEXT LEVEL

In a bid to reduce the consumption of electricity and because of their higher efficiency, power-starved Karnataka recently promoted LED (light-emitting diode) bulbs in a big way. Buoyed by the success of that 'experiment', the state is now taking power saving to the next level. To achieve better lighting while consuming lesser power, the Energy department has begun promoting LED tube lights.

Its LED bulb distribution programme was oriented towards tier-2 cities. The government will now distribute LED tube lights at subsidised prices in bigger cities, as the demand for them is huge in cities like Bengaluru.

Minister for Energy, Government of Karnataka, Shri D K Shivakumar said, "LED bulbs have been a huge hit in rural areas. Considering that urban people, especially in Bengaluru use tube-lights instead of bulbs for lighting purpose, we have decided to distribute LED tubelights in Bengaluru and other urban centres in the coming days."

Revealing that the tube lights will be given out to public at an affordable cost, the minister said, "A tubelight would cost you about ₹750 in the open market. However, it will be supplied to consumers at a subsidised cost of ₹250 per light on showing of the electricity bill. Further, the costs of the lights vary according to their wattage and it will be done through an EESL (Energy Efficiency Service Limited) programme." EF

Source: http://bangaloremirror.indiatimes.com

MICROSOFT SIGNS BIGGEST WIND POWER BUY FOR DATA CENTRE

Microsoft Corp. committed to its largest wind-power purchase to date with a deal to buy 237 MW of capacity from projects in Wyoming and Kansas.

Allianz Risk Transfer AG's Bloom Wind Project in Kansas and Black Hills Corp.'s Happy Jack and Silver Sage wind farms in Wyoming will provide all of the power needed by a data centre in Cheyenne, Wyoming, under two long-term contracts cover.

Under a new arrangement with Black Hills' utility in Wyoming, backup generators at the data centre will be available as a secondary resource to provide power to the local grid when needed. That means the utility can avoid building a new power plant.

Microsoft's data centres will get about 44% of their electricity from wind, solar, and hydro-power sources this year and 50% in two years, Smith said. The company already has deals for 20 MW of solar power and 285 MW of wind, according to the blog post. EF

Source: www.bloomberg.com/news

FIRST PHASE OF SARULLA GEOTHERMAL PLANT SET TO BEGIN OPERATIONS IN JANUARY '17

Ormat Technologies expects to begin commercial operations in January 2017 for the first 110-MW phase of its Sarulla geothermal power plant in Tapanuli Utra, North Sumatra in Indonesia, Ormat CEO Isaac Angel said.

Ormat, as part of an owners consortium with PT Medco Energi International, Itochu and Kyushu Electric, is developing the Sarualla project in three 110-MW phases.

"For the second phase [of the Sarulla project], engineering and procurement has been substantially completed, site construction is in progress and all of the equipment to be supplied by Ormat was delivered," Angel said. "For the third phase, engineering and procurement is still in progress, construction work at the site is in progress and manufacturing of equipment to be supplied by Ormat is underway as planned."

He added that drilling activities for the second and third phases are still going on. Operation of the second and third phases is expected to commence within 18 months after the commercial operation of the first phase. EF

Source: http://www.renewableenergyworld.com

TESLA SEALS $2 BILLION SOLARCITY DEAL

Elon Musk's Tesla Motors Inc. officially moved beyond cars and became a clean-energy company, as shareholders overwhelmingly approved the acquisition of SolarCity Corp. The deal, valued at about $2 billion, will integrate the maker of all-electric cars and batteries with the installer of rooftop solar panels. More than 85% of Tesla shares voted in favour of the merger.

The deal, which sparked controversy over debt and corporate-governance concerns, is a win for Musk's vision of Tesla as one-stop shopping for consumers eager to become independent of fossil fuels. Now comes the task of integrating two companies that have a track record of fleeting profits and frequent fundraising needs. Tesla plans to leverage its formidable brand and retail network with SolarCity's network of rooftop solar installers and recently announced a "Solar Roof" product. SolarCity is expected to cease being a stand-alone brand, as Tesla markets its Powerwall battery for the home as a Tesla Energy Product. EF

Source: www.bloomberg.com

SAUDIS, CHINESE TEAM UP TO BUILD 170 MW OF SOLAR POWER IN MOROCCO

Saudi Arabian renewables developer Acwa Power International and China's Chint Group Corp Ltd. were chosen to build as much as 170 MW of solar projects in Morocco.

The programme will consist of three photovoltaic projects, all with an electricity price of 4.22 Euro cents (4.52 US cents) a kilowatt-hour, according to an e-mailed statement from Morocco's renewable energy agency known as Masen. The Noor Ouarzazate IV project will have a maximum capacity of 70 MW, Noor Laayoune will have 80 MW and Noor Boujdour will have 20 MW.

The projects will be financed by Germany's KfW and with a green bond issue by Masen, the first in Morocco. The German development bank will provide 60 million Euros. The bonds raised 1 150 million Dirhams ($114 million) and were underwritten by Al Barid Bank, Attijariwafa Bank, the Caisse Marocaine de Retraite, and the Central Society of Reinsurance.

Morocco is targeting 52% of its energy generation from renewable sources by 2030. It's the only country in North Africa without significant fossil fuel reserves and imports over 90% of its energy. EF

Source: www.dailyhunt.in/news

GOOGLE TO BE POWERED 100% BY RENEWABLE ENERGY FROM 2017

Google's data centres and the offices for its 60 000 staff will be powered entirely by renewable energy from next year, in what the company has called a 'landmark moment'.

The internet giant is already the world's biggest corporate buyer of renewable electricity, last year buying 44% of its power from wind and solar farms. Now it will be 100%, and an executive said it would not rule out investing in nuclear power in the future, too.

Technology companies have come under increasing scrutiny over the carbon footprint of their operations, which have grown so fast they now account for about 2% of global greenhouse gas emissions, rivalling the aviation industry.

The company's biggest demand for energy is its data centres, and it admits their overall thirst for power is growing, despite experiments to improve their efficiency through AI.

The company's 100% renewable energy does not mean Google is getting all its energy directly from wind and solar power, but that on an annual basis, the amount it purchases from renewable sources matches the electricity its operations consume. EF

Source: www.theguardian.com

10-MW LANGTANG KHOLA SMALL HYDRO-POWER PROJECT IN NEPAL RECEIVES FINANCING

A consortium of banks has agreed to finance about ₹1.60 billion (US$23.7 million) for the 10-MW Langtang Khola hydro-power project on the Langtang River located in the Rasuwa district in the Himalaya region of Nepal.

The consortium, led by Nepal-based Sunrise Bank Ltd, includes Sidhhartha Bank Ltd, Nepal Credit and Commerce Bank Ltd, and Janata Bank Nepal Ltd.

The project's total cost is estimated to cost about ₹2.17 billion ($32.16 million), and Multi Energy Private Ltd is developing the project.

In 2014, Nepal Electricity Authority (NEA) cancelled the power purchase agreements of nine hydro projects including Langtang, saying they did not submit progress reports and did not begin the construction process. But, in September 2015, NEA's Department of Electricity Development issued a license for the project, which is valid until 2051, according to NEA. Hydropower is major source of electricity in Nepal and according to the company, Nepal has a theoretical generating potential of producing 83 GW of hydro-power. EF

Source: http://www.hydroworld.com/

STATOIL WINS US WIND LEASE SALE OFF NEW YORK

The US government's Atlantic Wind Lease Sale 6 for 79 350 acres offshore New York was held in December 2016, with Norway's Statoil being declared the provisional winner.

The New York lease area consists of five full Outer Continental Shelf blocks and 143 sub-blocks. It starts approximately 11.5 nm from Jones Beach, NY, at its westernmost point, extending approximately 24 nm southeast at its longest portion.

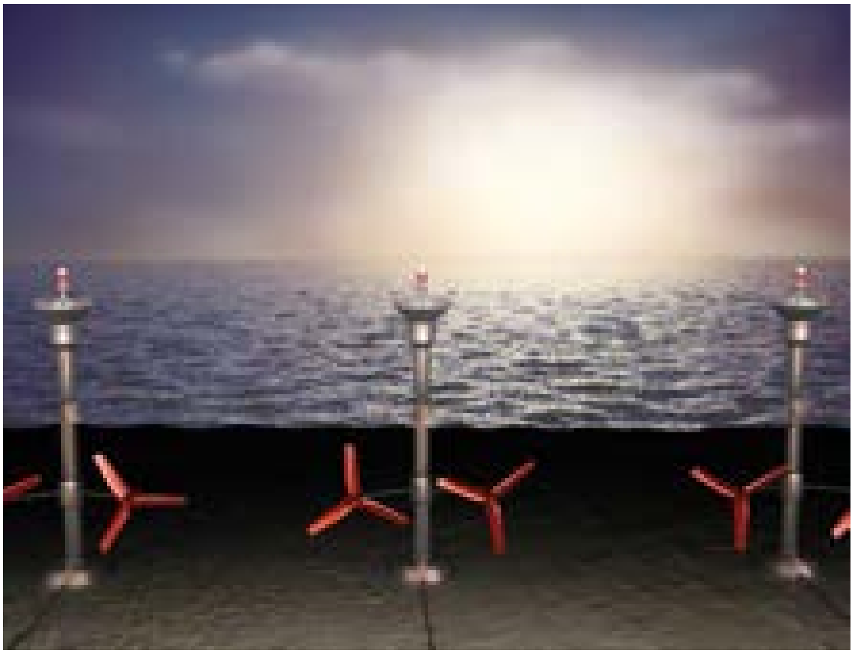
With Statoil being the provisional winner, the Norwegian giant said it will now have the opportunity to explore the potential development of an offshore wind farm to provide New York City and Long Island with a significant, long-term source of renewable electricity.

Statoil will next conduct studies to better understand the seabed conditions, the grid connection options and wind resources involved in the lease site.

Over the past eight years, BOEM has fostered offshore renewable energy development through a collaborative state-federal process to identify wind energy areas and hold competitive lease sales. To date, BOEM has awarded 11 commercial wind leases, including nine through its competitive lease sale process. These lease sales have generated more than $16 million in winning bids for more than 1 million acres in federal waters. EF

Source: http://www.oedigital.com

FIRST POWER BEGINS FROM MAJOR UK TIDAL POWER PROJECT MEYGEN



Following its recent installation, first power has been achieved from a 1.5-MW turbine in the MeyGen tidal power project in Scotland.

The 6-MW capacity of Phase 1a pales in comparison to the full scope for the MeyGen project though. Speaking to Renewable Energy World, Tim Cornelius, CEO, Atlantis Resources, said, "We're underway with a very successful construction campaign offshore with installation of the first four 1.5-MW turbines within Phase 1a. Installation is due to be completed before the end of the year."

He said that this part of the installation is only the precursor to rolling out the rest of the array to about 261 turbines in total. "With capacity of 398 MW, it will be the largest tidal array in the world. We expect to announce first power towards the end of this year," he said.

