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Government of India

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RE NEWS
5 National
10 International

FORTHCOMING EVENTS
52

RE CASE STUDY
38 Successful Use of Solar Power in Food Processing Industry

COVER STORY
12 2nd Global RE-Invest 2018

RE SUCCESS STORY
40 MP GRID-CONNECTED ROOFTOP SOLAR PV RESCO TENDER

RE FEATURES
16 Hybrid Renewable Systems
20 India's Remarkable Success in Solar Power Capacity Addition
22 Microalgae A Potential Source of Green Energy
28 Emerging Clean Public Transport Options for India and Associated Challenges
34 Challenges to Grid Integration of Renewable Energy in India

RE UPDATE
36 CABINET APPROVES NATIONAL MISSION ON TRANSFORMATIVE MOBILITY AND BATTERY STORAGE
37 GOVERNMENT TAKING IMPORTANT MEASURES TO POPULARIZE ROOFTOP SOLAR POWER SYSTEM
44 ACCELERATING TRANSITION TO RENEWABLE ENERGY IN INDIA
45 MNRE CIRCULATES DRAFT INDIAN WIND TURBINE CERTIFICATION SCHEME (IWTCS)
46 NET-ZERO CARBON EMISSIONS FROM HARDER-TO-ABATE SECTORS
48 POWER STATIONS DRIVEN BY LIGHT

RE EVENT
49 World Sustainable Development Summit (WSDS) 2019

BOOK ALERT
50

16

Dr Om Prakash Nangia says that for climate change mitigation, the hybrid solar–wind system will make economic sense in aiding growing economies with clean energy transformation to achieve development and climate goals.

28

Dr M R Nouni, Rudranath Sarkhel, and **Prakash Jha** analyse the present status of development, advantages, and challenges associated with deployment of buses powered by H-CNG, electricity, and hydrogen.

34

In this article, **Mr Jonathan Donald Syiemlieh** talks about some challenges to grid integration of renewable energy in India.

The August 2018 issue of *Akshay Urja* magazine is an excellent one. The new format, presentation, style, and layout of the newsletter is very good. I liked reading article on transforming women's lives in Rural Bihar by TERI – JEEVIKA Programme that has created market for clean energy access at the bottom of the pyramid and has lighted up 50,000 households though self-help groups in Bihar. The story of DURGA empowering women through sustainable solar ecosystem initiated by IIT Bombay is very motivating for women of rural India. TERI's partnership with local micro-finance institute that helps take clean cooking and lighting technology into poor houses in a village in Bihar is really very praiseworthy.

The other articles, such as Health Services Transformed by solar Electrification which won the Ashden Award 2018; solar-powered drip irrigation; hybrid solar system for power loom; Shakti Surabhi biomethanation plant; Development in Narotoli Village with mini- grids are all good and informative. *Akshay Urja* is serving well as a platform for informing about Government of India's policies, plans, and programmes in renewables at the grassroots level. Thanks to TERI and MNRE team for publishing such wonderful articles which are useful in my profession.

Er. Anant B Tamhane
Consulting Engineer, Renewable Energy, Nagpur, Maharashtra

I liked reading the RE feature article on CREDA that received Ashden Award 2018. It is heartening to note that CREDA is implementing solar PV, inverter and battery storage systems across health centres in Chhattisgarh state in central India in partnership with the state health agency. In an area where there is no reliable power source, this is enabling stable refrigeration to keep vaccines and medicines fresh, powering buildings and supporting equipment from heated baby units to solar lights for post-natal care.

T K Sharma
Indore, Madhya Pradesh

I feel that each issue of *Akshay Urja* magazine is very important as it helps us in keeping abreast of the latest happenings in the fields of renewable energy in India. The August 2018 issue of the magazine is quite informative and useful. I read in the magazine that under its Lighting a Billion Lives (LaBL) campaign, TERI has built a partnership with Bihar Rural Livelihoods Promotion Society's (BRLPS) JEEViKA programme through an innovative institutional model to make clean energy products affordable to local women-based Self Help Groups (SHGs). Till date, the programme has benefitted over 50,000 households across Bihar by providing access to Solar Home Lighting Systems (SHLS) and clean cookstoves. The programme aims to complement the government's vision of enriching rural livelihoods by providing reliable electricity to every household.

Arijit Kumar Jha
Patna, Bihar

The Story of Durga published in the August 2018 issue of *Akshay Urja* is very inspiring indeed. I was very glad to read that DURGA Energy has evolved from the Dungarpur initiative, under the Solar Urja through Localization for Sustainability (SoULS) initiative, a flagship program of IIT Bombay envisaging to create a thriving and sustainable solar ecosystem to provide clean, reliable, affordable, and complete energy access in the rural areas of India. Under the Dungarpur Initiative, the self-help group women formed under the Rajasthan State Rural Livelihood Mission (Rajeevika) were trained to assemble, distribute and repair and maintain the solar study lamps. Under the initiative, 136 women were trained in assembling the solar study lamp, benefitting 40,000 students and further resulting in five women opening their own solar shops in the region.

Mahesh Prajapati
New Delhi

I enjoyed reading the case study of Narotoli village in the latest issue of *Akshay Urja*. I was happy to read that an MNRE supported mini-grid of 22.5 kWp was installed in Narotoli Village in July 2016. The national grid reached Narotoli in early 2018. Both grids continue to co-exist supporting each other and the biggest beneficiaries are the people of Narotoli. The national grid supplies single phase power for 6–8 hours daily. The MNRE-supported Mlinda mini-grid provides 24x7, three phase electricity with less than 6 hours downtime per year and facilitating economic development in the village. This co-existing of the national grid with a mini-grid with MNRE support and facilitating pro-actively the GDP growth and farmer incomes is possibly one of the solutions to 100% access to energy in rural India.

Ratna Singh Rajput
Kanpur, Uttar Pradesh

Dear Reader, Thank you very much for your suggestions and encouragement. The editorial team of *Akshay Urja* will make every effort to make this magazine highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvements in the content and presentation.

Editor, *Akshay Urja*

सत्यमेव जयते

आनन्द कुमार
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सचिव
भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

Message

The beginning of 2019 witnessed release of India's second Biennial Update Report (BUR) to the UNFCCC; and in his interim Budget speech the Finance Minister presented the roadmap for the next decade. The BUR has estimated that energy sector accounted for 73 per cent of the net national greenhouse gases emissions. This makes renewable energy the centrepiece of India's strategy to achieving Nationally Determined Contribution (NDC) of reducing the emissions intensity of its gross domestic product by 33-35 per cent from 2005 level, and achieving about 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030. The interim budget has pegged renewable energy as the key drivers behind reducing India's import dependence as the government continues to work for attaining energy security.

Intergovernmental Panel on Climate Change (IPCC) special report on the impacts of global warming of 1.5℃ above pre-industrial levels, released in end 2018, underlined the need for urgent action to significantly reduce greenhouses gases emission. This IPCC report has estimated that for avoiding the climate apocalypse, investment in clean power will have to be significantly increased. By 2050 or thereabouts, most of the world's primary energy must come from renewable sources and different combinations of solar, wind, hydro, and bioenergy could accomplish the same goal. This makes climate change mitigation a challenge of energy policy and of managing the transition to sustainable energy sources.

We are well on the way in meeting the national and global aspirations. With 76 GW Renewable energy capacity on ground, and 54 GW at different stages of fruition, India is well on the way to achieve target of 175 GW renewable power installed capacity by 2022. This will make the renewable power share in the overall electric installed capacity about 37 per cent, and by then renewables in India will save about 326 million tons of CO_2 emissions every year. The renewable energy vision for the year 2030 requires significant departure from business as usual and would entail a new paradigm including support mechanisms, facilitative policies, and access to new technologies and investment. We have already undertaken a number of new initiatives and are in the process of developing a roadmap 2030 that would detail milestones, tasks, and investment requirement.

Akshay Urja newsletter has been successful in disseminating information about renewable energy programmes, policies, technology performance, capacity and generation statistics, and impacts of renewable energy on society. I encourage you to provide us with feedback on the programmes being implemented in your neighbourhood and any other suggestions. This will be of immense value and help us in reshaping the programmes and undertaking corrective measures.

With best wishes

Anand Kumar
Secretary,
Ministry of New & Renewable Energy
Government of India

अक्षय ऊर्जा से देश विकास
गांव गांव बिजली, घर घर प्रकाश

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From the Editor's Desk

Dear Readers,

The Intergovernmental Panel on Climate Change (IPCC) has recently released a special report on potential pathways to contain the Earth's temperature rise to 1.5 °C above pre-industrial levels. Amid pages of detailed scientific analysis, the Report reveals that limiting global warming will require extreme changes which will include significantly increasing the percentage share of electricity from renewables by mid-century. India's vision to bring clean and affordable energy within the reach of all and create a climate resilient sustainable world is fully synchronized with the outcome of the IPCC report. The report further underlines the need for embarking on significant outreach campaigns for creating awareness about increasing share of renewables.

Akshay Urja has been reporting the events; informing the new policy and programmes; reflecting the users' experience; bridging the information gap; and providing a platform to showcase the path-breaking achievements. In all these aspects, the Reader is at the centre and it has been our continuous endeavour to incorporate Reader's perspective.

I look forward to your continuous engagement with *Akshay Urja* magazine.

P C Maithani

RENEWABLE ENERGY NEWS

IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5 °C

Limiting global warming to 1.5 °C would require rapid, far-reaching and unprecedented changes in all aspects of society, the Intergovernmental Panel on Climate Change (IPCC) said in a new assessment. With clear benefits to people and natural ecosystems, limiting global warming to 1.5 °C compared to 2 °C could go hand in hand in ensuring a more sustainable and equitable society, the IPCC said. The report was prepared under the scientific leadership of all three IPCC working groups. Working Group I assesses the physical science basis of climate change; Working Group II addresses impacts, adaptation and vulnerability; and Working Group III deals with the mitigation of climate change. Ninety-one authors and review editors from 40 countries prepared the IPCC report in response to an invitation from the United Nations Framework Convention on Climate Change (UNFCCC) when it adopted the Paris Agreement in 2015. The report highlights a number of climate change impacts that could be avoided by limiting global warming to 1.5 °C compared to 2 °C, or more. For instance, by 2100, global sea-level rise would be 10 cm lower with global warming of 1.5 °C compared with 2 °C. The likelihood of an Arctic Ocean free of sea ice in summer would be once per century with global warming of 1.5 °C, compared with at least once per decade with 2 °C. The report also examines pathways available to limit warming to 1.5 °C, what it would take to achieve them and what the consequences could be. "The good news is that some of the kinds of actions that would be needed to limit global warming to 1.5 °C are already underway around the world, but they would need to accelerate," said Valerie Masson-Delmotte, Co-Chair of Working Group I. The report finds that limiting global warming to 1.5 °C would require 'rapid and far-reaching' transitions in land, energy, industry, buildings, transport, and cities. Global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45 % from 2010 levels by 2030, reaching 'net zero' around 2050. This means that any remaining emissions would need to be balanced by removing CO_2 from the air.

Source: www.sciencedaily.com

ELECTRICITY TO FARMERS THROUGH RENEWABLE ENERGY SOURCES

The Ministry of New and Renewable Energy (MNRE) is providing subsidy up to 30% of the benchmark cost of the solar water pumps to the farmers under Off-grid and Decentralized Solar PV Applications Programme. Till date (August 2018) over 1.85 lakh solar water pumps have been reported installed in the country under the Programme.

The MNRE provides financial support to various R&D/academic institutions for research in the field of solar, wind, biogas, biofuel, storage, etc., for technology development and demonstration leading to commercialization. A comprehensive policy and guidelines for research, development and demonstration (RD&D) for the new and renewable energy sector are in place. Under these guidelines Central Financial assistance up to 50% of the project cost can be provided for the projects that involve partnership with industry/civil society. However, for proposals from academic institutions, government/non-profit research organizations and NGOs, financial assistance up to total project cost can be provided. The MNRE sanctioned 112 R&D Projects to various R&D/academic institutions, industries, etc., with total financial support of ₹523.43 crore in renewable energy sector in the country during the 12th Plan Period.

Source: http://pib.gov.in/

INDIA'S FIRST ISTS CONNECTED WIND POWER PROJECT COMMISSIONED

The Solar Energy Corporation of India Limited (SECI) conducted India's first auction of wind power projects in February 2017 in which tariff of ₹3.46 was discovered, which was much lower than feed in tariffs in vogue those days. This was a 1,000 MW bid for projects to be connected on ISTS (Inter State Transmission System) wherein power generated from one state (renewable resource-rich state) could be transmitted to other renewable-deficient states. Mytrah, Inox, Ostro, Green Infa, and Adani were winners of the bid.

As a part of this bid, M/s Ostro Kutch Wind Private Limited was issued letter of award on April 5, 2017, for a capacity of 250 MW, with commissioning period of 18 months. A part capacity of 126 MW, located in Bhuj (Gujarat) was commissioned by M/s Ostro on August 24, 2018, ahead of schedule. The energy generated from this project is being purchased by Bihar, Odisha, Jharkhand, and Uttar Pradesh.

The first auction also signified a major shift from the earlier regime of state-specific feed-in-Tariff (FiT) model to a pan-India, market-driven mechanism. Beginning with this tender, SECI has brought out five tenders for wind power projects of cumulative capacity of 7,250 MW, of which 6,050 MW capacity has been awarded. Besides SECI and NTPC being central agencies, the State agencies of Tamil Nadu, Maharashtra, and Gujarat have brought out bids and awarded projects based on tendering.

This 126 MW ISTS project marks the beginning of capacity additions in wind power based on market discovered tariffs, in line with the Government's plan of 175 GW RE by the year 2022.

Source: http://pib.gov.in/

GANDHIJI'S CHARKHA GOES SOLAR

On December 6, 2018, the Chief Minister of Uttar Pradesh Shri Yogi Adityanath inaugurated a three-day long Khadi Exposition 2018, in Lucknow. At the event Navneet Sehgal, Principal Secretary, Khadi and Village Industries Board (KVIB) and Atul Bagai, UN Environment Country Head, India, signed a Memorandum of Understanding, under the aegis of Chief Minister on solar-based livelihood and rural enterprises. "On Gandhiji's 150th birth anniversary, the Khadi Charkha has been modernized and made renewable. Solar charkha's have been distributed in UP villages and are boosting women's livelihoods. Rural employment generation in Uttar Pradesh is very important and in this context Khadi and Village Industries Board (KVIB) and UN Environment have signed a Memorandum of Understanding on solar-based mini grids to enhance income generating activities in 100 villages in UP," said Shri Yogi Adityanath.

The Chief Minister also announced several incentives to promote rural employment such as sanctioning of loans up to ₹150 crore for solar-powered charkhas, leaf-based plate making machines, and electric-powered pottery wheels. He also encouraged farmers in Uttar Pradesh to transition from chemical fertilizers and pesticides to Zero Budget Natural Farming. The MoU signed between UN Environment and the KVIB focusses on rural electrification-based employment generation and provides value-added services on the strength of reliable electricity in rural areas of Uttar Pradesh. "The potential of solar-based mini grids on income generating opportunities for rural people of Uttar Pradesh is huge. Together with UN Environment we have identified activities which will be implemented in 100 villages or hamlets as a pilot project and thereafter scaled up to 10,000 villages," said Navneet Sehgal, Principal Secretary, KVIB.

Source: http://in.one.un.org/un-press-release/gandhijis-charkha-goes-solar/

MINISTRY OF NEW AND RENEWABLE ENERGY CONFERRED SKOCH AWARD FOR NATIONAL SIGNIFICANCE

The Ministry of New and Renewable Energy (MNRE), Government of India, has been conferred the Skoch Award for national significance at an event held in New Delhi in early December 2018. The award was received by Secretary, MNRE, Shri Anand Kumar.

The award has been conferred on the Ministry considering its purpose and critical role played in installing about 73 GW renewable energy capacity in the country. With 21 per cent of total installed capacity, within the year renewable energy grossed a magic figure of providing one billion units of electricity in the country. Today, India ranks 4th in the world in wind energy capacity and 5th in solar and total renewable energy capacity installed in the world. India has played a critical role in setting up of the International Solar Alliance. Further, India moved a resolution during the first meeting for making it a global initiative.

Source: http://pib.nic.in/

TEN PER CENT OF INDIA'S TOTAL ELECTRICITY OUTPUT NOW COMES FROM RENEWABLE POWER

India has crossed a milestone on the renewable energy front. Renewable-power units (solar and wind) have over the last few years been raising their share in India's electricity output; in April–October 2018, this share touched the 10% threshold. The share of renewables in the total installed power capacity is also on a rise—from 14% in FY2015, this has risen to the current level of over 20%.

Under the United Nations Framework Convention on Climate Change ratified in Paris in 2015, India has an obligation to increase the share of non-fossil-based power in total installed capacity to 40% by 2030. The government has set a target to achieve 175 GW of renewable energy capacity by 2022. Between 2015 and 2018, electricity generated by renewable sources increased at a whopping compound annual growth rate (CAGR) of 18.2%. To put this in perspective, the CAGR of conventional power production in the same period was only 4.8%. Not only was solar capacity addition in 2017 more than that of coal, solar capacity added in the year (8,040 MW) was more than twice the net addition in the coal-based power sector (4,004 MW). While solar capacity showed an annual increase of 95% in 2017, high-emitting generating capacities added in the year was 75% lower than in the previous year.

Experts have attributed the growth in renewable energy to the country's global commitments to cut carbon footprint, falling solar rates, and unlocking of potential energy demand through '24X7' power schemes.

Source: www.financialexpress.com

INGETEAM OPENS NEW PRODUCTION FACILITY IN INDIA

Ingeteam, headquartered in Spain, has opened a new facility in the vicinity of Chennai to satisfy the demand for wind power converters and control cabinets by both local and international original equipment manufacturers (OEMs) with operations in India.

