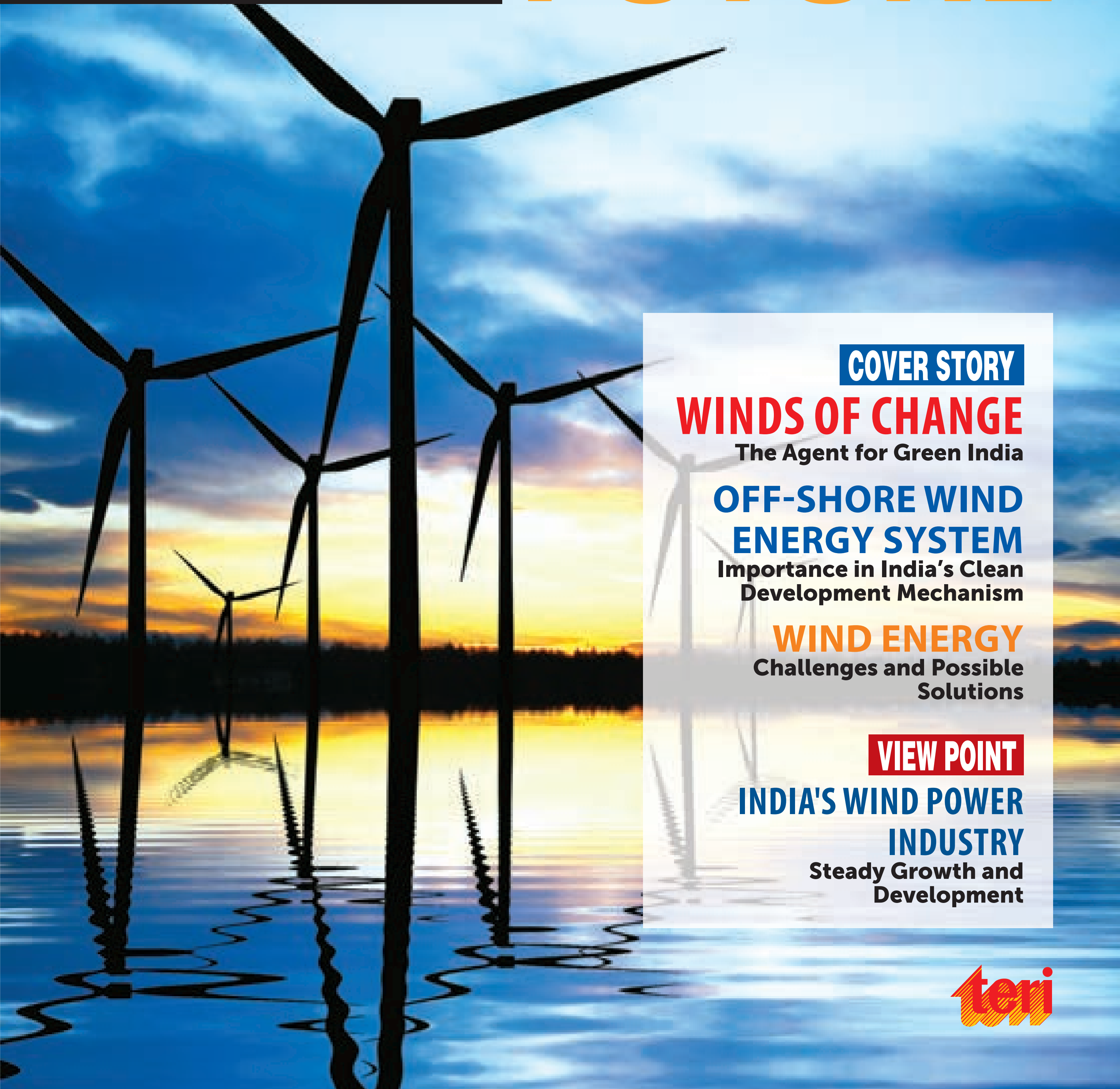
April–June 2017

ENERGY FUTURE

The Complete Energy Magazine

Volume 5 • Issue 3 • Annual ₹800



COVER STORY

WINDS OF CHANGE
The Agent for Green India

OFF-SHORE WIND ENERGY SYSTEM
Importance in India's Clean Development Mechanism

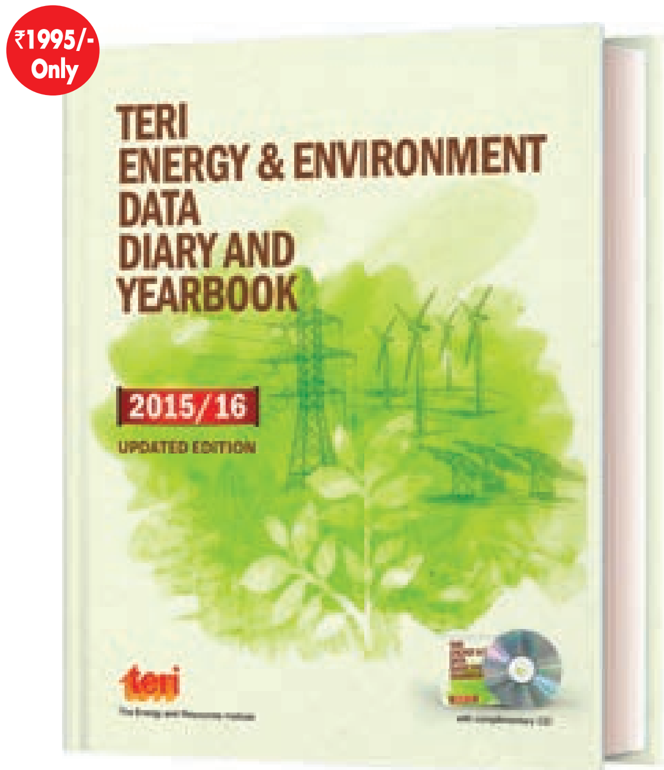
WIND ENERGY
Challenges and Possible Solutions

VIEW POINT

INDIA'S WIND POWER INDUSTRY
Steady Growth and Development

teri

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



ISBN: 9788179935910

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...

In a recent report launched by TERI on `Transition in Indian Electricity Sector 2017–2030', it is envisaged that if the costs of renewable electricity and energy storage systems continue to follow the expected trajectory, it is quite possible that the price of `firm' electricity from intermittent renewables, such as wind and solar, would become competitive with coal-based electricity after 2027. And in that scenario, investments for the new capacities could move to renewable energy. Looking at recent bids for solar and wind power in India, such an eventuality does not seem far-fetched although one must consider specific enabling conditions in such cases. So are we moving in a direction where today's `non-conventional' becomes `conventional'?

The role of wind energy in the overall renewable energy mix cannot be overemphasized. The fact that wind resources complement solar ones seasonally as well as diurnally, is critical while developing balancing strategies for a renewable-rich power system. Even from land-use optimization perspective co-locating wind and solar plants are attracting a lot of attention. Today, while on one hand larger wind turbines are being deployed on shore to help capture greater amount of energy from the same area, on the other hand the focus is also on off-shore wind. But another option that is yet to be exploited fully is about repowering. Many a good, windy sites in countries like India have low-capacity, inefficient wind turbines that were available decades ago. However, the same sites may yield much more energy if equipped with state-of-the-art wind turbines that are there today.

However, in this whole discourse, let us not lose our focus on one of the most commonly used fuel in developing countries, that is, biomass. Traditionally, this resource is used in a very inefficient and environment-unfriendly manner. The other challenge pertains to ensuring sustainable supply of biomass on account of it being dispersed. Therefore, if bioenergy is to reach the promising potential worked out generally on an aggregate level, it is essential to put equal emphasis on the complete value chain of biomass. This in turns implies a range of local and decentralized bioenergy solutions. That is how the future of energy is going to be!

Amit Kumar
Senior Director, Social Transformation, TERI

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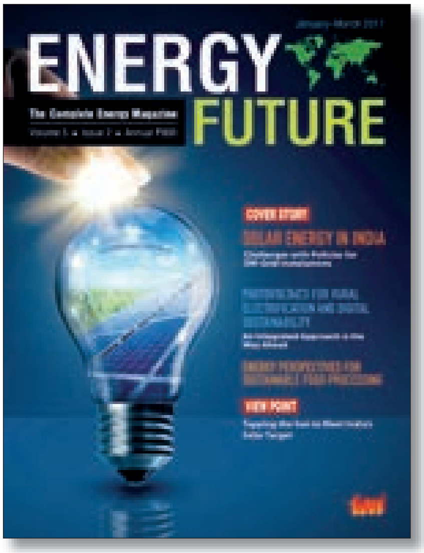
Printed and published by Dr Ajay Mathur for The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi- 110 003. Tel. +91(11) 24682100, 4150 4900, Fax +91(11) 2468 2144 or Email: teripress@teri.res.in, and printed by Batra Art Press, A-41 Naraina Indl. Area PH- II, New Delhi-28.



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Letter to the Editor

The article titled 'Towards a Renewable Energy Boom in India!' published in the January 2017 issue was an interesting read as it brought to light certain pressing concerns that have been at the forefront of the global energy crisis. It is a fact well known that for a sustained developmental growth, while cutting down GHG emissions, renewable energy sources are going to play an extremely crucial role. Also, in view of the ambitious target of 175 GW of installed renewable capacity, I agree with the view that the real boom is yet to come. Given the gravity of the situation, state participation is mandatory to achieve the ambitious objectives. While the policies adopted by the MNRE and other authorities promote renewable energy minigrids for which building a supportive microgrid ecosystem is necessary, I understand that this is easier said than done!

Sumita Sinha
Varanasi, Uttar Pradesh

"'Energy Perspectives for Sustainable Food Processing' an article published in the January 2017 issue, drives home the importance of terms, such as 'sustainability' and 'sustainable development'. In this, I appreciate the ways in which the food processing industry has been placed at the centre of sustainable development and lays emphasis on how such practices should not cause undue harm to the environment. I have always wondered how the existing methods can be replaced with more energy-friendly ways that will not only preserve the nutritional value but will add substantially to the energy-saving campaign. With this article I was acquainted with the various methods that can be deployed to achieve the same and hope to read more about it in the near future."

Iqbal Ahmed
Hyderabad, Telangana

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

"The article, 'Natural Gas: Is it the Alternate Fuel?' published in the January–March 2017 issue of *Energy Future* is very pertinent indeed. Significantly, natural gas is a more readily available resource, as compared to solar or wind energy that require intensive real estate provisions and government subsidies, etc. I agree with the author that natural gas can play a vital role in providing energy security while addressing climate change. The Product Update on 'Clean Cooking with Greenway Stoves' is also very useful, particularly for the womenfolk in India as the product has been designed to provide a sustainable way of clean cooking and, thus, helping in improving the standard of their lives. I also liked reading other articles and sections in the present issue. Keep up the tempo!"

Priyadarshini S Pandey
Secunderabad, Telangana

"The Solar Quarterly article published in the January 2017 issue is quite enriching for renewable solar energy professionals like yours truly. I have seen the solar industry from close quarters and surely feel that India has a strong potential for growth of solar power and this unmistakably presents an exciting opportunity to domestic and international investors. It is heartening to note that the Government of India has very recently approved the enhancement of capacity from 20,000 MW to 40,000 MW of the Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects. The enhanced capacity would ensure setting up of at least 50 solar parks each with a capacity of 500 MW and above in various parts of the country. This would contribute to long-term energy security of the country and promote ecologically sustainable growth by reduction in carbon emissions and carbon footprint, as well as generate large direct and indirect employment opportunities in solar and allied industries."

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Er Anshuman Biswas
Kanpur, Uttar Pradesh

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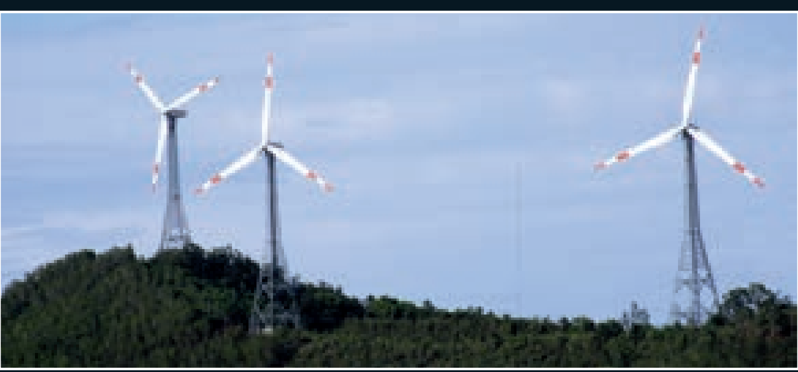


ROOFTOP SOLAR POWER GENERATION IS UP, BUT FUTURE UNCERTAIN

In the past year, Bangalore's rooftop solar power generation has jumped nearly fourfold. However, despite this apparently rapid response to the rooftop solar scheme, there is a growing concern that it is on the verge of losing steam.

The city had generated barely 7.5 MW of power in 2015–16 through the much-publicized scheme. By the end of 2016 however, the number had jumped nearly fourfold, making it a total of 36.7 MW generated through photovoltaic cells placed on rooftops in the city.

This number is bound to rise as nearly 1,000 applications are pending or unfulfilled.

Apart from this, inherent problems in the policy are seeing many of the older agreements, particularly with domestic consumers, falling apart.

Hippu Salk Kristle Nathan, assistant professor with the National Institute of Advanced Studies (NIAS), says the focus should be on getting institutions to adopt rooftop solar generation, instead of a generalized approach that also focuses on smaller domestic setups. Moreover, the financial burden becomes more manageable for institutions. EF

Source: The Hindu (Bangalore Edition)

INDIA SHOWS IT'S SERIOUS ABOUT SOLAR WITH GIANT POWER PLANT

It took 8,500 men working two shifts every day for six months—and three shifts for two months—to finish, ahead of schedule, the Adani Group's giant solar power plant in southern India. The vast, 10 sq. km project in Ramanathapuram, is the world's largest solar power station in a single location, according to the company. It has the capacity to power 150,000 homes, and shows how serious India is about meeting its renewable energy targets.

Considering the delays that commonly bog down infrastructure projects in India, the speed at which the 648 MW project was completed demonstrates the country's commitment to renewables, said an analyst.

As a signatory to the Paris Agreement on climate change, India is committed to ensuring that at least 40% of its electricity will be generated from non-fossil-fuel sources by 2030. Solar energy is a particular focus. It makes up 16% of renewables capacity now but will contribute 100 GW of the renewable energy capacity target of 175 GW by 2022. Of that 100 GW target, 60% will come from large solar installations.