Beyond question, tidal power stands to grow into a major source of clean, reliable power generation. It is estimated that in the UK alone there is a technical resource of 29 TWh of energy per year available in tidal currents, of which 11 TWh is found in the tidal flows of the Pentland Firth. EF

Source: http://www.renewableenergyworld.com

SOLAR ENERGY IN INDIA

Challenges with Policies for Off-Grid Installations

Easy and affordable availability of energy is the benchmark of development. Conventional sources of energy are fast depleting, and their use has adverse environmental effects. The challenge before the Government is to ensure supply of affordable energy for sustainable economic and human development while preserving the environment. In this regard, harnessing energy from sun affordably is essential. The Government of India has announced an ambitious solar target and is one of the leading nations in International Solar Alliance. **Meenal Jain**, **Dr Meenakshi Mital**, and **Prof. Matt Syal** discuss the need for solar in India and the steps taken towards achieving clean energy from sun.

Energy Scenario in India

Climate change is one of the key challenges that we are facing in this century. Climate change, as a phenomenon caused by historical concentration of greenhouse gases (GHGs) in the atmosphere over a period of time, is a cause of concern for the entire global community. Its effect on developing countries is particularly adverse as their capacity and resources to deal with this challenge is limited. At the same time, energy use, which is the primary source of global GHG emissions, is increasing at unprecedented rates. This poses a serious dilemma in front of the country that can only be reconciled with new and improved clean energy technologies to balance climate change mitigation and increased energy needs.

The reliance of the world on fossil fuels and their increasing consumption has led to the present scenario. Unless the issue of energy with all its implications is dealt with, the issue of climate change would not be solved. Future economic growth crucially depends on the long-term availability of energy from sources that are easily accessible. Today, India can well be identified as an energy guzzler. The demand for power is growing exponentially, and the scope of growth of this sector is immense. India is spread over a geographic area of 3.28 million km^2, occupying almost 2.3% of the world's land area, and holds nearly 18% of the world's population. Thus, the nation is under great stress to ably maintain a sustainable development pathway.

The energy sector in the country has witnessed a rapid growth, with total installed capacity of electricity generation expanding from 42 584.72 MW at the end of the Sixth Plan to 288 664.97 MW by the end of the Twelfth Plan (February 2017). Despite impressive growth in the generation capacity since independence, India has always experienced shortage in terms of peaking capacity requirement. Table 1 summarizes the energy shortage in India over the years.

The country lacks sufficient domestic energy resources, particularly of petroleum and natural gas, and must import much of its growing requirements. Moreover, inadequate coal supplies could delay India's power generation plans, thereby derailing the country's economic growth. Hence, it is crucial that India builds its own capacity and reduce dependence on imports. It is essential for India to shift to renewable energy sources to confront the challenges of climate change and energy security in India. However, it is seen that renewable energy in India is still in its nascent stage, and it is crucial to understand the issues associated with the same.

India presently has severe electricity shortage. It needs massive additions in capacity to meet the demand of its rapidly growing economy as well as population. As already mentioned,

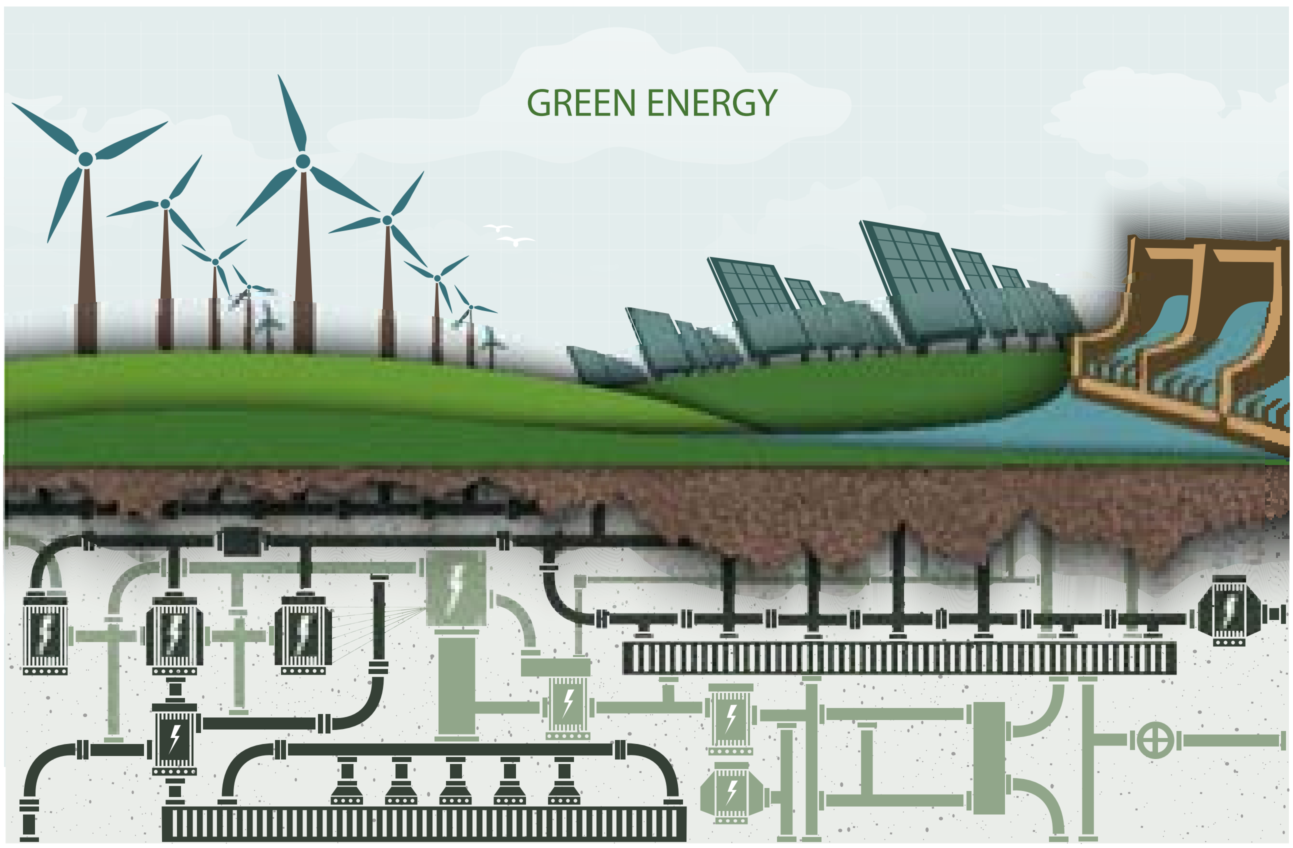


Table 1 Demand–supply gaps for electricity in India

Period	ENERGY (BU)			PEAK (MW)		
	Requirement	Availability	Shortage (%)	Demand	Demand Met	Shortage (%)
2001–02 (end of the Ninth Plan)	522.54	483.35	35.19 (7.5)	78 441	69 189	9 252 (11.8)
2006–07 (end of the Tenth Plan)	690.59	624.50	66.09 (9.6)	100 715	86 818	13 897 (13.8)
20011–12 (end of the Eleventh Plan)	937.20	857.89	79.31 (8.5)	130 006	116 191	13 815 (10.6)
2012–13 (April–September)	499.73	457.32	42.41 (8.5)	135.45	123.29	12.16 (9.0)
2013–14 (April–September)	512.14	487.72	24.42 (4.8)	135 561	129 269	6 292 (4.6)

Source: Adapted from 'Annual Report 2013–14', Power and Energy Division, Planning Commission, Government of India, 2014.

India has been dependent on fossil fuels, such as coal, oil, and gas for its energy requirements. It is evident by the fact that coal accounts for almost 55% of the country's total energy supplies, and about 75% of the coal in the country is consumed in the power sector. At the same time, continuation of the use of fossil fuels is set to face multiple challenges, such as depletion of fossil fuel reserves, global warming and other environmental concerns, continued and significant fuel price rise, and so on. Given this scenario, it is of paramount importance that the country develops all possible domestic energy sources. Therefore, renewable energy is the solution to these growing energy challenges as they are abundant, inexhaustible, and environmentally friendly. The key drivers for renewable energy are factors such as the existing demand–supply gap, a large untapped potential, concern for the environment, the need to strengthen India's energy security, and viable solution for rural electrification. Accelerating the use of renewable energy is also crucial for India to meet its commitments towards reducing carbon emissions. On an average, every 1 GW of additional renewable energy capacity reduces CO_2 emissions by 3.3 million tonnes a year. Investing in renewable energy would enable India to develop globally competitive industries and technologies that can provide new opportunities for growth and leadership.

Diversification of fuel sources is imperative to address energy security, climate change, and sustainable development issues. Furthermore, too much reliance on non-renewable sources to generate power is also unviable in the long run. Thus, it is essential to address the energy crisis through extensive utilization of the abundant renewable energy resources, such as biomass energy, solar energy, wind energy, geothermal energy, etc.

Status and Potential of Renewable Energy Sources in India

As per the Ministry of New and Renewable Energy (MNRE) in India, renewable energy has a share of 13% in the country's total installed power generation capacity. Figure 1 illustrates the energy mix of India for the year 2015.

As per MNRE, India is the fourth largest country with regard to installed power generation capacity in the field of renewable energy. Wind, hydro, biomass, and solar are the main renewable energy sources in India. The country has an estimated renewable energy potential of around 147 615 MW from commercially exploitable sources, which includes 102 772 MW from wind, 84 044 MW from hydro, and 18 000 MW from biomass/bioenergy. In addition, India has the potential to generate 35 MW/km^2 using solar photovoltaic and solar thermal energy. Table 2 summarizes the potential and installation base of various renewable energy sources in India from 2012 to 2016.

It is evident from Table 2 that all renewable energy sources have huge untapped potential. Moreover, with the increased targets for renewable energy by the government (175 GW to be achieved by 2022), it has become imperative to tap these resources to their entirety.

AS PER MNRE, INDIA IS THE FOURTH LARGEST COUNTRY WITH REGARD TO INSTALLED POWER GENERATION CAPACITY IN THE FIELD OF RENEWABLE ENERGY. WIND, HYDRO, BIOMASS, AND SOLAR ARE THE MAIN RENEWABLE ENERGY SOURCES IN INDIA.