Located in the Tamil Nadu region, Ingeteam's new 3,500 m^2 facility is equipped with state-of-the-art production technology. The production plant in India will manufacture electrical components following the same stringent standards and processes as Ingeteam's other production facilities in Spain, the USA, and Brazil.

The new facility has been specially developed to meet the needs of the Indian market. This cost-effective production center is based on a modular design and can be easily modified. The production lines are extremely agile, so they can

quickly be adapted to meet new client requirements. In addition, the floor space availability will enable Ingeteam to expand the facility on demand. Production at the new facility started in August 2018, with first deliveries made in September 2018. Serial production began in October 2018.

"With this new plant, we are able to increase our delivery of reliable and quality products to wind turbine manufacturers in India's extremely competitive market. The decision to manufacture locally was marked by the potential of the Indian market, by its protectionism and by the high potential of its people," said Ana Goyen, Director of Ingeteam Wind Energy.

Source: www.ingeteam.com

DELHI UNIVERSITY COLLEGE GOES THE GREEN WAY

Delhi University's Lakshmibai College has gone solar by installing a rooftop solar project on its campus. Taking a major step towards becoming an environment-friendly campus, the college has installed solar panels which would provide 77 kW of electricity. The project is expected to reduce the electricity bill by 40 to 50% with savings of over ₹5 lakh per annum for the next 25 years. The initiative was undertaken with the help of a private entity and the Delhi government's power generation arm Indraprastha Power Generation. The initiative is expected to generate 107,520 kWh of power per annum, reducing the college's dependence on grid electricity. The expected reduction in CO_2 emission is 88.7 tonnes in a year for the next 25 years.

The college has partnered with CleanMax Solar, which has provided solar power-based on the 'pay as you go' or commonly known as 'OPEX' model, at a tariff, 50 per cent cheaper than the prevailing grid electricity tariffs.

"Adopting solar power is a socially responsible step and ensures financial benefits which can be passed on to the development of the institute. We are extremely happy to be associated with CleanMax Solar to implement rooftop solar project at our campus. As an educational institute, we are committed to contribute to preserving the environment and also hope to create awareness about the solar technology among our students and patrons," said Lakshmibai College principal Dr Pratyush Vatsala. The soaring pollution level and high carbon footprint in Delhi is an indication that more institutes and corporates in the city should adopt solar energy not only to save cost but also reduce dependence on the grid power or diesel generators which are not environment-friendly.

Source: http://www.asianage.com/

INDIA BECOMES LARGEST RENEWABLE ENERGY AUCTIONS MARKET IN THE WORLD

India has become the largest market globally for auction of new renewable energy generation projects and the second-largest destination attracting clean energy investments. These are the findings of the latest Climatescope 2018 report by Bloomberg NEF (BNEF).

"India's renewable auctions market is the largest in the world. Over 11 GW of projects were awarded through auctions in 2017 resulting in the best year for solar capacity as installations jumped by 90 per cent over the year," Bloomberg NEF said.

India has secured second place in the global ranking driven by its policy thrust towards renewables and increasing investments in the clean energy sector. The country is the second-largest renewable energy investment market among all Climatescope countries, attracting $9.4 billion in new investments in 2017. Renewable energy installations in India exceeded those by coal power plants for the first time in 2017 as the country moved closer towards its target to install 175 GW of renewables by 2022. "India's well-established domestic supply chain facilitated the development of clean energy projects further, despite competitive auctions putting downward pressure on profit margins across the value chain," Blomberg NEF said.

The government has reduced its coal capacity target for 2027 by 11 GW to 238 GW as the country seeks to replace coal with renewables through auctions. The report said India's renewable auctions market is the largest in the world and auctioned capacity has ramped up by 68 per cent since 2017.

India was the world's fifth largest clean energy investment market in 2017, jumping up from being the sixth largest in 2016. Clean energy investment totalled $7.4 billion in the first half of 2018, with solar power projects accounting for the majority. India's solar market almost doubled in size in 2017, making it a record year with annual PV installations touching 9.4 GW.

Source: Energy.economictimes.indiatimes.com

CABINET APPROVES LAUNCH OF KISAN URJA SURAKSHA EVAM UTTHAAN MAHABHIYAN

The Cabinet Committee on Economic Affairs, chaired by Hon'ble Prime Minister Shri Narendra Modi has approved launch of Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) with the objective of providing financial and water security to farmers.

The proposed scheme consists of three components:

- Component-A: 10,000 MW of decentralized ground mounted grid connected renewable power plants
- Component-B: Installation of 17.50 lakh standalone solar-powered agriculture pumps
- Component-C: Solarization of 10 lakh grid-connected solar-powered agriculture pumps

All three components combined, the scheme aims to add a solar capacity of 25,750 MW by 2022. The total central financial support provided under the scheme would be 34,422 crore. The Component-A and Component-C will be implemented on pilot mode for 1,000 MW capacity and one lakh grid connected agriculture pumps respectively and thereafter, will be scale-up on success of pilot run. Component-B will be implemented in full-fledged manner. Under Component-A, renewable power plants of capacity 500 kW to 2 MW will be set up by individual farmers/ cooperatives/panchayats /farmer producer organizations (FPO) on their barren or cultivable lands. The power generated will be purchased by the DISCOMs at Feed in tariffs determined by respective SERC. The scheme will open a stable and continuous source of income to the rural land owners. Performance-based incentives @ 0.40 per unit for five years would be provided to DISCOMs. Under Component-B, individual farmers will be supported to install standalone solar pumps of capacity up to 7.5 HP. Solar PV capacity in kW equal to the pump capacity in HP is allowed under the scheme. Under Component-C of the scheme, individual farmers will be supported to solarize pumps of capacity up to 7.5 HP. Solar PV capacity up to two times of pump capacity in kW is allowed under the scheme. The farmer will be able to use the generated energy to meet the irrigation needs and the excess available energy will be sold to DISCOM. This will help to create an avenue for extra income to the farmers, and for the States to meet their RPO targets.

The scheme will have substantial environmental impact in terms of savings of CO_2 emissions. All three components of the scheme combined together are likely to result in saving of about 27 million tonnes of CO_2 emission per annum. Further, Component-B of the scheme on standalone solar pumps may result in saving of 1.2 billion litres of diesel per annum and associated savings in the foreign exchange due to reduction of import of crude oil.

Source: http://www.pib.gov.in/

CABINET APPROVES PHASE-II OF GRID CONNECTED ROOFTOP SOLAR PROGRAMME

The Cabinet Committee on Economic Affairs (CCEA) approved a total funding of 11,814 crore for Phase II of the grid-connected rooftop solar programme for achieving cumulative capacity of 40,000 MW from Rooftop Solar (RTS) Projects by the year 2022 on February 19, 2019. As of December 2018, the installed capacity was 1.4 GW. Originally, the scheme for Phase II was proposed and drafted in December 2017, under Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI). In the Phase-II Programme Central Financial Assistance (CFA) for the residential sector has been restructured with availability of 40% CFA for RTS systems up to 3 kW capacity and 20% for RTS system capacity beyond 3 kW and up to 10 kW. Under Phase-II Programme, focus will be on increased involvement of DISCOMs. Performance based incentives will be provided to DISCOMs based on RTS capacity achieved in a financial year (i.e. 1st April to 31st March every year till the duration of the scheme) over and above the base capacity, that is, cumulative capacity achieved at the end of previous financial year.

Source: http://www.pib.gov.in/

BAT DETERRENT SYSTEM REDUCES BAT FATALITIES AT TEXAS WIND FARM

NRG Systems, Inc. has stated that a trial of its ultrasonic acoustic Bat Deterrent System reduced overall bat fatalities at the Los Vientos Wind Energy Facility in Starr County, Texas, by 54 per cent. The results of the test suggest that NRG Systems' technology is an effective tool for reducing mortality of certain species of bats caused by wind turbines. The Bat Deterrent System is based on 'jamming' the echolocation capabilities of bats while causing no harm to wildlife encountering the treated airspace.

The test was led by researchers from Texas State University in partnership with Bat Conservation International (BCI), and involved installing NRG's Bat Deterrent Systems on 16 of the facility's 255 turbines. Brogan Morton, Senior Product Manager at NRG Systems, said, "It is no secret that wind turbines cause mortality to bats. This has become an increasingly critical issue as bat populations across North America continue to decline. NRG set out to develop a technology that would allow wind developers and operators to protect bats while creating more energy more of the time. We are incredibly pleased to say that we are well on our way to making this a reality." While 2018 marks three years of testing for NRG's Bat Deterrent System, research around using ultrasonic acoustic deterrents to reduce bat fatalities at wind turbines has been underway for over a decade. This was led by The Bats and Wind Energy Cooperative (BWEC), an organization that BCI helped launch and continues to coordinate.

Source: www.renewableenergymagazine.com

RENEWABLES CAPACITY SURPASSES FOSSIL FUELS IN THE UK FOR THE FIRST TIME

The capacity of renewable energy has overtaken that of fossil fuels in the UK for the first time. The result is thanks to a record third quarter for the UK tenant sector, with the capacity of wind, solar, biomass, and hydropower reaching 41.9 GW, exceeding the 41.2 GW capacity of coal, gas, and oil-fired power plants.

A milestone that experts said would have been unthinkable a few years ago, has been achieved so early with the recent boost in renewable capacity additions. These have, over the last five years almost tripled while fossil fuels have fallen by one-third, as power stations reached the end of their life or became uneconomic in the same time. Coal operators have been affected by the UK's carbon tax on electricity generation, as well as competition from gas, with nearly one-fourth of the coal capacity dropped just last year. The UK now has only 6 operational coal-fired plants.

Dr Iain Staffell, professor in-charge of the study at the Imperial College said, "Britain's power system is slowly but surely walking away from fossil fuels, and this quarter saw a major milestone on the journey." The data presented by the study also compares the recent boost in renewable additions to be greater than the 'dash for gas' in the 1990s which saw natural gas consumptions peak in 2001. Even with the unprecedented growth in the renewable sector, fossil fuels still generated more power over the quarter, at about 40% of electricity generation compared with 28% for renewable sources. However, 57% of all electricity generation was low carbon over the period, produced either by renewables or nuclear power stations.

Source: www.iamrenew.com

LARGEST STUDY TO DATE DISCOVERS 25 PER CENT POWER LOSS ACROSS UK

Researchers at the University of Huddersfield have undertaken the largest study to date into the effectiveness of solar panels across the UK and discovered that parts of the country are suffering an overall power loss of up to 25% because of the issue of regional 'hot spots'. Hot spots were also found to be more prevalent in the North of England than in the south.

Dr Mahmoud Dhimish, a lecturer in Electronics and Control Engineering and co-director of the Photovoltaics Laboratory at the University, analysed 2,580 polycrystalline silicon photovoltaic (PV) panels distributed across the UK. The UK has been fossil-free for two years and demand is constantly increasing for renewable energy.

After quantifying the data, Dr Dhimish discovered that the panels found to have hot spots generated a power output notably less than those that didn't. He also discovered that location was a primary contributor in the distribution of hot spots.

Photovoltaics hot spots are areas of elevated temperature which can affect only part of the solar panel. They are a result of a localized decrease in efficiency and the main cause of accelerated PV ageing, often causing permanent damage to the solar panel's lifetime performance. According to Dr Dhimish, this is the first time an investigation into how hot spots impact the performance of PV panels has been conducted from such a large-scale dataset and says the project uncovered results which demonstrate the preferred location of UK hot spots.

Source: www.sciencedaily.com

NEW TECHNIQUE FOR TURNING SUNSHINE AND WATER INTO HYDROGEN FUEL

A research team led by DGIST Professor Jong-Sung Yu's team at the Department of Energy Science and Engineering has successfully developed a new catalyst synthesis method that can efficiently decompose water into oxygen and hydrogen using solar light. It is expected that this method will facilitate hydrogen mass production due to higher efficiency than the existing photocatalyst method.

Due to the intensifying environmental problems such as air pollution and global warming caused by the increased use of fossil energy, hydrogen is recently drawing attention as an ecofriendly energy source of the next generation. Accordingly, research is being conducted globally on how to produce hydrogen using solar light and photocatalyst by decomposing water. To overcome the limitations of photocatalyst that only reacts to light in ultraviolet rays, researchers have doped dual atom such as Nitrogen (N), Sulphur (S), and Phosphorus (P) on photocatalyst or synthesized new photocatalysts, developing a photocatalyst that reacts efficiently to visible light.

With Professor Samuel Mao's team at UC Berkeley in the US, Professor Yu's research team developed a new H-doped photocatalyst by removing oxygen from the photocatalyst surface made of titanium dioxide and filling hydrogen into it through the decomposition of MgH2. Energy of long wavelength including visible light could not be used for the existing white titanium dioxide because it has a wide band gap energy. However, the development of MgH2 reduction could overcome this through oxygen flaw induction and H-doping while enabling the use of solar light with 570nm-wavelength.

Source: www.sciencedaily.com

2ND GLOBAL RE-INVEST 2018
A Resounding Success!

» Corporate Renewable Energy Buyers' Roundtable

Over 20,000 delegates and representatives from over 77 countries attended the 2nd Global RE-Invest 2018 as India lead the global discussion on renewable energy tech, innovation, and won praise from all over the globe. India successfully hosted the First Assembly of the ISA and 21 IORA countries adopted the Delhi Declaration on Renewable Energy. Also, 40 countries participated at ministerial level in the global summit as over 150 speakers, including 55 international speakers, participated in over 50 plenary, technical sessions.

RE-Invest is a global platform to explore strategies for development and deployment of renewables. It showcases India's clean energy market and the Government's efforts to scale up capacity to meet the national energy demand in socially, economically, and ecologically sustainable ways. This year, the Ministry of New and Renewable Energy (MNRE) hosted the First Assembly of the International Solar Alliance (ISA), the 2nd Indian Ocean Rim Association (IORA) Renewable Energy Ministerial Meeting, along with the 2nd Global RE-Invest Meet & Expo that concluded on October 5, 2018, at the India Expo Mart in Greater Noida. The three events were inaugurated by the Prime Minister of India, Shri Narendra Modi, in the presence of Mr Antonio Guterres, Secretary General, United Nations, on October 2, 2018, in Vigyan Bhavan, New Delhi.

Addressing the gathering at the inauguration ceremony of the RE-Invest 2018, the Prime Minister reiterated that in the last 150–200 years, mankind has been dependent on fossil fuels for energy needs and nature is now indicating that options, such as solar, wind, and water, are the sustainable energy solutions. In this context, he expressed confidence that in future, when people talk of organizations for the welfare of mankind established in the 21st century, the International Solar Alliance will be at the top of the list. Hoping that the International Solar Alliance could replace OPEC as the key global energy supplier in the future, he invested his trust on ISA being a concrete step towards climate justice.

As expected, one of the most sparkling event in the course of four days was the First Assembly of the ISA. ISA being the only international intergovernmental organization to be hosted in India, it was

» The Prime Minister, Shri Narendra Modi addressing at the inauguration of 1st Assembly of International Solar Alliance (ISA), 2nd IORA Renewable Energy Ministerial Meet & 2nd Global RE-Invest 2018, in New Delhi on October 02, 2018.

a matter of national pride to bring it to fruition as per the international standards. The Assembly witnessed participation from ISA's Prospective Member Countries, Partner Countries, dignitaries from the United Nations, Presidents of Multilateral Development Banks, global funds, international financial institutions, representatives from the corporate sector and civil society. Several senior officials of ISA Member Nations, as well as industry, investors, multilateral agencies and civil society representatives also participated. The Assembly purposefully strengthened the vision and mission of the ISA, that is to provide a dedicated platform for cooperation amongst solar resource rich countries where the global community, including bilateral and multilateral organizations, corporates, industry, and other stakeholders, can make a positive contribution to assist and help achieve the common goals of increasing the use of solar energy in meeting energy needs of prospective ISA member countries in a safe, convenient, affordable, equitable and sustainable manner. These deliberations were made during the business proceedings of the Assembly held on October 3. This was followed by three technical sessions on October 4 and 5, respectively. ISA's 5th programme on Scaling-up Solar E-Mobility and Storage was launched during the assembly and two memorandums of understanding (MoUs) were signed—one with countries in the IORA and the other with United Nations Environment. The ISA's 5th programme on Scaling-up Solar E-Mobility and Storage aims to promote, assess potential, harmonize demand, and pool resources for rapid deployment and scaling up of solar e-mobility and associated storage infrastructure in urban and rural areas of ISA member countries. During the assembly, ISA's corporate partners, Coal India Limited (CIL), Power Finance Corporation (PFC) contributed US$ 1 million and India Trade Promotion Organisation (ITPO) contributed US$ 2 million to the Corpus Fund of ISA.

» The Prime Minister, Shri Narendra Modi at the inauguration of 1st Assembly of International Solar Alliance (ISA), 2nd IORA Renewable Energy Ministerial Meet & 2nd Global RE-Invest 2018, in New Delhi on October 02, 2018. The Secretary General of the United Nations, Mr. Antonio Guterres and the Union Minister for External Affairs, Smt. Sushma Swaraj are also seen.

Besides this, on October 4, as many as 21 IORA member countries adopted the Delhi Declaration on Renewable Energy in the Indian Ocean Region. The Delhi Declaration calls for collaboration amongst IORA member states in meeting the growing demand for renewable energy in the Indian Ocean littorals, and development of a common renewable energy agenda for the Indian Ocean region to promote regional capacity building. As per the declaration, IORA member nations will collaborate with the ISA member nations to exchange knowledge and share views and potential interests in the renewable energy sector. The IORA was set up with the objective of strengthening regional cooperation and sustainable development within the Indian Ocean Region with 21 Member States and 7 Dialogue Partners. The last Renewable Energy Ministerial Meeting was held on January 21, 2014, in Abu Dhabi, UAE. Subsequently, during the meeting of IORA Council of Ministers, held in October 2016 in Bali, Indonesia, it was decided that the next conference will be held in India. In line with the commitment made, India hosted the 2nd IORA Renewable Energy Ministerial meet on October 4, 2018. India, Australia, Iran IR, Indonesia Thailand, Malaysia, South Africa, Mozambique, Kenya, Sri Lanka, Tanzania, Bangladesh, Singapore, Mauritius, Madagascar, UAE, Yemen, Seychelles, Somalia, Comoros, and Oman are members of the IORA.

