July–September 2015

ENERGY FUTURE

The Complete Energy Magazine
Volume 3 • Issue 4 • Annual `800

Efficient Energy
for a Brighter Future

Top Ten Drivers
for Wind Energy Business in 2015

Fuel Cells
Fuelling a New Energy Path

VIEWPOINT

Professor Kazuhiko Takeuchi
Senior Vice-Rector,
United Nations University;
Director and Professor,
Integrated Research System for Sustainability Science (IR3S),
University of Tokyo

A teri Publication

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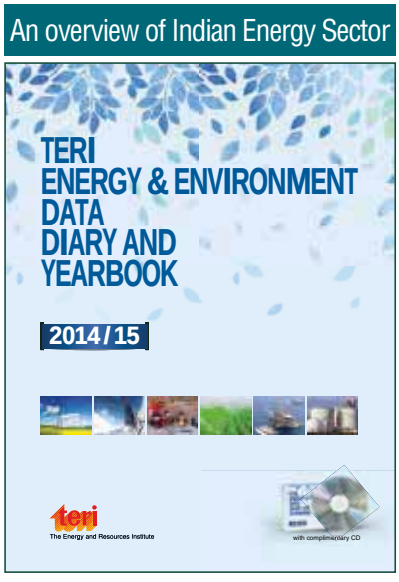

TERI Energy & Environment Data Diary and Yearbook (TEDDY) 2014/15

With Complimentary CD

2015 • ISBN: 9788179935743
Pages: 400 • Binding: Hardback
Size: 220 × 280 mm • Price: `1995.00

TERI Energy & Environment Data Diary and Yearbook (TEDDY) is an annual publication brought out by The Energy and Resources Institute (TERI) since 1986. It is the only comprehensive energy and environment yearbook in India which provides updated information on the energy supply sectors (coal and lignite, petroleum and natural gas, power, and renewable energy sources), energy demand sectors (agriculture, industry, transport, residential, and commercial sectors), and environment (local and global). It also provides a review of the government policies that have implications on energy and environment in India.

Key features

- Exhaustive compilation of data from energy supply and demand sectors
- Recent data along with data for the past years covered in the form of structured and easy-to-understand tables
- Recent advances made in the energy sectors are represented in the book
- Self-explanatory figures and graphs showing the latest trends in various sectors are also part of chapters
- The "Green focus" section in every chapter highlights a topical issue
- The book comes with a complimentary CD that contains all the chapters and additional tables

Topics covered:

• **Indian Energy sector:** An overview • Commercial energy balance tables and conversion factors • **Energy supply:** Coal and ignite, petroleum and natural gas, power, and renewable energy sources and technologies • **Energy demand:** Agriculture, industry, transport, and household energy • **Local and global environment:** Environment, Climate change • **Energy and Environment goals**: Sustainable Development Energy and Sustainable Energy

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

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From the editor's desk...

Whether we look from the perspective of climate change mitigation or from the viewpoint of a country's energy security, the strategic energy discourse usually is based on two key elements, i.e., clean energy supply and energy conservation. Indeed, greater focus on energy supply through renewables presupposes energy conservation to the extent possible, cutting limits across sectors such as industries, buildings, and transport. As per the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), industry, buildings, and transport sectors accounted for 28 per cent, 32 per cent, and 27 per cent of final energy use in 2010, respectively. If appropriate measures are not initiated right away, this demand is going to increase multifold. As such, these burgeoning energy demands are a big drain on already severely constrained nations, not to mention commensurate enhancement in Greenhouse Gas (GHG) emission levels.

The implications, therefore, are very clear and call for immediate and sustained efforts to help take energy intensities along a continuously decreasing trajectory. Given that challenges within a sector itself are varied and contextual, a specific and targeted approach needs to be developed. For instance, in the building sector, new constructions and the existing stock of the buildings present totally different issues that cannot be addressed by a generic measure. Likewise, the motivational factors to adopt conservation measures might be totally different for an individual, an industrial unit, urban local body, and a transporter. Thus, there is a need to develop a careful study of each user group and thus, a subsequent energy conservation programme.

While most of such programmes rely on technological and policy prescriptions, one crucial but normally overlooked point pertains to consumer behaviour or the social norms linked with lifestyles. As simple a thing as keeping the temperature setting of an air-conditioner at 26°C instead of 22°C could result in substantial energy savings without compromising the comfort levels of the user. Therefore, sustained campaigns making consumers aware of pros and cons of lifestyle choices also become a powerful tool for promoting efficient use of energy. However, an underlying thread among all these is the right energy pricing because that has a direct implication on consumer choices, whether that of a technology or that of behaviour. Thus, the major point to be considered is that energy future is intricately linked to the choices that we make now!

Amit Kumar

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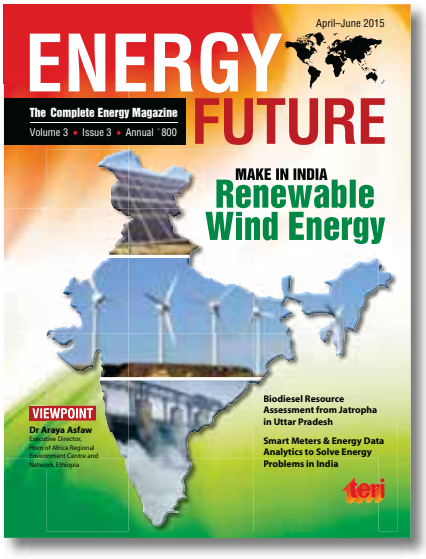
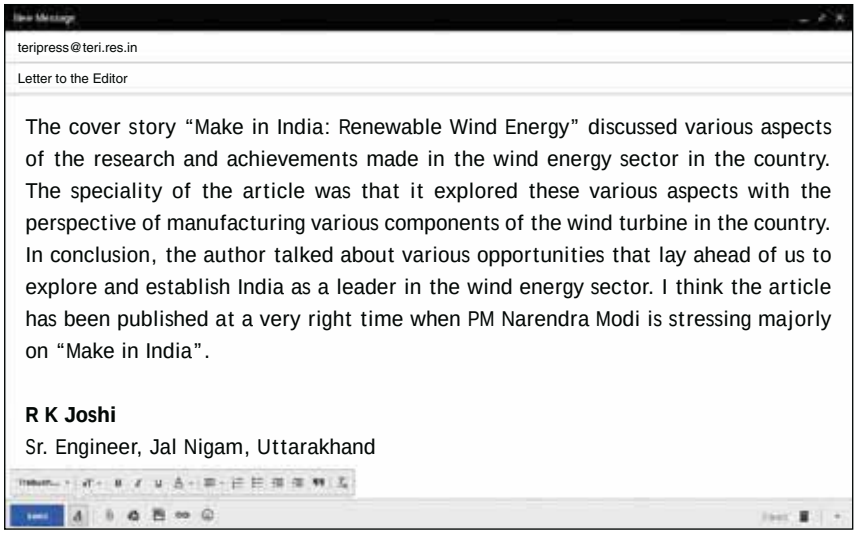
Printed and published by Dr R K Pachauri for The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi- 110 003. Tel. +91(11) 24682100, 4150 4900, Fax +91(11) 2468 2144 or Email teripress@teri.res.in, and printed by Batra Art Press, A-41 Naraina Indl. Area PH- II, New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





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Letter to the Editor

The cover story "Make in India: Renewable Wind Energy" discussed various aspects of the research and achievements made in the wind energy sector in the country. The speciality of the article was that it explored these various aspects with the perspective of manufacturing various components of the wind turbine in the country. In conclusion, the author talked about various opportunities that lay ahead of us to explore and establish India as a leader in the wind energy sector. I think the article has been published at a very right time when PM Narendra Modi is stressing majorly on "Make in India".

R K Joshi
Sr. Engineer, Jal Nigam, Uttarakhand

"The energy insight article, the one that discusses the usage of smart meters, is an eye opener. We normally go for the replacement of our equipment when we desire the reduction in energy bill and adopt energy efficient policy. However, that might not be required at all. Just by installing a smart meter, we can assess as to through which equipment the energy can be wasted and thus saved by diverting its flow, or send it back to the grid, which can consequently be used by other consumers. This is an amazing research field and the proper implementation of smart meters by the various discoms and consumers can save lots of energy for the country."

Santosh Nigam
Jodhpur, Rajasthan

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

"I must congratulate the team of TERI for bringing out such a good magazine. The articles in the magazine enhance knowledge of common readers like us. In particular, I would like to talk about article "PPP Models for Energy" where the author suggests the ways in which the PPP model can be implemented through various mutually agreed points between different stockholders. The Government of Indian must try to develop some consensus on the points suggested in this article and take some concrete steps in this direction."

Anu Divakar
Bhopal, MP

"The story of solar systems installed by the Brahma Kumaris is very interesting. It shows that they are not only making advances in the field of spirituality, but are also taking care of environment as well as adding value to the energy system of the country. I have visited once there and really been impressed with the entire system. Their story is inspiring and others must follow the suit."

Abhas Dey
Kolkata, WB

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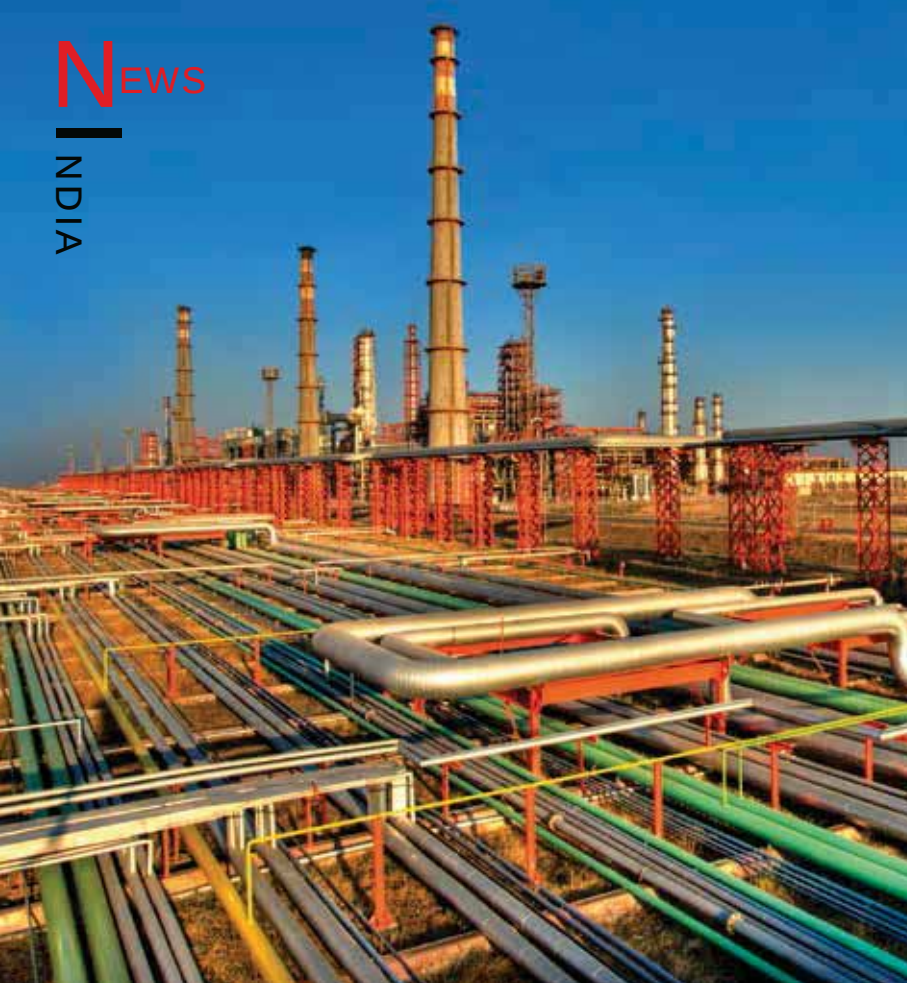


ESSAR OIL BECOMES INDIA'S BIGGEST CBM PRODUCER

Essar Oil has become India's largest Coal Bed Methane (CBM) gas producer with output at its Raniganj field crossing 0.5 million standard cubic metres per day (scmd). "While nearly 100 wells are already producing the CBM, an additional 155 have been drilled and are at various stages of the hydrofracking-completion-dewatering cycle for further ramping up production," Shri Manish Maheshwari, CEO, Exploration & Production (E&P) of Essar oil said. The company has built high quality infrastructure gas conditioning and compression stations, in-field pipelines of 120 km, and last mile pipeline connectivity network to end-users located 60 km away.

Essar is targeting completion of augmentation before May 2016, this as per its contract with the Ministry of Petroleum and Natural Gas, Government of India. With a total investment outlay of `4,000 crore, the Raniganj Project is a first-of-its-kind in India, aimed to responsibly produce methane from coal seams located 1,000 m below or deeper. EF

Source: www.financialexpress.com

A SUNNY PITCH AT CHINNASWAMY STADIUM

M Chinnaswamy Stadium will no longer be charged only by the enthusiasm of cricket fans; a rooftop solar plant will ensure a bright and sunny pitch to the cricketing nucleus of the State. Recently, a 400 kW rooftop solar power plant was successfully installed at the stadium.

Pegged as a first for any stadium in the country, the bi-directional net metering project under the Bescom grid-connected solar rooftop scheme is connected to the power utility's 11 kV substation. The plant is designed to generate 5.9 lakh units in a year, which is enough to power 200 AEH (all electric homes) using 3 kW power annually, and also cutting down about 600 tonnes of carbon dioxide emission annually.

The excess power will be sent to the Bescom grid with the Karnataka State Cricket Association (KSCA) being paid `9.56 per unit. Bengaluru-based solar solutions enterprise RenXSol Ecotech Pvt. Ltd executed the project for the KSCA, which was approved, commissioned, and installed in less than 50 days. Shri Brijesh Patel, Honorary Secretary, the KSCA, said, "This is the first cricket stadium globally, and also the first in India, to use solar power. The KSCA has set an example by using its space to help protect the environment for our children in the years to come." EF

Source: www.thehindu.com

INDIA AIMS TO CUT CRUDE IMPORT

Prime Minister Shri Narendra Modi has set a target for reducing the volume of imported crude oil by 10 per cent, i.e., up to 67 per cent by 2022, i.e., the year in which the country will celebrate its 75th anniversary of Independence.