Table 2 Potential and installation base of renewable sources of energy in India

Renewable Source of Energy	Potential (MW)	Installation Base (MW)		
		2012	2014	2016
Solar energy	748 980.00	1 282.00	2 390.00	8 505.00
Wind energy	102 772.00	18 420.40	21 996.78	26 769.00
Hydro power	84 044.00	34 640.00	38 690.00	45 000.00
Biomass	18 000.00	4 067.87	4 781.21	4 831.33

Source: Adapted from various MNRE sources: Retrieved from http://mnre.gov.in/mission-and-vision-2/achievements/; http://mnre.gov.in/schemes/grid-connected/biomass-powercogen/; http://mnre.gov.in/file-manager/akshay-urja/march-april-2016/EN/52.pdf; http://mnre.gov.in/file-manager/akshay-urja/november-december-2014/EN/52.pdf; http://mnre.gov.in/file-manager/akshay-urja/november-december-2012/EN/52.pdf

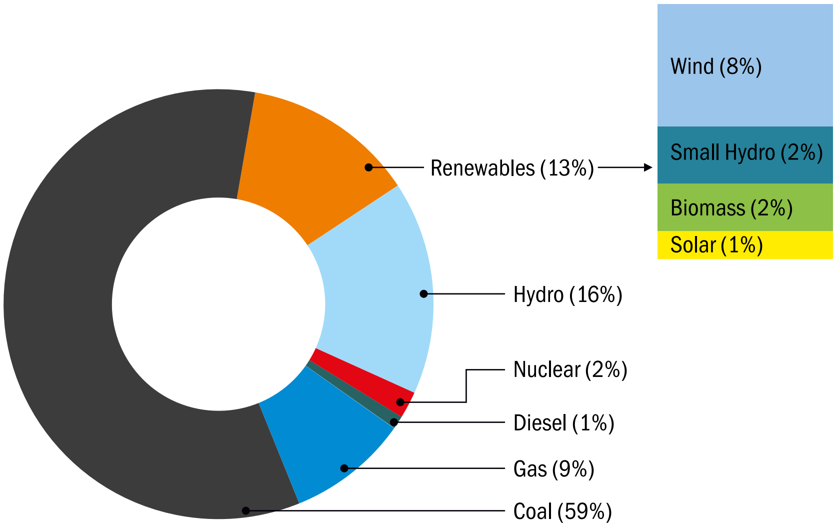


Figure 1 Energy mix for India.

Source: Adapted from CEA, 2015, as cited in "How India is gearing up to meet 100% Power Requirement?" by M. Mittal, 2015, Retrieved from https://www.linkedin.com/pulse/how-india-gearing-up-meet-100-power-requirement-madhur-mittal

Solar Energy: The Shining Future of Renewables

Among the renewable energy sources, solar power has been seen as one of the most important sources of clean power generation in the country. Its significance is manifested by the fact that the National Action Plan on Climate Change has 'solar mission' as one of the eight missions to address climate change in India. Most parts of India witness 300–330 sunny days in a year, which is equivalent to over 5 000 trillion kWh per year—more than India's total energy consumption per year. As per the new targets laid by the Government of India, India is expected to have an installed capacity of 100 GW through solar. As per Ernst & Young's Renewable Energy Attractiveness Index, India is among top five destinations worldwide for solar energy development. Because of India's location between the Tropic of Cancer and the Equator, India has an average annual temperature that ranges from 25°C to 27.5°C, which shows that India has huge solar potential.

MOST PARTS OF INDIA WITNESS 300–330 SUNNY DAYS IN A YEAR, WHICH IS EQUIVALENT TO OVER 5 000 TRILLION kWH PER YEAR—MORE THAN INDIA'S TOTAL ENERGY CONSUMPTION PER YEAR.

Why Off-grid?

A key opportunity for solar power lies in off-grid/decentralized applications. In remote and far-flung areas where grid penetration is neither feasible nor cost effective, off-grid solar energy applications are cost effective. They ensure that people with no access to light and power move directly to solar, leap-frogging the fossil fuel trajectory of growth. An off-grid/decentralized solar collection scheme is far more energy efficient than a grid-connected or centralized one. More than 30% of electricity is lost in transmission and distribution in the current system. An off-grid system can supply power to where it is needed directly without any transmission and distribution losses. An off-grid solar system is far more resilient to natural disasters as there is no single point of failure that can bring down the whole grid, as is the case with grid-connected/centralized power generation. Moreover, off-grid solar system utilizes unused space on rooftops to generate power, whereas a grid-connected system requires far more space in terms of land. Thus, off-grid solar system is much more efficient than the grid-connected solar systems in the current scenario.

AN OFF-GRID SOLAR SYSTEM IS FAR MORE RESILIENT TO NATURAL DISASTERS AS THERE IS NO SINGLE POINT OF FAILURE THAT CAN BRING DOWN THE WHOLE GRID, AS IS THE CASE WITH GRID-CONNECTED/CENTRALIZED POWER GENERATION.

Government's Initiatives for Solar Energy in India

Carbon emissions from economic activity are on a rise, and India is the third largest carbon emitter globally. Thus, the national focus is on policies that can rapidly remove carbon from the energy mix, stop degradation and destruction of forests, conserve water resources, and help communities adapt to the destructive impacts of climate-related events that will be unavoidable in the coming years. The most prominent step taken by the Government of India in this regard is the scaling up of renewable energy targets to 175 GW by 2022, of which solar power will form 100 GW (up from the current level of about 4 GW). Table 3 summarizes the revised targets for solar energy in India.

The Government of India is making conscious efforts to develop this infinite source of power (solar) and is developing appropriate strategies to promote accelerated use of the universally and freely available solar energy. The Central Government, through MNRE, prepares national-level policies and programmes, invests in research and development, and gives subsidies, tax benefits, and so on. The state governments then, through their respective nodal agencies implements

Table 3 Revised targets for solar energy for India

Scheme	Time Period	Year-wise Cumulative Targets for SPV		Total Investment
Revised targets for solar energy projects	By the year 2022	Year	Cumulative Targets (MW)	₹600 000 crore
		2015–16	5000	
		2016–17	17 000	
		2017–18	32 000	
		2018–19	48 000	
		2019–20	65 000	
		2020–21	82 500	
		2021–22	100 000	

Note: Adapted from various MNRE sources, Retrieved from http://mnre.gov.in/file-manager/UserFiles/Off-Grid-&-Decentralized-Solar-Thermal-Application-Scheme.pdf; http://mnre.gov.in/file-manager/UserFiles/OM-year-wise-cumulative-target-for-100000MW-grid-connected-SP-project.pdf

the central policies and programmes, in addition to making their own policies. There are three principal government bodies to promote solar energy in India. The first is the MNRE, which is the primary unit for all matters relating to renewable energy. The second is the Indian Renewable Energy Development Agency Ltd (IREDA), which is a public limited company established in 1987 to promote, develop, and extend financial assistance for renewable energy projects. Third is the Solar Energy Centre (SEC), which is a dedicated unit of the MNRE for the development of solar energy technologies and promotion of its applications through product development. Besides this,

government has also rolled out various policies and subsidies to promote this sector. In addition, every state has a nodal agency, focussing solely on the issues related to renewable energy.

The Government of India has come out with a number of policies and programmes for promotion of solar energy in India. The National Solar Mission is one of the major initiatives of the central and state governments to promote ecologically sustainable growth while addressing India's energy security challenge. Solar is currently high on absolute costs compared to other sources of power. The Mission recognizes that there are a number of off-grid solar applications particularly for meeting rural energy needs, which are already cost effective and provides for their rapid expansion. It also states that off-grid decentralized and low-temperature applications will be advantageous from rural electrification perspective and meeting other energy needs for power and heating and cooling in both rural and urban areas.

Rural electrification has been accorded top-most priority by the Indian government. Under the National Solar Mission, one of the programmes for off-grid power solution is the Remote Village Electrification Programme brought forth by MNRE. The Ministry is implementing this programme for providing financial support for electrification of those remote unelectrified census villages and unelectrified hamlets of electrified census villages where grid-extension is either not feasible or not cost effective. Such villages are provided basic facilities for electricity through various renewable energy sources, particularly solar. The beneficiaries of this scheme are the village households that get solar power for their basic requirements of lighting. For instance, about 1400 solar-powered villages in Chattisgarh, which are not connected to the national grid because they are in a remote area, have been enjoying the benefits of electrification under this Remote Village Electrification Programme.

As far as the urban areas are concerned, the government is working towards development of solar energy systems and devices. Under MNRE's energy-efficient solar/green buildings programme, GRIHA rating system is being promoted. Under 'Development of Solar Cities Programme', the Ministry had proposed to support 60 cities/ towns for Development as 'Solar/Green Cities' during the Eleventh Plan period with the aim to promote the use of solar

FOR INSTANCE, ABOUT 1400 SOLAR-POWERED VILLAGES IN CHATTISGARH, WHICH ARE NOT CONNECTED TO THE NATIONAL GRID BECAUSE THEY ARE IN A REMOTE AREA, HAVE BEEN ENJOYING THE BENEFITS OF ELECTRIFICATION UNDER THIS REMOTE VILLAGE ELECTRIFICATION PROGRAMME.

energy in urban areas. The programme is designed to support/encourage urban local bodies to prepare a road map to guide their cities in becoming 'renewable energy cities' or 'solar cities'. The MNRE has already initiated various programmes in the urban sector for promoting solar systems in homes, hotels, hostels, hospitals, and industry. The solar city programme aims to address the energy problem of the urban areas.

Challenges with Off-Grid Solar in India

It has been seen that there are a number of impediments and barriers associated with the use of off-grid solar energy and the associated policies. Impediments are faced by both—the government and the end users.

Lack of awareness and limited sources of information

One of the major barriers that the government is facing is lack of awareness among the end-users and beneficiaries regarding off-grid solar energy and its benefits. Also, there is no clarity regarding government initiatives for solar energy. Moreover, reliable sources of information available have been found to be limited in number. The available sources lack clarity in terms of the initiatives offered, the policies and programmes under which incentives are offered, who gives the incentives, and procedure to be followed for the same. Thus, publicity funding should be given by MNRE to the state governments to catalyse large-scale awareness campaigns for different sections of the society, focussing on the government policies and incentives for off-grid solar systems.

Availability of channel partners

Channel partners are the conduits between government and the beneficiaries. They help in getting the subsidy and undertake the installation of off-grid solar systems. As far as locating the channel partners is concerned, it is seen that there are limited number of channel partners available in the market. Moreover, list of MNRE-certified channel partners is not updated on the MNRE website. Thus, the MNRE website should be regularly updated with latest information and notifications regarding policies, programmes, and certified channel partners.

Undue delays

Once the building owner identifies and contacts the channel partner, the next step is preparation of Detailed Project Report to be submitted for availing capital subsidy from the government. It has been seen that there are delays in site inspection by the channel partners, which is the first step to prepare the application. Stringent rules should be laid for channel partners for meeting timelines, and penalties should be laid on them for not meeting the timelines. Moreover, there are delays caused by the state governments in doing site inspection once the project has been submitted to them. The reason being projects are spread across states and carrying out site inspection for each one of these is a humongous task. Therefore, government should have third-party verification to prevent undue delays. Regarding soft loans, banks also take a long time to revert back on the status. It is suggested that the government should set time frames for banks regarding sanction of loans. Moreover, off-grid solar loans should be brought under priority sector lending to speed up the process. Regarding the application submission by the channel partner to the state, it is suggested that there should be a provision for electronic submission of application to the state, and after submission, it should be forwarded to MNRE by the state within the recommended time period. Moreover, online mechanism should be free from any technical glitches and updated from time to time.