The three-day 2nd Global RE-Invest India-ISA Partnership Renewable Energy Investors' Meet & Expo saw participation of over 20,000 delegates including representatives of over 77 countries out of which 40 were at the ministerial level. Over 50 plenary and technical sessions were held at the event in which 150 speakers (including 55 international speakers) participated. There were nine different country sessions, eight state sessions, and over 500 business-to-business bilateral meetings.

The country sessions were organized by countries leading in renewable energy, such as France, the USA, European

» The Prime Minister, Shri Narendra Modi at the inauguration of 1st Assembly of International Solar Alliance (ISA), 2nd IORA Renewable Energy Ministerial Meet & 2nd Global RE-Invest 2018, in New Delhi on October 02, 2018.

Union, Australia, UK, and Finland, and experts from these countries shared the progress made in renewable energy technology. The 2nd Global RE-Invest India-ISA Partnership Renewable Energy Investors' Meet & Expo saw inspirational addresses by leading lights such as Softbank Group Chairman and CEO Masayoshi Son who said his solar energy projects in India would supply free power to ISA member countries after their 25 year-power purchase agreement.

The first day of the 2nd Global RE-Invest witnessed power-packed sessions, such as the Chief Ministerial Plenary that was attended by representatives from Himachal Pradesh, Puducherry, Andaman & Nicobar Islands, and Uttar Pradesh, who shared the renewable energy policy initiatives implemented by these states. Between October 3 and 5, states, such as Uttar Pradesh, Himachal Pradesh, Maharashtra, Karnataka, Madhya Pradesh, Gujarat, and Punjab showcased their policy initiatives to attract investors.

Addressing the gathering at the Chief Ministerial Plenary, Shri Jai Ram Thakur, Hon'ble Chief Minister of Himachal Pradesh, shared that Himachal Pradesh is planning to allot a solar power project of 1,000 MW in Lahaul Spiti, and has taken several steps to attract investments in renewable energy. "Himachal Pradesh is offering land at ₹1 per sq. m for renewable energy projects. The state has deferred royalty payments from renewable energy projects. Additionally, Himachal Pradesh has also taken another step to encourage the investors by declaring that for renewable energy projects of up to 25 MW, state electricity board will buy power directly."

Shri V Narayanasamy, Hon'ble Chief Minister of Puducherry said, "The government must support innovation in renewable energy to achieve India's ambitious targets. The government should protect domestic investors from foreign investors. It must provide subsidy, tax holiday for domestic players to set up solar panel manufacturing facilities in India." He added, "Puducherry is a Union Territory and needs the government's support to develop its renewable energy sector. The government's renewable energy policy should be implementable, feasible, and acceptable."

Briefing about the renewable energy initiatives of the Andaman & Nicobar Islands, Lt Governor of Andaman & Nicobar Islands, Admiral (Retd) Devendra Kumar Joshi said, "Andaman & Nicobar is witnessing the development of world class infrastructure and tourism projects. There will therefore be increased demand for energy and an opportunity to invest in the renewable energy sector. Projects of 45 MW of solar energy in and around Port Blair alone are planned to be set up. All new buildings in cities will mandatorily have provision for rooftop solar and this policy will be extended to rural areas."

Minister of Additional Energy Sources in the Government of Uttar Pradesh Shri Brajesh Pathak, said, "The UP government has provided for single window online clearance of rooftop solar. We have also provided 100% stamp duty exemption on land bought for setting up solar energy plants. Additionally, UP is

» Shri R K Singh, Minister of State (IC), Power and Renewable Energy addressing at the inauguration of 1st Assembly of International Solar Alliance (ISA), 2nd IORA Renewable Energy Ministerial Meet & 2nd Global RE-Invest 2018, in New Delhi on October 02, 2018.

providing 50% concession on charges on solar electricity sold within the state and 100% concession on solar electricity sold outside the state."

Shri Pathak called for a solar revolution akin to the country's telecom revolution. "Every house should install a 5-kW rooftop panel and reap the returns. We shall extend all our support to institutional investors as well as to individual households to adopt solar energy. Lucknow alone has 700 km of rooftops, which can be used for solar energy generation", he added.

The Renewable Energy Startup Awards were announced on October 5, the final day of the 2nd Global RE-Invest 2018. The awards recognize innovative technological solutions in renewable energy. Winners were felicitated during the valedictory session of the event by Shri R K Singh, Hon'ble Minister for New and Renewable Energy and Shri Piyush Goyal, Hon'ble Minister for Railways and Coal, Government of India.

A free app called S-Wurja was also launched at the valedictory session of the 2nd Global RE-Invest 2018. Developed by the National Institute of Wind Energy, the app is available on Google Playstore and Apple app store. It is a green energy tool which can be used to segregate micro level data related to solar energy and wind energy characteristics in any location in India.

The valedictory session was attended by Shri R K Singh, Shri Piyush Goyal, Mr Francisco Ismodes Mezzano, Energy Minister of Peru, and Shri Anand Kumar, Secretary, MNRE, amongst others.

» A panel discussion in progress

Speaking at the session, Shri R K Singh, Minister of State (IC), Power and Renewable Energy said, "The RE-Invest allowed the policymakers, speakers, scientists, and businessmen to meet and interact with each other. I think this is the perfect model to bring all of them together. This conglomeration conveys that the world wants to do something about the environment by taking the renewable route. Our Prime Minister has given us another challenge of one world, one sun, one grid. It is feasible and we will also achieve it."

Shri Piyush Goyal, Minister of Railways and Coal said, "I am sure a conference of this scale will recharge the sector. This is the take-off point for the next phase of renewable energy. I look forward to a day when sun, wind and biogas become the main source of energy. Let us lead the world to the next level of clean energy."

Praising India for taking the lead in hosting the 2nd RE-Invest, Mr Francisco Ismodes Mezzano, Energy Minister, Peru said, "I would like to thank the Government of India for the hospitality and support. I look forward to welcome all of you to the Peru World and Sun Expo next year in November." AU

Dr Megha Pushpendra, Lead- Strategic Communication, International Solar Alliance, Gurugram, India.

HYBRID RENEWABLE SYSTEMS

Aiding Growing Economies to Achieve Development and Climate Goals

Due to the accelerated global economic growth, energy consumption is increasing exponentially on a yearly basis. At the same time, the onslaught of greenhouse gases (GHGs) caused by the use of fossil-fuel-based energy technologies is creating numerous environmental hazards. With this looming threat, renewable energy (RE) is becoming the most-sought-after resource, and harnessing it has immense potential for generating eco-benign green energy. Here, **Dr Om Prakash Nangia** says that for climate change mitigation, the seamless harvesting of solar PV in combination with wind technology as a hybrid system is proving to be a key development. The hybrid solar–wind system will make economic sense in aiding growing economies with clean energy transformation to achieve development and climate goals.

Over the last decade, solar has been the single-largest contributor to green energy generation: it has zero emissions due to huge technological advancements in the field. Similarly, wind energy, a widely distributed renewable resource, produces clean and economical electric power with zero emissions. However, the use of solar and wind technologies is beset with challenges despite the sun and the wind being infinite sources of energy: the main challenge is their intermittent nature and the lack of dispatch ability in keeping the electric grid stable. It is reported that fluctuations in power output can negatively impact amortization periods for system owners. However, with the deployment of hybrid RE power generation systems that are backed with energy storage, the seamless harvesting of solar PV in combination with wind technology is the key to challenge generation variability and effective mitigation of climate change.

Overall, clean energy is expected to experience strong growth in pushing the markets in countries where economic policies provide incentives towards achieving the goals set in the Paris conference on climate change (UNFCCC: COP21, December 2015). For climate change mitigation, the seamless harvesting of solar PV in combination with wind technology as a hybrid system is proving to be a key development. The hybrid solar–wind system will make economic sense in aiding growing economies with clean energy transformation to achieve development and climate goals.

GREEN POTENTIAL OF KEY RE TECHNOLOGIES

Renewable energy (RE) sources will play a dominant role in harnessing clean and affordable energy, especially in the tropical regions where solar energy is available for the most part of the year. When put together, solar and wind energy have a huge potential to meet the world's

requirement for an economical source of clean power.

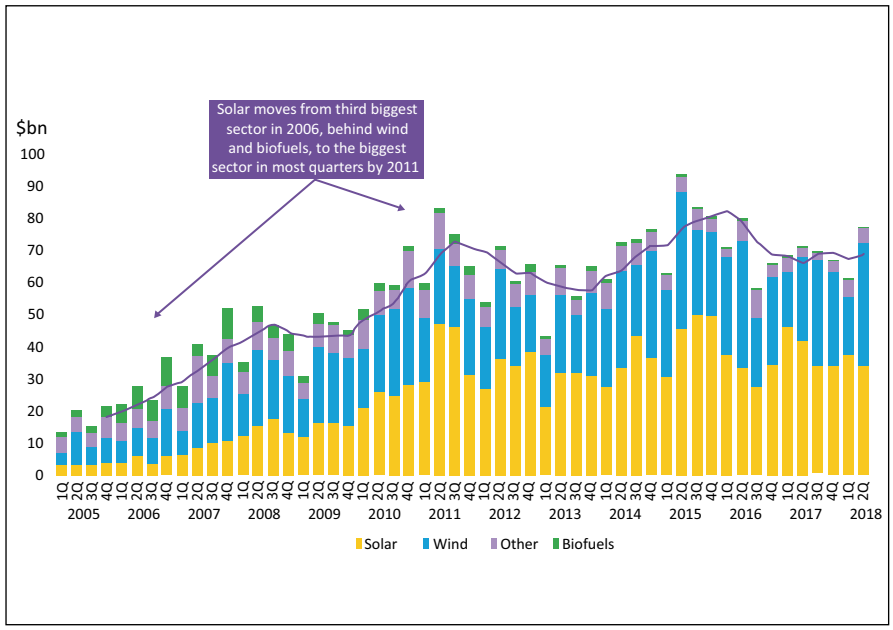
The eco-benign clean power generation from eternal solar energy that doesn't affect the ecology adversely, is increasingly supported by a consistent decline in generation costs and achievement of grid parity. The smart solar technology, with a high growth potential of 30%–40%, is emerging as an important media for energy security in the developing economies. Wind RE is an equally inexpensive alternative to fossil fuels. It is complimentary to solar energy and generates variable power. It is estimated that 13% of the world's land area has wind speeds greater than 6.9 m/s at commercial wind-turbine heights. In 2017, global wind power capacity expanded by 10% to 539 GW. It is economically beneficial to include wind energy resource as part of the overall national energy mix.The energy demands are set to increase in developing countries. The ambitious target set by the Indian government is to achieve 100 GW of solar power and 60 GW of windpower installations by 2022.

Figure 1 shows the details of sector-wise global investments in clean energy based on Bloomberg New Energy Finance. The International Energy Agency expects renewable electricity generation to increase by more than one-third by 2022, and estimates that investment in clean energy will rise to almost $900 billion by 2035. The hybrid solar–wind combination has a promising future in challenging the intermittency, and more so in its commercialization using energy storage systems. Ultimately, solar and wind power, by virtue of their adoptability and affordability, would play a key role in clean power generation and help in overall decarbonizing, protecting nature by reducing carbon footprints, and reviving the global economy.

The blockchain technology marks an advancement in the distributed RE sector which can solve data management challenges while providing a smarter energy grid. Experts (at CNET, May 2018) are of the opinion that in the long term, this technology could democratize solar energy and help transform the very architecture of the grid itself (Picture 1).

DEVELOPMENT AND CLIMATE GOALS THROUGH HYBRID RENEWABLE

The dependence on the use of low-carbon technologies—mainly solar and wind—is increasing day by day due to their emission-free nature which helps tackle the problems caused by climate change. The dual benefits of generating economically viable green electricity—as an innovative solution for a seamless transition to sustainable development—are leading the world towards accelerated growth. Deployment of RE technologies together or in combination is also establishing energy independence in the developing countries, including India. At the recently held World Economic Forum in Davos,



» **Figure1:** Global sector-wise investment in clean energy

» **Picture 1:** 3D representation of democratizing solar energy

the Indian Prime Minister Shri Narendra Modi (Picture 2) reiterated at the opening plenary that "we are not only aware of our responsibilities towards climate change; we are willing to take lead in mitigating its effects" (World Economic Forum Plenary, 2018).

Shri Modi demonstrated the sustainability of India's development process: "We have made major commitments and achievements in RE, and we are the fifth-largest producer of solar energy in the world."

During the past two decades, commercially matured RE technologies have made great strides in the global energy mix across all sectors, namely, industrial, commercial, institutional, and residential. The main focus is on new technological innovations that combine solar infrastructure with that of wind, resulting in low investments that will lead to overall bankability of full-scale generation of clean power in the foreseeable future. For India, the main challenge remains to electrify each and every household in all its villages with quality power by 2022. However, the major part of the solution lies in establishing indigenously, the key drivers for an upward growth through state-of-the-art industrialization (Make-in-India approach) for a robust energy infrastructure and capacity building. India has committed to extend lines of credit worth nearly $1.4 billion to cover 27 projects in 15 countries during the founding conference of the International Solar Alliance (ISA) in March 2018, which was hosted jointly by the Hon'ble Prime Minister of India and French President Emmanuel Macron.

In a climate action summit held in Austria, UN Secretary General António Guterres asserted in his keynote address that none of the world's challenges loom as large as climate change, and reiterated his belief that global warming poses an 'existential threat' to humanity (Climate Action World Summit, 2018). Climate change concerns across the globe have further propelled all nations to develop a detailed blueprint for clean and sustainable power for all. Grid stability, given the high penetration of clean energy, is critical for their economic growth, and thus has been given the highest importance. Solar–wind technologies are helping to create a situation where the share of electricity from both will play a central role in the future energy supply.

POLICY SUPPORT ON HYBRID SOLAR–WIND RE SYSTEMS

The MNRE has recently issued the final national solar–wind hybrid policy (MNRE: RE hybrid policy, 2018). The policy's goal is to reach wind-solar hybrid capacity of 10 GW by 2022. The salient features of the hybrid RE policy are discussed ahead.

The main objective of the policy is to provide a framework for promotion of large grid-connected wind-solar PV hybrid systems for optimal and efficient utilization of transmission infrastructure and land, reducing the variability in renewable power generation and achieving better grid stability. The policy also aims to encourage new technologies, methods, and ways involving the combined operation of wind and solar PV plants.

Being variable in nature,wind and solar energy pose certain challenges to grid security and stability. Experts have suggested that in India both solar and

» **Picture 2:** India's Prime Minister Shri Narendra Modi addressing the opening plenary at the World Economic Forum, January 2018 (Davos)

wind resources are complementary to each other. A further superimposition of solar- and wind-resource maps shows that there are large areas where both wind and solar have high-to-moderate potential. The hybridization of these two technologies would help in:

I. Minimizing the variability
II. Optimally utilizing the infrastructure, including the land and transmission system
III. The existing wind farms have the scope to add solar PV capacity and, similarly, there may be wind potential in the vicinity of the existing solar PV plant.
IV. An appropriate capacity of battery storage may also be added to the project to:

(a) reduce the variability of output power from the wind-solar hybrid plant; (b) providing higher energy output for a given capacity (bid/sanctioned capacity) at delivery point, by installing additional capacity of wind and solar power in a wind-solar hybrid plant; and (c) ensuring the availability of firm power for a particular period.

IMPLEMENTATION STRATEGY

The implementation of a wind-solar hybrid system will depend on different configurations and use of technologyas per the following details:

➢ Wind-Solar Hybrid: AC Integration

In this configuration, the AC output of both the wind and solar systems is integrated either at LT side or at HT side. In the latter case, both systems use separate step-up transformers and the HT output of both is connected to a common AC busbar. Suitable control equipment are deployed for controlling the power output of the hybrid system.

➢ Wind–Solar Hybrid: DC Integration

DC integration is possible in case of variable speed drive wind turbines using convertor-inverter. In this configuration, the DC output of both the wind and solar PV plants is connected to a common DC bus and a common invertor suitable for combined output. AC capacity is used to convert this DC power into AC power.

REGULATORY INTERVENTIONS

The central commission should lay down the guidelines for determining the generic tariff for wind–solar hybrid systems. Further, the commission should frame regulations for forecasting and scheduling for hybrid systems.

INCENTIVES

The government will encourage the development of wind–solar hybrid systems through various incentives. All fiscal and financial incentives available to wind and solar power projects may also be made available to hybrid projects. Low-cost financing for hybrid projects may be made available through the Indian Renewable Energy Development Agency (IREDA) and other financial institutions, including multilateral banks.

RESEARCH AND DEVELOPMENT

The government will support the technology development projects in the field of hybrid systems. Besides, support will be provided for the development of standards for hybrid systems. Detailed provisions for the existing and new wind–solar hybrid projects are also given in the policy document.

In order to remain energy-positive and to maximize the use of RE sources, the country will have to stay focussed on promoting grid-energy stability and efficiency. Recently, the Solar Energy Corporation of India or SECI (a government enterprise) invited bids for 2000 MW hybrid solar–wind projects (SECI: hybrid tender, 2018). This year, a private company installed a hybrid solar–wind project of 28 MW solar, close to its existing 50 MW wind plant in Raichur, Karnataka. It is expected that the savings in costs and increased efficiency with hybrid RE projects will in turn lead to lower tariffs and exponential growth in the power sector in India and other developing economies.