Union Minister of State (Independent Charge) for Petroleum and Natural Gas, Shri Dharmendra Pradhan, on his maiden stock-taking visit to the oil fields and oil installations in Assam, said, "India currently has to import 77 per cent of its total crude oil requirement and the Prime Minister desires that the import volume be reduced to 67 per cent by the year 2022."

"A high-level committee has been set up. It's headed by the Petroleum Secretary and aims to bring out a vision document in three months for boosting production of petroleum and natural gas in Assam," Shri Pradhan said. EF

Source: www.tribuneindia.com

GPS TO HELP RAILWAYS CUT FUEL CONSUMPTION

According to the latest report of the Indian Parliament's Standing Committee on Railways, the Indian Railways has devised a system for using Global Positioning System (GPS) to provide advance inputs on the terrain lying ahead and advice to locomotive drivers to increase or decrease throttle beforehand depending upon the gradient ahead. The trials of this system have already been conducted and the methodology has shown fuel saving up to 12 per cent.

Termed as 'Guidance for Optimized Loco Driving' (GOLD), it assists in optimizing fuel consumption by allowing the driver to increase the throttle and build momentum some distance before hitting an incline and thereby doing away with the need for a sudden surge of power that burns more fuel, or reducing throttle before a downward gradient. GOLD also alerts the locomotive crew of approaching signals, stations, and level-crossing gates ahead on the route. Based on the results of the trials, the Railways intends to proliferate the system across its fleet of locomotives.

The Indian Railways is the single largest consumer of diesel in the country, with its fleet of over 4,000 diesel locomotives consuming over 2 billion litres annually at a cost of about `15,000 crore. EF

Source: www.tribuneindia.com

INDIA ASKS OPEC TO STOP CHARGING PREMIUM FROM ASIAN BUYERS

Leveraging the subdued global crude oil price scenario, India made a pitch for price and terms correction with the Organization of the Petroleum Exporting Countries (OPEC).

This was articulated by India's Petroleum Minister Shri Dharmendra Pradhan at OPEC'S sixth international seminar in Vienna, where he said that countries like India should receive a concession rather than having to pay the so-called Asian premium. India is one of the major consumers of OPEC's production, with the grouping accounting for 85 per cent and 94 per cent of India's crude oil and gas imports.

"There is a strong feeling that Asian countries like India should receive Asian dividend rather than paying Asian premium while making bulk purchase of crude. I will not hesitate to say that Asian premium was historically never justified and more so not justifiable in the changed market scenario where Asian countries are the major buyers," Shri Pradhan said at the seminar titled 'Oil Market Stability'.

With Asian countries being primarily dependent on West Asia to meet their energy needs, it is perceived that customers from the continent pay a premium owing to this dependence as compared to the prices paid by the US or the European Union. EF

Source: www.livemint.com

INDIA'S FIRST ROCK CAVERN TO STORE CRUDE OIL READY FOR COMMISSIONING

The first among three underground rock caverns built by the Indian Strategic Petroleum Reserves Ltd (ISPRL) to store crude oil with an investment of `1,178 crore is ready for operation.

"After successful trials, we are awaiting arrival of crude to commission the cavern built at Lova Gardens, Visakhapatnam, in the close vicinity of LPG cavern," said Shri Rajan Pillai, ISPRL CEO and Managing Director.

ISPRL, a special-purpose vehicle wholly-owned by the Oil Industry Development Board, is on verge of completing two other caverns at Mangaluru and Padur (Udupi) at a cost of `1,227 crore and `1,693 crore, respectively. The three caverns will have a total capacity to store 5.03 million tonnes as a cushion in the event of external supply disruptions as a part of energy security. Shri Pillai said that work on construction of Mangalore and Padur caverns was nearing completion. They would be made operational once evacuation facilities with the laying of cross-country pipelines were completed.

The Visakhapatnam facility has two chambers with the Hindustan Petroleum Corporation Limited (HPCL) owning one with a capacity of 0.33 million tonne. The HPCL has invested `265.79 crore on the additional chamber. EF

Source: www.thehindu.com

MEGA E-VEHICLE RALLY TO PROMOTE FASTER GREEN MOBILITY ADOPTION

In an effort to promote faster adoption of green mobility and its consequential health and environmental benefits, the Department of Heavy Industry organized the country's first mega green-vehicle rally. Titled 'FAME India Eco Drive' on World Environment Day, the event on June 5 was supported by the Society of Manufacturers of Electric Vehicles (SMEV), the Society of Indian Automobile Manufacturers (SIAM), and the GMR Group.

Shri Anant Geethe, Minister of Heavy Industries and Public Enterprises, flagged the event off in the presence of Minister of State for Environment, Forest and Climate Change Shri Prakash Javadekar. A wide range of state-of-the-art electric and hybrid vehicles, including two-wheelers, cars, and buses covered a distance of 21 km, travelling from India Gate to IGI Airport Terminal 3. EF

Source: www.news.webindia123.com

INDIAN RAILWAYS TRIALS SOLAR-POWERED TRAINS TO HELP CUT POLLUTION

Indian Railways is soon going to materialize its ambitious plan of harnessing solar energy to run trains. The prototype of the solar power-enabled coach is undergoing trials, and soon the entire train will be fitted with solar panels. While solar power will significantly bring down diesel consumption, it will also prove to be cost-effective. "As the pilot project, one non-AC coach has been fitted with solar panels on the rooftop. The trial has been successful so far with the coach generating nearly 17 units of electricity every day. Depending on its success, decision will be taken to convert the entire train into a solar power-enabled one," said Divisional Railway Manager Shri Arun Arora.

According to a Northern Railway official, 40 sq. m of space is available on a train's rooftop. Of these, nearly 24 sq. m of space is covered with 12 solar panels. The remaining 16 sq. m of space can further accommodate six solar panels. As per the mechanism, alternate coaches are provided with solar panels and when required electricity is fed from the adjoining coach. EF

Source: www.dailymail.co.uk

SOLAR-POWERED ATMS TO DELIVER CLEAN DRINKING WATER IN PAKISTAN

Pakistan's Punjab province is set to launch an innovation, i.e., solar-powered Automated Teller Machines (ATM) that would dispense clean water when a smart card would be scanned. The two-foot-square prototype machine looks and functions like an ATM, but dispenses water instead of cash. Users are issued a card they could use to claim a daily share of water.

The project, a collaboration between the Punjab Saaf Pani (Clean Water) Company and the Innovations for Poverty Alleviation Lab (IPAL), a research centre in Lahore, aims to install a water ATM on each of a series of water filtration plants being established in rural and urban fringe areas of Punjab province.

The machine is designed to help the government cut water waste and ensure people have access to clean water. The innovative machines will help the government to maintain a record of the exact quantity of clean drinking water being dispensed in a day in a specific locality, besides ensuring its quality. The quality and quantity of water being dispensed would be tracked in real time online, through a central server. In its first phase, the project will cover three districts of Punjab including Bahawalpur, Rajanpur, and Faisalabad, all areas with particularly serious water contamination issues. EF

Source: www.tribune.com.pk

CROATIA AMONG FEW EU STATES TO PLAN ENERGY SAVINGS WELL

European Union (EU) member states' governments generally fail to correctly plan energy savings in their buildings but Croatia is one of the few to have done it well, according to a Coalition for Energy Savings analysis, carried by the European media.

The Energy Efficiency Directive requires member states to renovate 3 per cent of buildings owned by the central government each year or take other measures that will lead to energy savings, such as comprehensive renovation and change of staff behaviour. Member states must notify the European Commission which option they chose and submit plans and lists.

Croatia is one of the 17 EU member states that chose the second option, but only four of them (Austria, Croatia, Italy, and Slovakia) correctly calculated the savings. EF

Source: www.dalje.com

NORWAY OVERTAKES RUSSIA AS WESTERN EUROPE'S TOP GAS SUPPLIER

Data from state firms shows that Norway has overtaken Russia as the Western Europe's top gas supplier, indicating the European Union's drive to reduce its dependence on Russian energy is bearing fruit. The sharp drop in oil prices has been another factor, as Norway offers more flexible pricing and big buyers held off buying from Russia in the hope that the fall in crude price levels would eventually filter through to Russian gas.

Norway exported 29.2 billion cubic metres (bcm) to the Western Europe in the first quarter of this year, figures from Norwegian state operator Gassco show, while Russia sold 20.29 bcm, according to data from Gazprom's regulatory filing and Gazprom officials. The European Union has been striving to reduce its dependence on Russian imports and buy more from Norway and other gas producers, mindful of Russia's dispute with Ukraine, the biggest transit route for Russian exports to the EU. EF

Source: www.energyvoice.com

OBAMA ADMINISTRATION ANNOUNCES $4 BILLION FUND TO BOLSTER RENEWABLE ENERGY

The Obama Administration's support for clean energy took on a new dimension as the White House announced plans to invest $4 billion to help generate capital investment for renewable energy companies. According to the details of the deal, financial commitments will be generated from pension funds, family foundations, and other 'impact investors'. A new building, namely, 'office of technology transitions', will be established a 'go-to information' resource for clean energy investment.

"One of the real challenges is the gap in financing clean energy," US Secretary of Energy, Ernest Moniz, "there is a continuing need for new capital investment." He added that the office would not make investment decision or directly engage in them, but instead would provide information to help guide discussions by people who are not already steeped in the field.

This latest announcement is part of a strong of new initiatives from US President Barack Obama that are part of his Climate Action Plan, which includes recent announcements of $15 billion to modernize the country's energy infrastructure, an order for federal agencies to cut emissions by 40 per cent, plans to cut pollution from power plants by 30 per cent, and more. EF

Source: www.inhabitat.com

PHILIPPINES NOW AN E-VEHICLE HUB IN ASIA — DTI OFFICIAL

According to Department of Trade and Industry (DTI) Undersecretary, Dr Prudencio M Reyes, Jr., the Philippines has become an e-vehicle hub in Asia, with manufacturers setting up shop as the country remains fully committed to support the green growth advocacy of the Asia Pacific Economic Cooperation (APEC). Recently, e-vehicle manufacturer BEMAC Electric Transportation Philippines Inc. inaugurated its assembly plant in Carmona, Cavite. BEMAC's assembly line is built to produce 500–1000 units of electric tricycles and is set up for expansion to 1,000 units per month depending on the demand of the market.

"I am optimistic that these e-vehicles will have a great potential in replacing traditional tricycles that only induce air pollution. This vision is one with DTI to promote a safe and reliable electronic vehicle product for the Filipinos," Reyes said.

In March 2012, the National Economic Development Authority approved the P21.5-billion Market Transformation through Introduction of Energy Efficient Electric Tricycle Project to promote sustainable transportation and achieve energy efficiency. And in December 2012, the Asian Development Bank said it would lend the Philippines $300 million to roll out 100,000 e-trikes to replace some of the estimated 3.5 million gas-powered motorcycles and tricycles in the country. EF

Source: www.gmanetwork.com

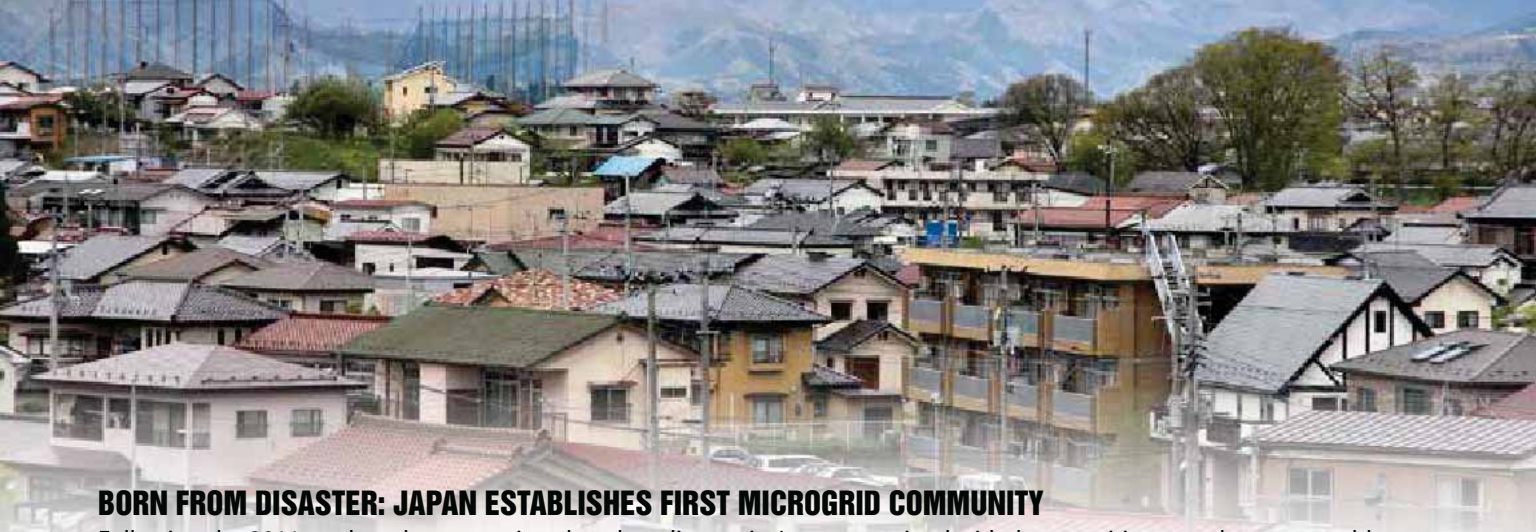
IRENA HQ NAMED TOP GREEN COMMERCIAL BUILDING

The International Renewable Energy Agency (IRENA) headquarters located at Masdar City in Abu Dhabi, UAE, has been named the Green Commercial Building of the Year by the Emirates Green Building Council (EGBC). IRENA is an intergovernmental organization that supports countries in their transition to a sustainable energy future.

Every year, the EGBC Award is given to a building in the Middle East and North Africa (MENA) region whose construction and completion has surpassed the highest sustainability standards and includes innovation in design and processes.

IRENA building architect and lead consultant Woods Bagot and design-and-build contractor Brookfield Multiplex were honoured at an awards ceremony dinner at the Murooj Rotana Hotel in Dubai, UAE. EF

Source: www.tradearabia.com



BORN FROM DISASTER: JAPAN ESTABLISHES FIRST MICROGRID COMMUNITY

Following the 2011 earthquake, tsunami, and nuclear disaster in Japan, one city decided to transition to a clean, renewable future and became Japan's first microgrid community. Although Japan's Fukushima prefecture is most commonly associated with the 2011 disaster due to the nuclear power meltdown, Miyazaki prefecture, located north of Fukushima, suffered the largest death toll, close to 10,000, and the largest flood damage in the nation.