The urgency also aims to fill a gap: India is among the world's fastest growing economies, yet one-third of its households have no access to grid power. The renewables goal will help ensure "uninterrupted supply of quality power to existing consumers and provide electricity access to all unconnected consumers by 2019," according to the blueprint. EF

Source: http://www.businesstoday.in/

TUSSLE BETWEEN BBMP AND CONTRACTOR LEADS TO CLOSURE OF 10 BIOGAS PLANTS

The bio-methanization plant in Domlur, Bengaluru, is not the only wet waste management centre that has shut down. Nine other plants commissioned in 2014 were shut down by the first week of January after a tussle between the Bruhat Bengaluru Mahanagara Palike (BBMP) and the contractor.

The BMPP alleges that the contractor has not fulfilled its obligations, while the contractor claims that they have not been paid dues of ₹21.09 crore since December 2013. However, it is the residents who are the biggest losers in this fight, as wet waste is now being transported many kilometres away.

"We want a biogas plant here as it would allow wet waste from at least two or three wards—Varthur, Hagathur, and Kadugodi—to be processed locally," said Anjali Saini, a member of Whitefield Rising, referring to the Varthur plant. This will reduce the incidence of garbage on the streets, she felt. In this case, the contractor claimed that the BBMP had not ensured water and electricity connections to the Varthur plant for two years.

In Koramangala, a plant that has been closed for the past 10 days had been processing commercial waste from nearby restaurants. "It helped manage commercial waste and light up lamps in the compound. We are planning to set up a similar plant for handling residential waste," said Padmasree, president of the Koramangala RWA. EF

Source: The Hindu (Bangalore Edition)

RENEWABLES PURCHASE OBLIGATIONS: CERC TO MAKE IT EASIER FOR DISCOMS

The Central Electricity Regulatory Commission (CERC) has proposed to decrease the floor prices of renewable energy certificates (RECs), making it easier for the state DISCOMs to meet their renewable energy purchase obligations (RPOs).

For solar, the proposed floor price is ₹1,000 per REC, substantially lower than the current rate of ₹3,500. For non-solar RECs, the proposed floor price has been suggested to be ₹1,000, down from the current ₹1,500. The proposed reduction in REC floor prices are in line with the fall in renewable energy costs. The forbearance prices of RECs, or the upper price limit at which the RECs can be traded, have also been proposed to be cut.

Since price evolution in solar has been more pronounced, fall in solar REC prices, both floor and forbearance, have been much steeper than its non-solar counterparts since 2010.

A total of 8.61 lakh RECs were traded in the REC trading session held in February at the Indian energy exchange. Out of this, 8.15 lakh were non-solar RECs and the rest were solar. In this quarter, the exchange has already traded 21.49 lakh RECs, 20% more than the trade done in first three quarters of this fiscal.

CERC has invited stakeholders' suggestions on the proposal. The quasi-judicial body would hold a hearing later this month before taking a final decision. EF

Source: The Financial Times

RENEWABLE ENERGY FIRM BHORUKA POWER IN TALKS TO RAISE $120 MILLION

Hydro and wind power producer Bhoruka Power Corp. Ltd is looking to raise about $120 million in equity investment and use the money to increase renewable energy capacity to 1 GW by 2020, said managing director S Chandrasekhar.

Bengaluru-based Bhoruka Power, which currently has 310 MW of hydro, wind, and solar power capacity, has hired an investment bank, and negotiations with potential investors are at an advanced stage, Chandrasekhar said over the phone on Tuesday. He declined to reveal any names, citing confidentiality agreements.

The company is in talks with some private equity investors and infrastructure funds for the equity investment, Chandrasekhar said.

The power company currently operates 110 MW of hydropower capacity, 170 MW of wind capacity, and 30 MW of solar capacity in Karnataka, Rajasthan, and Haryana, and is building a 200 MW wind farm in Karnataka. It plans to reach a total operating capacity of over 500 MW by 2018, and intends to double it to 1 GW by 2020. In 2008, Darby Overseas Investments Ltd, the private equity arm of Franklin Templeton Investments, invested in Bhoruka Power. Darby exited the investment in 2013, giving way to L&T Infrastructure Finance. EF

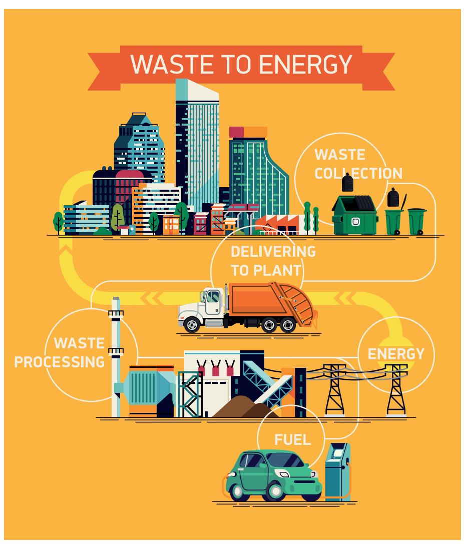
Source: LiveMint

NMC LAUNCHES INDIA'S LARGEST WASTE-TO-ENERGY PLANT

The North Delhi Municipal Corporation (NMC) on Friday launched India's largest 'Waste-to-Energy' plant.

The project, built at a cost of ₹650 crore and spread across around 100 acres at Narela–Bawana, will use 2,000 tonnes of waste daily to generate 24 MW of energy and 1,300 MW of refused derived fuel (RDF). The project has been developed on public–private partnership modeled by Ramky Group, a Hyderabad-based waste management company, in collaboration with the North Corporation.

Venkaiah Naidu, Union Minister for Urban Development, while inaugurating



the project at Civic Centre, said that solid waste management is one of the biggest challenges in the country. He said that the Swachchh Bharat Mission cannot be successful until there is proper scientific solid waste management. Union Science and Technology Minister Harsh Vardhan, who was also present on the occasion, said tonnes of sewer and solid waste every day is generated in the country and its disposal remains a challenge.

The power generated would be sold to distribution companies for a price fixed by the electricity regulator. EF

Source: The Pioneer

INDIA'S SOLAR CAPACITY TRIPLES TO 10 GW IN THE LAST 3 YEARS

India has surpassed the 10 GW solar photovoltaic (PV) installation milestone, having tripled its capacity in less than three years, according to Indian Minister Piyush Goyal; the Minister of State with Independent Charge for Power, Coal, New & Renewable Energy and Mines made the announcement in March 2107.

The new 45 MW project commissioned at Badhla solar power park in India helped the nation pass the 10 GW milestone. In May 2014, India's cumulative solar PV capacity stood at 2.6 GW. Since then the government has introduced a series of measures to foster renewable energy development.

Furthermore, a new report released last month revealed that if the cost of renewable energy and storage continues to fall at current rates, India could phase out coal power completely by 2050—significantly outperforming its commitments under the Paris Agreement. Under the Paris Agreement, the country has committed to source at least 40 % of its electricity from renewables by 2030, including 175 GW of renewable energy capacity by 2022.

Minister Piyush Goyal has said that India's solar power generation capacity would most likely cross 20 GW within the next 15 months. The news follows the announcement that a $500 million agreement has been reached for dedicated transmission lines for renewable energy projects in India. EF

Source: ClimateAction

STRONG TAILWIND POWERS BIDS FOR NEW WIND FARMS

India aims to build wind farms and installations to add at least 6 GW of capacity every year for the next five years, a high pace of growth that looks possible because of recent investor interest and the emerging change in tariff regime in the wind sector.

India's first ever wind power auction last month saw a record low tariff of ₹3.46 (USD 0.05) per kWh. This is a significant fall in rates compared with the more prevalent system of feed-in tariff at ₹4-6.

In wind power, the country's first reverse auction by state-run Solar Energy Corporation of India on February 23–24 saw aggressive bidding by wind power firms and tariffs crashed to ₹3.46 per kWh. Mytrah Energy, Green Infra, Inox, and Ostro Energy won rights to set up 250 MW wind projects each and sell energy to Power Trading Corporation. The tender provides a template for locating projects in high-wind resource states of Tamil Nadu and Gujarat, and reducing power costs for other states, Bridge to India said. Such auctions in the future will provide more transparency to the sector, break the domination of wind turbine manufacturers, and make the wind turbine market more efficient, according to the consultancy.

The financing of wind farms poses no problem as public sector banks and non-banking finance companies are eager to invest in this sector, D V Giri, Secretary General of industry lobby group Indian Wind Turbine Manufacturers Association, said at an investor briefing this week. EF

Source: India Climate Dialogue

RUSSIA BEATS SAUDI ARABIA AS CHINA'S TOP CRUDE SUPPLIER IN 2016

Russia overtook Saudi Arabia in 2016 to became China's biggest crude oil supplier for the first year ever, customs data showed on Monday, boosted by robust demand from independent Chinese "teapot" refineries. Russian shipments surged nearly a quarter over 2015 to about 1.05 million barrels per day (bpd), the data showed, with Saudi Arabia coming in a close second with 1.02 million bpd, up 0.9 % in 2016 versus the previous year.

While Saudi Arabia counts China's state oil firms as backbone clients through long-term supply contracts, China's independent refineries—nicknamed "teapots" due to their smaller processing capacity—saw Russia as a more flexible supplier. For the teapot plants, authorized to import crude oil for the first time in late 2015, shipments from Russia's eastern ports are easier to process, coming in smaller cargo sizes at a closer proximity.

Russia may be able to maintain the top spot in 2017 as it expands exports of its East Siberian-Pacific Ocean (ESPO) pipeline blend crude. Saudi Arabia, meanwhile, is set to shoulder the lion's share of supply cuts agreed to last year by the Organization of the Petroleum Exporting Countries (OPEC) and non-OPEC producers. Third-largest supplier Angola shipped 13 % more crude last year versus 2015, while the fourth largest seller Iraq recorded similar growth. EF

Source: The Financial Express

CHINA AND US LEAD WAY WITH WIND POWER INSTALLATIONS, SAYS GLOBAL ENERGY REPORT

The year 2016 saw 54.6 GW of wind capacity installed across the planet, with global installed capacity now standing at almost 487 GW, according to the Global Wind Energy Council (GWEC).

China installed 23.3 GW of new capacity, a 42.7 % share of the market. A distant second to China in terms of new capacity was the US, where 8.2 GW was installed.

The potential of wind power in China is significant. An MIT study said that wind power could—if certain adjustments were made—supply 26% of China's "projected electricity demand" by the year 2030. In the US, wind energy provided 4.7% of the entire electricity generated in 2015, according to the American Wind Energy Association. "Chinese installations were an impressive 23,328 MW (23.3 GW), although this was less than 2015's spectacular 30 GW, which was driven by impending feed-in tariff reductions," Steve Sawyer, GWEC Secretary General, said.

"Also, Chinese electricity demand growth is slackening, and the grid is unable to handle the volume of new wind capacity additions," he said, adding that the market was expected to pick up again this year. EF

Source: CNBC.com

WIND ENERGY IS NOW THE LARGEST SOURCE OF CLEAN ENERGY IN THE US

Wind power has now overtaken hydroelectric as the largest single source of clean energy in the United States. With 82,000 MWs of total installed capacity at the end of 2016, wind turbines exceeded the 80,000 MWs generated by the nation's hydroelectric dams.

Wind hasn't surpassed hydroelectric power in all categories; however, in terms of actual power generated, dams still out-perform wind turbines as they tend to stay on for more of the year. But with few dams planned for construction, its likely wind power will exceed hydroelectric in actual power produced in the next few years.

Much of the growth is being driven by Texas, by far the country's largest producer of wind power and the industry's leader in adding new capacity. Texan interest in wind power,

which grew under Governor Rick Perry, has wind energy advocates hopeful that Perry's current role as Secretary of Energy won't prove an impediment to additional growth.

Further interest in wind power may be generated by the sector's growing role as a job creator. Wind power provides employment for about 100,000 people nationwide. Bloomberg has reported that wind power advocates and developers have been urging the federal government to shift their attention to wind power.

Internationally, the U S remains way behind China in terms of wind power capacity. According to Chinese projections, by 2030 wind turbines will supply 26 % of the total electricity demand. EF

Source: Oil Price.com

GREAT RESOURCES SEES 'ENORMOUS' BIOMASS MARKET

Great Resources Co Ltd, a biomass heating provider, expects to achieve 50% sales growth this year, and plans to set up a research centre on the possible uses of straw, the company chairman said.

The company, based in the northeast city of Jilin, mainly develops biomass heating systems for homes and commercial users. Most commonly used types of biomass for such energy include agricultural residues, urban and industrial waste.

Hong Hao, chairman of Great Resources, said the use of biomass for heating has clear advantages over fossil fuels, citing sustainability as an example. Biomass heating technology, especially the use of straw, might have an "enormous market" in the future, Hong said.

So far, nearly 20 households in the nation's northern provinces of Jilin, Shandong and Shaanxi have adopted Great Resources' heating technology. Its commercial users are usually hotels, industrial parks, and commercial nurseries. In China, biomass has been drawing attention for its role as a reliable source of renewable heat in recent years. An efficient biomass industry would serve as an effective solution for climate change, said Cheng Xu, a professor of China Agricultural University. EF

Source: CHINADAILY.com

GEORGETOWN NOW 100% POWERED BY RENEWABLE ENERGY

The city of Georgetown is now one of the first cities in the US to run on 100% renewable energy. The milestone is met after the city ended a long-term power contract in 2012, and found new options for power suppliers that would source renewable energy—such as wind and solar power—from transmission lines in West Texas and the Panhandle.

On March 7, the city's mayor, Dale Ross, was featured on NPR's "All Things Considered" with Ari Shapiro to talk about the city's move towards renewable energy. "It's a great economic development tool because there are a lot of high-quality companies in this country that have robust green energy policies. Wal-Mart is one of them," said Ross in the NPR interview.