CONCLUSION

RE is at the centre of the transition to a zero-carbon-intensive energy portfolio. Renewable sources can produce electricity at close to, or even below, the cost of fossil fuel-based power stations and thus mitigate global warming. Today, India is amongst the fastest-growing solar markets (the fifth-largest in solar energy installations in the world). To meet the country's exponentially growing power requirement, the Indian government is taking a series of initiatives for improving energy access with transition to renewables to achieve the country's RE target of 175 GW, including 100 GW and 60 GW capacity for solar and wind power, by 2022. The main challenge for India remains to electrify each and every household in all its villages with quality power.

The existing growth opportunities along with high employment potential in the RE sector with the entire value-chain under its gamut is likely to benefit the diversified investors and funding agencies in bringing transformation in clean power generation while reducing the dependence on fossil fuels. The emission-free clean environment will be linked to the continued efforts of the ISA along with cooperation from other international agencies at the global level. The climate change challenge should be met by harvesting RE sources on a mass scale with cost-effectiveness and a time-bound programme and by simultaneously promoting skill development amongst the youth.

The green practices India follows to tackle energy challenges by harnessing renewables with scores of utility-scale projects are likely to provide holistic benefits to the country, its neighbours, and globally in terms of energy security, socio-economic development, job creation, and curbing GHG emissions. AU

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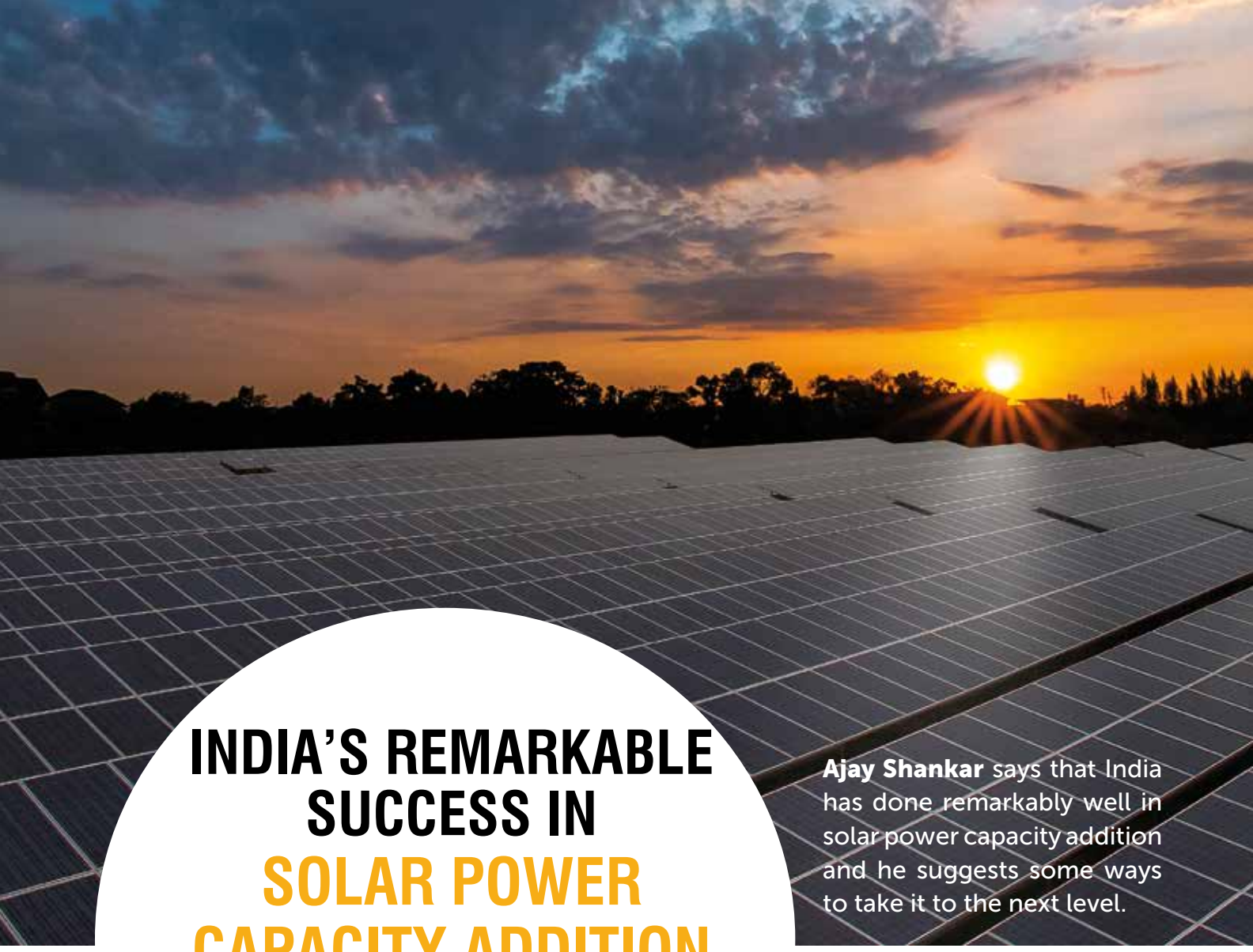

INDIA'S REMARKABLE SUCCESS IN SOLAR POWER CAPACITY ADDITION

Ajay Shankar says that India has done remarkably well in solar power capacity addition and he suggests some ways to take it to the next level.

When the National Solar Mission was launched in 2010, the target of 20,000 MW of solar power by 2022 appeared too ambitious, as the country had only 160 MW of solar power then. India announced its commitment to achieve 40% of its total generating capacity from renewables by 2030 for the Paris accord. Then, in 2015, the even more ambitious target of 100,000 MW of solar power by 2022 was announced. These did not appear feasible at all.

A real breakthrough has, fortunately, occurred with capacity addition of solar power now growing exponentially—the growth rate in 2016/17 being slightly over 80%. The total solar power capacity is now already 20,000 MW. What is remarkable is that this has been done through private investment and without large government subsidies. A competitive tariff-based bidding process every year for buying solar power from multiple firms through long-term contracts has been the instrument used by the Mission from the beginning. This created a competitive industry structure. Facilitated by the global reduction in manufacturing costs of solar panels, the decline in tariffs has been amazing. Tariff in one recent bid came down to below ₹2.5 per unit, whereas that approved by the Central Electricity Regulatory Commission for solar power was about ₹17 per unit when the Mission was launched.

While it would be only natural to have a sense of achievement, this success should also give the confidence to aim for new frontiers. The immediate requirement is to correct the distortion that India has 20,000 MW solar plants supplying electricity to the grid, but only about 1,000 MW of small decentralized/rooftop solar installations. These are, however, preferable as no new transmission lines need to be built for them. The potential of decentralized small solar generation in the over 6 lakh villages in India is enormous. Simple purchase with long-term contracts at substation as well as at the village level distribution transformers could be undertaken. Distribution companies should invite bids to arrive

at a feed-in tariff, which may then be used for the next 2–3 years for long-term power purchase contracts with all those willing to supply solar power at these rates. The maximum power that could be technically absorbed at a substation or the distribution transformer would need to be fixed at the outset.

The Energy Efficiency Services Limited (EESL) is well-positioned to work with state distribution companies to get this process going. It could undertake bulk procurement of solar panels to get lower costs and develop local partners for installation of solar panels for village-level farmers and entrepreneurs. The power purchase cost, which would definitely be less than ₹4.5 per unit, would be much lower than the actual cost of supply of over ₹6 per unit for distribution companies in rural areas and, therefore, economically beneficial for them. This programme should not need subsidies. A large programme would also bring additional income to small entrepreneurs and farmers across the country.

The EESL could also take up the foremost challenge of getting domestic manufacturing for the full value chain of solar PV panels as a part of the 'Make in India' initiative. Market forces on their own have not led to any significant progress in manufacturing of solar panels in India, nor is any real progress expected. This can, however, be made to happen by the EESL inviting bids for the supply of multiples of 1,000 MW solar panels for four consecutive years, starting from 2020, with the condition that the full value chain from the ingot to the panel be made in India. Similar orders may be placed on other bidders if they agreed to match the price of the lowest bidder. Assured offtake for four years would give potential investors confidence in the viability of their investment. The intention should be to have a competitive industry structure in manufacturing. Land and other infrastructure facilities should be earmarked along with the dispensation of duty-free import of capital goods before the invitation of bids, as was done for the ultra-mega power projects. With this risk mitigation, the bids should be sufficiently competitive. A new plant having the latest state-of-the-art technology should have lower manufacturing costs in comparison to earlier-generation plants. The EESL should be able to replicate its success in LEDs, in driving down costs substantially through its aggregation model of a series of bulk procurements of large volumes in succession. Procurement by the EESL with the condition of full domestic value addition would also have the advantage of being a non-issue as far as the WTO is concerned.

Solar thermal plants can take care of night-time electricity needs. These use mirrors to concentrate heat and pressure to generate electricity through the conventional turbine, with solar radiation substituting for coal. Using molten salt instead of steam enables storage and generation of electricity when there is no sunshine. It is time to invite bids for peaking power from a few solar thermal power plants to start the process of price discovery, creating a competitive industry structure and to progressively bring down tariffs. Solar thermal has the added advantage of having a high percentage of value addition in India in the beginning itself, and so should be relatively cheaper. Solar thermal offers the possibility of large-scale storage with readily available materials without adding to the demand for rare earths needed for the current generation of battery storage technologies. Once 5–6 small plants have overcome their teething problems and the technology has stabilized, a series of competitive bids for larger number of bigger plants should be invited. This should drive down costs as has been experienced in the case of solar power and LED bulbs. The aim should be to achieve a real breakthrough in the tariff of solar thermal power to make it competitive in comparison to coal- or gas-based peaking power at night. The day this happens, the actual phasing out of the use of coal in power generation in India would become feasible. AU

Mr Ajay Shankar, Distinguished Fellow, TERI.

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MICROALGAE

A POTENTIAL SOURCE OF GREEN ENERGY

Microalgae are microscopic algae, typically found in freshwater and marine systems. In this article, **Dr Dolly Wattal Dhar, Dr Pranita Jaiswal, Mr Sudhir Saxena,** and **Dr Randhir Bharti** discuss the promising possibilities of using microalgae as a source of renewable energy in the form of biofuels.

Microalgae are microorganisms (prokaryotic or eukaryotic), which accumulate biomass by the process of photosynthesis using sunlight, water, and carbon dioxide. The complete cycle of microalgae development ranges from 24 hours to several days and can double every few hours during their exponential growth period.

There are 50,000 microalgae species and only around 30,000 species have been studied. For a long time, microalgae have been used as nutritional ingredients but their active cultivation has begun over the last three decades. These organisms represent exciting possibilities as promising sources of a diverse range of metabolites of immense medical and industrial significance and can convert solar energy into biomolecules including carbohydrates, proteins, lipids, and triglycerides. Their ability to grow rapidly and adaptation to extremes of environment and ecologies make them suitable models for not only understanding the metabolic and evolutionary processes, but these are also miniature factories for producing useful value-added products. Microalgae can be used to make various products which are widely used in different industries. The reported market is 5,000 tonnes per year and $\$1.25X10^9$. An annual sale of microalgae is reported to be $\$6X10^9$ and the productivity is $7.5X10^6$ tonnes per year. Commercial production and harvesting of natural populations of microalgae predominantly take place in developing countries, indicating available experience, and good environmental and economical conditions, such as sunshine and low labour costs. Large-scale industrial applications require large amount of marginal, cheap but often ecologically valuable land and water sources. For

poor rural communities, well-designed small-scale Integrated Food and Energy System (IFES) approaches are the most suitable, potentially reducing ecological impact while providing fuel, animal feed, human protein supplements, wastewater treatment, fertilizers, and possibly more products that generate additional income. Capital inputs have to be minimized for this group, which means that the cultivation system would most likely be the open raceway pond, constructed in an area with an easily accessible, sustainable water supply, or *in situ* collection.

In recent years, microalgae grown in mass culture in either open or closed bioreactors have been identified as having a realistic potential for the production of biofuel on a large scale. An approximate per cent composition of three main components, namely proteins, carbohydrates, and lipids in microalgal biomass are in the range of 6%–71%, 2%–64%, and 2%–40%, respectively. The photosynthetic machinery from algae can be exploited to provide clean and green energy by utilizing solar power—one of the main sources of clean energy. The idea of using microalgae as a source of fuel is not new, but it is now being taken seriously because of the escalating price of petroleum and, more significantly, the emerging concern about global warming that is associated with burning fossil fuels.

MICROALGAE FOR BIOENERGY

Microalgae are a large and diverse group of aquatic organisms that lack the complex cell structures found in higher plants. These have received considerable attention as a potential feedstock for biofuel production because, depending on the species and cultivation conditions, they can produce useful quantities of polysaccharides (sugars) and triglycerides (fats). Microalgae have a very short harvesting cycle (≈1–10 days depending on the process) allowing multiple or continuous harvests with significantly increased yields.

Microalgae are reported to provide diverse forms of renewable biofuels (Figure 1) including biomethane (by anaerobic digestion of the algal biomass), biodiesel (from microalgal oil), bioethanol (by fermentation of the microalgal carbohydrates), and photobiologically-produced biohydrogen.

Biodiesel production

Lipids are one of the main component of microalgae and depending upon the species and growth conditions, 2%–60% of the total cell dry matter can be lipids as membrane components, storage products, metabolites, and storehouses of energy. Various extraction methods have been reported for microalgal lipids which include traditional solvent extraction, accelerated solvent extraction, subcritical water extraction, and supercritical CO_2 extraction. The conventional methods for lipid determination involve solvent extraction and gravimetric estimation. Nile Red—a lipid soluble fluorescent dye has been commonly used to identify the lipid content. Alternatively, lipophilic fluorescent dye BODIPY has also been used as a vital stain to monitor algal oil storage within viable cells. Studies have shown the use of Fourier-transform infrared spectroscopy (FTIR) as an efficient and effective tool to determine lipid contents in microalgae. The lipid content can be modified by varying growth conditions, such as nitrogen deprivation, silicon deficiency, phosphate limitation, high salinity, and heavy metal stresses. Factors, such as temperature, irradiance, and nutrient availability have been shown to affect lipid composition as well as content in algae. In addition, microalgae may assume many types of metabolisms, such as autotrophic, heterotrophic, mixotrophic, photoheterotrophic, and generally heterotrophic cultivation increases the total lipids as compared to phototrophically grown cells. Oil levels of 20%–50% are quite common and production of methyl esters or biodiesel from microalgal oil has been demonstrated and it is noteworthy to mention that the high quality oil produced by these microalgae can be converted to biofuel using existing technology. Biofuels produced from microalgae have the potential to replace a portion of fossil fuel consumption with a renewable alternative. Previous research in the early 1990s by the National Renewable Energy Laboratory showed that under controlled conditions, algae are capable of producing 40 times the amount of oil for biodiesel per unit area of land, compared to terrestrial oilseed crops. The interest in microalgae for oil production is due to the high lipid content of some species and synthesis of non-polar triacylglycerols (TAGs) which are the best substrates to produce biodiesel. A number of algal strains with the potential for

making biodiesel include *Botryococcus, Chlorella*, *Chlamydomonas*, *Scenedesmus*, *Crypthecodinium, Nannochloropsis,* and *Nannochloris.*

Algal oil is unsaturated to a larger degree making it less appropriate for direct combustion. Triglycerides and free fatty acids can be converted into biodiesel and triglycerides production rate in algae is 45–220 times higher than the terrestrial plants. Biodiesel is the mixture of alkylene ethers of fatty acids obtained as a result of inter-esterification of lipids. This reaction is a multiphase process during which triglycerides are first converted into diglycerides and later into monoglycerides which are transformed into glycerine and ethyl ethers of fatty acids (biodiesel). The homogeneous alkaline catalysis (sodium and potassium hydroxides) is typically used for the industrial production of biodiesel. Large amount of microalgal oil was efficiently extracted from *Chlorella protothecoides* using *n*-hexane and converted to biodiesel by acidic transesterification. Chloroform-based transesterification has been reported to lead to a high FAME content. Supercritical CO_2 extraction and thermochemical liquefaction have also been utilized for the production of biodiesel. Microalgal oils differ from most vegetable oils in being quite rich in polyunsaturated fatty acids and the lipids contain mainly unsaturated fatty acids; palmitoleic acid, oleic acid, linoleic acid, linolenic acid, and small amounts of saturated fatty acids, namely palmitic and stearic acid.