Intensive documentation

To avail government benefits, building owners are required to submit detailed documents, which is a time-consuming process. Even though the process of documentation is generally carried out by the channel partners, most of the documents have to be acquired from the building owners, which is a tedious process. Documentary proofs required while submission of application should be reduced. Further, it is suggested that same application should be considered for both capital subsidy and soft loan. This will reduce the time spent in preparing separate applications and documents for the two incentives.

Inefficient/cumbersome supply chain of off-grid systems

Limited availability of channel partners is another barrier stifling the growth of off-grid solar sector in India. Thus, MNRE needs to work on a package of fiscal/financial incentive policy to promote product/technology development, extensive distribution network, and quality standards. Government should provide incentives to new start-ups in the field of off-grid solar to boost the sector. There has to be transparency of vendors in terms of their listing, size of operations, and contact details for the building owners to be able to contact them without any hassles.

Inconsistent government initiatives

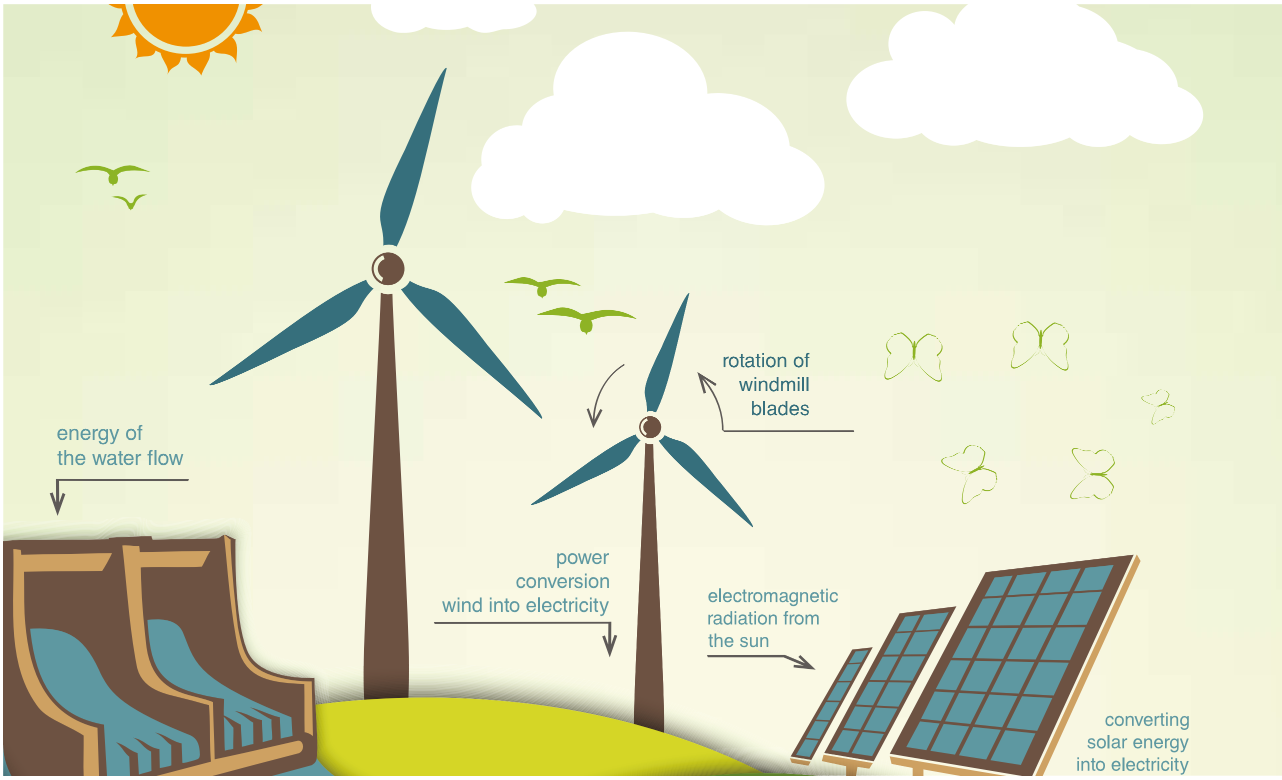
It has been found that most of the government initiatives have been inconsistent. MNRE policies change from time to time without any consultation with the stakeholders, causing undue hardships and delays. Recently, the capital subsidy scheme for off-grid solar applications in the commercial sector was withdrawn without any prior notification. Thus, beneficiaries are confused in terms of whether they should invest in the solar systems now or wait for the subsidy scheme to come again. It is suggested that national-level policies should be made in consultation with states and the changes should be notified on the MNRE website. It is strongly felt that state governments should assist MNRE in implementing the policies of the central government in an effective and efficient manner in order to boost the uptake of solar energy in the country without any delays. Both MNRE and state governments should develop targeted incentives that take into account the specific requirements of different regions and sectors.

Non-functional current schemes

Government schemes of soft loans and interest subsidy have been found to be non-functional as no bank is providing these loans. The major issue here is that of collateral. The banks do not consider the solar system as collateral, against which, they could approve the loans. Thus, these loans are normally rejected.

No release of subsidy

Capital subsidy, which has been found to be one of the most attractive government incentives, has been observed to be non-functional. As per the policy, the building owner gets the solar system at subsidized rates from the channel partners. However, the subsidy is not released to the channel partners in time by the government. It has been seen that capital subsidy has not been released for the past 3–4 years, and the money of channel partners is stuck. Moreover, the process of availing the government subsidy has been found to be very tedious and cumbersome, thus defeating the very purpose of subsidy. To reduce the time lapses in release of capital subsidy, it is recommended that some percentage of the capital subsidy should be directly given to channel partners in advance by MNRE once the application has been approved. Rest of the amount should be given to state governments to be released to channel partners after commissioning of the projects. Subsequently, after commissioning of the systems, the channel partners could avail the capital subsidy directly from the state rather than first applying to state and then forwarding the application to MNRE. To prevent any malfunctioning at this stage, penalties should be laid on the channel partners not meeting the timeline for completion of project.



The Way Forward

It is suggested that MNRE should frame national-level policy in consultation with the state nodal agencies. Awareness generation and provision for research and development should be an inherent part of the policy. Once the policy has been formulated, states should assist the MNRE in implementing the national-level policy rather than forming their own policies. Such an initiative will reduce any state-to-state differences. Awareness generation is crucial for creating demand for SPV/SWH systems, and thus, large-scale awareness generation campaigns should be taken up by the government (both MNRE and states) to motivate more number of building owners to install off-grid solar systems in their buildings. It is anticipated that once building owners are aware, they will be willing to pay for these systems, gradually moving away from the capital subsidy regime.

Solar energy being a dynamic area, latest and updated information needs to reach the consumer. Use of the right mix of media is important, and the social media needs to be tapped to the fullest. The awareness campaigns should be both general, talking about the benefits of solar energy, as well as targeted, specific technical details of solar systems, and government support for the same. Need-based training programmes ought to be designed and implemented for different stakeholders, such as commercial, residential, agricultural, and industrial. Facebook, LinkedIn, and Twitter should be used for effective dissemination of information. Mobile applications should be developed for better dissemination of information as it is the most widely used medium by the beneficiaries.

With the ambitious target of deploying 100 GW of solar energy by 2022, solar energy is in the forefront of India's energy policy. There are a number of barriers brought forth, which the stakeholders are facing. These barriers need to be addressed to have a better policy regime and a favourable environment for solar installations to flourish. It is imperative that government works on the barriers so that beneficiaries have a conducive policy environment, which is easy to understand and make use of. Through concerted efforts to improve the policy regime at central and state levels, combined with increased targets for deployment of solar energy, India has the potential to become a key player in the global initiative towards solar power. EF

Disclaimer: The views expressed by the authors in this article are their own and may not necessarily represent the views of TERI.

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PHOTOVOLTAICS FOR RURAL ELECTRIFICATION AND DIGITAL SUSTAINABILITY

An integrated approach is the way ahead

Overall, solar PV power has the potential to become a powerful tool that can change the current face of the rural establishments in India. By acting as a sustainable power source, it can increase the connectivity of these areas to cities, empower them digitally, and can also help in bringing awareness regarding various aspects of farming and other livelihood sources. With the available infrastructure and the goals set by the Ministry of Power as well as the Ministry of New and Renewable Energy, **Dr Rajneesh Kumar** and **Subrahmanyam Pulipaka** highlights how implementation of such project is not a distant dream rather a feasible solution, which is need of the hour.

Developing nations, such as India, have witnessed a surge in energy demands due to its rapid population growth in recent times. Technological innovations, increase in standards of living, and digitalized day-to-day life can be considered as factors for this surge. It is projected that the world is going to use 50% more energy by mid-twenty-first century than it does presently. Considering the scenario of rapid depletion of fossil fuels and the necessity of high-efficiency power generation systems, the entire world is looking towards renewable energy sources to meet the energy requirements in a greener way. Photovoltaic (PV) power is one such prominent renewable energy source, and researchers in the past two decades have achieved major breakthroughs for suggesting ways of efficient PV power generation. In countries, such as India, with sub-tropical climate, high irradiance levels throughout the year, PV power can be a reliable and sustainable solution for meeting power requirements.

The Government of India, realizing the potential of solar PV power production in the country, took major initiatives to encourage and facilitate measures to tap the huge potential of PV power. From setting up of the National Solar Mission that issues guidelines and targets of PV power production, to leading the recent alliance (International

India solar potential (Annual direct average irradiance)

Source: NREL India radiation database

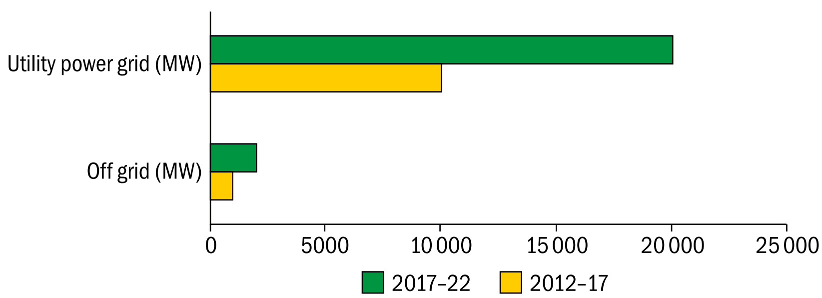

Figure 1 PV power production target set by the Ministry of New and Renewable Energy, India

Source: http://www.mnre.gov.in/solarmission/jnnsm

Solar Alliance) of 108 PV potential nations for exchanging knowledge and innovations in the field of PV, the Government is leaving no stone unturned. Additionally, the Ministry of New and Renewable Energy (MNRE), Government of India, is also planning to install large-scale grid-connected and off-grid solar power generating PV plants during its Twelfth plan (2012–17) and Thirteenth plan (2017–22) (Figure 1) to meet the power requirement of its increasing population. The target for off-grid solar applications and utility grid power, including rooftop, are 1000 MW and 10 000 MW during year 2012–17 and 2000 MW and 20 000 MW during year 2017–22, respectively.