The decision to move the city's sites on renewable energy has brought millions of dollars in new investments and offers a cost-effective and sustainable alternative to power. EF

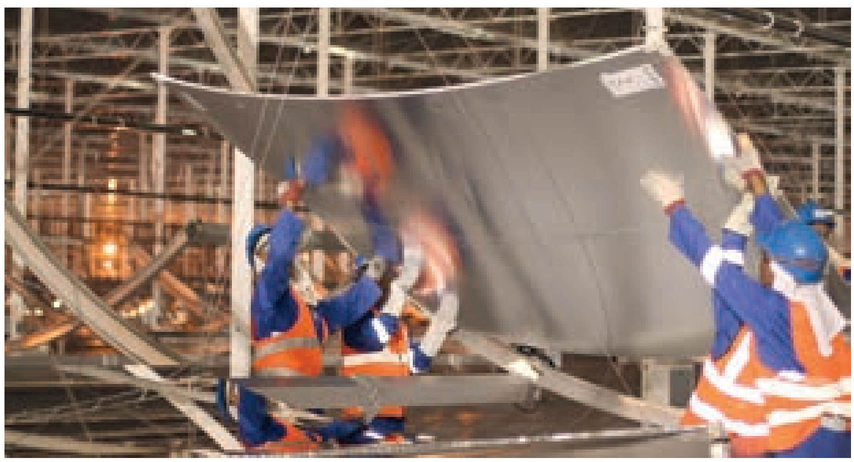
Source: The Statesman

OMAN'S SEARCH FOR RENEWABLE ENERGY SOURCES

Oman cannot rely on the same fossil fuel resources as its opulent neighbours. Oil reserves in Oman are more difficult to access, more expensive to exploit, and are also likely to run dry within 40 years. Oman's gas policy is also unsustainable. Gas accounts for 97.5 % of the country's fuel used for power generation. Despite possessing vast quantities of natural gas, domestic needs regularly outstrip production.

As a result, Oman seems to be turning a corner, and is now showing encouraging signs of progress in the renewables space. A 2008 study found that solar and wind power offer the greatest potential as renewable sources for electricity generation. Oman is now sensibly pursuing solar and wind technology prospects with gusto.

Oman has some of the best solar potential in the world. Oman's high ratio of "sky clearness" at roughly 342 days per year, along with its high solar irradiation, means it receives one of the highest solar energy densities in the world.



Harnessing powerful solar yields in the summer months would dramatically reduce the chance of blackouts. Moreover, utility-sized photovoltaic solar plants are now financially competitive with gas-fired thermal generation.

Oman's wind energy prospects also offer a strong potential. Particularly good wind resources exist in the southern and eastern areas of the country. Studies show that 375 MW wind turbine installations in Qairoon Haititi and Thumrait could produce 2.3 terra-watt hours of electricity per year alone.

The subsidization of electricity is the primary barrier to greater renewable energy access across Oman. Other challenges include a lack of policy coordination and a sluggish response to renewable energy opportunities. EF

Source: Earth Island Journal

IRAN'S RENEWABLE ENERGY CAPACITY TO HIT 700–850 MW IN A YEAR

Iran's renewable energy generation capacity will reach 700–850 MW in the current Iranian calendar year (which began on March 21), Seyed Mohammad Sadeqzadeh, the Deputy Energy Minister, announced. The official said that wind and solar farms will account for about 90% of the mentioned capacity, Mehr news agency reported.

Late in February, Sadeqzadeh, who is the managing director of Renewable Energy Organization of Iran (known as SUNA), announced that the country's total installed capacity of renewable power plants has exceeded 340 MW, ILNA reported.

For the time being, supplying 5% of the country's electricity need from renewable energies is a priority for Iran's energy industry but 10% or even 20% would be out of consideration. After the removal of the West-imposed sanction against Iran, foreign companies have been flocking to the country to contribute to its renewable energy sector. EF

Source: TehranTimes

APPLE TO USE 100% RENEWABLE ENERGY FOR MANUFACTURING IN JAPAN

Apple said it has partnered with component supplier Ibiden to power all of its manufacturing in Japan with 100 % renewable energy. To meet the commitment, Ibiden will invest in more than 20 new renewable energy facilities, including one of the largest floating solar photovoltaic systems in the country.

"We are proud to partner with suppliers like Ibiden who recognize that renewable energy investments are good for the environment and good for business," Lisa Jackson, Apple's Vice President for Environment, Policy and Social Initiatives, said in a statement this week.

Ibiden's renewable energy projects will produce over 12 MW of solar power, more than the energy they need for Apple's manufacturing purposes and support Japan's nationwide efforts to limit its carbon emissions.

"Our products help Apple devices run smarter, and now we are powering our operations with smarter energy too. We are pleased to partner with Apple and lead the way in helping Japan meet its clean energy goals," said Kyoichi Yamanaka, Managing Director of Ibiden's Environment Group.

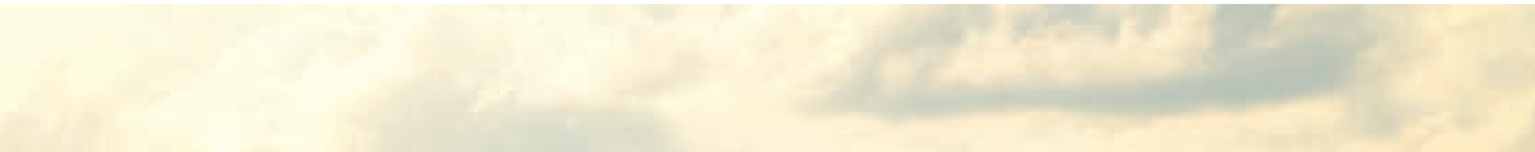
Apple and its suppliers will be generating over 2.5 billion kilowatt hours per year of clean energy for the manufacturing of Apple products by the end of 2018.

Apple has taken significant steps to protect the environment by transitioning from fossil fuels to clean energy. Today, the company is powering 100 % of its operations in 23 countries and more than 93 % of its worldwide operations with renewable energy. EF

Source: http://www.bgr.in/news

WINDS of Change

The Agent for Green India



India is fully committed to decarbonize its economy to maximum extent and the current government is moving with a clear vision to achieve sustainable development without sacrificing economic growth. In the process, renewable energy, such as wind, is stated to play a critical role. Wind energy, being one of the cheapest forms of energy with sustainable advantages, is poised to grow substantially in India. In this article, **Dr Sanjay Kumar Kar** and **Mr Vivek Kumar** present the opportunities for growth and the challenges faced by the wind industry in India. The authors discuss enabling factors for growth and suggest ways to address challenges to achieve growth targets by 2022 and beyond.

Energy is one of the vital inputs for growth and development of any country; in other words, energy is the back bone of economic and social progress. During recent years, India's energy demand has increased tremendously: primary energy consumption doubled from 345 million tonnes of oil equivalent (Mtoe) in 2003 to 701 Mtoe in 2015. Increased demand places enormous pressure on conventional and non-renewable sources of energy. Therefore, focus has shifted towards exploration and exploitation of renewable sources of energy, such as wind, solar, and biomass, to meet rising demand in sustainable ways. According to BP Statistical Review of 2016, primary energy consumption was predominantly fossil fuel based, which contributed 92.5% of total primary energy consumption. Amongst the fossil fuels, coal contributed 58% followed by oil (28%) and natural gas (6.5%). Dominancy of fossil fuel-based energy supply in India will be continuing in the near future. Presently, almost 90% of India`s crude oil availability is through imports, and with the current production level, crude oil would last for 18 years and natural gas would last for close to 51 years. At the current rate of production, coal offers long-term supply stability in India as the R/P stands at 89 years (Table 1). However, with increasing pollution of the environment due to fossil energy use, global leaders are striving hard to push greener energy agenda; therefore, renewable energy solutions are fast emerging across the globe.

To reduce the import burden of fossil fuel, India is strongly giving a strategic push to the development of renewable energy. Both at the Central Government and State Government levels, renewable programmes are getting various kind of support for faster production, distribution, and consumption. Renewable is the only medium that could lead India towards self-sufficiency—a step in the direction of energy independence.

India is blessed with a huge potential of renewable sources of energy, such as solar, wind, small- hydro, and biomass (Figure 1).

As per the Ministry of Statistics and Programme Implementation Energy Statistics of 2016, at the end of March 2015, total potential of renewable generation in the country was estimated at 896,603 MW. This includes solar power 748,990 MW (11.46%), wind power potential of 102,772 MW (11.46%), small-hydro power potential of 19,749 MW (2.20%), biomass power potential of 17,538 MW (1.96%).

Geographic distribution of renewable energy is also not uniform across the country. Rajasthan has major potential of renewable energy 148,518 MW (17%) followed by Jammu and Kashmir with 13% share (118,208 MW), Gujarat with 8% share (72,726 MW), mainly on account of solar power potential.

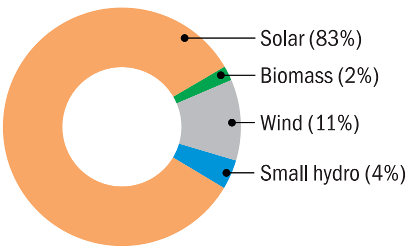


Figure 1 Estimated renewable potential as on March 31, 2015

Source: Energy Statistics 2016 Report

Table 1 Fossil fuel production & R/P ratio in leading economies in the world, 2015

Country	Oil Production (Million Tonnes)	R/P Ratio	Natural Gas Production (Mtoe)	R/P Ratio	Coal Production (Mtoe)	R/P Ratio
US	567.25	11.9	705.3	13.6	455.2	292
Saudi Arabia	568.50	60.8	95.8	78.2	-	-
Russia	540.7	25.5	516.0	56.3	184.5	422
Canada	215.5	107.6	147.2	12.2	32.1	108
China	214.6	11.7	124.2	27.8	1,827.0	31
India	41.2	18	26.3	50.9	283.9	89
World	4,361.9	50.7	3,199.5	52.8	3,830.1	114

Source: BP Statistical Review of World Energy, 2016

Status of Global Wind Energy

The year 2015 was a landmark year for global wind industry as annual installation exceeded 60 GW mark for the first time in history, and more than 63 GW of new wind power capacity was brought online. Governments of 186 countries finally agreed to protect the climate. Low fossil fuel price had no appreciable effects on growth of wind and solar.

The cumulative total global wind power at the end of 2015 was 432.9 GW, which shows a growth of 17% over the previous year (Figure 2). In terms of potential and actual development of renewables, Asia-Pacific is the major player. By the end of the year 2015, China was leading wind energy capacity with 145,362 MW followed by the US (74,471 MW), Germany (44,947 MW), India (25,088 MW), Spain (23,025 MW), UK (13,603 MW), Canada (11,205 MW), and France (10,358 MW). South Africa became the first African country to cross 1 GW mark.

Asia continued to remain as the world's largest wind power market, with capacity addition totalling about 33.9 GW. China almost doubled its capacity from 75 GW in 2012 to 145 GW in 2015. India continues to be the second largest wind market in Asia, and the fourth largest producer surpassing Spain with capacity of 25,088 MW (Figure 2).

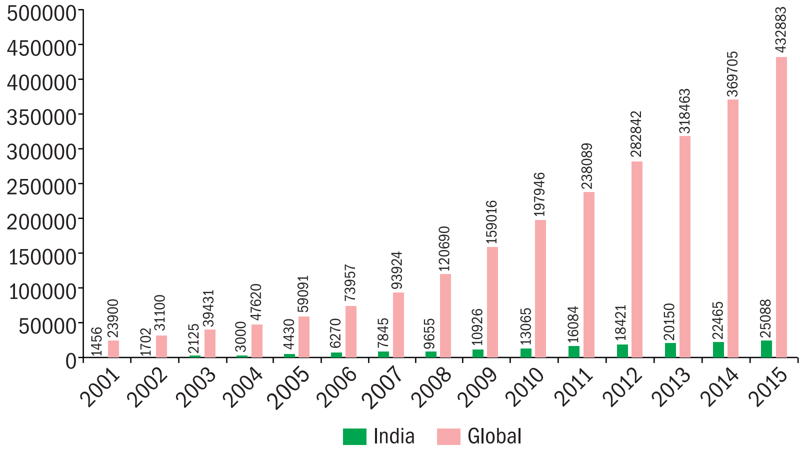


Figure 2 Global wind installation 2001–15

Source: Prepared by the authors based on Global Wind Report 2015

Development of Wind Energy in India

The Indian government set a target of 175 GW of energy from renewable sources by 2022, including 100 GW of solar capacity and 60 GW of wind power capacity. The government realigned its policies for rapid growth of renewable energy. Considering all factors, the target of 60 GW of wind installation by 2022 seems achievable. Undoubtedly India has the potential to achieve this target, but it still looks ambitious given the existing capacity as of 28,279 MW in October 2016. In 2015, an addition of 2,623 MW of wind shows the recovery phase and indicates better growth in future. India needs to add an average 6 GW of wind power every year during 2017–22 period to achieve the target of 60 GW.

Wind energy development in India has been relatively slow compared to China, the US, and Germany. The most probable reasons for slow growth in India could be ascribed to the Government's change in priority and shift in focus towards solar. Till 2007, India was the Asian leader with 7,845 MW installed wind capacity, but by the end of 2008, China overtook India.

The following sub-sections provide a brief account of wind power potential, growth, wind market developments, and enabling factors for growth in India.

India wind energy potential

The on-shore wind power potential in the country is over 302 GW at 100 metre height. Also, Ministry of New and Renewable Energy (MNRE) estimates 350 GW of off-shore wind potential remains unexplored. Both on-shore and off-shore wind potential of 652 GW is more than two times of India's current electricity installation capacity.

Wind energy growth of India

Growth of wind power installation in India has been slow (Figure 2). Table 2 shows the actual wind potential, installation, and potential utilization of leading wind resource-rich states in India. Tamil Nadu continues at the top position with 7,633.27 MW followed by Maharashtra (4,655.25 MW), Rajasthan (4,031.99 MW), Gujarat (3,930.94 MW), and Karnataka (2,877.97 MW). Wind energy production is concentrated in south-west India. As of March 31, 2016, average potential utilization was about 9% in the wind resource-rich states, whereas Tamil Nadu, Rajasthan, and Madhya Pradesh achieved more than 20% potential utilization. Maharashtra achieved 10% potential utilization, and all other states were below national average of 9% potential utilization.

Table 2 Actual wind potential utilization in leading states of India

State Name	Capacity (in MW; as of March 31, 2016)	Potential (in MW; @80m height)	Potential Utilization
Tamil Nadu	7633.27	33800	23%
Maharashtra	4655.25	45394	10%
Rajasthan	4031.99	18770	21%
Gujarat	3930.94	84431	5%
Karnataka	2877.95	55857	5%
Madhya Pradesh	2165.49	10484	21%
Andhra Pradesh	1432.95	44229	3%
Telangana	77.7	4244	2%
Kerala	55.8	1700	3%
Total	26,861.34	298,909	9%

Source: Prepared by the authors based on published reports and MNRE

As per India Wind Energy Association, about 70% of wind was generated during May–September months (Figure 3).