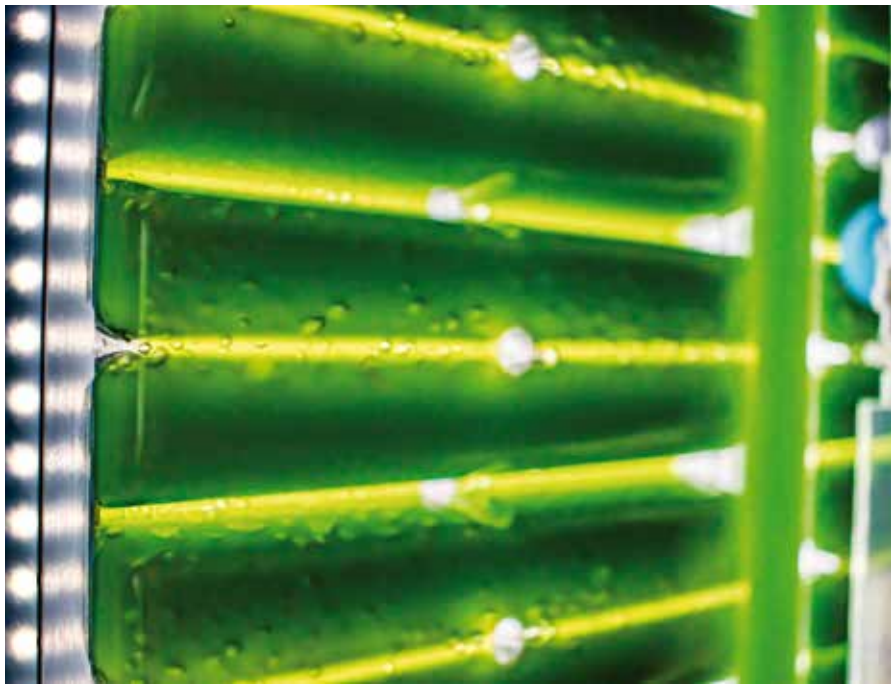
MICROALGAE FOR POLY UNSATURATED FATTY ACIDS (PUFAs)

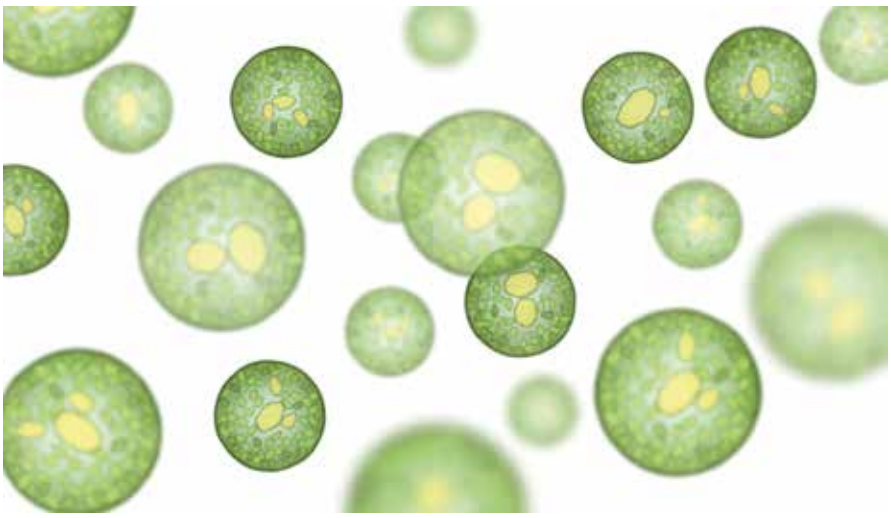
Higher plants and animals are known to have no fermentation responsible for the synthesis of unsaturated fatty acids with more than 18 carbon atoms. Therefore, these compounds must be introduced while feeding. Well known PUFAs include omega-3 fatty acids in fish oil, but their consumption has decreased because they may accumulate toxins. Fish oil has limitations to be used as food additive because of its unpleasant smell and taste, and low oxidation ability. PUFAs are known to play an important role in reducing the cardiovascular diseases and obesity in cellular and tissue metabolism including the membrane's fluidity, electron and oxygen transport, as well as adaptation ability. The use of fish oil is sometimes restricted because it contains such mixtures of unsaturated fatty acids that are structurally nonstandard. The production of eicosapentaenoic and docosahexaenoic acids from *Crypthecodinium* microalgae is prospective. OmegaTech (US) Company has shown that inexpensive oil (commercially known as DHA Gold) can be isolated from *Schizochytrium*. This oil is used as diet additive, non-alcoholic beverages, mediophylactic diet, and animal fodder. This product is also introduced in mediophylactic diet of pregnant women and patients with cardiovascular disease. Important PUFAs sourced from algae are reported in literature. PUFAs derived from microalgae, for example, docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA), α-linoleic acid (ALA), and arachidonic acid (AA) are known to be essential for

various larvae. Comparative proportion of important PUFAs in 46 strains of microalgae has been reported.

MICROALGAE FOR BIOETHANOL

With the rise in the demand of fossil fuels and realization of urgent need for their replacement, ethanol has become one of the most common biofuels worldwide as it reduces levels of lead, sulphur, carbon monoxide, and particulate matter. In many countries, it has been established/ considered for replacement of fossil fuels. Ethanol is generally produced mainly from alcoholic fermentation of sugar and starch (sugarcane, corn), utilizing fermentation of biomass sources, varying from agricultural crops (mainly sugarcane) to organic wastes. Use of agricultural crops poses huge competition for agricultural land for food. Another promising route for the production of ethanol is using lignocellulosic material, which is cheap, easily available, and renewable. However, its recalcitrant nature limits the commercial viability. Microalgae offer a perfect solution to the problem with simple cellular structure, carbohydrate-rich biomass, and no competition for agricultural land. They fix atmospheric CO_2 to complex carbohydrates utilizing solar energy. These carbohydrates can be converted to ethanol via fermentation. Many cyanobacteria have been reported to possess the ability to secrete fermentation products. However, it is not the primary source of energy for majority of microalgae/cyanobacteria. Therefore, in order to increase the ethanol production, suitable genetic modification in the strain/s had been reported. Hundredfold higher ethanol production has been reported by cyanobacteria under salt stress conditions (1.24 M NaCl) as compared with the low salt conditions (0.24 M NaCl). Therefore, microalgae with high carbohydrate content are the potential candidates for bioethanol production.





MICROALGAE FOR METHANE

Anaerobic digestion of organic matter produces biogas mainly consisting of methane (CH_4) and carbon dioxide. Organic matter contained in microalgal biomass can be transformed to CH_4 under anaerobic conditions. Lipid extracted cells from microalgae can be good material for conversion to CH_4, thereby, improving the total energy recovery. However, the methanogenic activity of microalgal biomass, in general, is less desirable as compared to fossil fuels or other organic wastes. High protein content in microalgae lowers the C/N ratio, which in turn affects the digestion efficiency. Co-digestion of microalgal biomass with products containing a high C/N ratio was proposed to be the possible solution to this limitation. Efforts have been made to link the CH_4 production with the natural ability of microalgae to mitigate contaminants from the environment. Studies have shown that a two-step system can be a viable approach wherein microalgae either produce nutrients (used by methanogenic bacteria) for methane

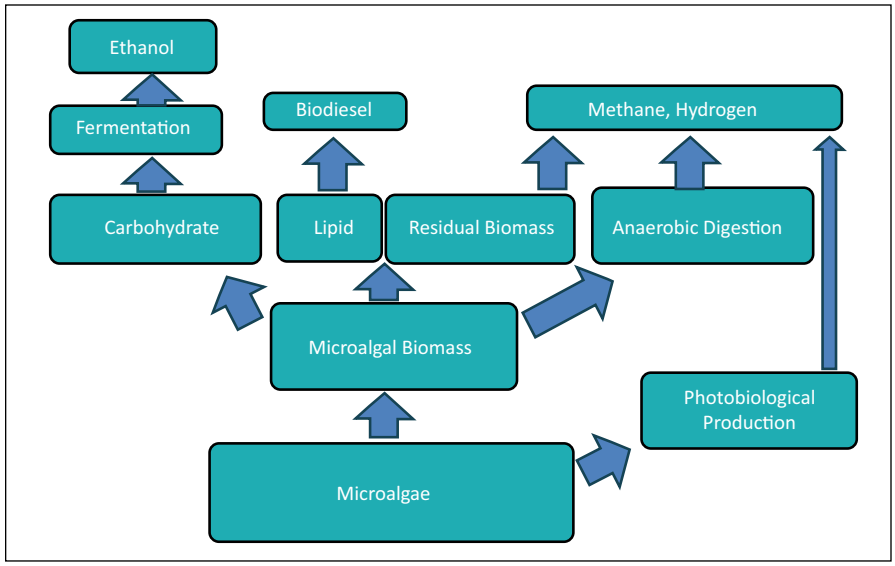
production or can improve the biogas quality by removing CO_2.

MICROALGAE FOR HYDROGEN

Hydrogen offers a potential alternative source of energy for the future in place of fossil fuels. It is a clean carbon-free fuel which ultimately oxidizes to water and has the potential to reduce the dependence on hydrocarbon-based fuels. The hydrogen production ability of microalgae is linked with the photosynthesis with water as direct source of electrons. Hydrogen production potential has been reported in many cyanobacterial strains. The mechanism of H_2 production in non-heterocystous cyanobacteria is similar to microalgae; heterocystous cyanobacteria have specialized cells for nitrogen fixation called heterocysts, which lack photosystem II (PS II), thus, maintaining low oxygen pressure due to absence of photolysis of water. Such conditions are required for nitrogenase and bidirectional hydrogenase activity. Efforts are being made to identify cyanobacterial strains with specific H_2 metabolism, optimizing cultural and environmental conditions, metabolic engineering, and genetic manipulation for enhancing hydrogen production.

CULTIVATION STRATEGIES

There are two main alternatives for cultivating photoautotrophic microalgae: A typical raceway pond system and a photobioreactor. Open ponds systems can be excavated and used unlined or lined with impermeable materials or they can be built up with walls. Unlined ponds can be used which will reduce the costs, but they suffer from silt suspension, percolation, heavy contamination, and their use is limited to a few algal species and particular soil and environmental conditions. Raceway ponds are open and outdoor ponds that are made up of circulating loop channels are typically shallow and unlined. Paddle wheels are used to circulate the suspended algae throughout the channels. Production



» **Figure 1:** Bio-energy from microalgae

in the ponds usually takes 6–8 weeks to mature and typically yields only 0.1–0.2 g/l algae. Photobioreactors can be located indoors and provided with artificial light or natural light or outdoors under natural sunlight. Photobioreactors have higher efficiency and biomass concentration, shorter harvest time, reduce contamination risks, and allow greater selection of algal species for cultivation and higher surface-to-volume ratio than open ponds.

Once the algal culture reaches maturity, the biomass is harvested from the culture medium and harvesting can be one of the more contaminating processes in the production of algae-based products. Three systemic components of the harvesting process are biomass recovery, dewatering, and drying. The cost of harvesting can be a significant proportion of the total algal production cost ranging from 20% to 30%. The technically simplest option is the use of settling ponds which are filled with fully grown algae culture and drained at the end of that day, leaving a concentrated biomass at the bottom, which can be stored for further processing. Other techniques may include flocculation (chemical flocculation, bio/electro-flocculation), dissolved air floatation, centrifugation, filtration, decantation and vacuuming, dewatering, and drying.

CONCLUSIONS

Microalgae find use with less extraction/processing and find application mostly as dried powder. Biodiesel production from microalgae provides technical and economic feasibility that also has the potential for CO_2 sequestration and is therefore, likely to find wide acceptance. Capital input, immature technology, knowledge required for construction, operation, and maintenance and the need for quality control are significant barriers to algae-based systems. Although productivity and sustainability are potentially much higher for integrated systems, the time and effort needed to create a viable algae-based concept seems to be significantly higher. In addition, the remaining biomass can be utilized in the area of other biofuel products, such as biomethane and fermentation products. The role of cyanobacteria in the area of hydrogen gas is also reported, however, the economic viability of the process is not very lucrative. AU

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Emerging Clean Public Transport Options for India and Associated Challenges

In July 2018, the Supreme Court of India (SCI) asked the Delhi Government and the Environment Pollution Authority (EPCA) to explore the feasibility of introducing hydrogen-fuelled buses for public transport in place of the electric buses in Delhi. The apex court made this observation in view of successful demonstration of hydrogen Fuel Cell Buses (FCBs) elsewhere. In this article, **Dr M R Nouni, Rudranath Sarkhel,** and **Prakash Jha** analyse the present status of development, advantages, and challenges associated with deployment of buses powered by H-CNG, electricity, and hydrogen.

In a time when dependence on imported petroleum is continuously increasing, when emissions from fossil fuel-powered automobiles are poisoning the air, when thousands of people are dying because of poor air quality, when stubble burning in some states is turning the northern part of the country into a gas chamber during early winters, and where keeping anthropogenic climate change at bay has become an important point of the political agenda at the global level, the demand for having a cleaner and greener public transport system is attracting attention of the public, government, judiciary, and regulators. In this background, the SCI in July 2018 asked the Delhi Government and EPCA to explore the feasibility of introducing hydrogen-fuelled buses for public transport in place of the electric buses (EBs). The SCI made this observation in view of successful demonstration of hydrogen FCBs elsewhere.

In response, the EPCA recommended to the SCI that the Indian manufacturers and oil companies are not yet ready for introduction of FCBs in Delhi and therefore, the Delhi Government may consider converting all CNG buses to H-CNG (fuel containing 18% hydrogen in CNG) in a phased manner by 2020/21 to improve Delhi's air quality. These developments point to the growing recognition that mobility solutions of tomorrow should use new energy resources, such as electricity and hydrogen with H-CNG serving as a transitional fuel before switching to hydrogen.

H-CNG FUEL FOR AUTOMOTIVE APPLICATION

H-CNG is an automotive fuel, where hydrogen is mixed with CNG to improve its combustion characteristics. This process, increases the gravimetric calorific value, but decreases volumetric calorific value. Global H-CNG testing has demonstrated its potential to reduce emissions, such as NO_x, CO_2, and CO compared to traditional CNG. Studies undertaken in India led by the Society of Indian Automobile Manufacturers (SIAM) have found that 18% hydrogen in CNG provides the optimal results for different types of vehicles. Emissions of CO and total hydrocarbon were found to be lower by using H-CNG in place of CNG. The study was however, inconclusive with respect to increase/decrease in NO_x emissions.

Production of H-CNG

H-CNG blend can be produced by having either separate high pressure supplies of hydrogen and CNG with mixing in the dispenser or using a compact reformer, wherein CNG is reformed to get H-CNG of the desired blend. Such a compact reformer has been developed by R&D Centre of the Indian Oil Corporation Ltd. (IOCL), Faridabad. Earlier two H-CNG dispensing stations operated by the IOCL at Dwarka in New Delhi and Faridabad were providing H-CNG to some test vehicles by mixing hydrogen and CNG. The dispensers at these stations were configured to provide 18% hydrogen blended with CNG by volume. The compact reformer obviates the need for either transporting hydrogen to H-CNG dispensing station or producing it on-site.

Issues associated with H-CNG

Cost of H-CNG fuel is expected to be higher than CNG, but better fuel economy coupled with reduced emissions of CO and hydrocarbon, make it a better fuel than CNG. Indian automobile industry already has experience of developing H-CNG buses, which will help them in supply of H-CNG buses and modify the existing CNG buses. In retrofitted engines reduction in NOx emission is highly dependent on the adjustment of the engine retuning, which may lead to higher NO_x emissions with H-CNG than CNG.

ELECTRIC BUSES

With a view to decarbonize the transport sector, which contributed about 24% of CO_2 emissions of 32.3 Gt in 2015; electric vehicles (EVs) are getting wider attention with many countries adopting different promotional strategies. As a result, the total global fleet of EVs at the beginning of 2018 was about 3 million. In comparison, the total number of EBs that may be in operation at the beginning of 2018 were only about 3.73 lakh, of which about 3.70 lakh were deployed in China alone and remaining in Europe, Japan, and the USA. Some cities in China aim to completely electrify their network of buses.

Drivers of EVs

EVs for road transport boost energy efficiency, require no direct fuel combustion, and rely on electricity, a versatile and diversified energy carrier. Adoption of EVs enhances energy security to nations and offers better air quality and less noise. Apart from stricter emission regulations, factors, such as lower battery costs, expanding infrastructure for fast charging, increasing consumer acceptance, and better total cost of ownership are also contributing to faster adoption of EVs.

Broad design features of EBs in global market

There are two principal parameters that determine the design of an EB: materials used for construction of bus body and the recharging strategy. Typical conventional bus body is built using steel frame, ensuring good structural stability at low cost. Some EBs make use of lighter materials, like aluminium or carbon fibre to ensure lower kerb weight, resulting in reduced energy consumption for propulsion of bus. Typical EBs using aluminium frame have kerb weight of 10.5–12 tonnes in comparison to about 14 tonnes with steel frame. The propulsion energy consumption of these types of EBs are around 90 kWh/100 km and 110–130 kWh/100 km, respectively. EBs can be designed to operate for a full day of operation with overnight recharging at a bus depot using slow chargers. This design requires batteries in excess of 250 kWh to satisfy range requirements. The alternative charging strategy, known as opportunity charging,

relies on fast chargers at the terminals or along a bus route. This strategy requires a much smaller battery (around 80 kWh) which results in a lower purchase price, lower fuel consumption, and more space for passengers. Li-ion batteries are heavy due to low gravimetric energy density and it results in increasing the kerb weight of the EBs. A specific challenge of EBs is requirement of meeting auxiliary loads for heating, ventilation, and air conditioning particularly in cold climates. The majority of EBs sold to date have been made by Chinese manufacturers with a battery capacity of around 330 kWh, which enables it to travel more than 250 km per charge.

Manufacturing of EBs in India

While electric cars may be the preferred option in Europe and America, for India EBs are more relevant as public transport is more sustainable from environmental perspective. Even NITI Aayog has prioritized EBs amongst different EVs for deployment in India. Introduction of EBs in India is in a nascent stage. Goldstone-BYD, Tata Motors Ltd. (TML), and Ashok Leyland are some of the active manufacturers of EBs in India. Regular operation of EBs commenced in Himachal Pradesh and Mumbai with buses supplied by Goldstone-BYD, a couple of years back. Ahmedabad, Bengaluru, Guwahati, Hyderabad, Indore, Jaipur, Jammu, Kolkata, and Lucknow are the nine cities in India that have decided to procure 530 EBs from the above mentioned bus manufacturers.

Acquisition and operating cost of EBs

The upfront cost of an EB is significantly higher in comparison to other alternatives, except FCB. The cost of an EB quoted by the suppliers for the ten cities referred above was in the range of ₹0.77–₹1.7 crore. However, procurement cost of an EB will depend on the specifications of the bus and especially the batteries used. The reported cost of an AC low-floor EB could be as high as ₹2.5 crore. Under FAME-India Scheme, launched in 2015, EBs with maximum energy consumption of 175 kWh/100 km were included for financial assistance of 60% of purchase cost or a maximum of ₹ 1 crore subject to at least 35% local content.

The cost contribution of Li-ion batteries to the total cost of the EB may be up-to 40%. The price of the Li-ion battery during 2017 was estimated at about $209/kWh and is expected to reduce to about $100/kWh by 2025. In India, cost of these batteries is high due to their import presently. Many companies have announced their plans to manufacture Li-ion batteries locally. However, Indian companies will have to largely depend on import of Li and Co and the prices of these materials are increasing due to increased global demand and only few countries controlling the supply chain.