Located on the coast, Higashimatsushima city was no exception. It had a catastrophic tsunami-caused flood, which put 65 per cent of the city under water, with over 1,100 lives lost. Approximately 10,000 residents lost their homes and were forced to evacuate.

However, Higashimatsushima city is currently building Japan's first microgrid community called Higashimatsushima Disaster–Prepared, Smart Eco–Town. The community not only can provide backup power for the grid in case of emergencies, but can also allow the community to be more energy independent and environmentally friendly. This microgrid community is a joint project between the city and Sekisui House, the Japan's leading house developer, with a research funding from the Ministry of Environment. The community consists of 70 detached, single-family homes and 15 multifamily apartment buildings, all of which are owned by the city and are rented to 85 families who lost their homes four years ago. EF

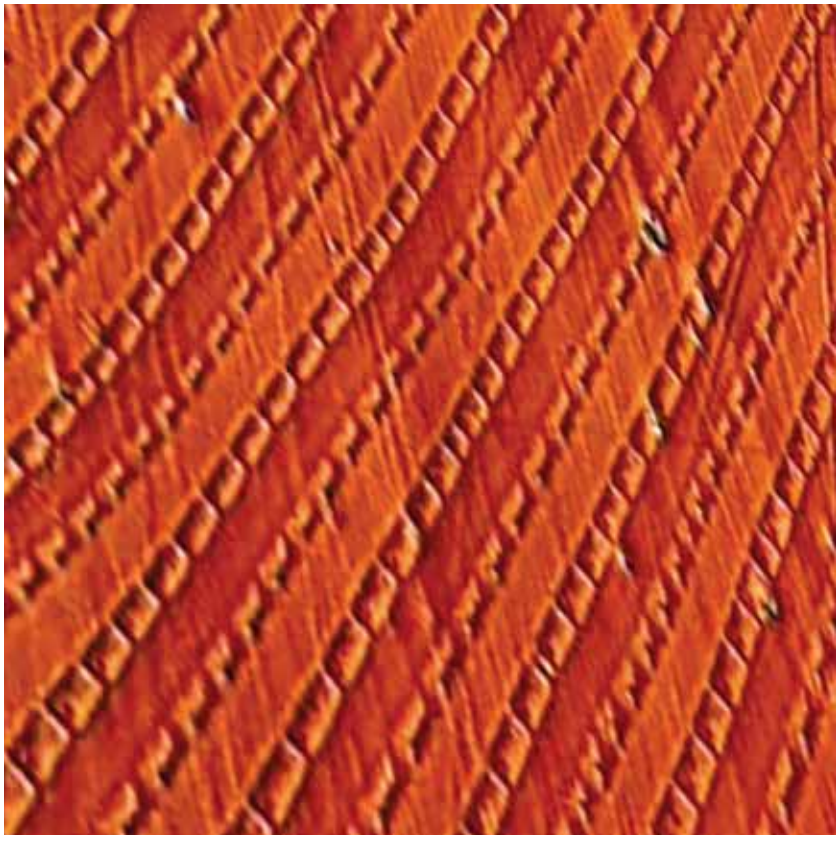
Source: www.renewableenergyworld.com

NEW CLASS OF SWELLING MAGNETS TO BOOST ENERGY EFFICIENCY

Researchers have discovered a new class of magnets that swell when placed in a magnetic field and have a small heat signature, attributes that scientists believe will make a variety of energy-harvesting devices more efficient. Until now, it was assumed iron-based magnets could only change shape, not volume. It's a principle—first described in the 1840s by physicist James Prescott Joule — called 'Joule Magnetostriction'. The principle describes all magnetic materials used today. These limitations make magnets one-directional, i.e., able to exert a force in only a single direction. This limits their efficiency when employed as actuaries in energy harvesting devices and other technologies.

But new research by scientists at Temple University and University of Maryland suggests a new type of magnetic material can change shape and volume—making them omnidirectional—and can transfer energy without generating much heat. These omnidirectional magnets could be used as sensors and actuators, and find a range of applications in aerospace, automobile, biomedical, space, and robotics fields. EF

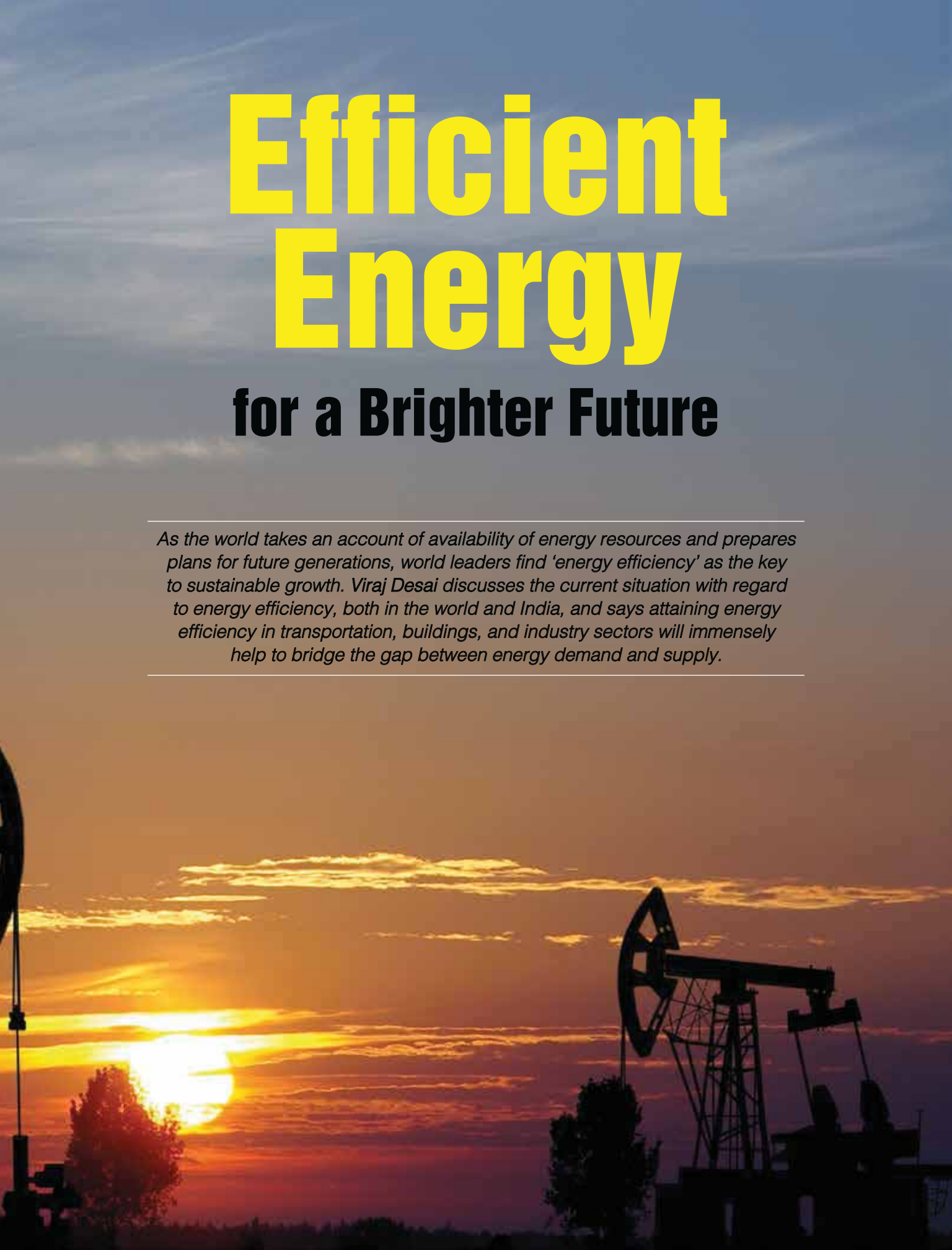
Source: www.upi.com



Efficient Energy

for a Brighter Future

As the world takes an account of availability of energy resources and prepares plans for future generations, world leaders find 'energy efficiency' as the key to sustainable growth. Viraj Desai discusses the current situation with regard to energy efficiency, both in the world and India, and says attaining energy efficiency in transportation, buildings, and industry sectors will immensely help to bridge the gap between energy demand and supply.



The effects of climate change are a reality and the rising temperatures and melting snow-caps across the world demonstrate that human beings must take immediate steps to improve the deteriorating situation.

Although the 1992 Rio de Janeiro Summit saw the heads of governments of more than 100 countries coming together for the first time to discuss the issue of sustainability and climate change, it is only in the last 10 years that the actual action has been taken by countries, thus providing the much needed impetus. At present, the world is witnessing a dual challenge. On one hand, it needs to ensure that the quarter of the world's population living at subsistence level moves out of it as soon as possible; however, at the same time, the world needs to make sure that the energy is generated in an environment–friendly manner. Hence, various researches have changed our mindsets due to which many people have switched over to cleaner fuels and adapted economically viable alternatives to fossil fuels like renewable energy.

However, the scenario not only demands more energy generation but also more energy saving. Hence, energy efficiency as a possible solution has caught the imagination of countries all across the world. Countries have increasingly come to accept the view that 'Energy saved is energy produced'. This means not just lesser wastage of electricity but also using energy efficient equipment for reducing energy consumption. This ultimately leads to immense savings both in terms of electricity and cost. This helps in meeting energy needs of the developing economies of the world. With the world's energy consumption projected to jump by over 40 per cent in 2040 from the current levels and global carbon emissions projected to rise by over 45 per cent from the 2010 levels, it is of utmost importance that not only cleaner energy generation, but also greater energy efficiency should be the motto of all countries across the world.

According to the IEA report, the annual expenditure on energy efficiency is expected to grow over four times to $550 billion by 2035 with over 60 per cent expected in transport sector, 9 per cent in industrial sector, and 29 per cent in infrastructure (buildings) sector.

Considering that awareness can lead to initiatives which can finally result in achieving goals, the world leaders have agreed to the fact that information dissemination to the public is a prerequisite towards energy efficiency.

ENERGY EFFICIENCY: A HIDDEN FUEL

The importance of energy efficiency was rightly highlighted by the International Energy Agency (IEA), an intergovernmental organization that advises its 29 member countries and some non-member nations on policies pertaining to energy matters for energy security and environmental security. The organization stated that energy efficiency is a hidden fuel and nations across the world need to harness it intelligently. An IEA report, published in 2011, demonstrated that the energy efficiency schemes had attracted investments of about $300 billion, which was equivalent to global investments in fossil fuel power generation or even renewable energy.

The report opined that about half of the climate mitigation measures would come from better energy efficiency; it added that reducing energy waste would provide financial resources for sustainable development.

POTENTIAL OF ENERGY EFFICIENCY

According to the IEA report, the annual expenditure on energy efficiency is expected to grow over four times to $550 billion by 2035 with over 60 per cent expected in transport sector, 9 per cent in industrial sector, and 29 per cent in infrastructure (buildings) sector.

Since mobility is one of the most crucial aspects for the world, improvements in cars dominate investments in transport, whereas space heating and insulation account for the major part of investment in buildings.

It is also estimated that households would need about half of the total investments; whereas, businesses would need 40 per cent of it. Hence, usage of energy efficient appliances, environment-friendly cars, and some investment for insulation would all be the need of the hour if the world has to ensure a sustainable growth in the decades to come. On the other hand, businesses would need to evolve by having green buildings, more energy efficient vehicles for transport, and a definite need of refurbishing buildings.

Attractive financial incentives for private sector can go a long way in creating a market for such equipment. However, what becomes a deterrent for energy efficiency is that in contrast to traditional energy-supply investment, energy efficiency investments are thought to be for future cost savings rather than as an asset giving a specific cash flow, which becomes attractive to private players.

GERMANY: LEADER IN ENERGY EFFICIENCY

According to an analysis done in 2014 on the top 16 economies of the world by the not-for-profit organization, i.e., the American Council for an Energy-Efficient Economy, Germany scored the best in terms of most energy efficient

parameters, whereas the United States ranked at a lowly 13th rank in the overall list. India, one of the fastest growing countries, managed to make it to the 11th rank, thanks to its recent push to renewable energy, whereas its immediate neighbour, China has climbed up to the 4th rank. The analysis included three sectors—buildings, industry, and transport.

WHY INDIA NEEDS TO MAKE ENERGY EFFICIENCY A PRIORITY?

India has made rapid strides in energy generation and the total energy production has gone up significantly in the last 10 years. However, a quarter of its population still does not have access to energy. If it wishes to have a sustainable development, it is imperative for India to not only scale up energy generation, but also ensure energy efficiency.

A number of reasons are critical as to why India needs to act more swiftly and decide on a plan that can be implemented for achieving energy efficiency. The country accounts for over 5 per cent of the global demand for energy; it's amongst the fastest growing economies in the world. The burgeoning middle class and the development of smart cities comprising an increased number of offices, cars, and residential homes are strong reasons that suggest that the energy demand will only rise in the times to come. The country is expected to account for 18 per cent of the world's energy consumption by 2035, a jump of more than three times over the current level.

What must not be forgotten is that it coughs up millions of dollars for importing over 70 per cent of the fossil fuels, especially petroleum. Besides, despite having access to one of the largest coal reserves in the world, it still imports a substantial amount of coal from overseas. Its coal-fired power plants rank low in terms of energy efficiency and the peak demand leads to power cuts even in the capital city of the country, i.e., New Delhi. Ironically, the Indian consumers pay highest electricity costs in the world in contrast to their incomes.

AMBITIOUS PLANS

The rising energy needs have led to a surge in pollution levels. The government did foresee some of these problems and started acting on them over a decade ago. In order to address energy inefficiency, the government proposed the National Mission on Enhanced Energy Efficiency under India's National Action Plan for Climate Change, which was aimed at reduction in the annual energy consumption. It has also announced another ambitious step to achieve sustainable energy. India is looking to quadruple the total renewable energy capacity to 160 GW in 2022 from the current level of 25 GW, a surge of over 600 per cent. While naysayers would say that the government is thinking on chewing more than it could bite, Prime Minister Shri Narendra Modi's will and action-oriented approach can be decisive factors. In his earlier role as the Chief Minister of Gujarat, Shri Modi transformed the power deficit state into a power-surplus state and then a power-exporting state through active engagement with private sector and greater focus on renewable energy. Taking into consideration that 1 GW of energy is able to power 700,000 homes, one can imagine the kind of reach that renewable energy may achieve and help ease the dependence on fossil fuels for the country.