Development of Indian wind market

The efficiency of wind turbine has been increasing year over year by increasing rotor diameter, height, and mechanical efficiency of turbine. Currently, 113–114 m rotor diameter is used in India and setting up a wind firm takes about 18–20 months. Most of the Indian wind firms are now old with lower efficiency. Hence, the Government is focusing on the upgradation of old wind turbines. The current manufacturing capacity of India is around 9,500 MW, which can be scaled up. Suzlon is one of the leading players in the wind turbine business in India; the company showed the concept of hybrid tower at 120 m with lattice structure at the base and tubular upper, which reduces the cost and increases efficiency. Also, large base of 24 m^2 enhances stability and strength of the structure.

Growth factors for Wind

Over the last couple of years, wind installation growth rate in India slowed down compared to China. However, in the global context, the wind growth rate in India is appreciable. Following factors were responsible for the progress of wind energy in India:

- » Extensive wind resource assessment data (800 monitoring stations installed since inception);
- » Technology development and a strong domestic manufacturing base;
- » Conductive policy framework for investment.

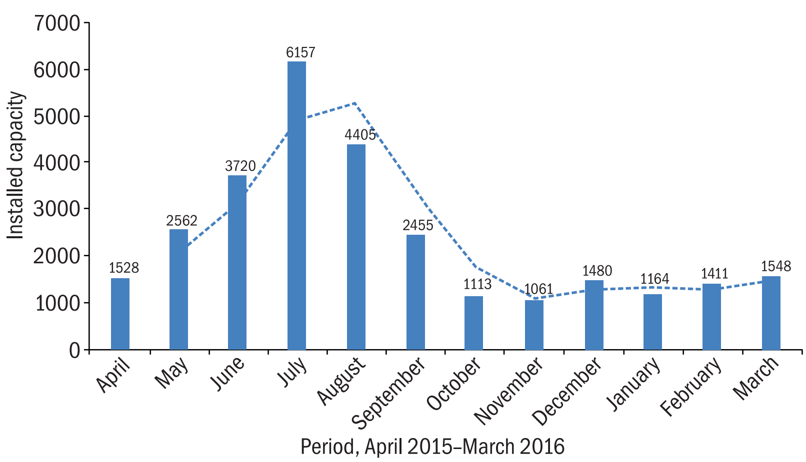


Figure 3 Month-wise wind power capacity installations in India

Source: Prepared by the authors based on Global Wind Report 2015

State-of-art technology and manufacturing

Domestic wind turbine and component manufacturing facility supports growth of wind market developments in many countries. For example, China's wind market growth is fully supported by domestic design and manufacturing of wind turbines and components. Indian manufacturers not only need to compete well with the global manufacturers to capture domestic market but need to capture a part of global market to thrive. As per the MNRE, Indian wind turbine and component manufacturing industry is becoming very competitive. Following facts about wind turbine and component manufacturers in India support the argument:

- » Cost of Indian wind turbines is among the lowest in the world
- » Capacity: 250 KW–3 MW; gear and gearless
- » Hub heights: up to 141 m
- » Rotor diameter: up to 125 m
- » A total of 21 manufactures with 58 models
- » Export to USA, South America, and Asia

Programme and Policies of Indian Wind Energy

Wind Programmes

Wind is a major source of renewable energy in India. By the end of November 2016, with 28.4 GW of installed capacity, wind contributed almost 61% of total renewable capacity of 46.67 GW. Like solar energy, wind power penetration could increase at a faster rate if wind energy is provided special attention. So far, most of the wind programmes have been on grid-connected wind power. Small wind energy applications and hybrid systems—for mechanical and electrical applications—in areas where grid electricity is unavailable is yet to generate momentum. Small wind aerogenerators in hybrid mode with solar panels are useful for off-grid renewable energy-based electricity generation. The Small Wind Energy and Hybrid Systems programme was launched in early 1990s and so far 2379.2 MW has been installed across 20 states. Under the scheme, a capital subsidy of ₹1.00 lakh per kW is available to an eligible beneficiary. It is to be noted that the exploitation of off-shore wind potential remains far from reality.

Wind Policies

Wind policy framing and implementation is being done at the Central and State Government levels. The Central Government develops policies through MNRE and its agencies. Further, state governments develop their own policies to promote production, distribution, and consumption of wind energy.

The Central Government is committed to increase wind power penetration in India. Therefore, on September 9, 2015, the Union Cabinet approved the 'National Offshore Wind Energy Policy' for promotion of wind power in India. The Government intends to aggressively push the exploitation of off-shore wind potential. The off-shore projects are almost two times costlier than onshore wind projects. So, the government will have to come up with appropriate policy interventions to enhance techno-commercial viability of off-shore wind in India.

One more problem cropping up for the wind sector is lower efficiency and productivity of old turbines. In order to address such a problem, repowering old wind farms is the way forward. Therefore, for optimization of wind energy resources, on August 5, 2016, the Government developed a policy for repowering wind projects. As per the policy, initially wind turbine generators of capacity 1 MW and below are eligible for repowering. The policy outlines the following provisions:

a. Repowering projects financed by the Indian Renewable Energy Development Agency (IREDA) will be entitled for availing an additional interest rate rebate of 0.25% over and above the interest rate rebates available to the new wind projects.
b. Repowering projects will be entitled to avail all fiscal and financial benefits available to the new wind projects subject to applicable conditions.

Incentive schemes

From time to time, the Government of India provides financial and non-financial incentives to promote renewable energy. Some of the important incentives available to wind producers are presented below:

- Accelerated depreciation
- Generation-based incentives (GBIs)
- Viability gap funding

» Concessional excise and custom duties
» Budgetary support for research, development, and demonstration of technology
» Income tax holiday

In 2010–11, the Government introduced generation-based incentive (GBI) scheme to maximize actual generation of wind power. Under the GBI scheme, the Government provides wind electricity producers ₹0.5/unit of electricity fed into the grid for a period of minimum four years and maximum 10 years. Under GBI-I (December 17, 2009–March 31, 2012) 2,031.38 MW wind capacity was registered and ₹1,047.83 crore has been released as incentives. Under GBI-II (April 1, 2012–March 31, 2017) 6,769.45 MW wind capacity was registered and ₹846.97 crore was released as incentives. Including the demonstration stage, so far ₹1,923.44 crore has already been released and ₹233.87 crore is under process.

Also, the government provides long income tax holiday period of 10 years to boost generation of wind power. Policy interventions impact growth and development of the renewable market in India, and Figure 4 highlights introduction of policy interventions. Further, to ensure purchase of renewable power, Renewable Purchase Obligation (RPO) concept was introduced. About 28 states and union territories have set RPO targets. Unlike solar, there is no specific wind RPO, so wind does not get priority.

In budget 2016/17, the Honourable Finance Minister Shri Arun Jaitley announced accelerated depreciation benefit should be reduced from 80% to 40% from April 2017. Also, GBI is set to come to an end in 2017. These initiative may create a rush for installation of wind farms among contractors, but till now it has not yielded any significant impact. Industry desired that accelerated depreciation benefit be restored to 80% and GBI extended beyond 2017, preferably till 2022; but the industry will have to wait for the Union Budget 2018.

Provisions in MNRE guidelines

MNRE is trying to create a conducive environment through its agencies and institutions for wind power growth. New guidelines suggest the following:

» Wind data by the National Institute of Wind Energy to be made available online free of cost.
» Wind site allocations to be developed within a maximum of four years.
» Creation of online registry and provision for mandatory reporting of monthly performance.
» Wind turbine to comply with grid regulations.
» Provision for noise and shadow flicker to ensure health and safety of people working/residing near the wind farm.

Wind power benefits

Wind power is eco-friendly, wind as an input is free, and with the latest technology, it can be captured efficiently. The remote areas that are still not connected to the power grid can use wind turbine to produce wind power and meet their own demand. The land below wind turbines can be used for agriculture, only small plot is required, which can be further reduced if a hybrid

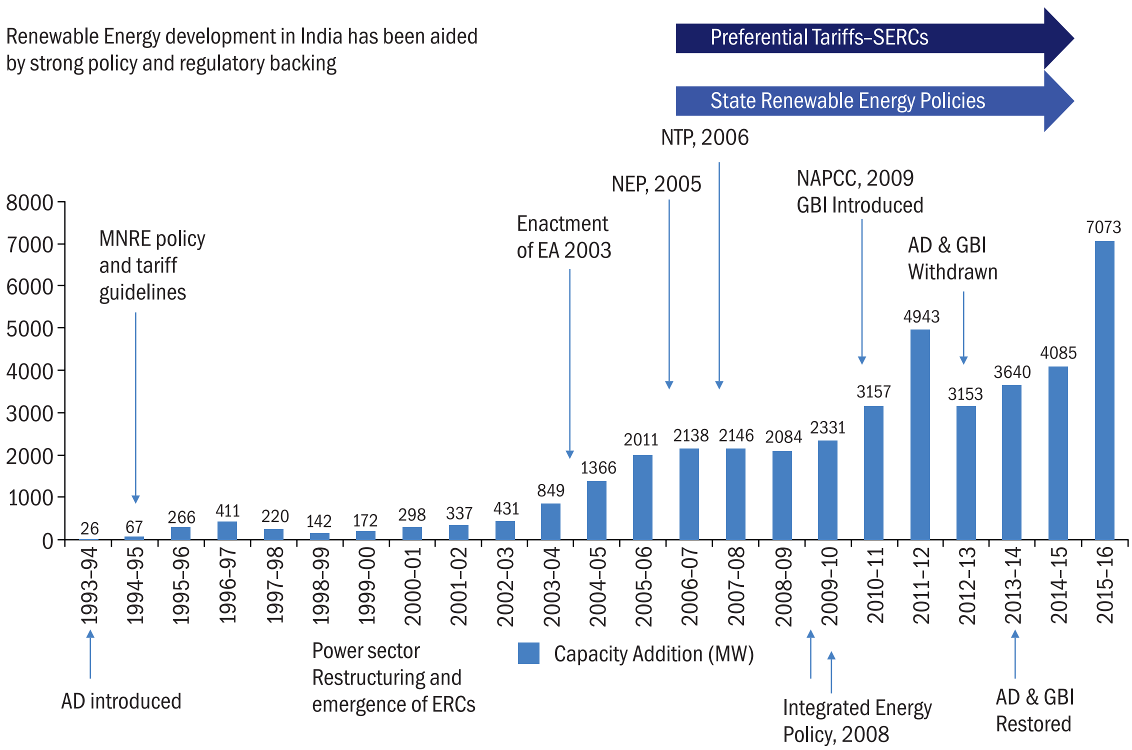


Figure 4 Impact of policy incentives on renewable growth in India

Source: Prepared by the authors based on Global Wind Report 2015 tower with a lattice structure at the base is used.

Barriers to Wind Power Growth in India

Spread of uneven wind resources: Wind resources are neither evenly spread geographically nor seasonally, hence, they require proper forecasting, scheduling, and balancing by the load centres. The Indian wind resources are rich in the south west. Table 2 confirms that there are windy states with high potential, such as Gujarat, Karnataka, Maharashtra, and Andhra Pradesh. Also, there are some states with relatively less wind and moderate to low potential.

Regulatory challenges: The Central Electricity Regulatory Commission is trying to enhance mandatory purchase of renewable power but successful implementation of RPO largely depends on State Electricity Regulatory Commission (SERC). Policy consistency is required for rapid growth of wind power. In the past couple of years, a strategic shift in focus towards solar was observed. On the regulatory front, solar RPO was introduced to boost solar production and purchase. However, wind falls under non-solar RPO; therefore, no specific attention was paid on wind RPO. At least in the wind resource rich states, SERCs may consider setting up of a separate wind RPO target.

Project financing: With reference to financing renewable projects, especially wind, getting capital is a big issue as historical evidence suggests that interest rate for renewable projects have been as high as 11%–13%, even more in some cases. As per the Planning Commission's Twelfth Plan document, increased capital cost acts as a barrier to the growth of wind sector. In the recent times, the falling interest rate brought down cost of capital, which would enhance project viability.

Availability of land: Availability of land for wind firm is a disputed issue in many states. Converting agricultural land to non-agricultural land for setting up of wind farm is a time-consuming process and results in delay of projects. Also, companies have to take permission from numerous departments for acquiring land, which leads to a delay in project initiation and completion.

Strategic Outlook

Need for stronger policy formulation, implementation, and control: Currently 28 states and union territories have defined RPO but only a few of states, such as Tamil Nadu and Maharashtra successfully implemented it. The regulators and Government should work together to ensure that the RPO targets are achieved within the time frame. As per the National Action Plan on Climate Change, RPO should be 15% by 2020. Therefore, customized incentive schemes should be devised for resource-rich and resource-deficit state for achieving RPO targets.

In recent times, it seems the balance of power tilted towards solar. A balanced approach is needed on solar and wind to promote wind energy in India. In case of renewable energy, each state follows its own policy, possibly to attract the investors. However, it seems such polices confuse investors. Therefore, during the Tenth Renewable Energy Conference almost all CEOs and higher authorities of top companies of the wind sector working in India suggest "One India One Policy System".

Thrust on renewable market development: Government has to take initiative to develop a proper market for renewables by ensuring capital security and developing logistic facilities in rural areas to make the construction of wind farm easier.

MNRE's proposal to extend performance-based incentive to the tune of ₹0.62 /kWh to distribution companies (DISCOMS) would serve as a catalyst to the enhance performance of the distribution sector. Further, this may incentivize DISCOMS to meet their RPOs.

As electricity is kept out of goods and services tax (GST), electricity would be expensive in the range of ₹0.30–0.40/kWh. Therefore, industry demands "Zero" rate GST for wind-operated electricity generators, which would be helpful to keep wind energy cost effective. Managing low-cost wind power production and distribution would automatically spur consumption and market development.

Further, to promote wind energy, concessional finance/interest subvention for manufacturing sector that invests in wind energy for captive utilization should be considered. This is not only going to boost wind but also manufacturing and 'Make in India' initiative. In addition, export subsidy may be introduced to substantially increase value of wind component export from India.

National power grid integration with renewable: Wind turbines, due to their control and operating mode, offer maximum grid compatibility. Wind farms should be able to be integrated in the grid control system for remote monitoring and control and control of all turbines in the grid as per wind world.