Apart from shortage of power production, there are still villages at remote locations with no power connection. As of May 31, 2015, it is estimated that there are 19 706 un-electrified villages in India. In order to ensure a continuous power supply to these villages, the Government is investing around $11 billion in Deen Dayal Upadhyaya Gram Jyoti Yojana. States, such as Rajasthan, which possess high solar potential, also initiated incentives, such as subsidies on solar PV pumps and rooftop PV installations. There are still 4 166 villages alone in the state of Rajasthan that are bereft of such incentives, which are yet to receive continuous power supply. In order to address the problem of rural electrification and achieve one of the projects of the Government (Digital India), PVs can play a phenomenal role.

Addressing the Reliability Issues

PV panels in rural areas are generally installed in open areas or sometimes in farms, in the case of solar PV power water pumps. In an open area, efficiency of panels is always lower due to deposition of dust or soil particles on a panel. Such deposition, which is known as soiling, can decrease the power output of the PV panel by up to 40%. In arid regions of Rajasthan, such as Shekhawati region, which receives high irradiance throughout the year, dust storms could be a catastrophe to PV power production. A worst-case scenario with complete blackout was reported by Reliance Industries Ltd. for its 5 MWp solar PV plant at Khimsar, Rajasthan, during May 2010, when a dust storm and twister hit the plant.

Other reliability challenges faced by this plant in 2010 and their effect on power production are shown in Table 1.

Table 1 Reliability challenges faced by the PV plant in Khimsar

Month and Year	Challenge	Effect
March–April 2010	>47°C temperature	No power production from 11 am–5 pm
May 2010	Dust storm and twister	No power production from 11 am–5 pm
June–July, 2010	Heavy cyclone and flooding	No power production from 11 am–5 pm

Source: http://www.rrecl.com/pdf/performance_analysis_5mwp_solar_pv_plant.pdf

During the installation of standalone or rooftop PV systems, the tilt angle is fixed and is usually not altered throughout the operation. At a given tilt angle, the power output drastically reduces with dust deposition on the panel, resulting in underperformance of the installed system. In many cases, rural population on noticing the underperforming PV panel shift to conventional power sources, thereby making the installation go underutilized.

Some recent studies specific to Shekhawati area in Rajasthan were carried out to understand the effect of dust particles on PV panels and the power losses due to soiling in these areas. According to these studies, if tilt angle of a panel for a location is calculated taking into consideration the soil properties of the location, the reduction in power output due to soiling can be minimized. Partial shading due to plant shadow is another major factor that reduces power output of a PV panel. Dynamic partial shading due to high wind speed may cause damage to the inverter connected to these PV panels to drive the water pumps. Lack of awareness regarding these effects is common among farmers in rural areas. So, in addition to these PV installations, a short-term programme must be initiated to educate the users for better utilization of existing resources.

Colocation of PV Power with Farming

In order to reduce the effect of soiling on panel, many farmers or PV plant owners opt for regular cleaning of the panel with water. Such a practice of cleaning panels at regular intervals increases the dependency of power output on frequency of maintenance and is not economically viable for large-scale PV installations. However, an intermediate solution of colocating PV installation with agriculture can be a viable solution in rural areas of India.

In rural areas at the locations of PV installations, medicinal plants or plants that require less water for their growth can be planted. The water used to clean PV panel can be directly used for the cultivation of these plants. In a research conducted by researchers from Temple University in collaboration with Council of Energy, Environment and Water, India, Standford University, USA, and National University of Singapore, it was concluded that colocation of PV panels with plants, such as aloe vera, can be achieved in arid regions through efficient land and water use (Figure 2). It was also found that such colocation can stimulate economies by creating employment and provide opportunities for rural electrification (Figure 3). Many rural areas possess fertile or semi fertile land and are optimum locations to implement this

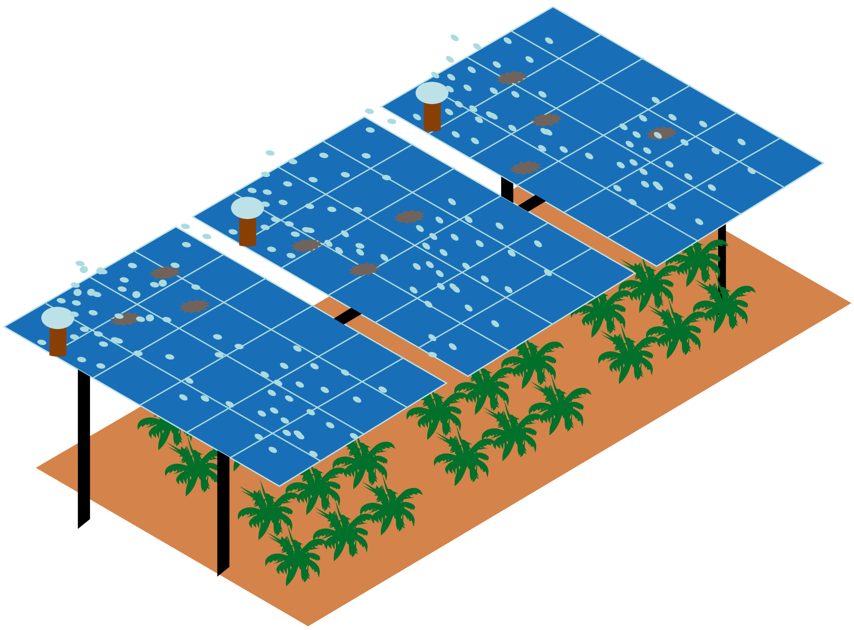

Figure 2 An illustrative representation of colocation of PV and aloe vera

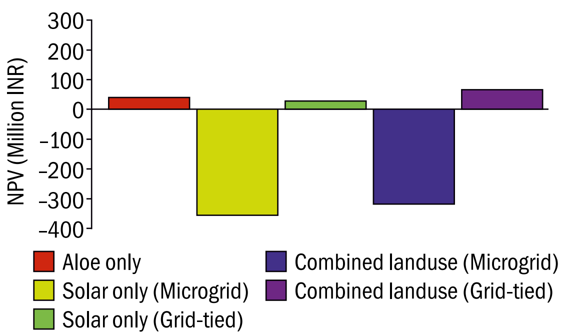

Figure 3 Estimation of revenue generated through various PV installations with and without colocation[3]

[3] Ravi S, Macknick J, Lobell D, et al. 2016. Colocation opportunities for large solar infrastructures and agriculture in drylands. *Applied Energy* **165**: 383–392.

A PV plant in Punjab—such large-scale installations will be more sustainable when colocated with crops

colocation feature. This colocation can be implemented in existing large-scale installations present across the country. Additionally, such colocation is directly in lieu with the mission statement of Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) for ensuring sufficient power to farmers.

Integrating PV Applications for Rural Digitization

PV installations installed in rural areas are generally used for a specific purpose. For example, some installations in rural areas are exclusively used for water pumps. The main drawback of these systems is their underutilization during idle time. Available power during these durations can be utilized for many purposes, such as charging battery as well as hydrogen generation for small applications. A little effort in these directions can change the lifestyle of our entire rural population. For example, in rural areas, governments generally provide subsidies to install solar PV water pumps or standalone systems to support agriculture work. Farmers and the population in unelectrified rural areas often are not aware of the crucial information regarding weather conditions, such as rain, fog, and storm, that govern the crop cycle. Additionally, their poor connectivity to the nearest town or city consumes their time to procure necessary amenities for farming as well as other necessities. To avoid the challenges faced by rural population and to initiate the penetration of digital footprint in rural India, the PV power sources applications can be integrated to digital village concept (Figure 4).

A plan of action can be formulated in integrating the PV sources in a village in a way that rural households become electrically as well as digitally self-sustained, thereby making the village a model one. A solar PV panel used to power a water pump can be used to power household appliances when the pump is not being used. Additionally, the government can take steps in constructing 'productive houses' in

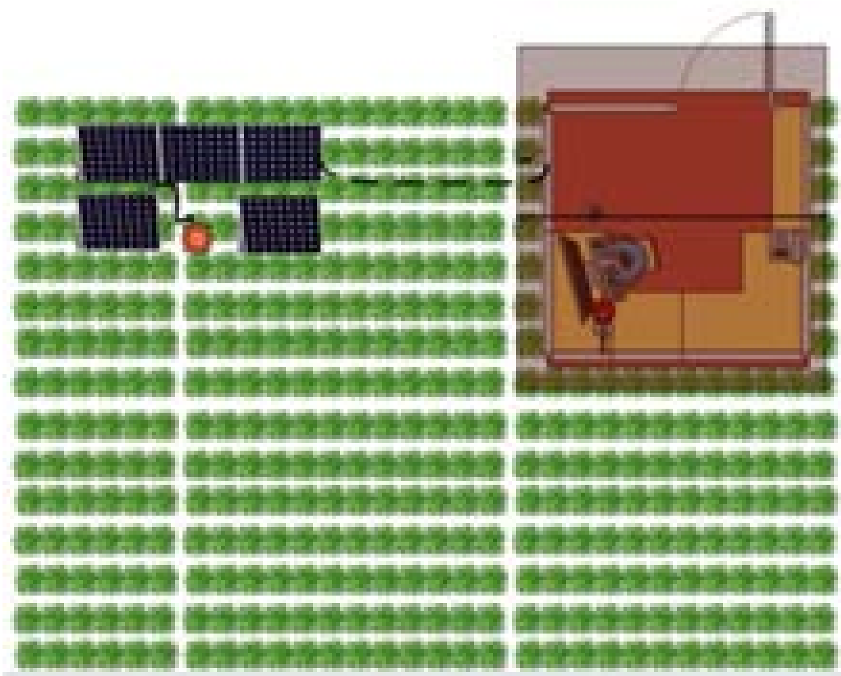

Figure 4 Integrating application of PV installations

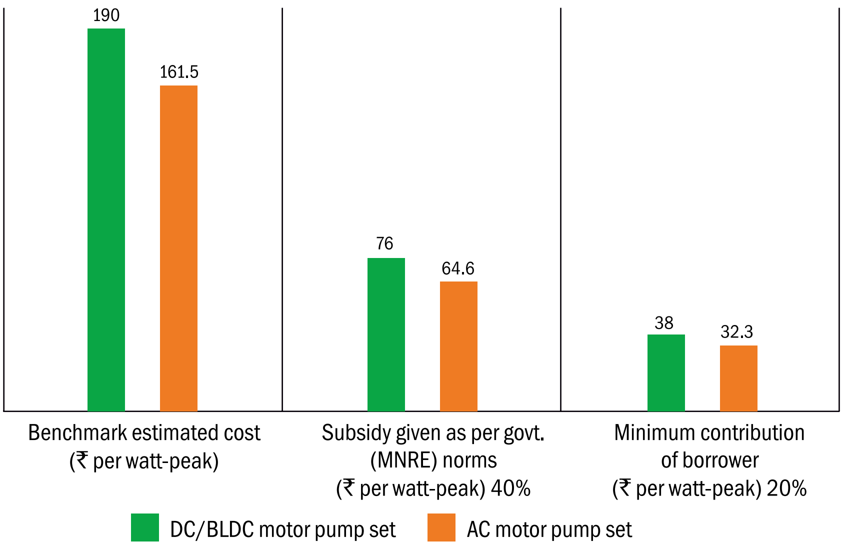

Figure 5 Solar pumping system cost distribution

Source: http://mnre.gov.in/file-manager/UserFiles/scheme-SPV-water-pumps-NABARD.pdf)

every household. These solar powered houses with appliances, such as computer and the Internet will open the world of information to the farmers. A subsidized landline or GSM connection with broadband or Internet connection can be provided by the government, which can enable the farmers to gain knowledge related to farming techniques, crop produce, selling options for their crop in the market by using the Internet. If these facilities are established across every farm in an area and connected with a local area network, to access dynamic data regarding crop yield information. This itself data, then, can be used by the government to assess the locations of demand for a certain crop and help the farmer fix a price at which the yield can be delivered to a particular location. With the newly launched eNAM (Electronic National agricultural market), this facility will improve the net value of the farmer and contribute in increasing economic as well as technological aspects of rural locations in the country.