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MARKET SIZE OF ENERGY EFFICIENCY

In contrast, it is estimated that the energy efficiency market is a $16 billion opportunity while the Bureau of Energy Efficiency (BEE) forecasts expenditure of $148 billion from 2012 to 2022. An Ernst & Young Report had stated that the country is expected to install 130 smart meters by 2021. All this proves that energy efficiency is a huge market and akin to renewable energy becoming the focal point of government's agenda over time, this too will see policies favouring growth of the sector.

With the McKinsey Global Institute estimating that India had tapped only 5 per cent of the potential energy savings capacity at the start of 2014 resulting in savings of $14.8 billion, the results are indeed extremely encouraging for private as well as public sector to aggressively pursue. The Institute further suggests that the country can improve energy efficiency by adopting a few minor modifications in buildings, i.e., standard energy efficiency measures in new construction as well as retrofitting in existing ones, which would lead to the saving of about 2,988 MW of generating capacity ultimately resulting in savings worth $42 billion per annum. Even though the cost of these improvements would be to the tune of $5–10 billion, the Institute has opined a payback time of 5–10 years. This is just a small indicator of the potential that lies in savings through energy efficiency.

BEGINNING OF ENERGY EFFICIENCY IN INDIA

The Energy Conservation Act of 2001 was the starting point since the Indian Government wanted to make a framework for policies on energy efficiency to ensure long-term sustainable development. Although, at that time, the focus was on augmenting the energy generation for meeting needs of the burgeoning population, energy efficiency has slowly become a priority amongst the other things such as switching to alternatives like renewables.

It is believed that it would play a bigger role in the times to come as it not only results in cost savings, but also ensures reduction in wastage of energy, increased productivity in offices and factories, along with eliminating the need for more power plants, improved air quality, and reduction in global warming. Ultimately, it translates to saving money for businesses and consumers. All this can be extremely significant for a power-deprived Indian state that looks to project itself as a superpower vis-a-vis its neighbour China.

BEE PLAYS A PIVOTAL ROLE

The Bureau of Energy Efficiency (BEE), which was set up in 2002, has managed to develop a policy framework on many fronts for improving the energy efficiency in the country. It has successfully developed star rating of appliances, which indicates their performance standards and spread the word among consumers through various mediums, which helps consumers to make an informed decision. With over two-thirds of buildings in India yet to come up by 2030 and buildings accounting for over 30 per cent of India's energy consumption, the BEE's energy efficiency code for buildings and industries is indeed going to play a major role in defining the air quality of the country one-and-half decades down the line.

STEPS THAT COULD PROVE TO BE A GAME-CHANGER

The government has estimated that industrial sector accounts for half of the total commercial energy available in India with energy-intensive sectors such as aluminium, fertilizers, textiles, cement, iron and steel, and paper almost having a share of 70 per cent. Through energy efficiency measures, the government may be able to avoid about 15–20 per cent from the current share of 70 per cent resulting in tremendous savings in cost and energy.

One of the unique initiatives that the BEE took was the Perform, Achieve, and Trade programme. Under this scheme, 468 industries in extreme energy-intensive sectors such as paper, chemical, steel, and non-metallic were asked to reduce their energy consumption by adopting energy efficient methods. In 2012, India gave the most energy-intensive industries a deadline of March 31, 2015 for reducing the amount of energy they consume for every unit produced.

According to Shri Ajay Mathur, head of the BEE, over 90 per cent of the companies are on track for meeting the targets after investing in new technologies and equipment. This is indeed a cause of delight for the BEE head who has been making persistent efforts ever since he was chosen to lead the initiative of introducing standards for energy efficiency in the country. Shri Mathur added that the Indian cement and fertilizer factories may end up being the most efficient in the world. The Indian Government awards companies surpassing targets with credits which can be sold to others falling short. Businesses exceeding energy efficiency targets are awarded credits which can be sold at power exchanges whereas those that fail to meet the goals can buy the credits.

A key to the programme is ensuring the independence of auditors measuring the energy use and economic output of the plants. According to Shri Mathur, all the auditors are trained and accredited. As a rule, another auditor would audit the plant for the second time to verify the initial report generated by the first auditor. The BEE has major plans in expanding the programme to more sectors including refining, petrochemicals, railways, and electricity distribution.

According to the government, this three-year cycle is expected to result in reduction of 23 million metric tonnes of carbon dioxide as well as 6.6 million tonnes of oil equivalent. In terms of cost analysis, it means the savings of $5 billion in oil imports and eliminating the need for electricity equivalent to the output of five coal-fired power plants.

AGENCIES FORMED TO ASSIST BEE

The Energy Efficiency Services Limited (EESL), a collaboration of various public sector units such as NTPC, PFC, REC, and Power Grid, aims to work as an Energy Service Company, consultant for Clean Development Mechanism and Energy Efficiency projects. It is the first company formed in South Asia to exclusively target energy efficiency. EESL aims to determine a baseline of energy use before and after the instalment of energy efficiency measures on demonstration projects.

EESL is already working in a few such projects, and would help in assessing potential energy along with costs savings that would happen as a result of the project. In order to attract private sector, demonstration projects in municipal, agriculture, and public buildings funded by the Government of India and international donors have been done for drawing a comparison between LED and Compact Fluorescent Lamp (CFL) appliances over a period of one year time. However, this needs to be expedited and hence the need of the hour is to involve private

sector and experts in some of the baseline calculations. Even the BEE is a unique that has been made by any government across the world that solely looks after designating policies and framework on energy efficiency.

However, the Indian Government's initiatives in recent years for energy conservation such as setting up of 'Green Buildings' under the purview of Indian Green Building Council (IGBC), Energy Conservation Building Codes (ECBC), star ratings by the BEE, and Green Rating for Integrated Habitat Assessment (GRIHA) are laudable. On the other hand, Indian Renewable Energy Development Agency (IREDA), set up under the Ministry of New and Renewable Energy (MNRE), is working with banks and subsidizing energy audits performed on companies which are seeking to carry out energy efficiency improvements. It is also providing funding to renewable as well as energy efficiency projects, which may see the increased participation of energy service companies.

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Another scheme launched by the BEE was the 'Bacchat Lamp Yojana', which aimed to offer subsidized LED lamps to households for reducing power demand and improving energy efficiency on the demand side. In the scheme, an energy efficiency services company was to procure lamps in bulk and sell them at subsidized rates to consumers. A total of about 29 million CFLs were sold during the 11th Five-Year Plan. This resulted in the non-consumption of generation capacity of about 415 MW. Although, it was far

lower than the target set out by the government, it was a beginning to switch to more energy efficient lighting.

ENERGY EFFICIENT TRANSPORTATION

In terms of transportation, the success of Delhi Metro in reducing carbon emissions with more people opting to take public transportation rather than drive by their own cars has resulted in more cities opting for construction of metro rail. This is expected to ease the traffic on the roads which are witnessing major congestion due to increase in the number of vehicles. Ultimately, it helps in lowering the levels of carbon dioxide, carbon monoxide, and other harmful gases.

The country is expected to be the third largest automobile market in the world after US and China with over 11 million light vehicles by 2020. The BEE has finalized norms which would be a binding for car manufacturers from 2017 onwards. It is expected that the fuel efficiency of cars would improve by 10–15 per cent over the next 5–7 years vis-a-vis 2009–10 as the base year.

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Regarding transportation, the Indian Government is also giving greater push to electric vehicles. It is offering subsidies and incentives for makers as well as buyers of electric vehicles in order to have at least six million electric vehicles on the road by 2020. The subsidy is part of a scheme named Faster Adoption and Manufacturing of Electric vehicles (FAME) (launched in 2015–16) which was announced in the budget this year with an initial expenditure of `75 crore.

Unfortunately, the levying of additional taxes by states is a deterrent and the government is trying to sort out this issue in order to spur sales. Mahindra Reva, one of the best-selling electric vehicles in India, is expecting a substantial growth once the policy pans out properly. Other companies such as Tata Motors, Maruti Suzuki, and Ashok Leyland are also waiting to launch their hybrid vehicles once the commercial viability of the product would fructify. Tata Group is going to supply 30 hybrid diesel cars to the Bangalore Metropolitan Transport Corporation (BMTC) by 2016.

However, the government has to enact policies quickly in order to ensure that electric vehicle can take off as anticipated initially. These measures in transportation sector in addition to alternative fuels such as biodiesel, which is expected to cut down some diesel consumption by 2020, can go a long way in ensuring energy efficiency for vehicles. Indian Railways, the largest passenger carrier network of the country, is also taking a slew of measures such as adoption

of energy efficient equipment and deploying new generation IIIrd phase energy efficient electric locomotives that have led to savings of electricity consumption in the past. The gigantic organization aims to save up to 15 per cent of energy by 2020 as envisaged in the Indian Railways' vision document for lowering carbon footprint. The Indian Railways has developed a web-based Electrical Energy Management System, RAILSAVER, through its technology arm Centre of Railway Informatics System (CRIS), and the portal is part of $5 million funding by the United Nations.

INACTION CAN HURT

However, some other measures announced have been stuck for many years acting as a deterrent for private players to foray into the sector. In June 2010, the Indian Government had announced its intent of establishing a Partial Risk Guarantee Fund (PRGF) for providing commercial banks with partial coverage of risk exposure against loans issued for energy-efficiency projects. The plan covers about 50 per cent of the loan amount or `300 lakh. However, the fund has neither been developed, nor deployed, thus indicating one of the reasons why banks are not coming forward in having complete faith on energy efficiency projects.

However, multilateral funding agencies like The World Bank have signed a $43 million grant with the government recently to guarantee agreement towards 'Partial Risk Sharing Facility for Energy Efficiency project' that would aid 'Energy Service Companies' in mobilizing commercial finance for investments in energy efficiency initiatives.

The study done by American Council for an Energy-Efficient Economy stated that India ranks at 11th in energy efficiency vis-a-vis the world's 16 largest economies. While the country has taken steps in energy efficiency over the last decade, the ageing power plants and inefficient manner of electricity generation along with transmission and distribution losses are reasons indicating that lot more needs to be done in energy efficiency for a long-term sustainable development.

ENERGY SERVICE COMPANIES TO THE RESCUE

What needs to be taken into perspective is that most of the ESCO efficiency projects have a payback period of less than two years and the clients of service companies can manage to save 20–25 per cent of baseline energy costs. An example of the success and cost savings is of the famous Lilavati Hospital of Mumbai. The hospital hired Sudnya Industrial Services, an ESCO, for analysing the energy scenario and the results stated that air-conditioning system comprised 60 per cent of its energy usage and proposed to upgrade the same. While it ended up spending a whopping $12,000 for the upgrade, the energy savings are $17,000, and the payback time was just nine months.

Need to create awareness through education

States have also been proactive in taking steps for ensuring energy efficiency. Recently, the Punjab Government launched a state level 'Energy Conservation and Efficiency' campaign and promoted the teaching of renewable energy-related concepts in schools. The state's energy minister had highlighted the importance of teaching lessons pertaining to the topic in schools so that the country could produce more energy auditors in future besides saving energy.

The number of course options for power sector are also limited and hence the government needs to take initiatives to attract youth to be a part of the steadily growing energy sector. An increased focus in schools on the subject can also lead to children and youth making an active contribution to energy efficiency by ensuring less wastage of power both at home and schools. Ultimately, it helps in making the population aware of the need of the hour.

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RECENT EVENTS

A meeting held recently saw the Planning Commission, the BEE, and Natural Resources Defence Council, an international environmental group, discussing the possibility of the country saving about 3,453 TW (terawatt) hours of electricity by 2030, if Indian states could develop stronger building efficiency codes and developers become a part of the programmes for rating commercial buildings.

India has highlighted its commitment at various international forums, the latest one being done by Minister of Environment, Forest and Climate Change Shri Prakash Javadekar at Lima in Peru at the UN Climate conference on India's pro-activeness in enhancing energy efficiency and that it was on its way of achieving 20–25 per cent of reducing carbon intensity of the 2005 levels.

PRIVATE SECTOR LEADS BY EXAMPLE

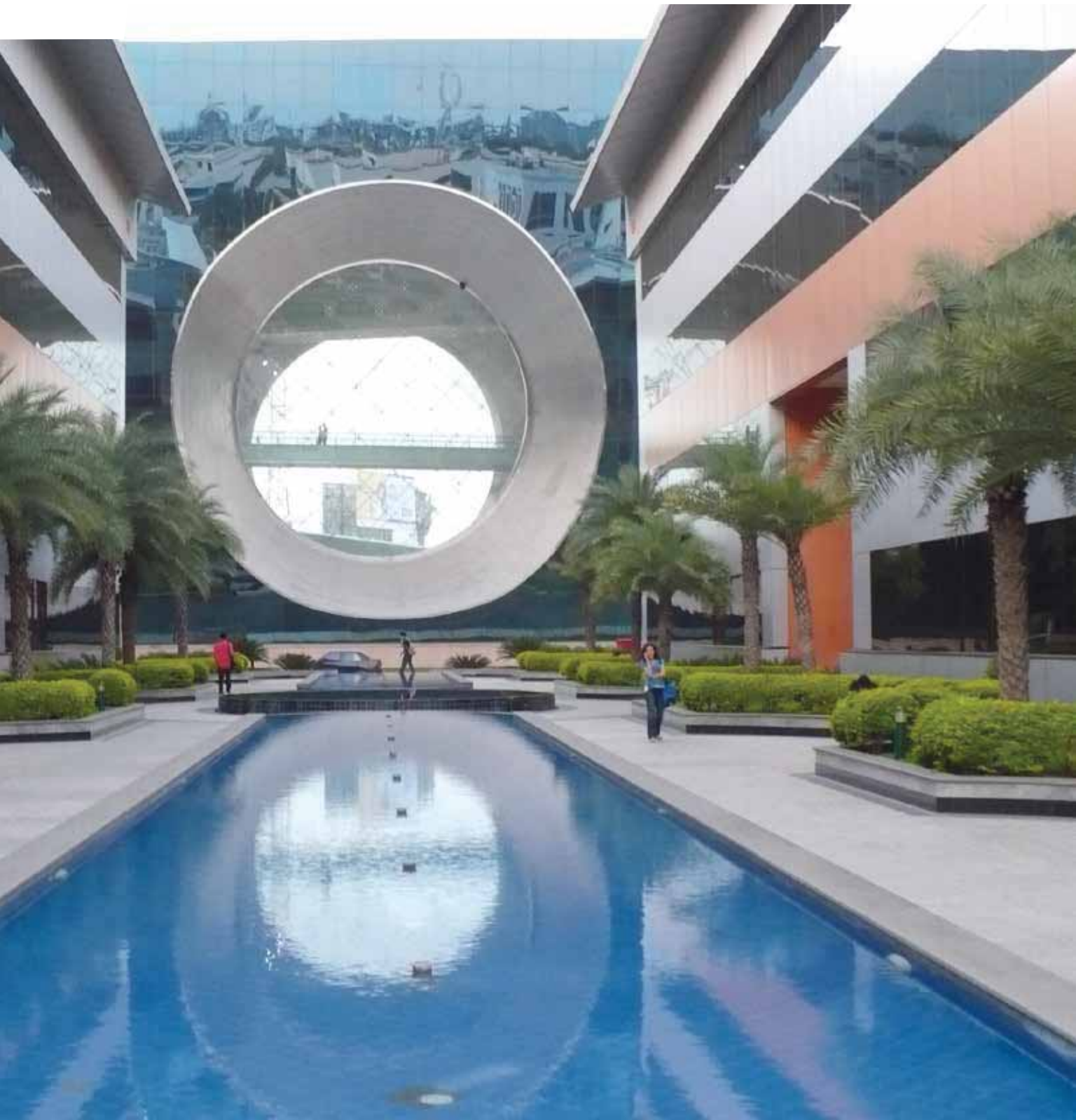
Big corporate such as Infosys has taken a lead by making gargantuan efforts in order to ensure that all its campuses across the country are designed for ensuring maximum energy efficiency. While this has resulted in savings of over $80 million over the last six years for the IT giant, it has also earned several awards at the international level. Banks have also started getting active in funding energy efficiency projects now; recently, this year,

Yes Bank, stated that it would raise $500 million for funding such projects.