Improving financial accessibility: Most of the renewable projects are funded by banks and financial institutions; the rate of interest is as high as 11%–13%, which should be reduced for rapid growth. Even banks and financial institutions are more cautious while lending to wind projects. With the Reserve Bank's liberal policy, the lending rates are coming down, which would bring down cost of capital for wind projects. Further, the Government is constantly trying to attract foreign capital to improve supply of capital to the developers. The Government's plan to set up a $400 million fund, sourced from the World Bank, which could act as a shock absorber for the renewable energy producers against delayed payments from the distribution firms. The Government plans to create additional funds to provide investment support to stressed renewable assets.

Conclusion

India is a developing country, and for its sustained economic growth, development of power infrastructure plays a significant role. Renewable is the only source that can enable India to be energy self-sufficient. The Government

of India is highly determined for rapid growth of renewable, with a tilted focus towards solar. However, as on date, wind is the largest renewable power contributor. So far, on-shore wind has competed well with conventional power. Time has come to harness off-shore wind, which is costlier, and with scalability in mind, the cost will come down.

The Government has taken steps towards harnessing grid-based and off-grid wind power in the country, but off-grid gives robust result. Modern wind turbines are now more efficient and productive, therefore repowering of old wind farms have drawn much-needed attention. The wind component manufacturing industry stands to heavily benefit from the 'Make in India' initiative of the Government.

We are sure that by 2022 the Government will be able to achieve 60 GW of cumulative wind installations. This demands efficient grid integration, for which the Government has been pushing the concerned companies to do the needful. Needless to mention, there are multiple impediments at various levels in achieving this target. One of the biggest impediments is the funding of risky but rewarding renewable energy projects. All possible efforts are being made to create a better investment climate and facilitate funding of renewable projects. Wind power is certainly acting as an agent of change for green and clean India.

Suggested Readings

» Press Information Bureau. 2015. Approval of National Offshore Wind Energy Policy. New Delhi: Government of India. Last accessed from http://pib.nic.in/newsite/PrintRelease.aspx?relid=126754 on March 14, 2017.

» IRENA. 2012. Renewable Energy Technologies: Cost Analysis Series. 1(5). Last accessed from http://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis_wind_power.pdf on March 14, 2017.

» Kar S K and Sharma A. 2015. Wind power developments in India. Renewable and Sustainable Energy Reviews 48: 264–275.

» Union Budget 2016. Last accessed from www.indiabudget.nic.in on March 14, 2017.

» MoEFCC. National Action Plan on Climate Change. New Delhi: Government of India. Last accessed from www.envfor.nic.in/ccd-napcc on March 14, 2017.

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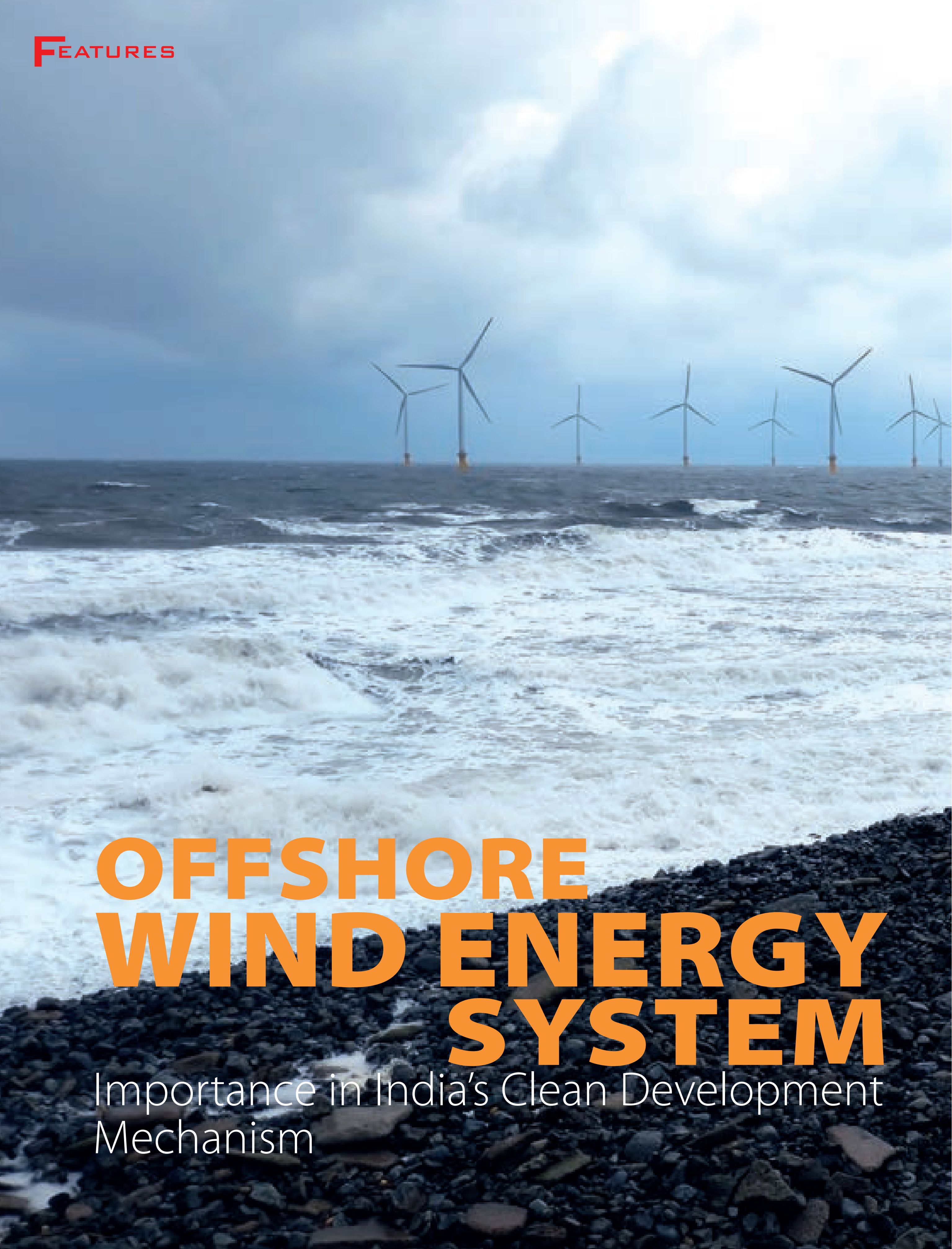

OFFSHORE WIND ENERGY SYSTEM

Importance in India's Clean Development Mechanism

Nowadays, off-shore wind energy system is the emerging trend in electricity generation in the form of non-conventional energy system. Offshore wind power is the use of wind farms constructed off-shore, usually on the continental shelf, to harvest wind energy to generate electricity. **Dr Vikas Khare** presents the role of offshore wind energy system in clean development mechanism in India. This article explores offshore wind system parameter, software tool used to assess offshore wind system, offshore wind system potential in India, grid parity, and greenhouse gas emission from offshore wind system. Further, Indian government policy and challenges towards offshore wind energy system are also presented in this article.

India is motivated to extend new and non-conventional energy resources on a large scale, to meet its future electricity demand. To fulfil the requirement of renewable energy resources, operation of wind energy system is a good solution to avoid different issues of greenhouse gasses (GHGs) and climate change caused by the consumption of fossil fuel and play effective role in clean development mechanism (CDM). The recent upcoming trend in generation of electricity through renewable energy sources, especially in harnessing wind power, is offshore wind energy system. India has an extensive coastline of over 7,000 km that can be harnessed using floating wind turbines that can become a great source of energy. The Global Wind Energy Council (GWEC) launched a new report "Supply Chain, Port Infrastructure and Logistics Study" for offshore wind development in the states of Gujarat and Tamil Nadu in India. This study is a noteworthy step forward in preparing a framework for offshore wind power in India by the GWEC.

At any floating or offshore wind enlargement site, water depth is crucial for identifying a suitable foundation technology. For this, bathymetric data for the Indian Exclusive Economic Zone (EEZ) ocean area up to 370 km from the baseline is obtained from the General Bathymetric Chart of the Oceans with a resolution of 1 arc-minute. Development of offshore wind farms requires rationalized spatial information of current impacts on marine ecosystem. Data for cumulative human impacts on marine ecosystem was obtained from the National Centre for Ecological Analysis and Synthesis. The floating foundation is tethered to the seabed by a type of anchoring device adapted from oil and gas offshore platforms. If capital cost of offshore wind turbines is brought at par with onshore wind energy, it is a good prospect for India. In order to make offshore wind energy at par with conventional sources of energy in India, policy regimes of the government of India supporting and incentivizing its development are essential. On September 9, 2015, the Union Cabinet gave its approval for the National Offshore Wind Energy Policy, 2015, with the intent to support and incentivize the development of offshore wind energy in India. The Policy was released in the public domain by the Ministry of New and Renewable Energy on October 1, 2015, and shall come into force from the date of notification in the Official Gazette. Figure 1 shows key players expected to play an important role in the development of offshore wind energy system in India.

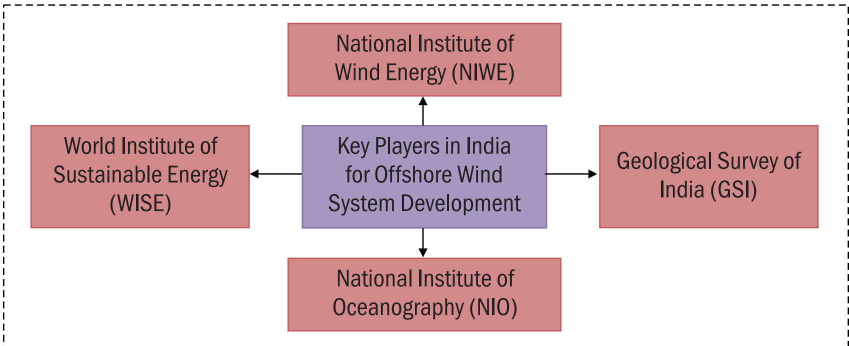

Figure 1 Key players for off-shore wind system development in India

Offshore wind turbines (OWTs) offer a striking, sustainable resolution to the impending worldwide electricity disaster. A key challenge in fixed-bottom OWT intend is accounting for soil–structure interaction (SSI) under the influence of random dynamic loading from wind, waves, and currents. The CDM was one of three mechanisms recognized by the Kyoto Protocol in 1997 to meet the environment convention intention of stabilizing GHG concentrations in the atmosphere at a level that would avert hazardous anthropogenic interference with the atmosphere. The other two mechanisms are Emissions Trading and Joint Implementation, both of which are not viable options for developing countries.

Offshore Wind System Modelling Parameter

When modelling an offshore wind energy system, different parameters are considered for effective designing of that energy system, which play an important role in CDM. Offshore wind resource distinctiveness spans a range of spatial and temporal scales and field data on external conditions; further, the energy per sea area is roughly independent of turbine size. Essential data includes water depth, currents, seabed, migration, and wave action, all of which drive mechanical and structural loading on potential turbine configurations. Other factors include marine growth, salinity, icing, and the geotechnical characteristics of the sea or lake bed. A number of things are necessary in order to attain the necessary information on these subjects. Existing hardware for these measurements includes light detection and ranging, sonic detection and ranging, radar, autonomous underwater vehicles, and remote satellite sensing. A typical OWT hub height of 85 m is selected for the purpose of analysis at any study area and wind resources are measured by Ocean Sat 2 Scatter metre (OSCAT) at 10 m above the sea level and the data needs to be extrapolated to the required hub height, for which the logarithmic law was used which is given by the relation:

Where Z, Z_r represent the turbine hub height and a reference height above sea level, respectively. $V_z V_{zr}$ are the wind speeds at height Z, Z_r respectively. Z_0 is reference length which is 0.2 mm.

All over the world, conventional fixed-bottom deployment of offshore wind has progressed but is still inadequate because of a number of constraints. One of the most stimulating emerging technical advances for the wind industry is development of floating wind turbine platforms. With a number of advantages over conventional offshore wind, floating wind turbine concepts have spawned from start-ups worldwide and at least three different designs are being actively tested off the coast of Portugal, Norway, and the United Kingdom. Finally, there are also several mechanized advantages to floating platforms, such as using less material in construction and reducing the need for specialty marine engineering expertise. One major cost driver for conventional offshore wind is the heavy lift vessels required to erect the turbine. Very expensive special purpose ships are required to transport the parts on site and perform the assembly. Floating turbine platforms, however, are designed to be assembled in port and towed into position using simple barges or tugboats. This can result in major cost savings and greatly increases flexibility in construction. In India, different companies are working in this field and they are trying to develop a new concept related to floating wind energy system. Figure 2 shows the path of advancement in wind energy system from onshore to offshore technology in India and all over the world. Figure 3 shows the depth of the turbine below the sea water surface in offshore wind system technology.

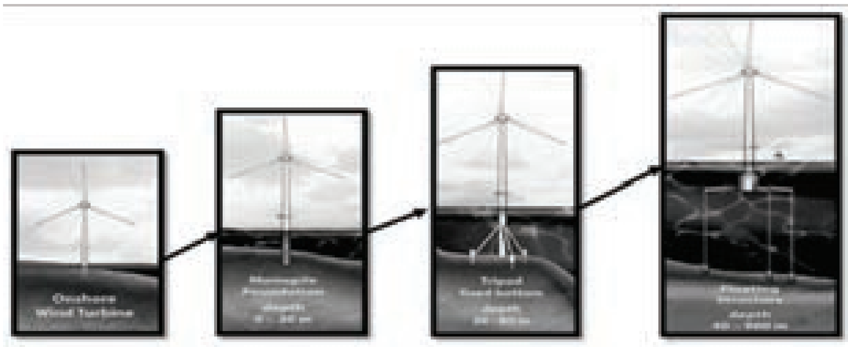

Figure 2 Path of advancement in wind energy system

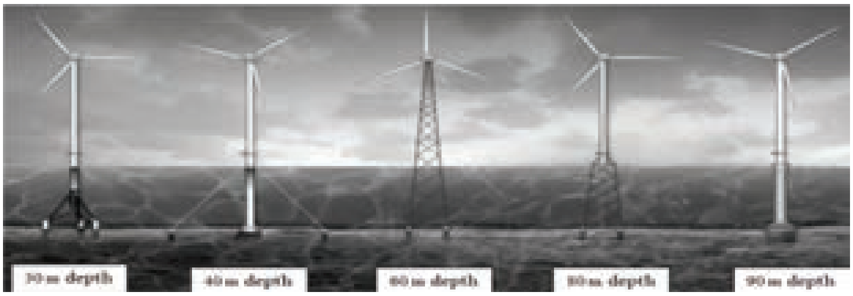

Figure 3 Depth of turbine below the sea water surface in off-shore system

Software Tool Used to develop Offshore Wind System

In India ESRI products, such as 'ArcView', 'ArcInfo', and 'MapInfo' are mostly used to find out Geographical Information Systems, which provide pre-feasibility analysis of offshore wind energy system site. In the wind energy specific area, 'Wasp' and 'Wind-Pro' have great shares in the market. For electrical systems, 'Power Factory', 'PSS SINCAL', and 'PSS/E' are favoured systems. In the financing and economic sector, 'Microsoft Excel' plays an important role in India in offshore wind energy system data analysis. Table 1 shows a summary of the different software, that are used in offshore wind energy system analysis and implementation.