If government provides a subsidized lifetime plan of Internet with solar system installation, it will improve the knowledge of technologies used in farming and can improve growth of farmers. Basic subsidized Internet system, such as a package of ₹39 per month, can be provided equal to the lifetime of solar pumping system.

Presently, benchmark cost for Solar Pumping System is given as per government norms and is discussed here. After initial technical approval, borrower has to contribute 20% of the estimated cost and 40% subsidy is given as per NABARD circular (Figure 5). Remaining system cost is balanced by bank loan, as per RBI norms. If BSNL provides subsidized internet data pack with different time duration period, as shown in Table 2, it will add ₹39–45 per month extra for the borrower.

Table 2 Cost details of internet packages

BSNL Packs	Annual Cost	Subsidized Amount 40%	Minimum Contribution of borrower 20%
198 = 1GB/30 Days	2376	950.4	475.2
444 = 3GB/60 Days	2664	1065.6	532.8

Source: www.bsnl.co.in

A Case Study

To support the idea of digitization in villages, some of the villages around Pilani, Rajasthan, were surveyed for information about solar pump installation benefits in these areas.

Mr Vinod Hiranwal is a farmer in Hanumantpura village which is about 2 km from Pilani. He supports his family, comprising his father, wife, two sons, and daughter, with farming largely due to the support provided by the Government in installing highly subsidized solar pump nearly four years ago.

He farms on 10 acres of land with drip irrigation using solar pump round the year. He has been able to cultivate nearly 25 quintals of good-quality cotton using drip irrigation on one hectare land. Similarly, he cultivated a variety of cash crops, such as peanuts, mustard, gram, wheat, etc., using drip irrigation in rest of the land, which got him the best farmer award of this region. Currently, he has developed an orchard of unconventional but profitable fruit trees.

He happily discussed the benefits of solar pump with and without trackers, with an increase of two hours operating time in case of installation of pump with trackers. Other benefits, such as availability of water during no power supplies days and necessary light during night, were also a part of our detailed discussion. On taking up topics, such as government schemes and their benefits, how to maintain the solar pump for efficient usage, advantages of digitization scheme, etc., lack of awareness was clearly visible.

If the government provides the Internet facility, which is possible at very small cost, many problems of farmers like Vinod Hiranwal can be resolved. This would also enable farmers receive weather forecast on hourly basis and minimize the damage of crops due to sudden storm or heavy rain. They will get regular updates about government policy for farmers, a facility which is missing at present. Children will also benefit with availability of educational resources at their doorstep. Housewives can plan suitable vocation taking benefit of government help in these areas. Even telemedicine is also possible to help people living at remote places. EF

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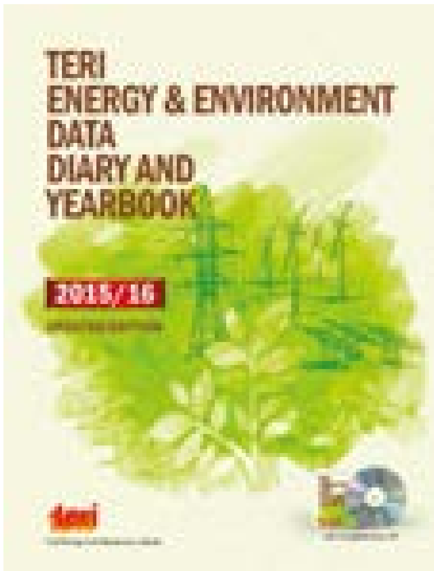

OVERVIEW ON INDIAN ENERGY SECTOR

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TEDDY (TERI Energy Data Directory and Yearbook), is an annual publication brought out by TERI which provides updated information on the energy supply sectors (coal and lignite, oil and gas, power, and renewable energy sources) as well as the energy-consuming sectors (agriculture, industry, transport, residential, and commercial sectors). Given the relevance of linkages between the energy and environment, topics on local and global environment have also been dealt with in detail.

Unique features of TEDDY

- The yearbook provides the cutting-edge analysis and latest available information on the topic of energy and environment.
- The publication provides a detailed overview of sectors and sub-sectors related to energy demand and supply.
- Starting form this year, the state of the environment has also been discussed with respect to forestry and biodiversity. This includes listing of data in the form of separate tables as appendices.
- Sankey Diagram that depicts the commercial energy flows in India has been introduced since the last year edition (TEDDY 2011/12). This is an innovation on the part of the researchers as it has been designed exclusively by TERI.
- Each edition of TEDDY presents tables on commercial energy balances with conversion factors.

LIGHTING THE WAY AHEAD....

By looking at the technologies, policy decisions, and business ventures that have the potential to overcome energy shortage and our crippling dependence on depleting fossil fuels, Energy Future draws from a deep well of expertise at TERI (The Energy and Resources Institute), India's leading research institute on energy and green growth. Knowledge of energy security and development is a critical requirement in the modern global economy, and Energy Future aims to educate and inform you about the wide world of energy; its history, its future, how the energy industry works, how it has affected the world, and how it continues to affect you and me.

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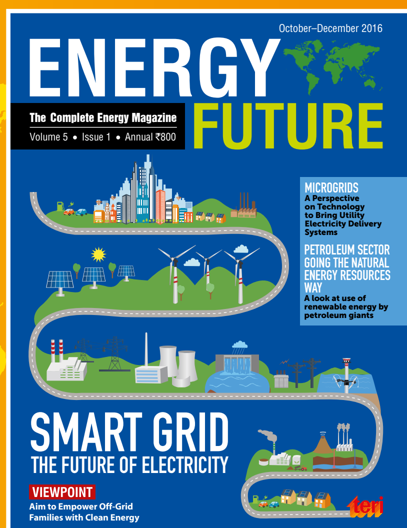

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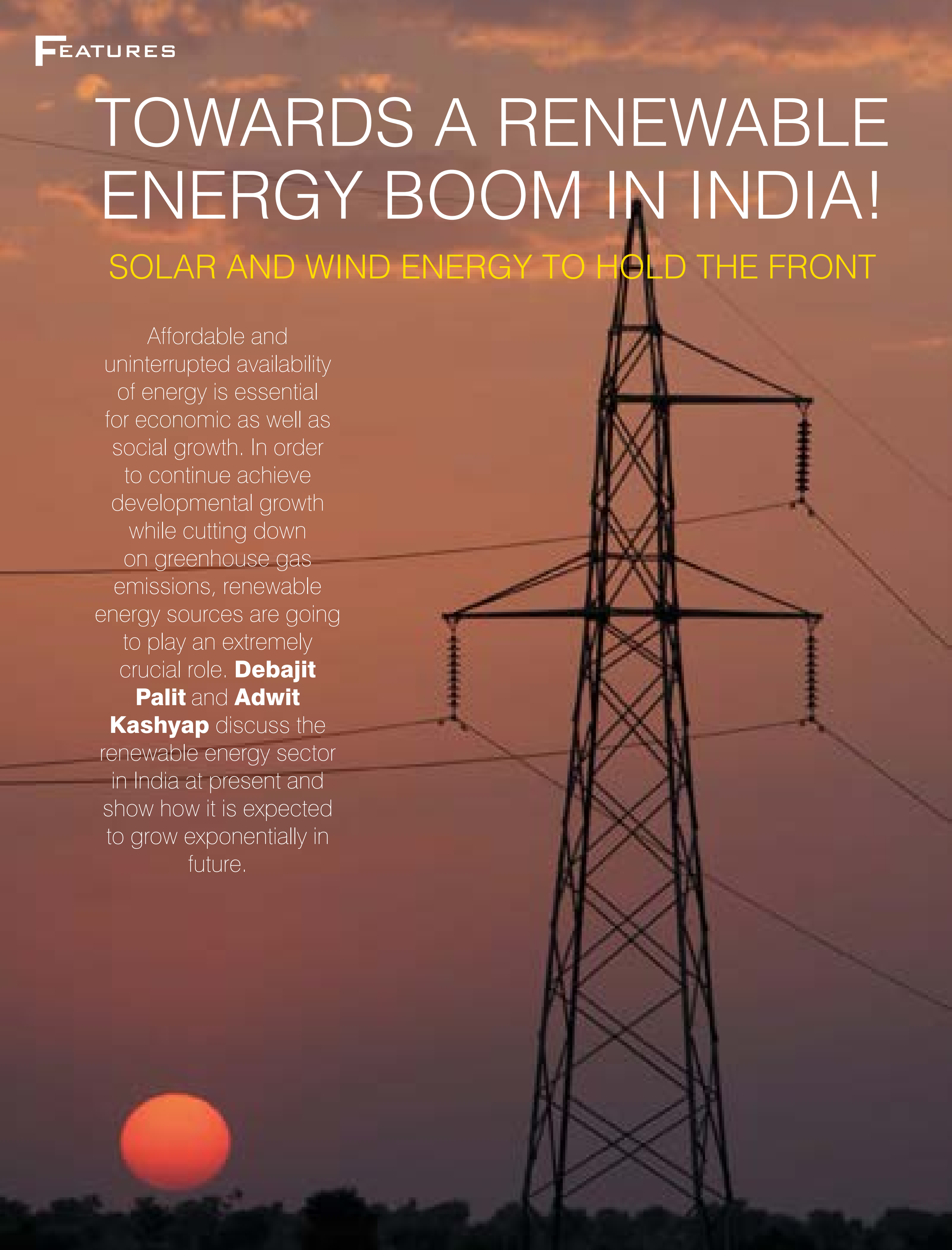
TOWARDS A RENEWABLE ENERGY BOOM IN INDIA!

SOLAR AND WIND ENERGY TO HOLD THE FRONT

Affordable and uninterrupted availability of energy is essential for economic as well as social growth. In order to continue achieve developmental growth while cutting down on greenhouse gas emissions, renewable energy sources are going to play an extremely crucial role. **Debajit Palit** and **Adwit Kashyap** discuss the renewable energy sector in India at present and show how it is expected to grow exponentially in future.