CONCLUSION

While there have been some achievements of the energy efficiency measures taken by the Indian Government in the past decade or so, a lot more needs to be done for helping the country achieve self-sufficiency in its energy needs. Financial institutions, government bodies, and citizens, all have a role to play in ensuring that energy efficiency can save precious dollars and help in providing energy access to millions who still lack it. EF

A former banker and a journalist, Mr Viraj Desai has had stints with Citibank and The Economic Times. He currently works with an NGO and loves to travel and read on diverse topics especially energy, environment, and technology. Email: virajd29@gmail.com.



Solar–Hydro Mix Energy Model

A new approach

*In this article, **Mamta Bajetha** discusses the design and working of a special kind of log power plant, i.e., solar-hydro mix power plant. In this model, the energy is generated from both, i.e., the solar panels and the turbine set under the falling water. Through this unique way of generating the power, as the author claims, we can keep our cities clean and green, since these plants will be built on the solid waste landfills.*

Honourable Prime Minister of India Shri Narendra Modi has launched two very ambitious projects, i.e., 'Swachh Bharat Abhiyaan' and 'Make in India'. The aim of both the projects is to make our country clean and developed. A sustainable industrial development can only be achieved by adopting renewable energy sources.

Severe shortage of coal is posing threat to reliable power supply in every part of India. Population explosion is seen in every nook and corner of the world as much as heaps of filth and waste. Landfill and garbage dumping zones are mounting day by day. Untreated sewage water and garbage are dumped into rivers and thus pollute them.

This article presents the solution of the above-mentioned problems by 'Solar–Hydro Mix Energy Model'. It is constructed on a landfill site to produce electricity by solar panels and hydro power (water from sewage treatment plant is used to generate hydro power). The following are the technical and physical resources, which are integrated to produce energy through this model:

- Scientific landfill site
- Sewage treatment plant
- Solar panels
- Pump storage hydro power plant

SCIENTIFIC LANDFILL SITE

In India, waste or garbage is a common sight and a major part of every city is littered with it. It is a source of pollution and accounts for many diseases which affect humans and animals. It has been estimated that India generates around 100 million tonnes of solid waste every year. There is no proper mechanism to dispose off or treat this waste. Waste management is simply not followed, which has led to chronic situation in cities. It has been estimated that half of the waste is simply not collected which has further compounded air pollution, water pollution, and health related problems.

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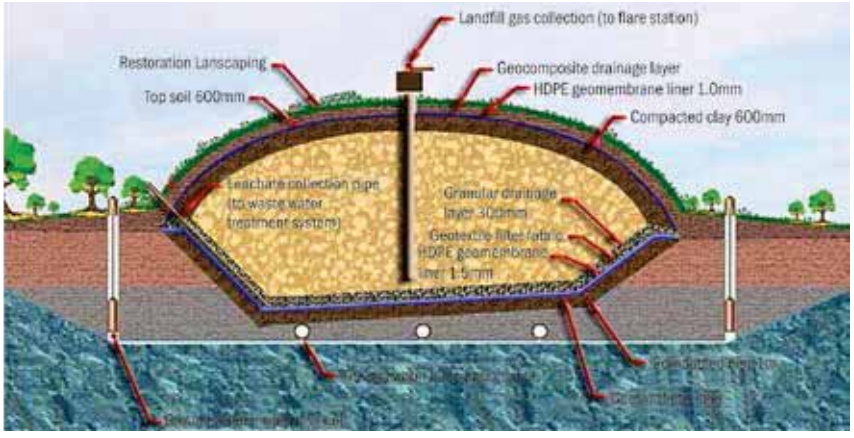

Figure 1: Scientific landfill structure

Delhi is the highest municipal solid waste producer in the country, dumping nearly 8,000 tonnes of waste per day. There are four landfill sites in Delhi—Ghazipur (70 acres), Okhla (56 acres), Bhalswa (40 acres), and Narela-Bawana (100 acres). Among these, Narela-Bawana is about to become the first scientific landfill site that will have the capacity of the 4,000 metric tonnes of the solid waste.

In a scientific landfill structure (Figure 1), it is proposed that the waste is dumped at barren land which would be in compact form. The following would be the anatomy of such a landfill:

a) The scientific landfill system will have a 'composite liner system' at the bottom of landfills. It would prevent leachate from leaving the landfill and entering the environment. Leachate is a liquid that has filtered through landfill. It is generated by natural decomposition of the waste. This composite liner system consists of geo-membrane, compacted clay, and prepared sub-grade soil.

b) The landfill will also have a 'leachate collection system' above the composite liner system. It will collect the leachate so that it can be removed from the landfill and thereafter it is properly treated. The system consists of leachate collection layer, filter geotextile, and leachate collection pipe.

c) The 'working landfill' would be above the leachate collection system. It consists of waste and layers of soil. Each waste layer is covered with soil after each working period.

d) A 'composite cap system' is placed above the working landfill. The purpose of this cap system is to cover the landfill when it has reached a permitted height. It will thus prevent the percolation of water from protective cover soil to working landfill. It consists of drainage layer, geo-membrane, and compacted clay.

e) A 'protective cover' is placed above the composite cap system which consists of cover vegetation, top soil, and protective cover soil.

SEWAGE TREATMENT PLANT

Water pollution has become a serious environmental issue. It is posing threat to meet demand for clean water for increasing population, agriculture, and marine life. The largest source of water pollution is untreated sewage, which finds its way into rivers, ponds, lakes, ground water system, and finally into the sea.

In India, most of the cities have lower treatment capacity than their sewage generation. A 'State Jal Board' is responsible for the treatment and disposal of waste water by the network of sewage lines across the city. Most of the sewage treatment plants in many cities are barren, non-functional, or working under their proposed capacity. This condition has resulted in sinking of the untreated water into the river and thus its pollution.

In a sewage treatment plant (Figure 2), many processes such as mechanical, physical, biological, chemical, and disinfection are carried out to change the properties of the sewage/waste water. Thereafter, it can be discharged into environment without any harmful effect or can be re-used for many other purposes. These sewage treatment plants are run by electrical energy. A systematic treatment of waste water can produce biogas (a cooking gas), fertilizers, and re-usable water.

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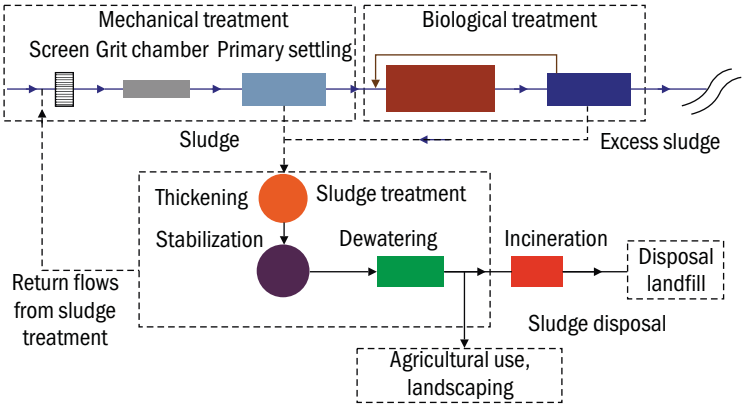

Figure 2: Working of sewage treatment plant

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In this model, it has been proposed to channelize the sewage/waste water from cities to sewage treatment located at landfill sites. The broader working steps of the sewage treatment plant are as follows:

a) **Filter treatment:** It removes large objects and non-degradable materials. Bar screens or grit chamber are used to protect pumps and equipment from damage.

b) **Primary treatment:** Primary treatment is a physical process, in which waste water is slowed down and suspended solids, called sludge, settle to the bottom by gravity. This sludge can be used as a fertilizer or manure.

c) **Secondary treatment:** Secondary treatment is a bio-chemical process depending on the type of content present in the water. Utility algae and bacteria are used to metabolize organic content in the wastewater and a specific process is used to remove the metals. Then distillation, oxidation, and neutralization are carried out in wastewater to obtain clean water.

d) **Disinfection:** Disinfection is done to reduce the number of microorganisms in the treated water so that this water can be re-used as drinking, bathing, or irrigation purposes. Mainly chlorine, ultra-violet light, and ozone gas are used for the disinfection.

SOLAR PANELS

Solar energy is a clean sustainable energy source which is abundant in India. Solar cell can generate electricity via semiconductor materials that exhibits the photovoltaic (PV) effect. Solar (panels) modules are composed of number of solar cells to produce electricity from sunlight.

A PV module can produce electricity when sunlight falls on its surface. Maximum solar power density will be achieved when the angle between module surface and sunlight is 90° but it keeps on changing as the sun changes its path with respect to a particular position on earth. Therefore, the single and double-axis trackers are used to maintain the module surface always perpendicular to the sunlight to obtain maximum solar power density.

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Solar modules are rated in peak watt (Wp); it is the maximum rated output of the module under standard test conditions (25°C and wind speed 1 m/s). The amount of solar energy received on the surface of module in a given time is called solar insolation. It indicates the total hours for which the rated peak watt from the module can be obtained. The average solar insolation in India is 5.5 kWh/m^2/day. Dirt, dust, and moisture should be cleared from the module to avoid any losses.

A site having 250–300 sunny days in a year is considered to be a solar potential site. The everyday average solar energy incident over India varies from 4–7 kWh/m^2. It has been calculated that 35,000 km^2 of the Thar Desert is sufficient to generate 1,000–2,000 GW of electricity. Approximately 6 per cent of India's land area is barren and 8 per cent is fallow land. These vast tracts of land can be used as scientifically treated landfills. Further, this unused land can be used as a potential site for this hybrid energy model for power generation.

Energy output (electricity generated) from a PV system is:

$$E = A \times r \times H \times PR,$$

where,

E= Energy (kWh)

A= Solar module area (m^2)

r = Solar module yield (%)

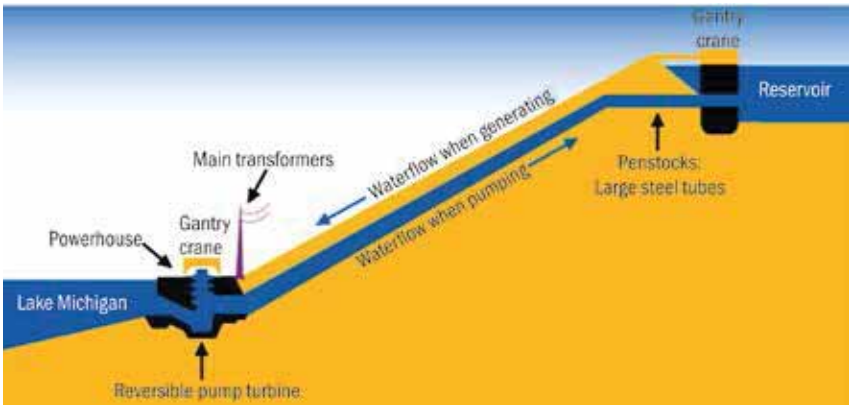

Figure 3: Working of pump storage hydro power plant

(r= Electrical power (in kWp) of a solar module divided by the area of one module)

H = Annual average solar radiation on tilted panels (This value can be obtained from solar radiation data)

PR = Performance ratio; it gives indication about the performance of the installation, orientation, and inclination of the panel. It includes all losses (0.5–0.9)

Main reservoir for pump storage type hydro plant will be constructed on the mount of a scientifically treated landfill. This reservoir will store the treated water from sewage treatment plant and provide the requisite water-head to run the turbine–generator assembly. Lower reservoir and power house will be constructed at the base of the landfill mount.

PUMP STORAGE HYDRO PLANT

Pump storage type hydro power plants (Figure 3) are most reliable and it can be switched on and off quickly. Pumped storage projects store and generate energy by moving water between two reservoirs at different elevations.

During the periods of high electricity demand, the stored water from upper reservoir is released from the height (water-head) with requisite water discharge and reaches the turbine-generator assembly. This water-force moves the turbine-generator assembly and produces electricity.

During the low electricity demand, such as at night or on weekends, excess energy is used to pump water from lower reservoir to an upper reservoir. In this process, motor-pump action takes place. Generator acts as a motor which consumes electricity and drives the prime mover (turbine) and water is lifted up to the upper reservoir.