Table 1 Summary of different software used in off-shore wind analysis

	Software	Developer	Description	Covered Area	Suitability
Geographical Information System	Arc-view	ESRI	Desktop GIS	Geographical data base analysis for off-shore wind energy system set-up	High
	Arc-info	ESRI	Desktop/Server GIS	Geographical data base analysis for off-shore wind energy system set-up	High
	Map-info	Map-info corporation	Desktop GIS	Geographical data base analysis for off-shore wind energy system set-up	High
	Grass	Open source, GPL	Desktop/Server GIS	Geographical data base analysis for off-shore wind energy system set-up	High
Wind Energy Specific	EMD Wind PRO	EMD	Module based s/w for wind energy project	Wind speed calculation, layout optimization, and energy calculation	High
	Windfarmer	Garrad Hassan	Module based s/w for wind energy project	Wind speed calculation, layout optimization, and energy calculation	Medium
	Wasp version 4.5	Risoe	Wind turbine and wind climate analysis software	Wind speed calculation, layout optimization, and energy calculation	Medium

Potential Site in India for Offshore Wind Energy System

There is a huge potential for power generation from offshore wind farms from the Indian seas. India has a geographical advantage with regard to cost-effective installation and operation of large-scale offshore wind farms in that the quality of the spatial, substrate, and wind conditions exceeds those of the neighbouring countries. One of the leading manufacturing companies is scheduling to invest about ₹6,000 crore on India's first offshore wind mill project in Gulf of Kutch in Gujarat. Offshore windmill projects require more copex as compared to onshore ones, with investment being almost 2.5 times that of onshore. According to the company, the economically feasible potential in the west coast for offshore is nearly 90,000 MW and in the south coast is nearly 120,000 MW totalling 210,000 MW in these regions. Moreover, offshore enables larger wind energy projects, leading to potential for building 1,000 MW to 2,000 MW facilities. Additionally, the capacity factor of such projects can range from 30%–45%. Gujarat has over 1,600 km of coastline (the longest in India) and a significant number of developed and protected harbours. The Adani port facility has the potential to be used as a wind turbine marshalling facility during construction. Figure 4 shows the potential site for offshore wind energy system in India in green colour.

Larsen and Toubro's fabrication facility in Hazira would be a possible fabrication site for several types of offshore wind foundations and possibly substation topsides. The Port of Pipavav has facilities to accommodate foundations and potentially turbines, if suitable coal dust insulation is used. Bhavnagar has a narrow lock-gate on the approach channel so is unsuitable for installation vessels. There is, however, a well-developed limestone handling facility, which could be utilized as a base of scour protection marshalling during construction and operation and maintenance (O&M) phases. Port Okha, the nearest port to development zones, however, would require substantial infrastructure development before being suitable to support offshore wind developments.

In Tamil Nadu, 3 major and 22 minor ports have been identified during the pre-feasibility study of offshore wind energy system. The development zones identified during the pre-feasibility study are mostly concentrated around the Gulf of Mannar. There are three facilities that are of interest in the present construction port study in Tamil Nadu for offshore wind energy system development. Tables 2–4 show different project specification and parameter of Gujarat and Tamil Nadu offshore wind energy system projects.

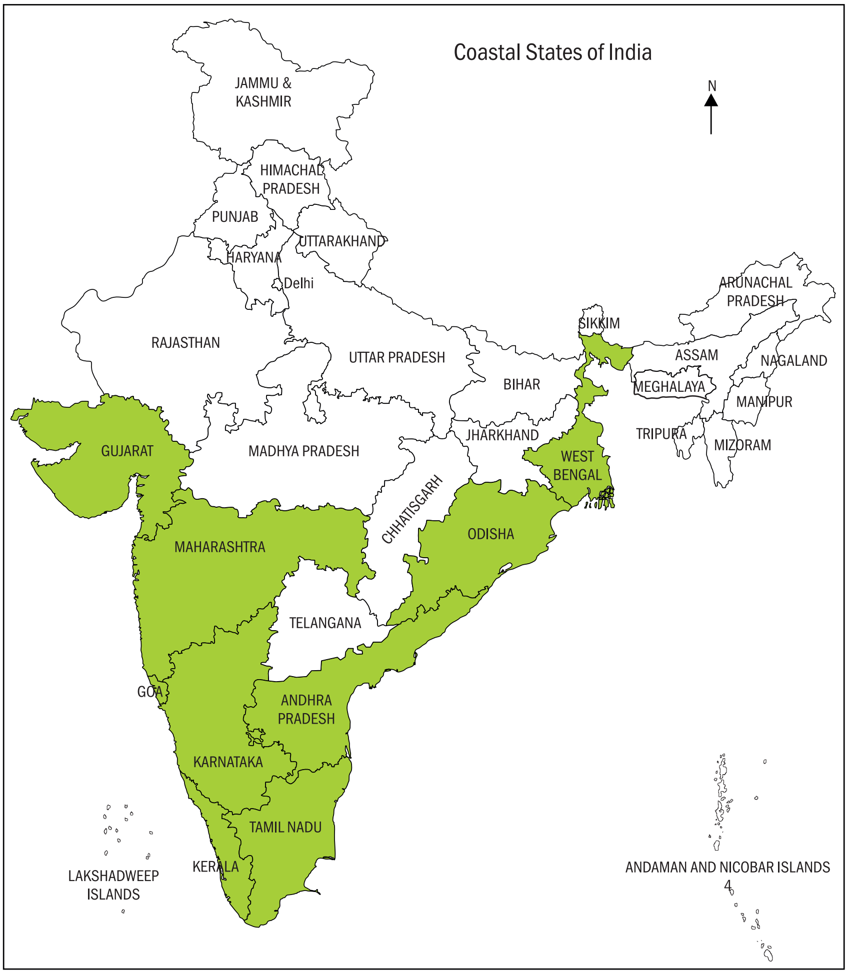

Figure 4 Potential site for off-shore wind energy system in India

Key Aspects of the Government Policy for Offshore Wind Energy System in India

In India, preliminary assessments along the coastline have indicated prospects for development of offshore wind power. Wind resource data collected for the coastline of Rameshwaram and Kanyakumari in Tamil Nadu and Gujarat coast show a reasonable potential. A preliminary assessment suggests potential to establish around 1 GW capacity wind farm each along the coastline of Rameshwaram and Kanyakumari in Tamil Nadu.

Electricity generation from renewable sources of energy is an

Table 2 Gujarat and Tamil Nadu project specification

Parameter	Gujarat	Tamil Nadu
Wind turbine capacity	5–6 MW	5–6 MW
Project capacities	150–500 MW	150–500 MW
Minimum distance to existing substation	9–45 km	12–46kM
Water depth	15–43m	10–53 m
Foundation type Considered	Monopile jacket	Monopile jacket

Table 3 Selected facilities of interest in Gujarat

	Draft (m)	Harbour Entrance Width (m)	Turning Radius (m)
Adani Port	13	470	300
L&T fabrication facility	4	160	180
Port of Pipavav	15	490	310
Bhavnagar	4	270	190
Port Okha	4	180	146

Table 4 Selected facilities of interest in Tamil Nadu

	Draft (m)	Tidal Range (m)	Outer Channel Length (kM)	Inner Channel Length (kM)	Channel Width (m)	Turning Basin Diameter (m)
Kattapalli	14	1	2	1.3	165	570
Chennai	18	2	7		410	600
Tuticorin	9.5		10			

important element in the Government's National Action Plan on Climate Change (NAPCC) announced in the year 2008. The policy related to wind energy system will be known as the 'National Offshore Wind Energy Policy—2015'. The policy will remain in force in its entirety unless withdrawn or suspended in whole or part by the Government of India. The Government of India will undertake a review of this Policy as and when required in view of any technological breakthrough or any changes taking place in any related policy or goals. The Government of India in its interest to develop offshore wind farm has decided to have a policy that will enable optimum exploitation of offshore wind energy in the best interest of the nation. Figure 5 shows offshore wind system development model by the Government of India and

Preliminary Wind Resource Assessment, Oceanography & Bathymetric Surveys

Request For Clearance/No Objection Certificate

Leasing of the seabed and allocation of blocks

Power Evacuation

Final Approval for Commissioning of Offshore Wind Farm

Security of Offshore Wind Farm

Decommissioning, Monitoring, Incentives

Capacity Building and Technology

Figure 5 Off-shore development model by Government of India

Figure 6 shows the path of offshore wind system in CDM in India.

- To investigate and endorse exploitation of offshore wind farms in the exclusive economic zone (EEZ) of the country, including those under public–private partnership;
- To promote investment in energy infrastructure to increase electricity generation through offshore wind energy system;
- To encourage spatial framework and management of maritime non-conventional energy resources in the exclusive economic zone of the country through suitable incentives;
- To achieve energy security and reduce GHG emissions;
- To encourage indigenization of the offshore wind energy technology;
- To promote research and development in the offshore wind energy sector;
- To create skilled manpower and employment in the offshore wind energy sector; and
- To develop coastal infrastructure and supply chain to support heavy construction and fabrication work and the O&M activities.

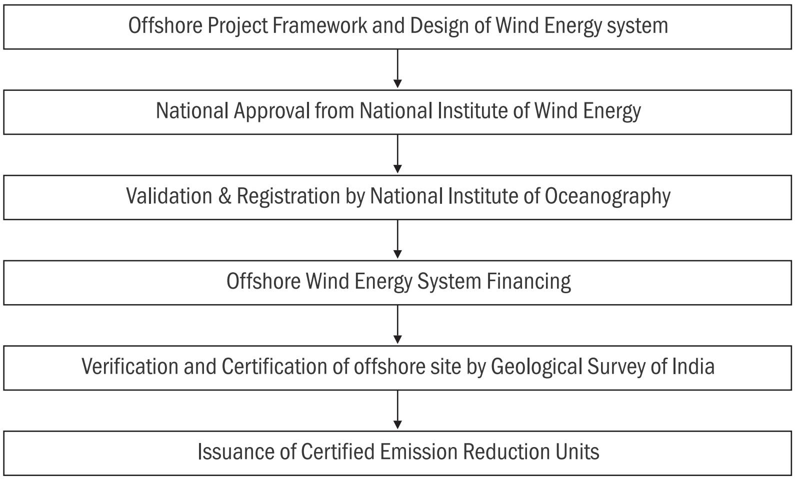

Figure 6 Off-shore wind energy system project cycle for the CDM

GHG Emission from Offshore Wind Energy System

Less GHG emission plays a significant role in CDM. For electricity generation, offshore wind power sites offer significantly better wind conditions compared to onshore, but due to the demand for raw materials, wind power converter, and additional component requirements, increases environmental impact and GHG emission. Parameters influencing energy yield has a strong collision on the GHG emissions; similar effects can be achieved by a comprehensive operational time of the wind farm (i.e., 20–30 years), if the O&M efforts do not increase proportionately.

With a life cycle of 30 years, the wind energy converters produce about 50% more energy but the GHG emissions increase only by 5% due to the O&M, which shows that the offshore play significant role in CDM. This reduces the specific GHG emissions to about 11.7 g CO_2-eq/kWh. On the other hand, a change in wind speed from 10 m/s to 8 m/s decreases the power production by about 28% and thus results in significantly higher GHG emissions. The cradle-to-grave approach is used for investigating GHG emissions of utilization of offshore wind energy for electricity generation. In a different study, impacts of several parameters are analysed to identify the unit sizing of wind farm with low overall GHG emissions depending on the site, which are then compared with the results of an onshore wind energy generation. The greater part of the GHG emissions for offshore wind power generation are released during the construction process of large section and supporting structures, which is made by stainless steel and cast iron. The GHG emissions highly depend on the location of the offshore wind farm defining the type of the substructure, water depth, and the O&M concept in case of larger distances to shore. The increase in material demands and logistic efforts for wind farms located far offshore could be compensated by the application of wind mill technology with a high-power generation. Figure 7 shows approximate breakdown of GHG emission from offshore wind energy system because less GHG emission play a significant role in CDM in India.

Grid Parity of Offshore Wind Energy System

Grid parity is the tip at which the cost of generating electricity from alternative energy becomes equal to or less than the cost of purchasing power from the grid. In view of the fact that as a result of the condition, exact place of 'grid pricing' varies not only from site to site but also customer to customer and even hour to hour. The point at which grid parity occurs is a function of two variables, the rate of increase in conventional power prices

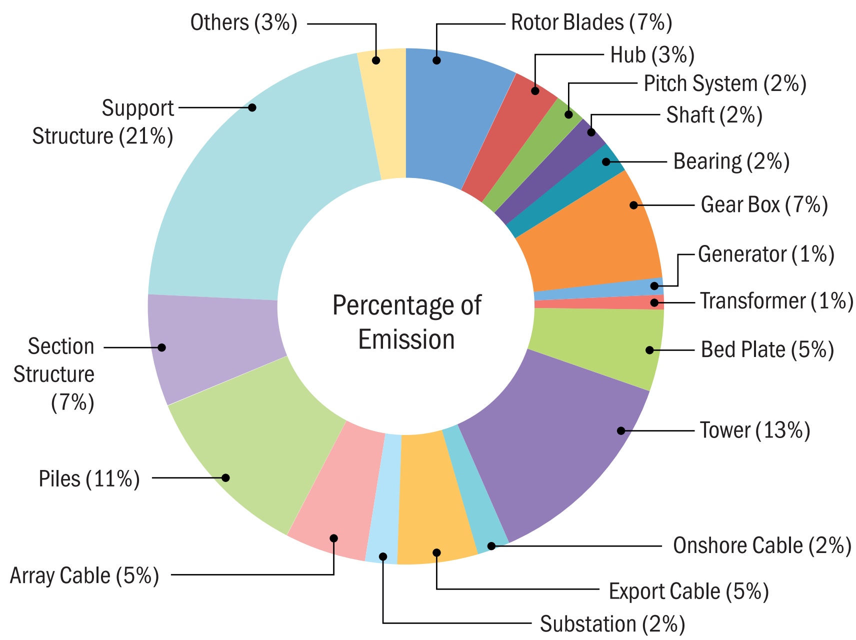

Figure 7 Approximate breakdown of GHG emission from off-shore wind system

and the rate of decrease in offshore wind power prices. It is expected that landed cost of conventional electricity to consumers will increase at a rate of 4% per annum in the base case and 5.5% per annum in an aggressive case. These factors include increasing proportion of raw material imports, cost of green field generation, and higher investments in network assets to improve operational efficiencies of the utilities. Grid parity is also implemented in wind power, where it depends on wind quality and distribution factor. In India, predicted offshore wind power's real cost will approach grid parity with coal and natural gas without carbon sequestration and will be much cheaper than natural gas and coal with carbon sequestration by 2030. If offshore wind energy systems achieve grid parity as early as possible, then it will provide tremendous contribution to India's CDM.