It is economical to operate an EB in comparison to a conventional bus due to low maintenance cost on account of fewer moving components, high fuel efficiency, low cost of power and option of utilizing off-peak power during night. Besides, EBs could make use of renewable electricity as its penetration in the grid increases. During daytime, the buses owned by educational institutions usually remain unutilized for longer duration and can be used for storing excess solar electricity for feeding a part of it into the grid in the evening.

Challenges associated with EBs

Factors, such as high initial cost, dependency on imported Li-ion batteries, absence of charging infrastructure, operational range, and long charging time are attributed to slow adoption of EBs. Bus depots could in fact, make use of the vacant land and roof area for installation of solar charging systems. Procurement of buses and installation of dedicated power generation capacity may require additional funds, which may be a constraint with government-owned bus transport corporations.

HYDROGEN-FUELLED BUSES

Hydrogen can be used for powering buses using either Internal Combustion Engine (ICE) or Fuel Cells (FC) technologies. A Hydrogen ICE (HICE) bus uses hydrogen as fuel in place of diesel/CNG. Hydrogen is the lightest element with density of about 0.0898 kg/m^3. Therefore, it requires on-board storage at very high pressure (350 bar/700 bar) in composite cylinders for storing enough hydrogen to provide desirable operational range. Compressing hydrogen to such high pressures may consume up to about 13% of energy. An FCB is an electric bus that makes use of FC stack for generating direct current through electrochemical reaction between hydrogen and oxygen for running it. Energy conversion efficiency of an FC may be as high as 60% with no emissions except water vapour and heat. HICE bus may produce some emissions in the form of NO_x and traces of particulates resulting from combustion of lubricating oil. Even NO_x emissions can be eliminated by using after treatment processes.

Energy density of hydrogen and Li-ion batteries

Gravimetric energy density of hydrogen is in the range of 1.47–1.83 kWh/kg, depending on the volumetric capacity of the storage vessel used and storage pressure. In comparison, energy density of Li-ion batteries is in the range of 100–265 kWh/kg. Therefore, for storing same amount of energy, Li-ion based storage system would be about ten times heavier. Thus, for a given driving range, hydrogen storage system will be lighter than Li-ion batteries. Coupled with it, hydrogen vehicles can be refuelled as quickly as similar petrol/diesel vehicles with hydrogen filling rate of about 1 kg/minute in comparison to several hours taken by EBs. Hydrogen vehicles, therefore do not pose any 'range anxiety' fears but finding a Hydrogen Refuelling Station (HRS) is going to be a big concern till infrastructure for HRSs is developed.

Infrastructure for hydrogen

EVs have advantage over hydrogen vehicles as the electricity infrastructure is fairly well developed. The only incremental building block required to be put in place is regarding charging infrastructure. In contrast, infrastructure for production, storage, transportation, and dispensing of hydrogen for automotive sector is non-existent. Hydrogen for road transport vehicles can be produced in a centralized facility with distribution through either pipeline or trucks. Hydrogen so produced will be economical with high delivered cost that depends on transportation distance. On the other hand, on-site hydrogen can be easily produced using electrolysers though at a higher cost than centralized production but will have almost negligible transportation cost. The cost of HRS ranges from $2.1–3 million in California, USA for average daily hydrogen supply of 120–180 kg. On an average, the California Alternative and Renewable Fuel and Vehicle Technology Programme is providing about $1.5 million in grant for construction of a HRS. Japan, Germany, the USA, and other countries in Europe have set up about 330 HRSs so far. Japan alone has more than 100 stations. So far as India is concerned, two stations with on-site electrolytic hydrogen production are currently in operation at Faridabad and Gwalpahari, Gurugram. There are 32 operational chlor-alkali units in the country that are producing by-product hydrogen and a significant proportion of it can be utilized for powering hydrogen vehicles in their vicinity to minimize transportation cost.

Types of electrolysers

For on-site hydrogen production, two types of electrolysers are used—alkaline and PEM. Alkaline electrolysers are extensively used and is a proven technology. Its efficiency is of the order of about 65% and efforts are currently underway to further improve it. On the other hand, PEM electrolysers are compact and more efficient with efficiency of about 75% that may improve upto 80%. However, PEM electrolysers are more expensive, and have low footprint and better load response. With increasing penetration of variable solar and wind power generation in the grid and problem of power-curtailment from such sources, hydrogen production using electrolysers would become attractive.

Status of deployment of hydrogen-fuelled buses

Technically ready for the marketplace, hundreds of FCBs have undergone extensive demonstration in many cities in Europe and the USA. Japan is planning to showcase FCB technology during the 2020 Tokyo Olympics, where about 100 buses are expected to be deployed. China has plans to deploy a large number of FCBs in the next five years. TML has developed FCBs in India using some imported components. These buses will be ready for introduction after their extensive field trials. The SCI has taken these developments into account, while asking the Delhi Government to explore introduction of FCBs in the capital.

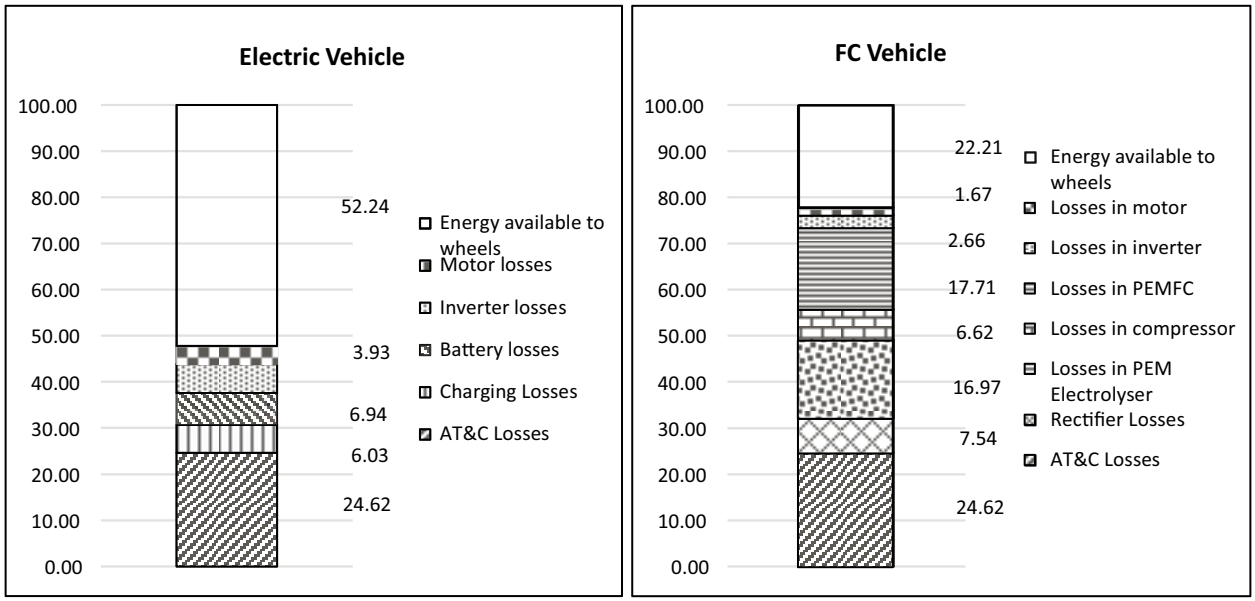
Safety issues related to hydrogen

Hydrogen requires very low ignition energy of 0.02 mJ for initiating combustion. Besides, hydrogen is combustible in air in a very wide range of concentrations from 4%-75% by volume, indicating combustion of very lean to very rich mixtures of hydrogen and air, which is not the case with conventional auto-fuels. These properties of hydrogen make it a fuel that needs safe handling. Since hydrogen has high diffusivity in air, it would get dispersed very quickly, whenever there is any leakage. In the event of hydrogen ignition resulting from its leakage, the flame travels vertically up rather than spreading and therefore, safety issues with hydrogen are similar to other auto-fuels.

Cost of hydrogen and hydrogen-fuelled vehicles

Cost of hydrogen varies considerably depending on the process by which it is produced, purity of hydrogen, capacity of

» Flagging off of a fuel cell bus



» **Figure 1**: Comparing availability of energy to wheels in an EV and an FC vehicle considering 100 units of grid electricity

the production facility, and transportation distance between production and delivery stations apart from other factors. Its cost in India may vary from ₹200–₹800/kg based on the above-mentioned factors. Internationally, FCBs are expensive at present with their unit cost in the range of ₹6–₹7 crore. As per indications provided by the TML, the cost of producing FCBs in India may be half of the international cost. The cost of HICE bus is expected to be significantly lower compared to FCBs due to their lower import content.

Hydrogen-fuelled buses: FC versus ICE

Globally, FCBs have been preferred to HICE buses in view of high energy conversion efficiencies and no tailpipe emissions. In contrast, India, while working out its priorities for development of hydrogen-fuelled vehicles, opted for HICE technology, mainly on account of: (i) ICE can use hydrogen as a fuel with few inexpensive modifications in the existing engine technology; (ii) HICE vehicles have higher efficiency compared to petrol vehicles and also lower emissions in comparison to petrol/diesel engines; (iii) existing manufacturing facilities can continue to be utilized for manufacturing of HICE and thereby requiring no new capital investment; and (iv) HICE could act as a bridging technology for making transition from fossil fuelled to FC vehicles. Mahindra & Mahindra in association with IIT-Delhi have already developed HICE-based three-wheelers and mini buses, which have undergone partial field trials. Initial results have been encouraging and these vehicles can be introduced in the market on completion of field trials. High cost and durability of FC make FC vehicles unattractive to users presently. Keeping this in view, HICE buses may have relevance in the Indian context in the coming years and therefore, must be a part of any strategy to decarbonize the transport sector.

Comparison of energy utilisation in EV and FC vehicles

Figure 1 compares availability of energy to wheels in an EV and an FC vehicle considering 100 units of grid electricity. After considering different losses in the various sub-systems of the two options, it may be seen that while about 52.24 kWh energy is available to wheels in an EV, only about 22.21 kWh energy is available in the case of an FC vehicle. Therefore, in terms of energy utilization, an EV is far better than an FC vehicle.

CONCLUSIONS

For de-carbonizing transport sector, both electric mobility and hydrogen-fuelled vehicles, especially FC vehicles have relevance, though the latter may be somewhat behind in terms of readiness for commercial introduction in India. Both the solutions can make use of renewable energies for production of the two versatile energy carriers— electricity and hydrogen, thereby, reducing the dependence on fossil fuels to begin with and ultimately eliminating their use. In terms of fuel, shifting to H-CNG from CNG and thereafter to hydrogen will certainly help in improving the air quality. In terms of vehicles, HICE could be the intermediate technology before making transition to FCBs. EBs can be introduced in city public transport quickly, provided the charging infrastructure can be developed in bus depots. Overall, it will be in the interest of the urban population in India, if these clean public transport options are deployed at the earliest. AU

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Challenges to Grid Integration of RENEWABLE ENERGY IN INDIA

India has witnessed increasing capacity additions in renewable energy (RE) with an installed capacity of close to 22 GW for solar and 34 GW for wind as on March 31, 2018. The achievement of the planned capacity shall have the country's task cut out in terms of planning the transmission infrastructure and managing the integration of the laid-out capacities with the grid, which indeed is a challenge. The transmission infrastructure is still a fragile link observing additions far from what was envisaged to evacuate the kind of green power injected in the grid. Although, the central government has embarked upon the Green Energy Corridor (GEC) initiative and the integration of storage systems on grid scale is envisioned, there are challenges to setting up the evacuation infrastructure. As observed, the biggest challenge is to guarantee that transmission systems are in place before the renewable projects are ready, since executing transmission projects takes up to five years as compared to the 12–18 months in case of solar projects.

DIFFERENCE IN NUMBER OF DEMAND CENTRES AND THE AVAILABLE CORRIDORS FOR RE

There is some incongruity in the number of demand centres and the available corridors for RE due to the lack of an effective plan to design a dedicated infrastructure for RE evacuation. For instance, the 1 GW substation project at Kayathar in Tamil Nadu, which was scheduled to be commissioned in early 2018 could not be commissioned on time because independent power producers are more inclined to evacuate the power to Gujarat and Maharashtra which have adequate demand centres as compared to the north-eastern states through the planned corridor. This is because there are limited demand centres to consume the power and less likelihood to earn premium under open access in the north-eastern states. However, the GEC is being established to evacuate power from large scale renewable energy systems, therefore are being implemented in states where RE resource is huge and large RE projects are coming up. The excess power being generated in these states are being transmitted to other states through the national grid. The grid infrastructure to

connect to the demand centres is already in place and any strengthening required is done by the States.

DISTANCE

In the case of solar power, distance is a major constraint for the planned long-range transmission due to the power purchase agreements (PPAs) under the auctions of solar power. Six states in the western and southern parts account for 80% of the country's installed solar capacity but only 38% of the power demand, and at present India lacks affordable storage facilities for RE power. However, on a positive note the excess power being generated in these states are being transmitted to other states through the national grid, i.e., Inter State Transmission System.

INADEQUACIES IN GRID INFRASTRUCTURE

Adequate transmission networks for upcoming RE projects have been planned and are under approval. These would be set up as and when Stage-II connectivity is received from developers so as to match the grid infrastructure with RE generation and to not keep the grid idle. But there is a need to address issues of the existing grid infrastructure. In India, several electrical parts of the country are unevenly connected to the national grid in order to optimally evacuate large wind farms or solar parks, which otherwise demand the installation of the entire infrastructure. Although the GEC programme is aimed at evacuating power from renewable-energy-rich states to other states through 765 kV and 400 kV high-voltage transmission lines, but there have been delays[1] and infrastructural development does not match the pace of tenders coming out.

In some states, tenders are released without consulting the respective state electricity regulatory commission (SERC); as a result, when PPAs go to regulatory commissions for approval, they get held up because the SERC cites a lack of transmission infrastructure.

BACKING DOWN OF WIND POWER IN WIND-RICH STATES

In spite of the must-run status for renewables, given their near-zero variable/marginal costs and higher ranking in the merit order, there have been some instances of backing down of renewable power, especially wind power. Ideally, such generation cannot be backed down except in the case of grid contingency. The Indian Wind Power Association has noted that the Tamil Nadu State Load Dispatch Centre (TNSLDC) has been backing down 50% of the wind generation in the state, as 'variation in wind power endangers the grid'. (CERC, 2016). This is causing financial losses for wind generators. In 2015–16, there was an apparent backing down of 5000 MU of wind power. At a tariff of ₹3.5/kWh, this adds up to a potential loss of ₹1,650 crore. At present, there is no provision for compensation for 'deemed generation' when wind power generators are available but are backed down by grid operators.

Grid operators and generation owners face major technical issues, such as intermittency (which is an uncontrolled variability) and location dependency. The three distinct issues that affect the grid integration of wind and solar energy are:

- Variability of resources: Power plant operators cannot control the wind and solar output because wind speeds and solar intensity vary dramatically, affecting power output. To balance the supply and demand on an instantaneous basis, there should be additional energy input as well as peripheral ancillary services, such as voltage and frequency regulation.

- Unpredictability: The availability of wind and solar energy is unpredictable to an extent. Electricity is only produced when the wind is blowing, and the presence of sunlight is crucial for PV systems to work. Systems that use advanced forecasting technologies can manage unpredictability. The availability of standby reserves to supply power when the renewable sources provide less power than predicted and the presence of dispatchable load to soak up excess power in case of renewables producing more power than predicted are parts of technological systems.
- Location dependence: Quality wind and solar resources that are most feasible for renewable energy generation are, unfortunately, based only in specific locations, and unlike in the case of various fossil fuels, such as coal, oil, gas or uranium, transporting them to a generation plant that is grid optimal is not possible. Generation is co-located with the resource, and the place where the power is ultimately used is often far from these locations. Connecting wind and solar energy resources to the grid involves the use of new transmission capacity. Moreover, transmission costs are especially high for offshore wind resources, often utilizing technology not employed in land-based transmission lines. AU

Disclaimer: The views expressed by the author in this article are his own and do not necessarily reflect the views of MNRE/TERI.

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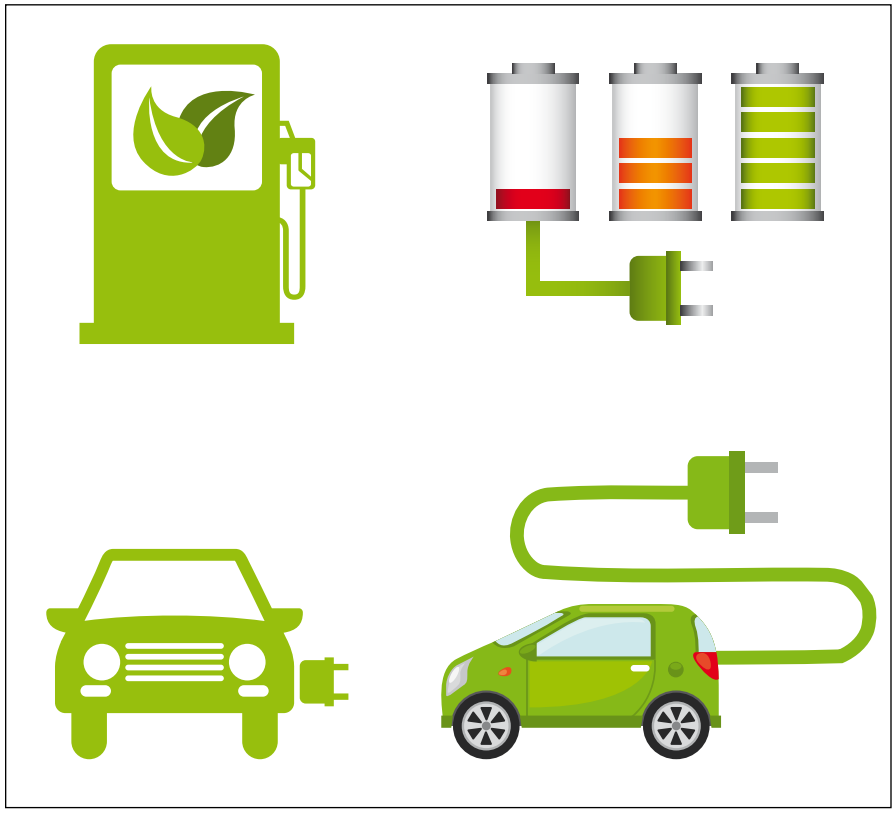
1 The Ministry has already replied to the comments of the Standing Committee. In the initial years, the State Transmission Utilities have issued and awarded tenders for these lines and substations. Therefore, there is a less installation in the starting years and target increases exponentially during the completion period. Further, as per the GEC scheme guidelines, the Government of India share is given to the States in two instalments: a) 70% Advance on the award of contract, b) Balance 30% after commissioning. The fund disbursal does not depend 'proportionately' upon the completion of transmission lines in terms of ckm.