India recognized the importance of increasing use of renewables in the transition to a sustainable energy base during the 1970s, and since then, a significant effort has gone into the design, development, trial, and induction of renewable energy technologies for use in different sectors of the economy. The renewable energy sector has leapfrogged in the last two years, especially the solar power generation, with the country's solar power capacity having more than doubled to 8.7 GW in the last 18 months. From the start of this decade, the solar power capacity has grown from as little as 31.45 MW in March 2010 to 8.7 GW in October 2016.[1]

At the same time, cost of solar power generation has dropped drastically to under ₹5/kWh in 2016 (Figure 1). REN21—the global renewable energy policy network—in its 2016 Global Status Report listed India among top five countries for annual investment/net capacity additions in renewable power and fuels (including solar and wind power) in 2015, behind China, the US, Japan, and the UK. India is also seeing a rapid expansion of small-scale renewable systems, including renewables-based mini-grids, to provide electricity to people, who do not have access to grid-based electricity. While the above achievements are noteworthy, many experts believe that the renewable energy boom is yet to come, as India aims to realize its ambitious target of 175 GW of installed renewable energy capacity by the year 2022.

On a Dynamic Solar Path

India is currently implementing one of the largest renewable energy expansion programmes globally with the long-term objective to achieve 40% cumulative electric power installed capacity from non-fossil fuels by the year 2030. India also took the lead to form the International Solar Alliance (ISA) at the United Nations Climate Change Conference in Paris on November 30, 2015, consisting of 121 countries, to collaborate on increasing solar energy use around the world. The alliance, headquartered in India, aims to bring together countries situated between the Tropic of Cancer and Tropic of Capricorn, which receive abundant sunshine for around 300 days a year.

Ahead of taking the lead in forming the ISA, in June 2015, Prime Minister Shri Narendra Modi scaled up the 2022 target for solar capacity generation under the National Solar Mission from 20 GW to 100 GW. This includes around 60 GW from utility-scale solar and 40 GW rooftop solar. The government also set a target for renewables-based power capacity of more than five times the capacity of 32 GW in 2014 to 175 GW by 2022. This includes, in addition to the target for solar capacity 60 GW from wind, 10 GW from biomass energy, and 5 GW of small hydro-power (Figure 2). Another key development, as notified in the new tariff policy released in January 2016, is that the electricity distribution companies (DISCOMs) have been mandated to procure 100% power produced from all the waste-to-energy plants in the State, which is also expected to contribute to the *Swachh Bharat* initiative. Further, the tariff policy

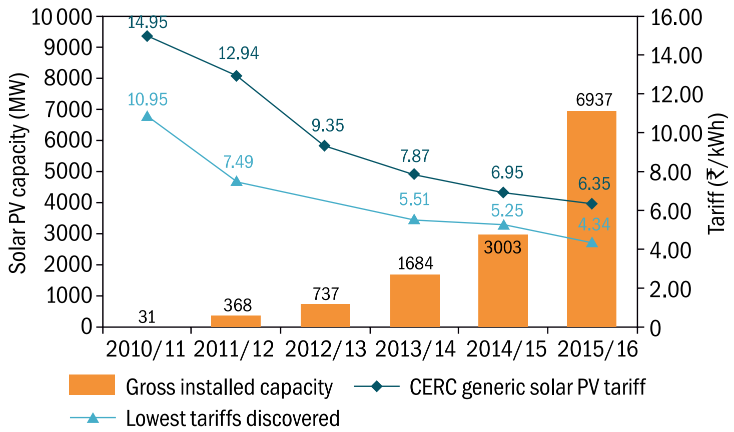


Figure 1 Capacity addition and price trends in Indian solar market[2]

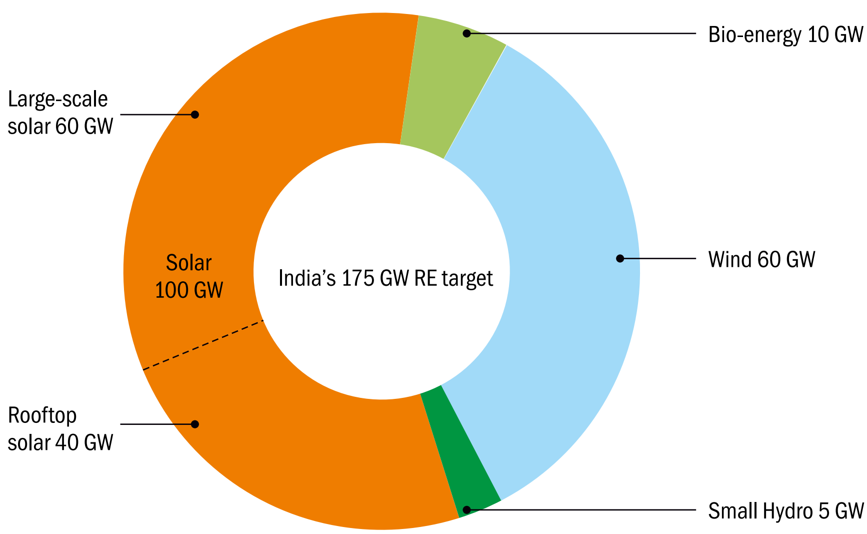


Figure 2 Break-up of India's 175 GW renewable energy target for 2022

1 http://mnre.gov.in/file-manager/UserFiles/grid-connected-solar-power-project-installed-capacity.pdf

2 TERI market research

also mentions that all new coal/lignite-based thermal generating stations shall be required to establish renewable energy generating capacity or procure and supply renewable energy equivalent to such capacity. The policy also states that the renewable energy produced by the generator may be bundled with its thermal generation so as to keep the electricity price affordable.

Wind Energy

In the wind sector, while India has achieved significant success in the onshore power development with about 28 GW of wind energy capacity already installed, the national off-shore wind energy policy released in October 2015 aims to set up wind generators both within Indian territorial waters and exclusive economic zone (beyond the 12 nm territorial limit and up to 200 nm[3]). The policy intends to support the development of offshore wind energy through fiscal incentives, allowing foreign direct investment, public–private partnerships, and international collaborations.

Further, as most of the wind-turbines installed up to the year 2000 are of capacity below 500 kW and are at sites having high wind energy potential, the Ministry of New and Renewable Energy (MNRE) has announced a Repowering Policy with the aim to promote optimum utilization of wind energy resources by creating facilitative framework for repowering and support installation of wind turbines of megawatt scale capacity in place of the kilowatt ones.

Challenges

Electricity being a concurrent subject, state participation is equally important to achieve the ambitious objectives. The central electricity regulator has taken steps to encourage state participation by mandating state DISCOMs to source 8% of electricity from renewable energy sources (excluding hydro-power) by March 2022,[4] waiving of the interstate transmission charges and losses for solar and wind. A total of 33 states and union territories have released their respective solar policies for rooftop and utility-scale solar projects with 13 states releasing new or amending their existing policies during the last two years. For ease of bank financing, renewable energy projects have also been included in priority sector lending norms by RBI as per notification issued in April 2015.[5] This will particularly assist to scale up small-scale renewable energy systems, as small projects and individual consumers find it difficult to access finance from the banks.

In the small-scale renewable energy sector, an important development has also been the explicit reference to renewable energy based mini-grids within the National Tariff Policy, notified in January 2016. The tariff policy has recognized the importance of ensuring last mile connectivity by creating an enabling condition for investing in minigrids and also mandated for appropriate regulation to make these viable. The tariff policy explicitly mentions that the investment involved in setting up of mini-grids is substantial and one of the biggest investment risks is of the utility grid network reaching the area before the developer has fully recovered the project investment. The policy further states that to mitigate such risks and incentivize investment, an appropriate regulatory framework needs to be put in place to ensure purchase of power into the grid from such minigrids.

While tariff-based bidding for solar power has seen the rates plummet to as low as ₹4.34 per kWh, the actual pace of project implementation appears slow. Though more than 20 000 MW solar projects were tendered in 2015/16, the actual achievement during the year was just over 3000 MW.[6] Notably, the planned solar power project commissioning in FY 2016/17 is 12 GW,[7] though a marked improvement but less than what is required to achieve the 100 GW target by 2022. Financing appears to be one of the key challenges limiting faster scale-up in the sector. The total investment required to achieve the 2022 target, as estimated by different agencies, is about ₹600 000 crore or almost $100 billion. This is quite a large sum of money, and the government's outlay for the Twelfth Plan period is a fraction of the required investment.

3 "nm"→Nautical mile(s)
4 National Tariff Policy 2016
5 Available at: https://www.rbi.org.in/Scripts/NotificationUser.aspx?Id=9688&Mode=0
6 http://articles.economictimes.indiatimes.com/2016-04-19/news/72453504_1_power-generation-capacity-mw-target-power-projects
7 http://mnre.gov.in/mission-and-vision-2/achievements/

Further, low bidding price though appears good at the first instance, given the fact that the projects enter into power purchase agreements for 20–25 years, the government may also focus on quality control of the components and assurance infrastructure as well as sensitivity of the electricity price bid with respect to any climatic and other changes from a longer term perspective. Major efforts and investments may be considered in building accurate solar resource database. Else, the institutions financing these projects may end up having non-performing assets in the long term, in case of low generation from these projects because of the externalities and climatic factors.

On the positive side regarding financing, the World Bank has recently committed to lending more than $1 billion to support India's solar energy initiative, including $625 million in support of India's 40 GW target for grid-connected rooftop solar power. The US Government, as well as some of the other bilateral agencies, are also supporting the solar energy programme, especially for distributed renewable energy for off-grid communities.

Another key challenge that the solar sector may have to address in future, as capacities are scaled-up, is land availability. With large tracts of land being used for agriculture in most states, finding adequate land in one site for utility-scale solar projects is expected to pose a challenge. To address the challenges in terms of land availability, transmission and evacuation lines, access roads, availability of water, etc., the solar park scheme was initiated with a cumulative capacity target of 20 GW.[8] Under the scheme, financial support is being provided by the Government of India to states to establish solar parks, with individual capacities ranging from a few hundred megawatts to more than 1 GW, with the creation of necessary infrastructure. However, recent reports indicate that solar park scheme is suffering from delays in land acquisition, land development, and setting up of the requisite evacuation infrastructure. In addition to the mega projects, sub-megawatt scale grid-connected photovoltaic (PV) plants also need to be supported in villages where land for such plants may be available with *panchayats* or public institutions. Further, improvement in solar PV efficiencies or new design innovation (such as solar tree or solar balloon etc.) can address some of the land concerns and the government needs to actively support research and development towards such innovations.