Challenges

There are different types of challenges that are hurting development of offshore wind energy system in India. Turbulent winds, irregular waves, gravity inertia, elasticity, mooring dynamics, lack of effective control system, aerodynamics, and hydrodynamics are the main constraints that are necessary to improve to efficiently develop offshore wind energy system. Other features in the surrounding topography cause turbulent winds. Such wind causes the continual variation in the incoming loads to the drive train. The contours of the land, obstacles, and even thermal variations can cause the wind to slow down or accelerate. Even seasons cause a greater or lesser increase in roughness and turbulence as crops and other features change and high winds can magnify the problem. The significant challenges that exist in offshore wind power deployment relates to resource characterization; subsea cabling; turbine foundation; installation of turbines, including logistics, grid interconnection, and operation; development of transmission infrastructure; and coastal security during construction and operation period. Adding large capacities of offshore wind generation to the power system would also require reliable integration to the national grid.

While the benefits of floating offshore wind are compelling, there remain significant obstacles to widespread deployment. The engineering challenges are extremely complex and many of the concepts are yet to be rigorously tested. Various early stage computer models attempt to predict turbine performance with varying degrees of success. Prototypes are gathering valuable data to drive further design refinement but the longest has been operational for only three years, so the actual realistic lifetime of a floating wind turbine is still unknown. Long-term survivability of floating platforms has been demonstrated by the oil industry; so, multiple-decade performance should be technically feasible. Pitching and rolling are huge concerns as these movements add tremendous stress to turbine components and can possibly even threaten to cause the spinning

blades to impact the water. Designs are addressing this concern with solutions, such as automatically feathering blades to steady the tower by adjusting the magnitude of the wind force on the blades, but anomalies, such as storms and rogue waves, are difficult to account for. From an infrastructure standpoint, floating wind turbines would require substantial upgrade to existing ports. In order to assemble a platform in port, there must be dedicated cranes, lay down lots, dock space, repair boats, towing channels, and staging areas to name a few specific shortfalls. Once an assembly area has been constructed, production can scale rapidly, but these facilities would need to be built in every region looking to deploy floating offshore wind. As opposed to conventional offshore wind farm, whose parts can be shipped around the world, a complete floating turbine can likely be towed a limited distance. Offshore wind power plants are highly capital-intensive. Upfront investment costs make approximately 75% of the total lifetime cost, which is extremely high in comparison to conventional power plants (where investment costs typically constitute around 40% of the lifetime cost). Offshore wind is also considerably more expensive than onshore wind: Investment costs per mega-Watt are approximately 50% higher, which is mostly due to the larger structures and complex logistics of installing the towers. The costs of offshore foundations, construction, installations, and grid connection are significantly higher than for onshore wind. Typically, offshore turbines are 20% more expensive and towers and foundations cost more than 2.5 times the price of an onshore project of similar size.

Future Scope

India ranks fifth in the world in onshore wind energy and is sure to grow in offshore industry too. Since offshore wind industry is yet to begin in India, it can take lessons from well-experienced countries such as Britain. Every development to a transmission network has an interaction with the existing network. Reinforcement of onshore is very much required for the introduction of generation offshore as these will provide routes for bulk power transfer. However, both offshore and onshore networks are symbiotic that will assist one another and minimize overall development requirements. Transmission network developments must be designed not only to meet the initial needs of the network but to be resilient to the future needs as well. However, predicting the future needs with any level of certainty is a challenge for the country. The best- practice approach is to envisage a number of future scenarios that cover a plausible range of developmental changes to the network. EF

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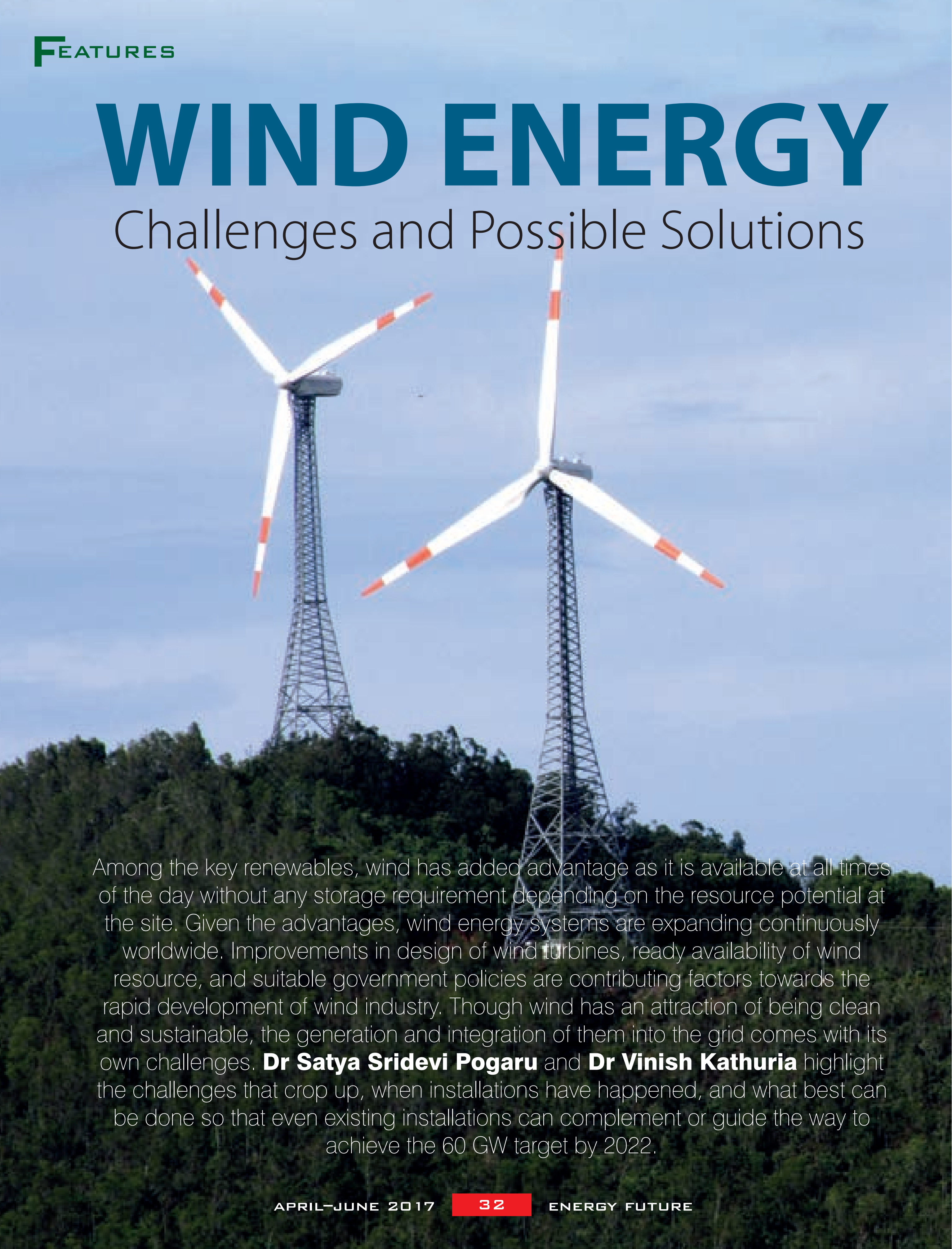

WIND ENERGY

Challenges and Possible Solutions

Among the key renewables, wind has added advantage as it is available at all times of the day without any storage requirement depending on the resource potential at the site. Given the advantages, wind energy systems are expanding continuously worldwide. Improvements in design of wind turbines, ready availability of wind resource, and suitable government policies are contributing factors towards the rapid development of wind industry. Though wind has an attraction of being clean and sustainable, the generation and integration of them into the grid comes with its own challenges. **Dr Satya Sridevi Pogaru** and **Dr Vinish Kathuria** highlight the challenges that crop up, when installations have happened, and what best can be done so that even existing installations can complement or guide the way to achieve the 60 GW target by 2022.

Renewable Energy (RE) is increasingly becoming a clean and sustainable energy generation method due to its significant potential to reduce green-house gas (GHG) emissions. Increased reliance on RE, which has low marginal generation cost, can also facilitate reduced oil and import dependence and, thereby, increase energy security. Decentralized nature of RE generation also helps in providing much needed energy to remote (off-grid) people to promote economic development. There are several common types of RE sources, such as wind, solar, hydro, tidal, geothermal, and biofuels. Renewables, in particular wind, solar, and hydro, are being added at a fast pace. As of March 2015, RE generation has a share of nearly 12% (i.e., 31 GW) in the total installed capacity of 263.66 GW in the Indian grid. A constant share of RE in total installed capacity in the last five years is also a testimony of RE keeping pace with conventional sources. India is the fifth leading country in installed wind capacity, totalling 22.6 GW, and eleventh in installed solar capacity, totalling 3.3 GW as on December 2014. The Government of India in December 2015 has set an ambitious target of 175 GW from RE by 2022 with 60 GW coming from wind installations and 100 GW coming from solar installations. Small hydro (10 GW) and biofuels (5 GW) complete the rest of the target. The proposed target implies a CAGR of 15% in wind installations and 63% in solar installations in the next seven years.

Among the three key renewables—solar, wind, and hydro—wind has added advantages. Solar energy is available only during daytime and hydro energy is feasible where the potential energy can be stored with the available water resources. Wind resource, however, is available at all times of the day without any storage requirement depending on the resource potential at the site. Another advantage of wind power plants is that they need very less land (less than one acre/mega Watt for tower foundation, access road,

substation, power evacuation lines, etc.) compared to other power-generating technologies. The use of air space by wind power plants also does not affect vegetation on the ground. Given these advantages, wind energy systems form the main energy production capacity of renewables and are expanding continuously worldwide as well as in India. Starting with a meagre 39 MW installed base in 1991, the installation has reached 26,777 at the end of 2016 implying a CAGR of 31% in last 25 years (Figure 1). Improvements in design of wind turbines, world class manufacturing, ready availability of wind resource, and favourable policy are contributing factors towards rapid development of wind industry in India. There are many diverse support mechanisms, policies, and regulations that are being planned and have been put in place, such as renewable purchase obligation, generation-based incentives, accelerated depreciation, etc., to encourage more renewable integration into the grid.

Though wind has an attraction of being clean and sustainable and has several other advantages, the generation

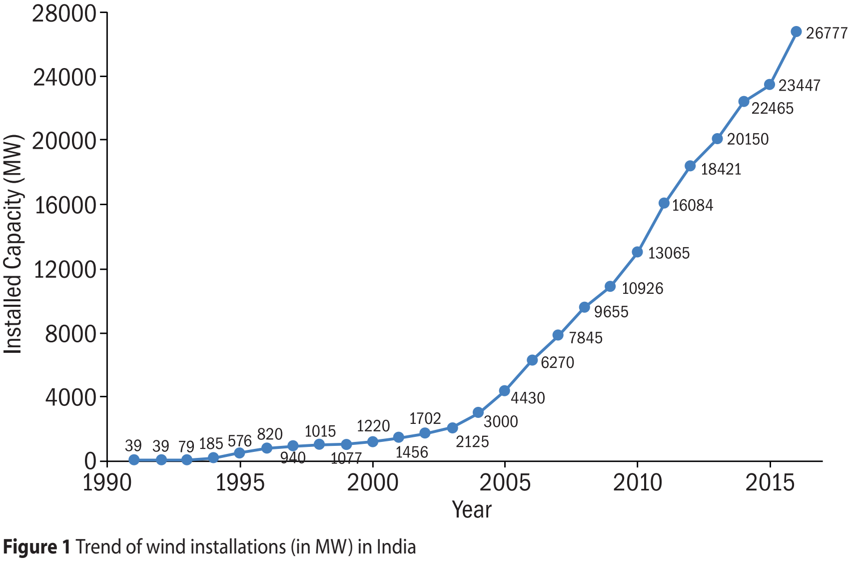

Figure 1 Trend of wind installations (in MW) in India

and integration of them into the grid comes with its own challenges. Although there are several sites that have wind potential, these have not been able to attract installations. For instance, Tamil Nadu and Maharashtra are dominated by wind installations, though more resource is available in Gujarat (Table 1). Similarly, within a state, there are districts/sites that have attracted most installations whereas comparable sites have not received much. Table 2 illustrates this in the context of Maharashtra.

This article flags out the challenges that crop up with installations and what can be done to ensure that even existing installations can complement or guide the way to achieve the targets set by the Government of India.

Table 1 Wind potential and installed capacity across various states of India

Sl. No.	State	Potential @ 50 m	Potential @ 80 m	Installed Capacity (percentage of potential @ 50 m)
1	Andhra Pradesh	5,394	14,497	447.65 (8.3)
2	Gujarat	10,609	35,071	3,174.66 (29.92)
3	Karnataka	8,591	13,593	2,135.30 (24.86)
4	Madhya Pradesh	920	2,931	385.99 (41.96)
5	Maharashtra	5,439	5,961	3,021.85 (55.56)
6	Rajasthan	5,005	5,050	2,684.25 (53.63)
7	Tamil Nadu	5,374	14,152	7,162.27 (140)
8	Others	6,866	9,280	3.2
	Total	**49,130**	**102,778**	**19,050.37**

Note: Centre for Wind Energy Technology (CWET), an autonomous institution established under the aegis of the MNRE has estimated wind potential at two heights—50 m and 80 m. The seven states account for over 80% of the potential. Share of these states grows to around 88% (of total 102 GW) when installable height of 80 m is considered instead of 50 m.