Cabinet Approves National Mission on Transformative Mobility and Battery Storage

The Union Cabinet has approved the National Mission on Transformative Mobility and Battery Storage. The Mission will finalize and implement strategies for transformative mobility and Phased Manufacturing Programmes (PMP) for electric vehicles, their components, and batteries. The Mission will finalize the details of PMP for Electric Vehicle ecosystem and drive its implementation. The details of the value addition that can be achieved with each phase of localization will be finalized by the Mission with a clear 'Make in India' strategy for EV components as well as battery technologies. A phased roadmap to implement battery manufacturing at giga-scale will be an initial focus on large-scale module and pack assembly plants by 2019–2020. This will be followed by integrated cell manufacturing by 2021–2022. Details of the PMP for Batteries shall be formulated by the Mission. The Mission will ensure holistic and comprehensive growth of the battery manufacturing industry in India.



Composition of National Mission on Transformative Mobility and Storage

The multi-disciplinary National Mission on Transformative Mobility and Battery Storage with an Inter-Ministerial Steering Committee will be chaired by CEO NITI Aayog. The Steering Committee will be comprised of Secretaries from Ministry of Road Transport and Highways, Ministry of Power, Ministry of New and Renewable Energy, Department of Science and Technology, Department of Heavy Industry, Department for Promotion of Industry and Internal Trade, and Director General, Bureau of Industrial Standards.

Impacts of the Mission

- The Mission will drive mobility solutions that will bring in significant benefits to the industry, economy, and country.
- These solutions will help improve air quality in cities along with reducing India's oil import dependence and enhance the uptake of renewable energy and storage solutions.
- The Mission will lay down the strategy and roadmap which will enable India to leverage upon its size and scale to develop a competitive domestic manufacturing ecosystem for electric mobility.
- The actions in this regard will benefit all citizens as the aim is to promote 'Ease of Living' and enhance the quality of life of Indian citizens and also provide employment opportunities through 'Make-in-India' across a range of skillsets. AU

Source: www.thehindubusinessline.com

Government Taking Important Measures to Popularize Rooftop Solar Power System

Under the present rooftop solar programme, which was approved by the Government in December 2015, an aggregated capacity of 2,100 MW is targeted to be achieved in residential, institutional, social and Government sector through central financial assistance by the year 2019–20.

As per data captured on the SPIN portal of the MNRE, a total of 1,279 MW capacity grid connected rooftop solar PV systems have been reported installed in the country as on January 31, 2019.

While no formal study has been commissioned to study the rooftop solar scenario, the Government is taking a number of steps to promote rooftop solar in the country, these include:

- Providing central financial assistance (CFA) for residential/institutional/social sectors and achievement linked incentives for government sectors through rooftop solar scheme.
- Persuading states to notify the net/gross metering regulations for RTS projects. Now all the 36 States/UTs/SERCs have notified such regulations and/or tariff orders.

- Prepared model MoU, PPA and Capex Agreement for expeditious implementation of RTS projects in Govt. Sector.
- Allocate Ministry-wise expert PSUs for handholding and support in implementation of RTS projects in various Ministries/Departments.
- Suryamitra program is being implemented for creation of a qualified technical workforce.
- Initiated DG S&D rate contract for solar rooftop systems.
- Creation of SPIN—an online platform for expediting project approval, report submission and monitoring progress of implementation of RTS projects.
- Initiated Geo-tagging of RTS project, in co-ordination with ISRO, for traceability and transparency.
- Facilitated availability of concessional loans from World Bank and Asian Development Bank (ADB) to SBI and PNB respectively, for disbursal of loans to industrial and commercial sectors, where CFA/incentive is not being provided by the Ministry. AU

Source: http://www.pib.gov.in/

GOVERNMENT IMPLEMENTS VARIOUS SCHEMES FOR PROMOTION OF GRID INTERACTIVE RENEWABLE ENERGY

The Government of India is implementing various programmes/schemes for promotion of grid interactive renewable energy such as solar, wind, bio-power and small hydro power in the country. The details of major steps taken by the Government to attract investment in the renewable energy sector are as follows:

- Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to March, 2022.
- Permitting Foreign Direct Investment (FDI) up to 100% under the automatic route.
- Notification of standard bidding guidelines to enable distribution licensee to procure solar and wind power at competitive rates in cost-effective manner.
- Declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year 2022.
- Implementation of Green Energy Corridor project to facilitate grid integration of large-scale renewable energy capacity addition.

The details of generation of electricity through renewable sources of energy during the last three years are as follows:

Year	Generation in billion units (BU)
2016-17	81.54
2017-18	101.83
2018-19 (up to December, 2018)	97.92

AU

Source: http://www.pib.gov.in/

Successful Use of Solar Power in Food Processing Industry

The Society for Energy, Environment and Development (SEED) was founded in 1987 by a few professionals with expertise in engineering, management, solar energy, law, and social work. The purpose of the NGO is to draw upon the expertise of these fields of study to create awareness about environment and energy issues and creating devices to enhance the quality of life. SEED works in the areas of green energy applications, solar food processing, and rural women and youth empowerment. SEED believes in taking a holistic approach to achieve rural employment, food and nutrition security, and environmental sustainability.

SOLAR-POWERED AIR CABINET DRYERS

SEED has designed and developed solar-powered air cabinet dryers based on solar radiation with greenhouse effect (solar thermal) and with the introduction of solar fan for the first time. In the experimental set-up, they have used heaters operated by solar photovoltaic energy. This has given a good impetus to solar food processing technology. The cabinet dryer processed 96 solar-dried products based on fruits, vegetables, and forest produce, and the processing data is preserved under the headings of loading capacity kg/m^2, yield (%), finished product moisture (%), drying hours, cabinet temperature (°C), and ambient temperature (°C).

Even though solar power is introduced in SEED's innovative solar cabinet dryer to drive the fans, but solar power is not completely utilized in the operation of the machinery for food processing industry. Hence, the objective of their investigation is to interface solar power with the operation of food processing machinery.

FOOD PROCESSING EQUIPMENT: LOAD ESTIMATION

Subsequently, SEED calculated the load estimation of different units in food processing industry for the application of solar power. The following are the equipments (Table 1):

DESIGNING AND DEVELOPMENT OF 10-KW ROOFTOP SOLAR POWER SYSTEMS

With the previous experience in building up solar power systems, the SEED R&D has designed and developed a model solar power system for application in food processing technology. It is a rooftop 10-kW Solar Power System. It was divided into two parts—5 kW is connected battery backup and another 5 kW is connected on grid. This mode facilitates the machinery to operate with solar power only when the grid is on and also when the grid is off. In other words, it is connected with the string invertor and also hybrid (or) dual input inverter. The machinery will draw power from the battery bank.

The cost of 10-kW Rooftop Solar Power System is ₹10 lakh and the savings are ₹1.44 lakh per year and its payback period is 7 years.

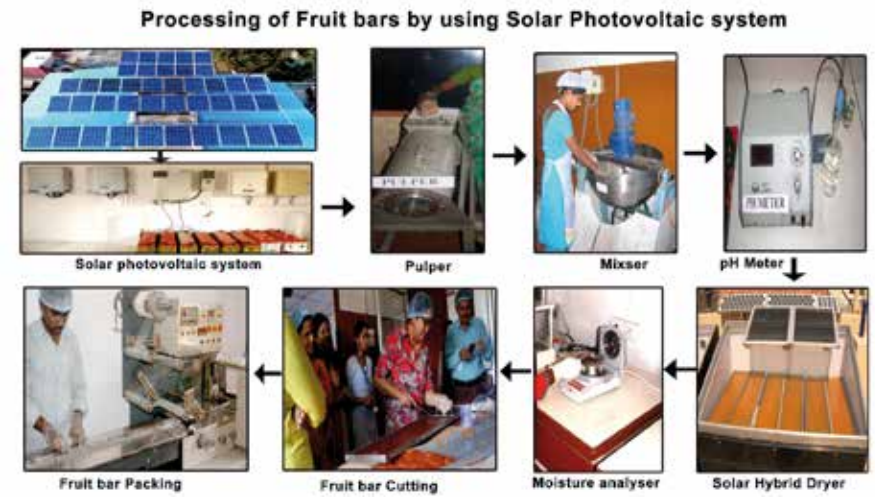
INTERFACING FOOD PROCESSING EQUIPMENT

The machinery will draw the total solar power generated, which is distributed

Table 1: Food processing equipment

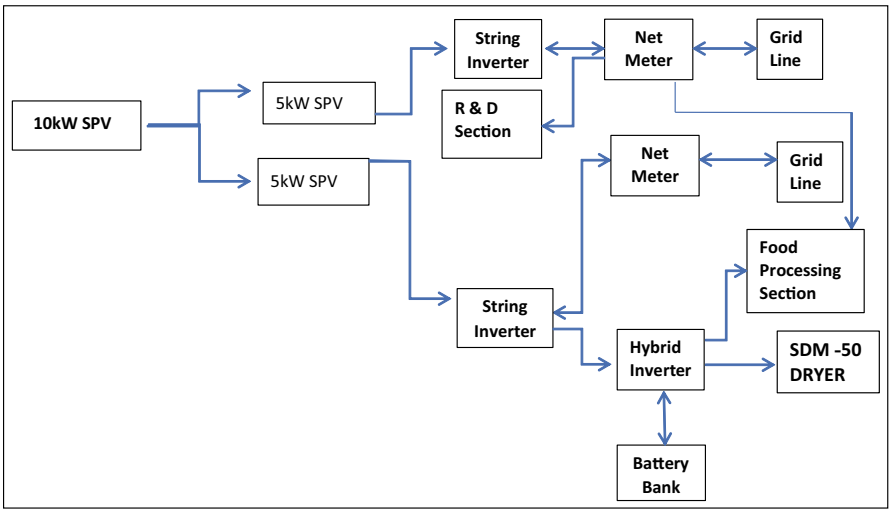
Sl. No.	Name of Components	Watts (w)	No. (#)	Total watts (w*no) (W)
1	Solar Cabinet Dryer -SDM-50 Model	3,600	1	3,600
2	Pulper	750	1	750
3	Pulverizer	1,500	1	1,500
4	Mixer-9ltr	1,500	1	1,500
5	Mixer-1ltr	750	1	750
6	Micro Oven	1,150	1	1,150
7	Water purifier	150	1	150
8	Packing System	100	4	400
9	Vegetable Cutter	1,500	1	1,500
10	Vegetable Peeler	750	1	750
11	Lights (5) & Fans (4)	650	1 set	650
	Total			12,700 W

Mango and Sapota Fruit Rolls Packing



through three sections namely, R&D Section, Food Processing Section, and Solar Hybrid Dryer—SDM-50. It successfully operates micro food processing machinery so that the total solar power is drawn and used with varying series of operations. The system was tested with load at variable times so that the total solar power drawn is equivalent to about 10 kW limit. The detailed diagram is given as Figure 1.

The 10-kW solar photovoltaic system generates about 50–55 units per day in a single phase. During the research period, SEED made great progress and was successful in introducing new innovations in solar food processing technology. Alongside using solar-based cabinet dryer for dehydration of fruits and vegetables, SEED successfully integrated solar energy to operate the downstream and upstream small-scale food processing equipment, such as pulpers, transfer pumps, pulverizers, and heat sealing equipment. etc., in conjunction with the dehydration process. The solar power distribution system interfacing with other smaller capacity food processing equipment was installed as a demo model with 10-kW rooftop solar power system. This innovative working prototype is working successfully at SEED R&D Center. These efforts will continue in future as well to further scale up to solar power generation system and utilize the solar energy for full-scale operation of small- and medium food enterprises. All the practical purposes to complete the process of the product from pulping stage to finished product are tested successfully.



» **Figure 1:** Interfacing food processing equipment layout

EXPERIMENTS ON PROCESSING OF SAPOTA AND MANGO FRUIT BARS USING SOLAR POWER

The SEED researchers chose Solar Hybrid Dryer–SDM-50 model for experimentation during non-sunny hours of operation for processing of fruit bars from fruit pulps drying. The full load of the pulp is 24 kg including all ingredients and loaded in solar cabinet dryer's trays for drying. The drying process is completed within 10 hours during non-sunny hours operation, that is, exclusively on solar power and the yield is 11 kg per batch. The equipment that are used in production of fruit bars is food processing machinery, which includes dryer, pulper, mixer, and packing machine.

The required power for the whole operation is 25 kWh and drawn from integrated PV system of 10 kW which gives us 50–55 kWh power per day. The rest of the power is supplied to laboratory equipment, general lighting for factory, and office maintenance. Balance power, if any, is supplied to grid.

In this experiment, a total of 10-kW rooftop solar power system is connected in three sections, that is, R&D Section, Food Processing Section, and Solar Hybrid Dryer – SDM-50, and 12,700 watt hours are required for this operation as already mentioned above.

THE WAY FORWARD

SEED successfully completed the introduction of solar energy in the food processing industry for the first time. It is an uninterrupted source of energy for sustaining the food industry.

The solar cabinet dryer is operated with zero energy cost and zero carbon emissions. The income for the farmers and rural women through processing of the food products will be sustainable in the long run. This additional income will be an excellent means for the welfare of the farmers' families involved in the agri-horticulture produce in villages. AU

Prof. M Ramakrishna Rao and G Harikrishna, Society For Energy, Environment & Development (SEED); www.seedngo.com

MP GRID-CONNECTED ROOFTOP SOLAR PV RESCO TENDER

A Lot to Learn

Despite India's huge potential for installing grid-connected rooftop solar PV projects as well as financial assistance from the government for the same, bidders or project developers are not finding such projects lucrative enough. In many cases, this results in higher-quoted tariffs and allocated capacities not translating into work orders. **Lucky Aggarwal** looks into some of the major issues faced by bidders and developers and outlines the lessons from the success story of the Madhya Pradesh RESCO tender which can be replicated elsewhere.

India has a huge potential for installing grid-connected rooftop solar PV projects. Plenty of unused rooftop space is available in the buildings in the government, institutional, industrial, commercial, and residential sectors that can be utilized for installing grid-connected rooftop solar PV projects.

The Government of India has also set up a target for 40 GW of solar power from rooftop installations by 2022. However, as per the MNRE's recent report, the cumulative achieved capacity as on July 31, 2018, is only 1.2 GW.

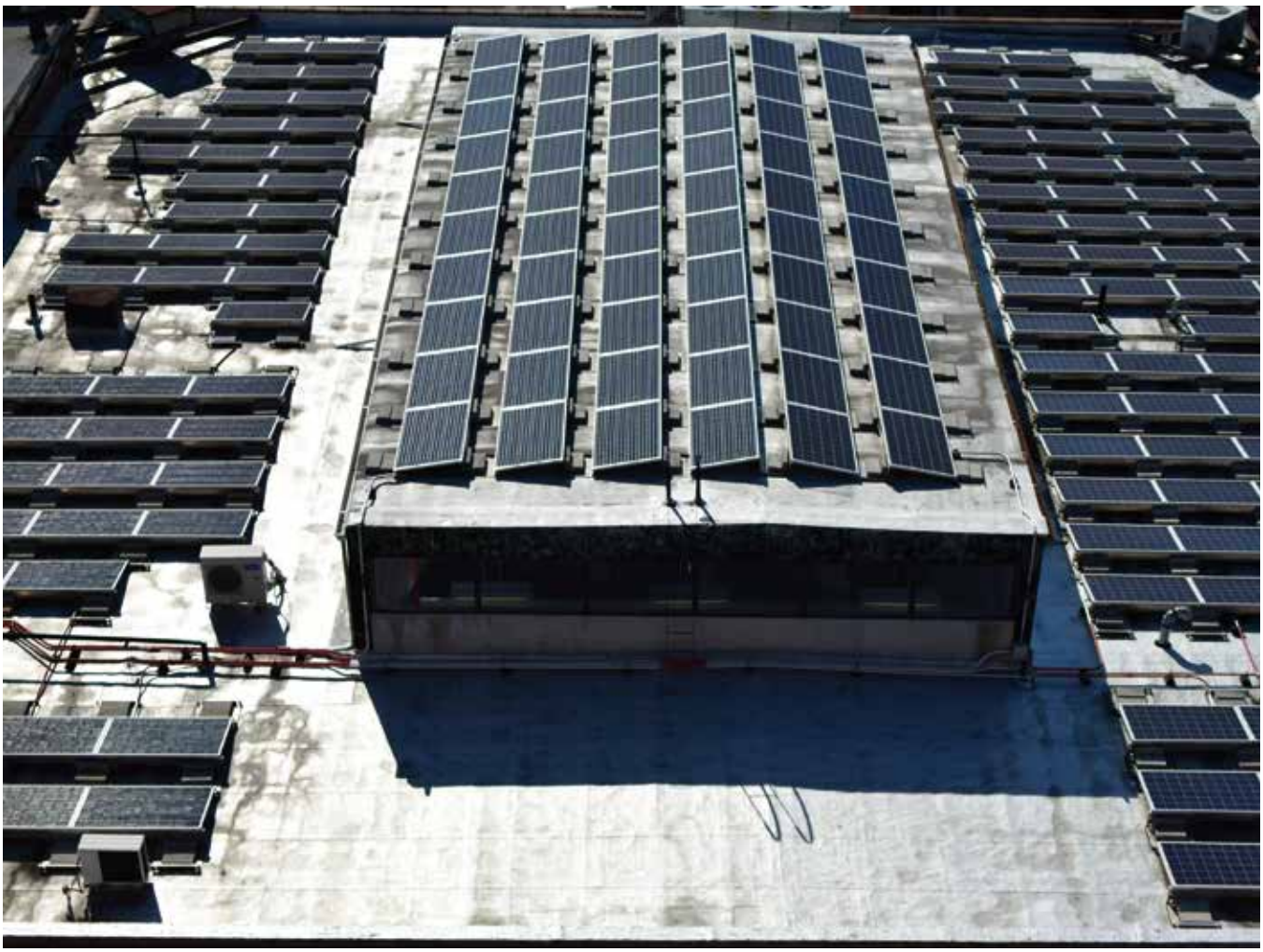
Many state governments, state nodal agencies (SNAs), and the Solar Energy Corporation of India (SECI) have floated several tenders in the last few years, with Central Financial Assistance (CFA) available for developers under the renewable energy service company (RESCO) and capital expenditure (CAPEX) models. Even after such initiatives and subsidies, grid-connected rooftop solar PV projects are not appearing lucrative enough to project developers, and the result is higher-quoted tariff and allocated capacities not translating into work orders in many cases.