Technical equation of hydro power plant for available power (P)

Potential energy per unit volume =

$$\rho \times g \times h$$

where,

ρ = Density of the water (103 kg/m^3)

h = Head of water (m)

g = Gravitational constant (9.8 m/s^2)

The power P from a dam =

$$P = \eta \times \rho \times g \times h \times Q$$

Q = Volume of water flowing per second (m^3/s)

η = Efficiency of the turbine

DESCRIPTION OF SOLAR–HYDRO MIX POWER PLANT MODEL

Solar–hydro mix power plant model will be constructed on a scientific landfill site where a sewage treatment plant will be established to purify the sewage water coming from the city. Output of the sewage treatment plant is clear water, which will be stored in the tail pool. As shown in Figure 4, the upper reservoir is constructed on the top of the highest mounts of the landfill and the tail pool (low head reservoir) will be constructed at the base of the mount.

There is a generator–turbine assembly in between the upper reservoir and the tail pool to produce electricity from pump storage hydro power plant. During the off-peak hours, motor–pump action will take place to feed water to the upper reservoir from the tail pool. This pump storage type hydro power plant will run when upper reservoir will provide head and requisite water discharge to the generator–turbine assembly.

Both the reservoirs and slope of landfill mount will be covered with solar modules which will produce electricity during day time. During night or cloudy days, to maintain the 24-hour reliable supply of electricity, the hydro power plant will come into action. Thus, we can say water reservoir on landfill acts as a battery, which supplies power when there is no power output from solar panels.

Rest of the components of plant such as inverter, battery, and control panels are further connected to the outset of the generator–turbine assembly and control panel. Finally, the continuous and reliable power supply is fed to the grid after some in-house power consumption in the plant.

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COMPONENTS OF THE PLANT

Main reservoir

There are many landfill sites in every city of India. These landfills stand tall, up to tens of metres and are stretched up to hundreds of square metres in area. These landfill mounts can be pressed hard and scientifically treated and then on their top, a main (upper) reservoir could be constructed. This reservoir will be surrounded with waterproof walls as shown in Figure 4, which is equivalent to an upstream water reservoir in pump storage scheme. This main reservoir will get water from sewage treatment plant.

The main reservoir will be covered with high efficiency solar panels (20 per cent efficiency or more). These solar panels not only produce power, but also prevent water to get evaporated and getting dirty. Sloping side of landfill, tail pool, and water collection pit will also be covered with solar panels.

Pump storage power house

A pump storage power house will be constructed at the base of the landfill mount. This power house will consist of turbine (pump), generator (motor), and DC–AC converter. It will also have the facility of switching circuits which will change the machines modes, i.e., generation to motor action and vice-versa.

Penstock connects the turbine–generator assembly to the main reservoir. It is analogous to a big slant water-pipe spreading from the main reservoir to the base of power house. This penstock will carry the sufficient water discharge from the reservoir with speed and rotate the turbine.

Tail pool

At the base of power house, a tail pool will be constructed where the clean water from the sewage treatment plant will be collected. Collected clean water from tail pool will be supplied to the main reservoir with the help of pump and motor. During power generation mode, when the machine works as a generator, this tail pool will again collect water from the turbine. Excess clean water could be supplied to the city to meet its water requirement for several purposes.

Sewage treatment plant

The sewage treatment plant will treat the sewage water coming from household, commercial buildings, and industries. Incoming sewage water lines will be connected to this plant and at the outlet, clean water will be collected in the tail pool. Manure (sludge) and biogas are some useful by-products of this plant which can be put into productive use.

Control and switching panel

The solar panel output will be connected to the DC–AC converter which comes with filter. The AC output will be connected to switching circuits which will connect the generator and grid. Some part of power output will be used for station auxiliaries and sewage treatment plant.

During the day time, the small part of the solar power will drive the motor-pump to fill the main reservoir and then the net maximum power could be fed to the grid via DC–AC converters. During night time, the water in the main reservoir could be used to drive the generator-turbine to produce AC output power, which can be fed to the grid.

ENERGY PRODUCTION

To calculate the total power generation from this model, let's assume that the total base area and top area of a landfill mount is 500 m × 500 m and 300 m × 300 m, respectively. The height of the main (upper) reservoir is 60 m. The mount of this landfill has been properly treated and compacted and then a waterproof sloping wall with 12 m height (approximately) is constructed all around the top of it.

Let's say at the bottom of main reservoir, we have an area of 300 m × 500 m or more which is used as a tail pool and other construction. This tail pool is excavated to 10–12 m below the surface level, which collects the treated water from sewage treatment plant.

Solar power generation output

If the slope of landfill mounts and tail pool is covered with solar panels, then power output from solar panels would be:

- Let's take 1 m × 1 m of solar panel with 20 per cent efficiency which would produce 200 W under standard test conditions.
- For 8 hours of continuous sunshine, the power output from solar panel would be 1.6 kWh.
- Total area of the plant (landfill + tail pool) is 800 m × 500 m = 40,000 m².
- Assuming only 80 per cent of the plant area is covered, then power output from solar panel per day would be equal to 1.6 × 400,000 × 0.8 = 512,000 kWh (Eq. 1)

Hydro-electric power generation output

- Dimensions of the main (upper) reservoir: Length (l) = 300 m
  Breadth (b) = 300 m
  Depth (d) = 12 m
- Water head, i.e., base height of reservoir from tail pool = 60 m
- Volume of water stored in the reservoir = l × b × d =
  300m × 300m × 12m = 1,080,000 m³
- Let's take the discharge of the water during power generation (Q) = 20 m³/s
- Power output in watts =
  ρ × H × Q × g × K
  where,
  ρ = density of water (1,000 kg /m³)
  H = Head of water
  Q = Flow rate in cubic metres per sec.
  g = Acceleration due to gravity
  K = Efficiency of turbine
  (approximately >0.95 for Francis)

Power output = 1,000 × 60 × 20 × 9.8 × 0.95 = 11,172,000 W = 11.17 MW (Eq. 2)

Duration for which this power output of 11.17 MW is available = 1,080,000 / (20 × 6 0 × 60) = 15 hours

The power output in 15 hours duration = 15 × 11.17 × 1,000 = 167,550 kWh (Eq. 3)

When water will be supplied to the main reservoir from tail pool, motor–pump action will come into play, but pumps have relatively lesser efficiency (0.85).

Therefore, the amount of power required to fill the main reservoir will be = (167,550 × 0.95) / 0.85 = 187,262 kWh (Eq. 4).

From the above calculations (Eqs. 1–4), we can conclude that:

- Power output from solar panel per day would be 512,000 kWh, whereas power consumption in filling the main reservoir would be 87,263 kWh.
- It can be seen that power output from solar panel is 2.73 times the power required to fill the reservoir.
- Therefore, power available, which can be supplied to grid, would be = 512,000 – 187,262 = 324,738 kWh.

There will be some in-house power consumption such as in the operation of sewage treatment plant, pumping the water to the main reservoir, lighting, cleaning, and maintenance purpose. Therefore, it can be concluded that the proposed model which is built in (approximately) 800m × 500m of area can supply maximum 10 MW of continuous power supply to the grid. It contributes the following benefits in the sustainable development of the nation and environment:

a) This model presents a best possible combination of hydro and solar power which utilizes every aspect of renewable energy in a very productive way.
b) Land requirement for this energy model is met by landfills, barren lands, and waste disposal zones. The scientific use of the landfill site gives healthy solution to the waste disposal problem, which otherwise lie abandoned or simply exhausts its limits.
c) Application of sewage treatment plant in this model not only provides water for hydro power generation, but also provides clean water for public use. This way, it contributes to the healthy environment without polluting our rivers or lakes which eventually sustain the aquatic life.
d) Solar-hydro technology leaves least carbon footprint to the environment and thus making the society clean and green.
e) This solar and hydro mix energy model provides a continuous and reliable power supply without any harmful by-products, pollution, and waste to the environment. EF

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Top Ten Drivers

for Wind Energy Business in 2015

P Vinay Kumar takes a look at the current situation of the wind energy sector in the country, discusses government policies in this regard, and suggests points to improve business viability in future.

A new financial year has begun and it has brought with it the inevitable stock-taking of the year gone by, and the resolutions to be made for the next year. The business landscape for renewables appears to be rosy and the general mood is buoyant. I will speak about wind in particular and renewables in general, and the onset of 2015 is as good a reason as any to draft a listicle of the following ten main drivers for the wind business for this year.

1. RESTORATION OF AD BENEFIT AND GBI

Since a long time, wind has been essentially an Accelerated Depreciation (AD) driven business. The withdrawal of the AD benefit in 2012–13 was a blow the wind business could have done well without. The restoration of the AD benefit in July 2014 came as a shot in the arm again. The lack of AD benefit, in the interregnum, saw a sharp fall in wind capacity addition for the two years and the demand has been restored only recently. The reinstatement is expected to provide the necessary impetus and attract investments back into the industry. Like the AD benefit, the reinstatement of the Generation Based Incentive (GBI) by the Ministry of New and Renewable Energy (MNRE) in September 2013, and the release of the final guidelines in December 2013, was another shot in the arm for the wind industry. GBI incentivized the Independent Power Producer (IPP) segment and has led to its growth. The GBI is currently applicable for all wind farms commissioned on or after April 2012 and has limited visibility till the end of the 12th Five-Year Plan period. While we can complain about lack of visibility of the GBI beyond 2017, its restoration last year, and widely expected continuance this year, is expected to spur investments by the wind IPPs.

2. TREND TOWARDS AN IPP-DRIVEN MARKET

There are noticeable trends that the wind sector is moving away from an AD-driven market to a more IPP-driven market. Rise of IPPs is changing the market structure of the wind business with IPPs driving a majority capacity addition every year. A shift in the policy towards generation-based incentives and the temporary withdrawal of the AD benefit has led to the rise of the IPPs and this is bound to continue in the years to come. IPPs led capacity addition is expected to result in overall capacity addition in the years to come.

3. AGGRESSIVE GOVERNMENT TARGETS

Wind sector has a 20 year-old existence in the country, and as of today, we have an installed capacity of 21,000 MW. Now the government has upped the ante. In an aggressive move that is aimed at augmenting India's energy security, the government is now targeting capacity addition of 10,000 MW every year. Now, that is ambitious. Imagine adding half of what we have done in 20 years to be done every year from now on. Installed manufacturing capacity does not appear to be constraint to achieving this. Combined manufacturing capacity of wind turbines in India is at the 9,600 MW mark and it is not difficult to meet the 10,000 MW figure with a stretch. What is more important is, of course, the softer aspects of meeting the target like access to long-term financing, availability of wind sites, land acquisition policies, and other minor factors which could spoil the party. However, the government has signalled its bold intent and is expected to back it up with action, which is good for the sector. A lot is awaited from the government for creating an enabling environment to achieve this target.

4. CONDUCIVE REGULATORY REGIME

It is heartening to the note the thrust being by the new government on renewable energy in general. The latest amendments being proposed to the Electricity Act 2003, by the Electricity Bill 2014, have a predominant renewable energy tilt. The main amendments to the Act which will have an impact on the wind business in particular and the renewable energy space in general are as follows:

a) Defining a Renewable Energy Generation Obligation (RGO) to ensure 10 per cent of the total generation comes from renewable energy. This is expected to bring in more investments into the renewable energy space from conventional generators.

b) It has proposed higher penalties on discoms and other obligated entities for RPO non-compliance. While I am cynical about penalties being able to revive the REC market, it will definitely have a deterrent effect on the discoms and is expected to breathe the much-needed life back into the Renewable Energy Credit (REC) markets, which seem to have gone into a coma now.

c) Exemption from cross subsidy charges for open access customers buying power from renewable energy sources is expected to pave the way for a faster road map to grid parity for renewables and open up a considerable market and incentivize

Wind sector has a 20 year-old existence in the country, and as of today, we have an installed capacity of 21,000 MW. Now the government has upped the ante. In an aggressive move that is aimed at augmenting India's energy security, the government is now targeting capacity addition of 10,000 MW every year.

third party renewable energy sales under open access.

d) It provides for a Renewable Energy Act, the first draft of which was expected to be unveiled in February 2015.

e) It proposed to provide for timely update of the National Tariff Policy, National Electricity Policy, and the National Renewable Energy Policy.

All the above points to a conducive regulatory regime for renewables and is expected to create a feel good factor for investment into the wind sector. Of considerable importance is the amendment proposed in the electricity bill to separate content from carriage and giving a deemed supplier status to renewable energy generators. This is expected to open up completely new markets for renewable energy generators and pit them directly against the discoms as alternative suppliers of power directly to the consumers without going through the hassles of open access.

5. COAL AND GAS SUPPLY UNCERTAINTIES

Coal and gas supply situation has been the bugbear of the conventional energy business for a while. It has led a gold rush among conventional IPPs to acquire coal mines abroad. The Planning Commission estimates about 16–17 per cent of India's total requirement of coal to be imported by 2017. This is burden on the exchequer and opens up the entire power generation supply chain to uncertainties like FOREX fluctuations, attendant cost increases, and, in general, dents energy security. On the gas front, continuing supply shortages have plagued the sector, with large idle capacities. Under the circumstances, an emphasis on increasing the share of renewables is a no-brainer. There is talk of increasing the RPO obligations for solar and wind under the National Action Plan for climate change. The coal and gas supply uncertainty will be a determinant factor in deciding the expansion growth plans of renewables in general, and wind in particular. While the depressed coal prices can be a dampener in this direction, the huge cost of mining coal in an overseas location, handling the logistics of transportation, port handling, and inland transit, and bringing them to power plants in India are the processes fraught with uncertainties and considerable commercial risk. With dropping prices of solar tariffs, and wind too, the rising costs of conventional fuels are expected to drive grid parity of renewable sooner or later. This will provide the much needed demand side boost to wind energy in time to come.

6. NON-PREFERENTIAL PPA BUSINESS TO RISE

Wind has almost exclusively been driven by the regulator determined preferential feed in tariffs with discoms signing the Power Purchase Agreements (PPA) at these preferential tariffs. Very little of the wind capacity today is on a third-party PPA basis under open access. Restrictions on open access, coupled with high wheeling and transmission charges, have been hindering the deepening of a viable third-party sale market in wind. There are early signs, especially in the southern states like Karnataka and Tamil Nadu that this may be changing. Rising tariffs, with an enabling open access regime, will make more and more wind developers look at private PPAs and open access. While the bankability of private PPAs is a concern, this segment is bound to expand the cake of overall business. Regulatory changes on the anvil, like the provisions in the Electricity Bill 2014 to exempt cross subsidy charges on consumers buying renewable will help this market. A more free open access regime in states is also expected to usher and boost this segment.