The Central Government is also reportedly offering viability gap funding to the state governments, so as to cap the tariff to ₹4.5 per kWh in states where generation from solar energy is relatively less viable compared to good sunshine states, such as Rajasthan, Gujarat, and Tamil Nadu.[9] However, solar PV deployment in arid and water-stressed regions has its own

8 http://mnre.gov.in/file-manager/grid-solar/Scheme-for%20development-of-Solar-Park-&-Ultra-Mega-Solar-Power-Project-2014-2019.pdf

9 http://timesofindia.indiatimes.com/city/kolkata/Centre-uses-VGF-tool-to-boost-solar-power-generation-in-Bengal/articleshow/53227802.cms

set of challenges. The problem with solar panels in arid and water stressed regions is that dust accumulates easily, drastically decreasing efficiency. By not factoring in water constraints, the amount of electricity generated by solar plants will be much lower. Thus, water scarcity in these regions can increase cost and effort for module cleaning at the plant; availability of water for use by local population is also threatened in parallel. It is thus important to consider the implications of solar expansion on water demand. There are, however, some positive examples that show solar PV can help conserve water if used in innovative ways. For instance, solar panels have been installed in Gujarat on top of canals to decrease water loss from evaporation. An initiative to address the water–energy linkages could be the first step towards meeting the country's rising energy demands in a sustainable manner. Such an approach would also guide further innovation and support technological innovation such as dry brushing (cleaning panels without water) at the industrial level.

Another challenge for the country's renewable energy sector is the poor financial health of the state DISCOMs as they are the ones who procure the power from renewable energy generators. Due to the DISCOMs' poor financial condition, foreign investors are reportedly reluctant to invest in the sector due to uncertainty in payments from the DISCOM. The central government, taking cognizance of such challenge and for ensuring 24×7 power for all, launched the Ujjwal DISCOM Assurance Yojana (UDAY) in November 2015 to transfer the liabilities of the state DISCOMs to the respective state governments, conditional to improved performance and with provisions for tariff increments to offset any rise in conventional fuel prices. However, the performance of the scheme will hinge on actual improvement in the DISCOMs' operational efficiencies. Given the political competitiveness in the states, the DISCOMs may find it difficult to raise tariff. Thus, to ensure revenue sustainability, efficient performance will be the key. This will need large-scale capacity development at all levels in the DISCOMs as well as the strengthening of the distribution infrastructure to reduce aggregate technical and commercial loss and improve service delivery.

In case of rooftop solar, while there has been more than 1000% increase in capacity addition in the last 2 years (higher growth is mainly due to lower base); in the year ahead it may be difficult to sustain such growth. Some of the critical issues faced by the sector are highly disaggregated and distributed demand, which is often not visible to developers; difficulty in obtaining attractive project debt; availability of adequate roof space and their structural stability; and value chain issues, such as quality assurance, skilled manpower, etc.

One way to address the challenge will be to ensure that all new institutional and housing society roofs are used for setting up PV plants. Railway stations, stadiums, and warehouses are also good sites for rooftop power plants. Further, technology development towards producing lightweight solar panels or design innovation will also enable use of panels in older buildings, thereby expanding the technology's potential. A good sign of growth in the rooftop solar market is the announcement of tenders amounting to 1.5 GW by the Solar Energy Corporation of India Ltd (SECI) in the recent past. One of these is a tender for 1000 MW rooftop solar capacities in government buildings where the sites and roofs will be pre-identified by SECI; this is expected to significantly expedite the deployment of this capacity as developers will not be required to scope out and identify suitable sites themselves after the bids have been awarded.

The Way Forward

Renewable energy minigrids are promoted by the Ministry of Power (MoP) under the Deen Dayal Gram Jyoti Yojana as well as by the MNRE under their various programmes. Around 3500 projects have been sanctioned under the Decentralised Distributed Generation scheme of MoP to cover remote un-electrified villages, where extending grid is economically daunting. The MNRE has released the draft national policy on renewable energy based mini/microgrids in June 2016. This policy aims to mainstream renewable energy based microgrids, through building a supportive microgrid ecosystem and encourage rural energy service providers and investors, for enhancing access to affordable energy services and improving the local economy. The draft document in now being discussed with different stakeholders and is expected to be operationalized after due approval by the government.

However, in the case of mini-grids and small renewable energy systems, a point worth highlighting is that end-users of renewable energy-based minigrids often compare the cost of electricity to that from the main grid and are therefore prone to believe that expensive power is being sold to them. Further, at present, the renewable energy system operators do not get the benefit of tariff cross-subsidization, which is available to the electricity distribution companies. The sector will be ready to scale up rapidly once improved services can be offered at or below the monthly expenditure incurred on kerosene or similar to the price of regulated tariffs. To bring parity and at the same time ensure the viability of micrograds, the regulators could think of creating a universal service obligation fund, through a suitable mechanism, such as using cross-subsidy or levying a cess on conventional electricity and/or deploying savings from the reduction in kerosene subsidy. Using *Aadhar* platform, this amount can be used to provide a direct subsidy to underprivileged consumers.

Human resource development to install and service the grid connected as well as off-grid installation is another challenge that MNRE has to deal with. While the National Institute of Solar Energy is organizing *Suryamitra* skill development programmes in various parts of the country to develop skilled workforce, it is important that the training also includes placement of the trainees in actual project implementation sites to make them attain field skills and be employable. It will also be important to include renewable energy as a vocational course under the Industrial Technical Institute curriculum to create a large workforce in the country to service the industry.

While the developments in the sector are very positive, what is needed is to ensure that the different challenges are addressed on priority, through consultations with all stakeholders, for electricity access to all households with affordable consumer tariffs, ease of doing business by the developers, and achieving the developmental and climate goals. EF

Mr Debajit Palit, Associate Director, and Mr Adwit Kashyap, Research Associate, TERI.

ENERGY PERSPECTIVES FOR SUSTAINABLE FOOD PROCESSING

The terms 'sustainability' and 'sustainable development' are today, vital to all the sectors of the economy, ranging from industries to the government. In the context of food processing, this implies that the methods should be based on raw materials that can be produced without causing undue harm to the environment; are centred on renewable sources of energy; and produce foods that will not adversely affect the health and well-being of human beings. **Dr Yogender Singh Yadav** and **Dr Praduman Yadav**, through this article, explore and describe, in detail, the various energy-intensive approaches in the food processing industry.

Energy management is an essential and energetic approach for sustainable development of the food and allied industries. In order to increase its viability in food processing, energy efficiency has been a major focus. Several studies indicate that up to 30% energy saving can be attained, without additional capital investment, by relying only on procedural and behavioural changes. The current energy cost of the food industry, in developed countries, is less than 2% of the total production cost, but this distribution of energy use in different food sectors may be different. However, it has increased over time. Energy indicators are the major tool used to monitor the trend of energy cost in the food industry which defines the amount of energy used for manufacturing a given quantity of products.

Conventional energy-intensive food processes replaced by innovative technologies include the potential to reduce energy consumption and production costs with increased food production which not only provides economic benefit but also environmental protection, social sustainability, and business competitiveness. Food processes make use of significant expenses on labour, machinery, and energy to convert edible raw materials into value-added food products. Various emergent technologies including heat pump, heat pipes, heat and power cogeneration cycles, non-thermal food processes, irradiation, pulsed electric fields, high pressure processing, microwave, ohmic, and infrared heating have been developed to replace existing systems used in the food processing industry.

Due to energy scarcity and to reduce greenhouse gas emissions, it has become essential to develop energy-efficient technologies, replace energy-intensive operations, and increase the use of alternative energy sources. The measures for energy conservation, to be used in food processing, should be technically viable and economically useful.

Energy use in Food Production

The amount of energy used for food production depends on the type of products resulting from involvement of different unit operations. For example, on an average, the drying process consumes 6 MJ of heat to remove 1 kg of water from products and a freezing process consumes 1 MJ (or 0.3 kWh) of electricity to process 1 kg of food products at –20°C. There are mainly six food processing sectors in terms of food products which include grains and oilseed milling, sugar and confectionery processing, fruit and vegetable

processing, dairy processing, meat processing, and bakery processing.

Energy Sources for Food Processing

The key energy sources used in the food processing industry are petroleum, natural gas, coal, renewable energy, and electricity mainly utilized for process heating, process cooling, refrigeration, machine drive, and automation. About half of all energy input is used to process raw materials into products; process heat is also used for thermal processing and dehydration consumes more than 50% of total energy.

Steam supply

Most of the food processing operations, such as pasteurization, sterilization, evaporation, and dehydration, etc., require steam in huge quantities; out of this a significant amount of energy is lost due to steam leaks, stack flue gas, blow down water, and poor surface insulation. About 20% of total energy use in the steam systems could be saved through an efficient steam distribution system via steam trap maintenance, condensate recovery, repairing steam leaks, insulation, correct selection and sizing of traps, minimize operating pressure, and use of condensate as hot water.

Compressed air supply

This is another important handling medium for conveying foods and process control such as cooking retorts, wrapping machines, colour sorters, lid machines, and labelling and pneumatic controls. Appropriate advancement to compressors and compressed air systems can save up to 50% energy consumed by the systems. This includes prevention of leaks in compressed air system, use of high efficiency and variable speed motors, restoration of generation capacity of air compressor, reduction of inlet air temperature, use of cooling or waste heat recovery unit for compressors, and reduced compressor delivery pressure.

industry in order to reduce the moisture content to decrease water activity as also the weight and volume of food products for easy handling and storage. The common drying methods include hot air drying, microwave, freeze drying, vacuum drying, etc., while some mechanical processes such as filtration and centrifugation can also be used. Energy conservation can be achieved through mechanical vapour recompression, thermal vapour recompression, multiple effect evaporators, operating temperature optimization, exhaust heat recovery, use of multiple stage drying, and heat recovery from product. The greater number of evaporators in the series leads to decreased energy consumption.

Power supply

Power is a key factor in the food industry wherein motor drives and refrigerators are the major electricity consumers. The energy loss in a motor is up to 30% of the input power. Increased power factors should be considered for improving the electrical efficiency by reducing the energy costs which could be achieved through selection of a high power factor and variable speed motor, correct sizing of motors, speed control using VFD, and ensuring and recording efficiency of rewound motors.

Recovering waste heat

The processing air, vapour, and water effluent streams, above the ambient temperature in food processing, may be a useful source of energy obtained from flue gas, steam condensate, exhaust gas, cooling air, and vapour from cookers. Recovering the waste heat could lead to a 40% reduction in energy consumption, which not only saves money due to the reduced energy consumption but also prevents thermal pollution to the environment. Heat exchangers play a key role in waste heat recovery. Various energy conservation technologies, such as heat transfer enhancement, performance improvement, fouling removal, reducing the size and costs, can be used to improve energy efficiency.

Thermal food processing

Thermal processes are energy-intensive unit operations used for food preservation and safety. The energy conservation opportunities for food processing operations include replacement of energy-intensive units with novel units, use of renewable energy as alternate sources, particularly food processing waste utilization.

Dehydration and drying

Drying and dehydration are the most common unit operations in the food

Refrigeration and freezing

The food processing industry relies majorly on refrigeration systems, estimated up to 15% of the total energy consumed worldwide. The dairy and meat sectors are the most dependent users in the food industry. Energy conservation for refrigeration can be done by monitoring system performance, improved insulation, use of novel refrigeration cycles, checking for refrigerant contamination, automated controls, segregation of refrigeration systems, efficient piping design and insulation, and use of vapour absorption machine (VAM).