Source: MNRE, 2014

Table 2 District-wise installed capacity (in MW) of wind power technology in Maharashtra

Sl. No.	District	Wind potential in MW	Installed Capacity in MW	Installed Capacity as % of potential
1	Nashik	954.65	101	10.58
2	Satara	931.23	1,176.24	126.31
3	Pune	843.10	106.4	12.62
4	Ahmednagar	794.15	233.85	29.45
5	Beed	616.65	56.95	9.24
6	Kolhapur	430.72	4.25	0.99
7	Dhule	229.54	535.25	233.18
8	Nandurbar	210.00	313.75	149.4
9	Sangli	155.66	813.97	522.92
	Total	**5,165.7**	**3,386**	**62.25**

Source: MEDA, 2013

Challenges in Grid Integration and Grid Management

Variability and intermittency

For large-scale deployment of renewables in the grid to be feasible, integration issues and mitigation strategies need to be understood and analysed quantitatively at the systems operation level. One of the biggest challenges for RE integration is their variability and intermittency in energy generation. Wind power plants differ from conventional power plants due to their stochastic nature. These plants generate energy only when the wind is blowing. For instance, 70% of wind generation in India is during the five months duration—from May to September coinciding with south-west monsoon and 50% in three months only during June to August. In the traditional grid (having coal- or gas-based plants), demand is unpredictable but supply sources are mostly and accurately predictable as well as controllable, but with renewable resources, such as wind, an element of unpredictability is introduced on the supply side of the equation. There are three time-scales where the variability in generation/ supply produces an impact:

1. Unit commitment (scheduling of resources)—day ahead to around 1 week
2. Load following—with in 1 hour in 5 to 10 minutes increments
3. Regulation/ancillary services—in real time (seconds).

In unit commitment, the requirement is to know how much the generating plant will generate in the next 24 hours. In load following, the requirement is to have adequate reserve capacity to ramp units up and down to follow the load profile. In *regulation/ancillary services*, sufficient regulating capacity must be available to maintain the load–frequency control within the specified grid frequency tolerance. Given the fact that the load as well as wind generation both are unpredictable as well as uncontrollable, the problem becomes more challenging in all the three time frames.

Variability and intermittency in renewable generation is tackled currently by varying conventional generation (thermal plants), load following hydro and gas based generation plants and in worst cases curtailing wind generation. In states, such as Gujarat, there are policies that mandate RE plants as 'must run' generation. In such a scenario, distribution companies (DISCOMS or utilities or load dispatch centres) face commercial disadvantage for backing down cheaper conventional generation from thermal plants or having to buy costlier power (gas based) from the markets. These frequent ramping rates induced on thermal plants due to absorption of wind gives rise to wear and tear impacts on conventional generation leading to increased maintenance costs, increased emissions, and decreased lifetime. Gas-based generation as a load following option has a huge operational cost influence as variable cost can go up to ₹10/kwh depending on the market gas price. Integrating of renewables at large volumes has to be better planned to minimize such operational and maintenance impacts on traditional plants.

There are two possible technology paths to enable better integration of wind energy into the grid, first is by improved forecasting and second by enabling grid storage.

Forecasting

Load dispatch centres usually plan unit commitment based on forecasts received from wind-generating sites. Any improvement in the forecasted values has significant technical and cost implications in the long run. Forecasting wind power and energy are particularly challenging due to the factors that influence the variability and intermittency of the generation, such as their location, terrain, local climatology, availability of historic data, and turbine placement in the farm. Traditional forecast methods include a simple persistence model, in which the next hour's power generation will be same as current generation, and simple forecasts based on projections of the historic values of the site. Using physics-based forecasting models, real-time data from wind plants, and computational learning methods, such as artificial neural networks, support vector machines, etc., it is possible to deliver more accurate and better results in the field of wind forecasting. These improvements certainly will have short-term and long-term benefits in the grid operations.

Grid-level storage

One of the technologies that can address the problem of renewable integration is through grid level or utility scale storage. Some storage systems, such as Li-ion batteries shift some of the off-peak energy production to deliver at peak demand times and some other storage, such as high-speed flywheel systems, can provide regulation services or frequency control. It can also help with ramping issues as they have almost instantaneous ramp rates. Since storage devices, such as batteries, can be located anywhere on the grid system, they can provide the benefit of integration of intermittent resources as well as mitigating the transmission congestion.

Storage technologies have their operational characteristics, such as power capacity; energy capacity; maximum ramp up and down rate; conversion losses; dissipation losses; depth of discharge; efficiency; and financial parameters, such as capital investment cost, operation and maintenance (O&M) cost, and lifetime. These characteristics of the storage technologies make them suitable for specific applications, such as, storage technologies for high power applications (lots of power in short bursts) or energy dense applications (lower power for long durations). There will be life time, performance, and cost penalties for using them in unintended ways.

Transmission network planning

A key integration issue when renewables are involved is planning transmission network to carry the energy from the generation point, which is typically a remote location where the wind resource is high, to the demand location. Because of the high variability in the power production at various points of time, the transmission network has to be overdesigned and hence is economically intensive. This problem can be partially taken care by integrating storage technology on the grid as it can be placed anywhere on the grid.

Reliability and cost of maintenance

Wind turbines have grown in size from 100 kW in the 1980s to 2.5 MW today. Average O&M costs for onshore wind farms are between USD 0.01/kW and USD 0.025/kW. Total O&M costs also tend to increase with operating years as the wind turbines age. A typical wind turbine today is a huge machine operating at 300 ft above the ground with about 400 ft diameter of the blades. Onshore installation of such wind energy system on an average costs between USD 1,800/kW and USD 2,200/kW, out of which the major costs are accounted for the wind turbine itself. In order to make best use of the equipment, the wind turbine machinery has to be reliable and should be able to generate energy whenever the wind resource is available. One of the biggest disadvantages is with the failure rate of the wind turbine and the down-time it causes. Understanding failure rates and strategizing the maintenance is very important towards ensuring and improving the system availability. It has been observed from the study of European wind farms under Wind Measurement and Evaluation Programme (WMEP) that the longest down-times are caused by gearbox, rotors, and drivetrains (Figure 2).

It is important that availability of wind turbines is as high as possible to increase their utilization and hence the capacity factor. Capacity factor of a power plant is the ratio of its actual output over a period of time to its potential output, if it were possible for it to operate at full nameplate capacity. This can be achieved by decreasing the downtime of turbines by predicting when it is likely to fail and planning the maintenance using condition-based maintenance (CBM) system during the well suited time slots (i.e., low wind times). CBM is a system in which the there is a continuous monitoring and inspection of the equipment, which can provide information on incipient faults as early as possible and determine the necessary maintenance tasks ahead of failure. This will contribute to higher availability and hence more generation of the wind energy.

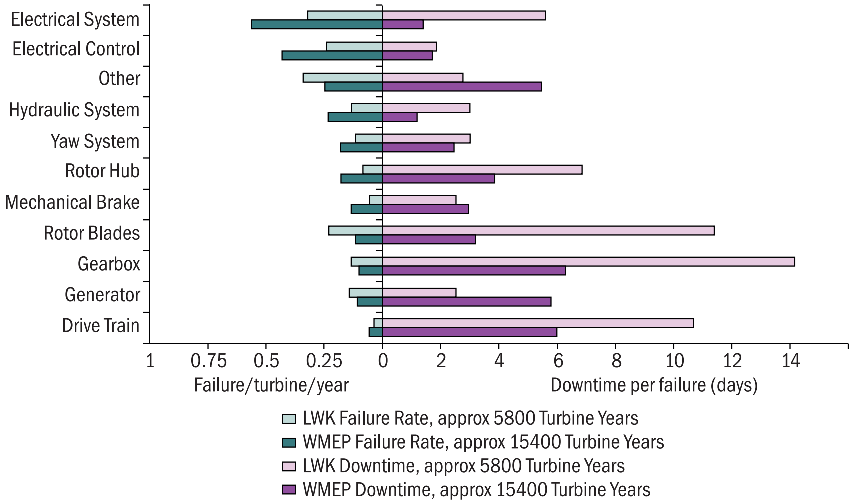

Figure 2 Failure rates and downtimes from wind farm analysis

Power quality—control technologies and power electronics

Due to intermittency of wind power generation, grid-connected wind turbines would cause power quality problems, which include voltage dips, frequency variations, and low power factor (PF). PF for an AC system is defined as the ratio of the real (active) power flowing to the load to the apparent power in the circuit. An ideal value of PF is 1.0, which implies that the real power is equal to the apparent power. When reactive power exists, apparent power is greater than active power leading to PF value of less than one. PF value less than one leads to power quality and stability

issues in voltage and frequency. Since wind turbines are inductive machines, they tend to absorb reactive power from the system and produce a low PF. Reactive power is one of the major causes of voltage instability in the networks due to associated voltage drops in the transmission lines. It also contributes to system losses. Poor power quality causes loads to operate inefficiently, such as flickering of lights, excessive heating of devices, tripping of fuses, etc.

Traditionally, utilities have relied on switched capacitors to keep the voltage steady and maintain PF. These tend to increase the maintenance cost of the gear box of the turbine due to increased stress. New state-of-the-art wind generators utilize power electronics and variable-pitch turbines that allow the wind turbines to produce energy at various speeds. These power electronics in the turbine regulate the output voltage while keeping the PF close to unity.

Repowering—low plant load factor (PLF)

Another issue of wind power is its low plant load factor (PLF) in comparison to fossil fuel, nuclear, and hydropower plants, and it is also low vis-à-vis international standards. Data from *BP Statistical Review* shows that there is a considerable variation in PLFs across various countries, with the USA having maximum average PLF whereas India and China have lowest average PLFs (Table 3).

A low PLF in India is because most of the wind power farms in India have reached the end of their commissioned period; thus, requires repowering. Repowering will not only help them

Table 3 Variation in PLF across top five leading countries

Country	Minimum PLF	Maximum PLF	Average PLF	Std. Deviation
USA	16.3	31.5	24.2	3.8
China	10.6	20.6	16.4	3.5
Germany	13.7	20.4	16.8	2
India	12	19.9	16.5	2.5
Spain	16	27.8	22.7	2.4

Source: BP, 2015

to remain productive but also could create a possibility of power generation capacity enhancement to their best performing sites. Studies have estimated that repowering of old wind farms could increase the wind energy PLF percentage significantly from existing 15% to 30%. This however requires suitable policies.

PLF is also an important variable contributing to Internal Rate of Return (IRR) of the wind project. This is because the revenue from a wind project is generated based on tariff, which is in turn is offered on PLF. Policies similar to what Maharashtra power sector regulator has embarked on would be useful for firms to go for repowering. Maharashtra has mandated on maintaining a certain minimum PLF and tariff based on wind power density since 2010 (Table 4). PLF has an implication on site selection for wind farms as a recent study in Maharashtra has found that sites having more expected PLF are preferred considering the variability of wind resource.

Concluding Remarks

Among the three key renewables—solar, wind, and hydro—wind has added advantages. Wind resource, however, is available at all times of the day without any storage requirement depending on the resource potential at the site. Given the advantages, wind energy systems are expanding continuously worldwide. Improvements in design of wind turbines, ready availability of wind resource, suitable government policies are contributing factors towards the rapid development of wind industry. Though wind has an attraction of being clean and sustainable, generation and integration into the grid comes with its own challenges. Several of these challenges, such as low PLF, over designed transmission network, low power quality, is because of stochastic nature of wind and hence wind power generation. In order to overcome these challenges, several new technologies would aid, that include continuous improvement in forecasting these resources with more available data and advanced methods, grid-level storage, reliability centred maintenance strategies, and new control technologies combined with power electronics. In essence, this note highlighted what challenges crop up, when installations have happened, and what best can be done so that even existing installations can complement or guide the way to achieve the targets set by the Government of India.

Table 4 Norms for PLF for wind power technology in Maharashtra

Annual Wind Power Density (Watts/m²)	Minimum PLF (in Percentage)	Tariff* (₹./kWh)
200–250	20	5.52
250–300	23	4.85
300–400	27	4.05
> 400	30	3.8

Note: Figures for tariff are average of tariff offered with and without accelerated depreciation benefit

Source: MERC, 2010

Suggested Readings

Blaabjerg F, Chen Z, Teodorescu R, Iov F. 2006. 'Power electronics in wind turbine systems'. *Power Electronics and Motion Control Conference, 2006* (IPEMC 2006), *CES/IEEE 5th International, Volume 1*.

BP. 2015. *BP Statistical Review of World Energy*. Mumbai.

Carnegie R, *et al*. 2013. *Utility Scale Energy Storage Systems: Benefits, Applications and Technologies*. West Lafayette, IN: State Utility Forecasting Group, Purdue University.

Chen Z. 2005. Issues of connecting wind farms into power systems," *2005 IEEE/PES Transmission & Distribution Conference & Exposition: Asia and Pacific, Dalian, pp. 1–6*.

Foley AM, Leahy PG, Marvuglia A, and Mckeogh EJ. 2012. Current methods and advances in forecasting of wind power generation. *Renewable Energy* **37**(1): 1–8.

Georgilakis PS. 2008. Technical challenges associated with the integration of wind power into power systems. *Renewable & Sustainable Energy Reviews* **12**(3): 852–863.

GoI. 2015. *Report of the Expert Group on 175GW RE by 2022*. New Delhi: Niti Aayog.

Hanh B, Durstewitz M, and Rohrig L. 2006. *Reliability of Wind turbines, Experiences of 15 Years with 1500 Turbines*. Germany: ISET.

IRENA. 2012. *Renewable Energy Technologies: Cost Analysis Series. Volume1, Issue5/5.* International Renewable Energy Agency (IRENA).

Kathuria V, Ray P, and Bhanganokar R. 2015. FDI (Foreign direct investment) in wind energy sector in India: Testing the effectiveness of state policies using panel data. *Energy* **80**: 190–202.

MERC. 2010. *Maharashtra Electricity Regulatory Commission (Terms and Conditions for Determination of RE Tariff Regulations, 2010*. Mumbai: Maharashtra Electricity Regulatory Commission (MERC), p. 13.

Panse R, and Kathuria V. 2015. Modelling diffusion of wind power across countries. *International Journal of Innovation Management* **19**(4) (August).

Panse R and Kathuria V. 2016. Role of policies in deployment of wind energy—Evidence across states of India. *Renewable & Sustainable Energy Reviews* **53**: 422–432.

Sheng SS. 2013. *Report on Wind Turbine Subsystem Reliability – A Survey of Various Databases*. Golden, CO: National Renewable Energy Laboratory. EF

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