7. REMUNERATIVE TARIFFS

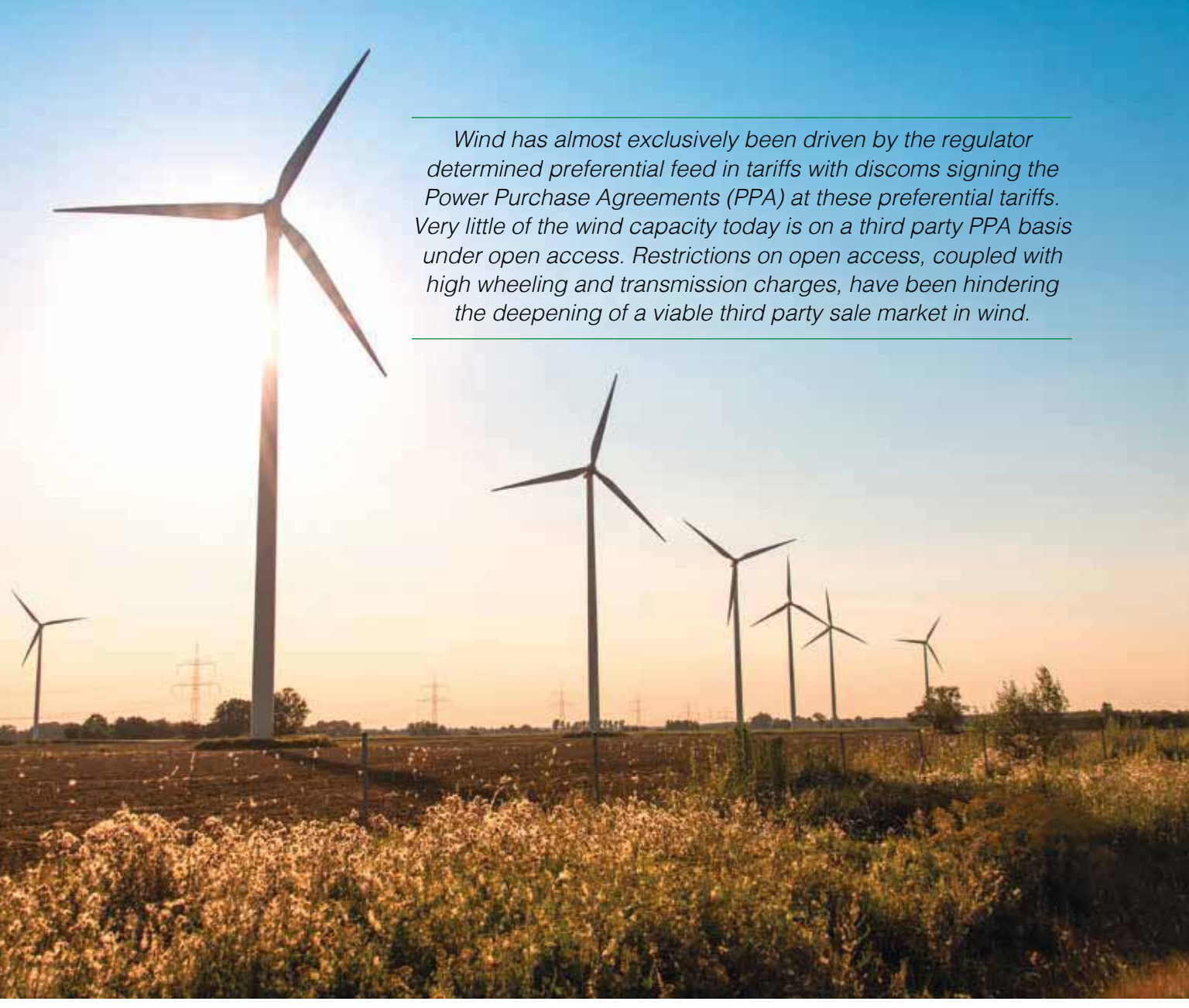
States like Gujarat, Tamil Nadu, and Odisha have not raised their tariff for over two years now and are expected to raise them shortly. Similarly, Andhra Pradesh and Telangana are due to bring changes. The states are also widely expected to revise their tariffs and prescribe a graded tariff based on wind zone. Currently, only Maharashtra, Haryana, and Uttarakhand have adopted wind zone based tariffs in their tariffs. This has traditionally prevented wind developers in adding capacity in low potential areas. More states are expected to come out with wind zone based tariffs, which is expected to make wind project financially viable even in low wind potential areas.

8. AVAILABILITY OF LONG-TERM FINANCE

The government appears to be backing its aggressive policy with action on the ground. Lack of long-term finance at affordable rates has long been a bugbear for the wind sector. There appears to be some movement in this direction. The recent visit by the US President and the announcement of a $2 billion funding arrangement for renewables under the US Trade Authority, credit line of $1 billion by the US Exim bank to Indian Renewable Energy Development Agency (IREDA), and Japanese ODA line to IREDA of $2.48 billion are all positive moves. Meanwhile, IPPs are also exploring various fund-raising options for equity and debt. While falling fuel prices could dampen the ability of the IPPs to raise funds in the markets, recent developments point to an ease of raising long-term finance.

9. TURBINE TECHNOLOGY IMPROVEMENTS

Turbine technology improvements



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in wind harnessing technology have been driving hub heights and rotor diameters. The highest hub height available in India today is 120m with a capacity of 2-MW higher hub heights are being planned by OEMs accompanied by wider rotor diameters and higher machine capacities. Many OEMs are remodelling their high capacity off turbine designed for offshore applications and re-launching them for on-shore applications. Improvements in turbine technology are expected to allow designers to harness the wind potential of even low wind zones and add to capacity.

10. NATIONAL WIND ENERGY MISSION

There has been some discussion about the National Wind Energy Mission, modelled on the lines of the Jawaharlal Nehru National Solar Mission (JNNSM), which has been hugely successful in ramping capacities very fast. If the contours of the wind energy mission are in anyway on similar lines of the JNNSM, we can expect central procurement of wind power. This is expected to widen the market since so far only the states are buying the wind power. If the central government starts buying wind power directly, it is widely expected to widen and deepen the market and enhance the quality of PPAs in general, not to mention the higher quality of PPAs this would entail.

CONCLUSION

The renewables sector is passing through optimistic times. Innovations in technology, dropping project costs, grid parity, and a conducive regulatory environment bode well for the sector. EF

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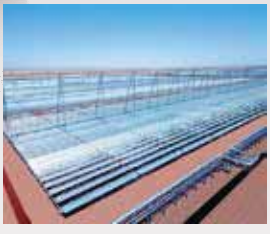

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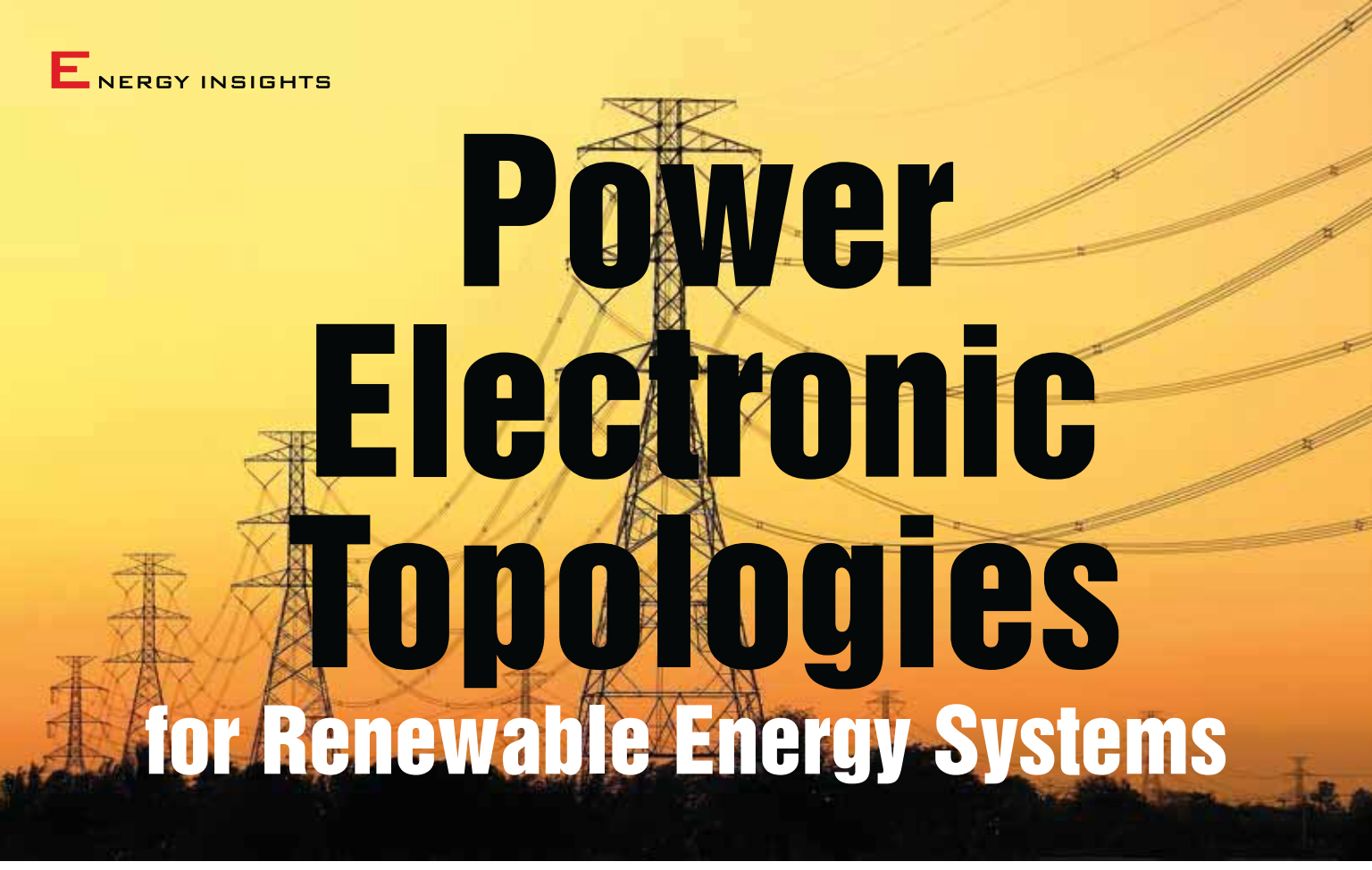

Power Electronic Topologies for Renewable Energy Systems

Jayesh G Priolkar and Dr Vinayak N Shet discuss how the regulation of voltage, frequency, and power output of renewable energy devices is difficult without power electronic topologies and suggest that power electronic interfaces can help us in proper regulation of these parameters.

Power electronics technology is fundamental for the growth and development of Renewable Energy (RE) systems. As RE sources are intermittent in nature; the regulation of voltage, frequency and power output characteristics from the source becomes difficult without power electronic topologies. Integration of power generated through distributed generation sources, to the utility grid at distribution or low voltage network is done predominantly through power electronic interfaces. Power Electronic Interface (PEI) receives power from Distributed Energy (DE) resource and converts it into power at grid compatible voltage and frequency. Fundamental power electronic devices are solid state semiconductor switches (SCR, IGBT, and MOSFETs), which are periodically switched on and off at desired frequency to obtain the preferred conversion. Power electronics contributes to nearly 40 per cent of the total cost of DE system.

As shown in Figure 1, four major modules for power electronic interface include, source input converter module, an inverter module, output interface module and controller module. The design of input converter depends upon the type of distributed energy resource or storage system used for integration. DE system that generates alternating current output need an AC-DC converter. Photovoltaic source, fuel cells (FC), or battery output is DC in nature. A DC–DC converter is needed to change the DC voltage level. DC to AC inverter module is the most generic of modules and converts a DC source to grid-compatible AC power. Output interface module filters AC output from inverter and the monitoring and control module operates interface, containing protection for DE and utility point of common coupling (PCC).

Power electronic interfacing also contains some level of monitoring and control functionality to ensure that the DE system can operate as required. Monitoring functions include real and reactive power and the monitoring of voltage and frequency at the point of DE connection with a utility at the PCC. These functions are necessary for the proper synchronization of DE system with utility grid.

Here, we discuss the requirements of power electronic interface as applicable with respect to Solar Photovoltaic (SPV), wind power, and fuel cells as they

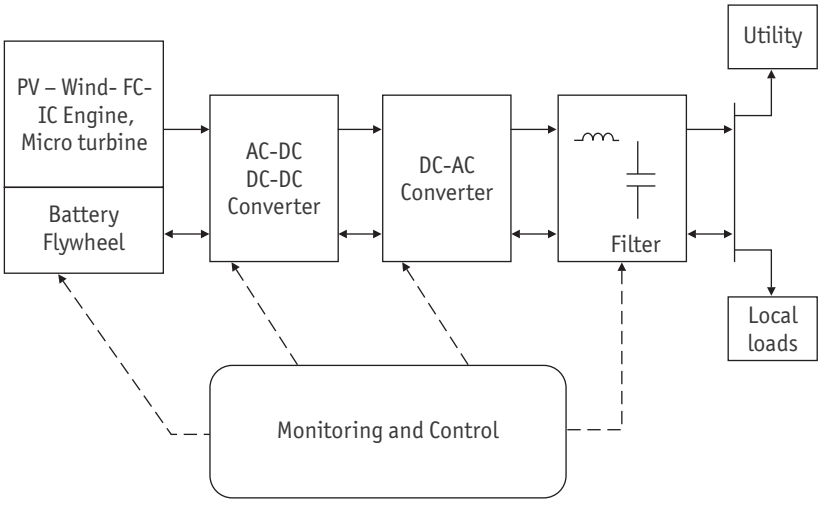

Figure 1: Block diagram of typical DE power electronic systems

Power electronic interfacing also contains some level of monitoring and control functionality to ensure that the DE system can operate as required. Monitoring functions include real and reactive power and the monitoring of voltage and frequency at the point of DE connection with a utility at the PCC. These functions are necessary for the proper synchronization of DE system with utility grid.

are the most promising RE sources for the generation of electricity.

Demands of renewable energy systems from PEI

The common demands of RE source from PEI are to transfer energy to the grid based on the RE characteristics. The other demands include i) reliability of power supply, ii) high efficiency, low cost, and small volume, iii) control of active and reactive power injected into the grid, iv) proper monitoring and communication with the system, and v) grid compatibility (ride through operation).

The following are the factors for the design of power conditioning system for DE:

a) Maximum utilization of primary resource
b) Easy power flow management
c) Simplest power converter topology
d) System voltage requirements
e) Isolation requirements
f) Energy storage requirements

CONVERTER TOPOLOGIES FOR SPV SYSTEM

The design and operation of power electronic converters for PV systems depend on grid requirement, energy demands between PV generation and load, and voltage difference between PV source and load voltages. The power electronic connection between PV systems and their load or grid is established to do the following:

a) Convert PV DC voltage to AC voltage
b) Adjust the PV panel load to obtain maximum output power
c) Match the voltage level difference

In case of off-grid (isolated) systems, there is need to use DC voltage and current with stable characteristics independent from irradiance fluctuations.

The output characteristics of PV arrays are non-linear in nature, there exists one operating point at which it generates maximum power. For optimal utilization of PV array, Maximum Power Point (MPPT) controller is used. MPPT is a power electronic DC–DC converter inserted between PV module and its load to achieve optimum matching. It serves the purpose of transferring maximum power from solar PV module to load by continuously changing the duty cycle of the converter circuit. MPPT algorithms are used in solar modules in order to ensure that the system operates with maximum efficiency. Basic converter topologies for PV system are buck, boost, and buck–boost. The function of buck converter is to set the PV operating point (Vpv, Ipv) to maximum power point and efficiently step down Vpv to lower DC voltage Vdc as per load requirement. The function of boost converter is to set the PV operating point (Vpv, Ipv) to maximum power point and efficiently step up Vpv to higher DC voltage (Vdc) as per load requirement. The Function of buck–boost is to set the MPP and it can either step up or step down the voltage depending upon the requirement. MPPT algorithms are used in SPV systems in order make the system operate with maximum efficiency. Their main mission is to automatically find out the voltage Vmpp or Impp at which PV array should operate to obtain Pmpp under given conditions of temperature and insolation. Some of the MPPT algorithm techniques are:

a) Hill climbing method, Perturb, and Observe
b) Incremental conductance method
c) Fuzzy logic control
d) Curve fitting method

Figure 2 shows the power converter topology with the MPPT control for the SPV system.

Depending upon the load and storage system voltage, current, and power requirement, the converters can be connected in either a series or parallel. A series connection is used

Depending upon the load and storage system voltage, current, and power requirement, the converters can be connected in either a series or parallel. A series connection is used when the converter is connected in between source and load.

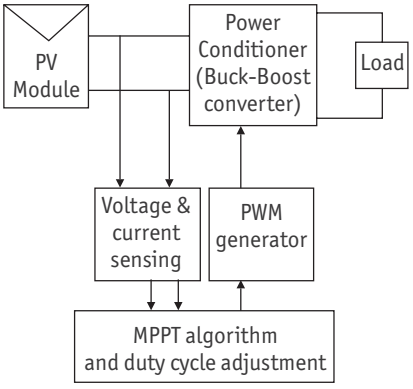

Figure 2: Power converter topology with the MPPT control

when the converter is connected in between source and load. The panel voltage has different voltage level with respect to battery bank and load. A parallel connected converter is used when there are two independent converters; here, one connects PV panel to battery and other connects it to DC bus.

The main function of PV inverter structure is to convert DC power generated by PV panels into grid-synchronized AC power with correct voltage and frequency. Depending upon the rating and usage, inverters can be classified as—Module Integrated Inverter, String Inverter, and Central Inverters.

Module integrated inverters

In module integrated inverters (Figure 3), there is one inverter for each module, typically in a range of 50–400 Wp. This topology optimizes the adaptability of inverter to PV characteristics, since each module has its own MPP tracker.

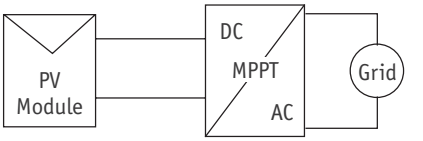

Figure 3: Topology for module integrated inverter

String inverters

In this system (Figure 4), the PV plant is divided into several parallel strings, each PV string is assigned to a designated inverter known as a string inverter; typically, PV plant has the range of 3–10 kWp. A string inverter has the capability of separate maximum power point tracking of each PV string which increases energy yield and enhances supply reliability.

Central inverters

In central inverters (Figure 5), PV plant (typically > 10 kW) is arranged in many parallel strings that are connected to central inverter on DC side. Such inverters are characterized by high efficiency and low cost/kW. The energy yield of PV plant can decrease due to module mismatch and potential partial shading conditions.

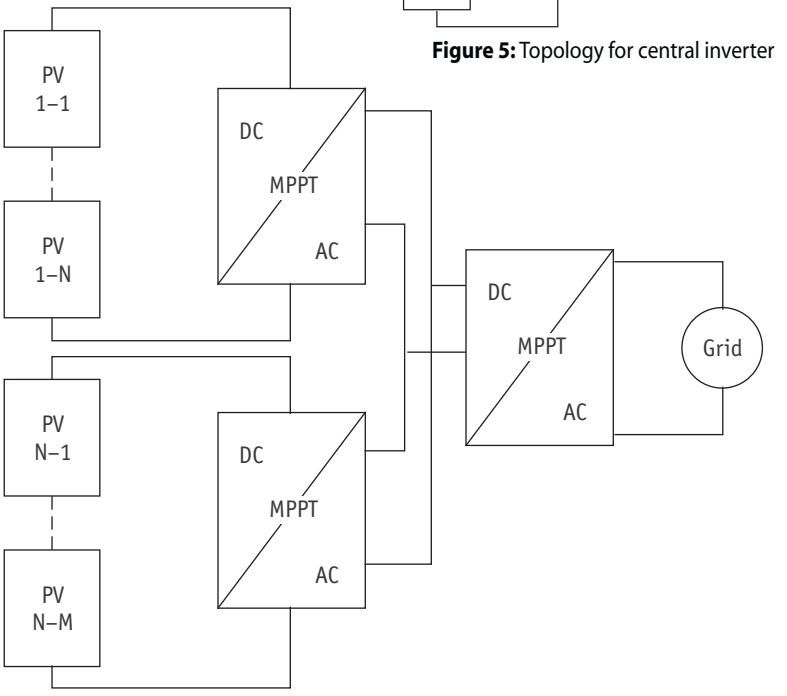

Figure 4: Topology for string inverter

Control of SPV systems

Two main structures are used in PV application namely, double stage conversion (DC to DC plus DC to AC) and single stage conversion (DC to AC only). In case of DC–DC boost converter, in order to control DC output voltage to desired value, control system is needed, which can automatically adjust duty cycle regardless of load current or input changes. In case of DC–AC converter, control strategies adopted are direct duty cycle and current control which will decide the switching signals for the inverter.

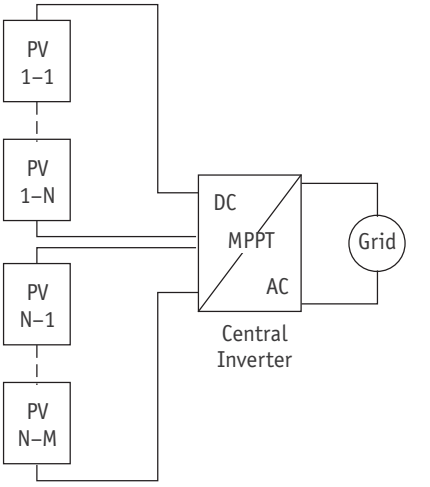

Figure 5: Topology for central inverter

CONVERTER TOPOLOGIES FOR WIND POWER SYSTEM

Wind energy can be harnessed by a wind energy conversion system, composed of wind turbine blades, a power electronic interface with a suitable control system, and an electric generator. There are different wind energy conversion system configurations based on use of synchronous or asynchronous machines, stall, or pitch regulated systems, etc. Power electronic converter plays two important roles first in interfacing of wind turbine to the electrical utility and second, in controlling the wind turbine power.

For interconnecting with electric power systems, basically there are three types of wind turbine technologies. In first case, the wind turbine drives the Squirrel Cage Induction Generator (SCIG) (Figure 6), which is directly connected to grid without any power electronic interfacing. The induction generator requires Volt Ampere Reactive (VAR) support, for operation, which can be supplied by utility power system or capacitors connected at machine terminals.

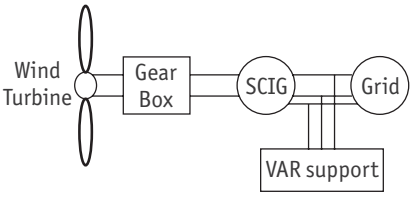

Figure 6: Wind turbine system with SCIG

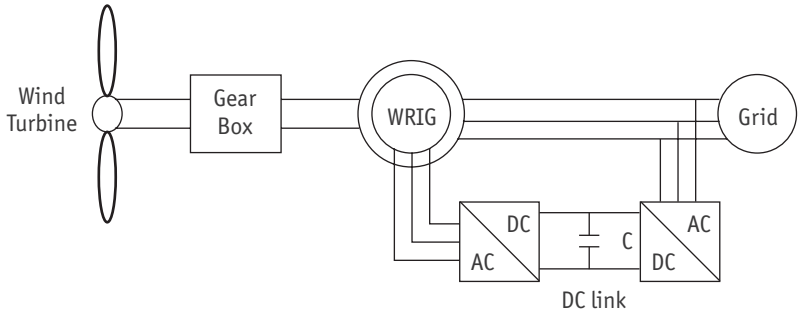

Figure 7: Wind turbine system with DFIG

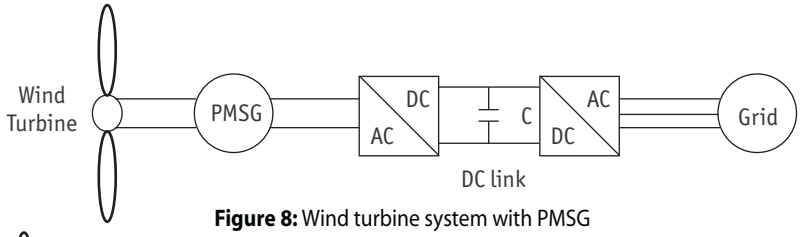

Figure 8: Wind turbine system with PMSG

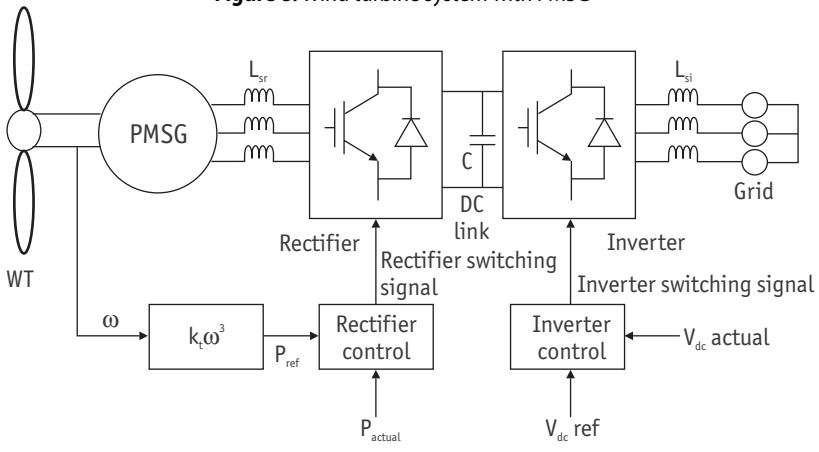

Figure 9: Block diagram for control of variable speed WT system

In second type, Doubly Fed Induction Generator (DFIG) (Figure 7) with wound rotor design is used. In this case, power from spinning rotor at slip frequency is collected via slip rings. The power obtained from slip rings is not at the rated voltage and frequency which can be compatible with electric power system; it requires power electronic-based rectifier and inverter system, which transforms it into grid compatible AC power. This arrangement allows generator stator winding to be undersized by 25–30 per cent with the PE making up the power difference from rotor power.

In third type, conventional or Permanent Magnet Synchronous Generator (PMSG) design (Figure 8) is used, which converts the wind turbine power to a variable voltage variable frequency output that varies with wind speed. A PE-based rectifier and inverter are then used to convert the full rated output of machine to power that is compatible with the electric power system, i.e., at constant voltage and constant frequency. The use of PEI allows wind turbine to operate in variable speed mode that helps to improve the overall wind power capture ability of the machine and improve the capacity factor of the system.

Grid power topologies

The AC–AC conversion for tapping the wind power can be direct or indirect. In the indirect case, there is a DC link that connects two converters performing AC–DC and DC–AC conversions whereas in the direct case, a DC link is not present. The advantage of indirect conversion is the decoupling between the grid and generator. The advantage of direct conversion like matrix converter topology is that it is a one stage power conversion. The grid converter topologies which can be adopted for indirect conversion are voltage source converter, current source converter, or Z source converter.

The voltage source converter is buck (step down) inverter for DC–AC power conversion. The current source converter is a boost converter for DC–AC power conversion.

The most generalized form of power electronics topology for wind energy application is the back-to-back rectifier/inverter connection as shown in Figure 9, which provides the improved power flow control as well as increased efficiency.

CONVERTER TOPOLOGIES FOR FUEL CELLS

Fuel cell is a low voltage device with non-linear voltage/current source characteristics. Power electronic converter is required to interface a FC stack with power train DC bus voltage. The DC–DC converter is required not only for voltage boost, but also for voltage conditioning as the FC output voltage varies strongly with load. The DC–DC converter uses the fluctuating DC fuel cell voltage as input and converts it to a stable DC voltage output which is fixed at specified value. Due to slow dynamic response of fuel cell, a battery or super-capacitor is required to handle any high power transients during acceleration or deceleration and store braking energy as fuel cells do not absorb power back.

Boost converter is most often used in fuel cell applications because fuel cell is a low voltage high current device. Step up conversion is needed to match fuel cell voltage with DC bus voltage. Interleaved boost converter topology helps to improve the performance of single boost converter by connecting a number of boost converters in parallel. Full bridge, isolated series resonant full bridge, isolated push pull, and fly-back are the other converter topologies which can be used for fuel cell integration.

CONCLUSION

Power electronic topologies plays very important role for integration and growth of RE sector. Power electronic interfacing helps to optimize energy conversion from the sources, improves operational efficiency, power quality, and system reliability of RE systems. EF