ISSUES FACED BY BIDDERS/PROJECT DEVELOPERS

Bidders or project developers face issues and challenges at the time of bidding and, in many cases, after getting the LOA (letter of award) from the concerned authority/department. There is always some lack of information from the tendering authorities that is considered as uncertainties and risks by the bidders or project developers. These uncertainties and risks add up in the tariff calculation, which leads to higher-quoted tariffs. In many cases, the capacity allocated to the bidder remains unutilized or uninstalled due to various factors and bottlenecks. Some of the issues faced by most of the bidders or project developers are discussed below:

Lack of information about site location

Individual site names and geographical coordinates for the sites are not provided in most of the tenders. Due to the lack of such information, it is difficult for the bidders or project developers to judge the actual site conditions correctly, which causes them to add various assumptions and risk factors in the financial costing.



Lack of information about individual site capacities

Most of the tenders provide the aggregated capacity allotted to a particular bidder or project developer. However, the individual site capacity or roof capacity is not provided. Such lack of information can cause a wrong estimation of cable lengths and inverter sizing.

Though some of the authorities provide indicative individual site capacity, information on how that capacity is estimated, or the approach or assumptions considered while estimating that capacity, is not shared with the bidders or project developers.

Lack of information on existing evacuation infrastructure and electricity consumption

Grid-connected rooftop solar PV projects should be connected to the existing grid network, and information on the connected/sanctioned load, distribution transformer capacity, supply voltage, and so on should be made available to the bidder or project developer. Also, for RESCO bidders or project developers, information on the electricity-consumption pattern of a particular customer is also required for better tariff estimation. But as of now, information on evacuation infrastructure and electricity consumption is not provided to the bidders or project developers.

End customers are not identified

Most of the tenders do not identify the end customers, and it is the responsibility of the bidder or project developer to find them and close the deal. A cost for this business development activity is then included by the bidder or project developer in the quoted tariff. This may also lead to non-utilization of the allocated capacity in case the bidder or project developer is unable to convince the customers.

Open-market mode

Usually tenders are open-market mode, which means that bidders or project developers are free to approach any customers and vice-versa. In such a scenario, it is difficult for the customer to finalize a particular bidder or developer and a situation of uncertainty is created in the market. This leads to a long gestation period for project confirmation.

Time-consuming process of getting work order/LOA from tendering authority

Every tendering authority or government authority takes its own time for tender evaluation, financial bid opening, and allotting the LOA. Such delays may have financial implications for the bidder or project developer in the form of interest to be paid against bank guarantees or EMDs.

Difficulties faced during PPA signing

In most of the tenders, signing the power purchase agreement (PPA) is the sole responsibility of the bidder or project developer. Getting a PPA signed from different customers who may be located at different locations is time-consuming and requires a lot of effort from the bidder or project developer. In many cases, it is very difficult for a bidder to make the customer agree on all the points in the PPA, which causes unnecessary delay in the project timelines.

Stringent subsidy/CFA-releasing conditions

Most of the tenders link subsidy disbursement with project commissioning and DISCOMs' net-metering approval. Currently, not all DISCOMs are in favour of solar PV projects and hence take a long time to give the approval for a net-metering connection. In such cases, bidders or project developers do not get the subsidy on time despite the timely completion of the project.

MADHYA PRADESH RESCO TENDER

In its attempt to eradicate or dilute the uncertainties, risks, and challenges faced by bidders or project developers, Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL) floated two back-to-back tenders (RESCO Tender 1 and RESCO Tender 2) for government colleges, police establishments, private institutions, ITI colleges, and many other customer segments. Around 31 bidders or project developers participated in the RESCO Tender 1 floated by MPUVNL. The success of both the tenders can be gauged from the lowest tariff achieved of ₹1.38 per unit for the first year for grid-connected rooftop solar PV projects in the country for one of the tendered customer categories.

The lowest tariff can be linked to the double subsidies from the centre and state governments and a yearly tariff escalation of 3%. However, the MPUVNL team also took other recommendable steps to remove the ambiguity and challenges faced by bidders or project developers and made the process and financial estimation easier.

Some of the features of the RESCO tenders floated and their implementation are discussed below:

Pre-identified end customers

The MPUVNL team pre-identified the customers and sites, such as colleges under the Department of Higher Education, government medical colleges, government ITI colleges, police establishments, private institutions, and several other categories. This reduced the marketing and business development efforts and activities of the bidders or project developers. Unlike usual tenders, in these MP tenders if a bidder or project developer is allocated a capacity, he need not run in search of possible customers. This reduction in the project developer's efforts and activities will help in reducing tariff to some extent.

Creation of project groups and demand aggregation

Unlike the open-market mode tenders, in MP tenders for several project groups were created. Groups were fashioned in such a way that project sites from the same departments fall under one group, for instance, all the buildings related to police departments were added to a group named 'MP Police Establishments'

and so on. And so, the bidder or project developer needs to quote for the complete project group. Hence, the customers will face no confusion or second thoughts while selecting bidders or project developers, and a department will get the same tariff for all of its buildings irrespective of the physical location of the sites. The bidder or project developer now needs to get in touch with only one department for all the activities and approvals. Aggregating the capacities and grouping them will reduce the hassle faced by bidders and project developers and will also help in reducing the quoted tariff.

India's first-ever innovative data room

MPUVNL, with the support of the World Bank–SBI technical assistance programme 'SUPRABHA', created an innovative data room to dilute the ambiguities and risks faced by bidders or project developers during the computation of bid tariffs. The data room helped bidders or project developers in getting details, such as site coordinates, estimated site capacity, indicative array layout, and electricity bill for each proposed site. By getting access to such information, bidders or project developers got more clarity on the site and the result was a better tariff estimation.

This data room was made available to the interested bidders or project developers as a link to Google Drive. The features of the data room are listed below:

Advance payment of up to 50% of subsidy against bank guarantee

To provide financial support to the bidders or project developers, MPUVNL included the issuance of advance payment of up to 50% of subsidy against bank guarantee, if required by the bidders.

Pre-cleared and approved PPAs from end customers

PPA documents were pre-cleared and approved from the end customers. This reduced the efforts of the bidders or project developers. This will also help in reducing the project timelines.

Relaxed subsidy/CFA-releasing conditions

The subsidy/CFA-releasing milestone was linked to project commissioning rather than net-metering approvals from DISCOMs. However, a self-attested copy of a net-metering application submitted to the DISCOM is required.

Single platform for mass PPA signing

To reduce the efforts and timelines of bidders or project developers in getting the PPA signed from different customers, MPUVNL organized a PPA-signing event. All the customers and project developers were invited to this event and PPAs were signed on the same day.

Public opening of financial bid and on-the-spot issuance of LOA

To show more transparency and reduce the effective timelines of the project, MPUVNL organized a public opening of the financial bid. On-the-spot LOA was given to the bidders or project developers and the PPA was also signed on the same day.

Innovations like the clear identification of sites and their potential and procedural aspects, such as on-the-spot issuance of the LOA and pre-cleared PPAs will really help in developing confidence in the bidders or project developers.

CONCLUSION

Such models can be directly replicated by other SNAs or tendering authorities to help in increasing the deployment of grid-connected rooftop solar PV projects in India and diluting all the bottlenecks faced by the bidders or project developers during the tendering process. AU

Mr Lucky Aggarwal, Senior Consultant, GSES India Sustainable Energy Pvt. Ltd., New Delhi.

Accelerating Transition to Renewable Energy in India

By Infusion of Capital

A transition to renewable energy is taking place in India and for it to be accelerated, there has to be an infusion of capital, which requires reducing risks, transaction costs, and enabling large-scale replication. These were some of the points discussed by experts at a special session on 'Energy Transitions: Reconciling Competing Imperatives of Development and Environmental Sustainability'. The session was held on September 25, 2018, at Climate Week NYC on the sidelines of the United Nations General Assembly.

Dr Ajay Mathur, Director General, TERI, and co-chair, Energy Transitions Commission (ETC), who chaired the session, said, "You need private capital as well as public capital and public capital needs to be more risk-taking, while risks have to be reduced for private capital."

"While it has to be ensured that costs remain low so that power is affordable, there also have to be returns that attract investors. Amid the rapid development taking place, more than half of the India of 2030 is yet to be built. This means that it can be done in a sustainable manner to balance development imperatives with the need to tackle climate change," he added.

India's political leadership has repeatedly reaffirmed a commitment to climate action, and to the Paris Agreement. This is driven by the country's own imperative of ensuring energy security and the need to save the environment. "India targets 175 GW of renewable capacity by 2022 (or 20%–22% of generation), and 265 GW by 2027. For reducing risk to investments in renewable energy, what is required are timely payments, agreements that are in place and honoured, and a financial structuring that allows the kinds of returns that make it profitable," Dr Mathur said.

Ms Rachel Kyte, CEO of Sustainable Energy for All and Special Representative of the UN Secretary-General for Sustainable Energy for All, said in her keynote address that "there was no longer a dualistic view that looked at development and environment in opposition to each other. Individuals should be at the centre—they want clean air, safe medicine, healthy food, and these are the priorities—and India is moving in the right direction. While the use of electric vehicles and greater use of electricity is being promoted, there is an underlying 'thermal economy' when it comes to power generation and manufacturing," she said.

Mr Remy Rioux, CEO, Agence Française de Développement (AFD) and Chairperson for International Development Finance Club (IDFC), said that the private sector has to work with development banks to get adequate capital. Development and climate action cannot rely entirely on overseas development aid, even with the efforts of leaders, such as the French President Emmanuel Macron increasing the aid given by their countries, he said.
Mr Rioux said other alternatives for financing for the UN Sustainable Development Goals and climate action have to be created.

Mr Sumant Sinha, Chairman and CEO, ReNew Power, said that "Transition will become a revolution as it reaches sectors beyond power generation. But there is a need to create capital for the transition and, at the moment, the capital is not following to the sector to the extent needed. Investors need returns and are risk averse, he noted. Due to the huge potential that the renewable energy sector has, its listed stocks should be trading at the rate of e-commerce stocks. However, the markets do not buy into it because they are not sure of the policies and, therefore, of the risks. One of the problems in scaling up renewable energy production is that power tariffs are reduced each time there is an increase in production, which in turn inhibits increase in capacity. If there was a certainty in the tariffs and they held steady, there would be a much larger increase in renewable power generation capacity." AU

Source: www.teriin.org

MNRE CIRCULATES DRAFT INDIAN WIND TURBINE CERTIFICATION SCHEME (IWTCS)

The Ministry of New and Renewable Energy, Government of India, in consultation with the National Institute of Wind Energy (NIWE), Chennai, has prepared a draft of new Scheme called Indian Wind Turbine Certification Scheme (IWTCS) incorporating various guidelines of the Turbine Certification Scheme.

The IWTCS is a consolidation of relevant National and International Standards (IS/IEC/IEEE), technical regulations, and requirements issued by the Central Electricity Authority (CEA), guidelines issued by MNRE, and other international guidelines. It has also strived to incorporate various best practices from other countries to ensure the quality of the wind energy projects.

The draft Scheme enlists the guidelines for the benefit of all the stakeholders from concept to lifetime of wind turbine, including Indian Type Approved Model (ITAM), Indian Type Certification Scheme (ITCS), Wind Farm Project Certification Scheme (WFPCS), and Wind Turbine Safety & Performance Certification Scheme (WTSPCS).

The IWTCS is envisaged to assist and facilitate the following stakeholders: (i) Original Equipment Manufacturers (OEMs); (ii) End Users—utilities, state nodal agencies (SNAs), developers, independent power producers (IPPs), owners, authorities, investors, and insurers; (iii) Certification bodies; and (iv) Testing laboratories.

Wind energy has matured over the decades to be the mainstream source of renewable power generation in India. The steady growth of the sector has seen different types of wind turbines with diverse performance and safety criteria. The MNRE, Government of India, through various policies and schemes has facilitated the healthy and orderly growth of the wind energy sector. The guideline for the recognition of the certification schemes in India by the MNRE was paramount for the success of quality wind turbines installed in India. The successful evaluation under the recognized schemes resulted in the wind turbines being listed in the Revised List of Models and Manufacturers (RLMM). This listing has resulted in stakeholders having confidence on the quality of the wind turbines offered by various manufacturers in India. Wind sector in India is growing at a rapid pace with increased utilization of wind energy for power development. The modern wind turbines have higher hub heights, larger rotor diameter, higher capacity, and improved capacity utilization factor (CUF) along with technological improvements. Under these developments, there is a need for a comprehensive document which provides the complete technical requirements which shall have to be complied by the wind turbines for the safe and reliable operation by all the stakeholders, viz., OEMs, IPPs, wind farm developers, financial institutions, utilities, and others. Also, there is a need for technical regulations which shall facilitate common ground for OEMs, developers, investors, and financial institution for systematic development.

Type Certification of wind turbines plays an active role in ensuring that wind turbines in India meet the requirements of requisite IS/IEC/IECRE standards in vogue. Internationally, IEC/IECRE Certification schemes for wind turbines are well recognized and widely used and the IWTCS in its formulation has incorporated the rules and procedures of IS/IEC/IECRE. AU

Net-Zero Carbon Emissions From Harder-to-Abate Sectors

Is it Possible?

New report by the Energy Transitions Commission shows that reaching net-zero carbon emissions from harder-to-abate sectors, such as heavy industry and heavy-duty transport can be done through ambitious policy, accelerated innovation, and investment, with minimal cost to the global economy. It is technically and financially possible by mid-century.

Reaching net-zero carbon emissions from heavy industry and heavy-duty transport sectors is technically and financially possible by 2060 and earlier in developed economies and could cost less than 0.5% of global GDP, according to the report published by the Energy Transitions Commission (ETC). The report *Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century* outlines the possible routes to fully decarbonize cement, steel, plastics, trucking, shipping and aviation—which together represent 30% of energy emissions today and could increase to 60% by mid-century as other sectors lower their emissions.

The 'Mission Possible' report was developed with contributions from over 200 industry experts over a 6-month consultation process. Its findings show that full decarbonization is technically feasible with technologies that already exist, although several still need to reach commercial readiness. The total cost to the global economy would be less than 0.5% of GDP by mid-century, and could be reduced even further by improving energy efficiency, by making better use of carbon-intensive materials (through greater materials efficiency and recycling) and by limiting demand growth for carbon-intensive transport (through greater logistics efficiency and modal shift).

In India, the decarbonization of heavy industry and heavy-duty transport is crucial, not only to reduce the carbon in the atmosphere, but also to improve air quality and enhance the quality of life and health of Indian citizens. The Indian industry is growing and has the opportunity to build new industrial capacity with state-of-the-art technology. In heavy-duty transport, electric trucks, and buses (either battery or hydrogen fuel cells) are likely to become cost-competitive by 2030, while, in shipping and aviation, liquid fuels are likely to remain the preferred option for long distances but can be made zero carbon by using bio or synthetic fuels. Improved energy efficiency, greater logistics efficiency, and some level of modal shift for both freight and passenger transport could reduce the size of the transition challenge.

In industry, more efficient use of materials and greatly increased recycling and reuse within a more circular economy could reduce primary production and emissions by as much as 40% globally—and more in developed economies—with the greatest opportunities in plastics and metals. Reaching full decarbonization will require a portfolio of decarbonization technologies, and the optimal route to net-zero carbon will vary across location depending on local resources.

ACROSS ALL SECTORS OF THE ECONOMY

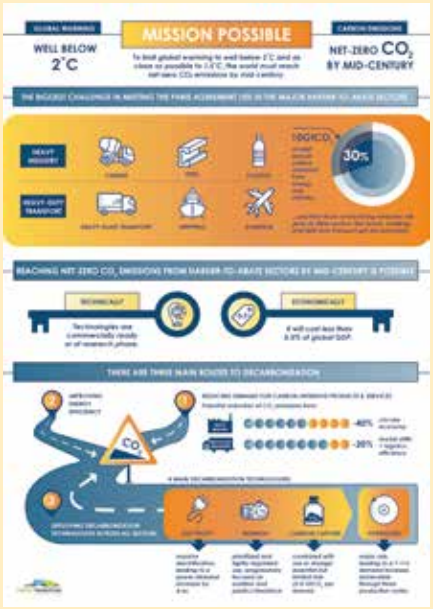
- Direct and indirect electrification (through hydrogen) will likely play a significant role in most sectors of industry and transport, leading to a sharp increase in power demand—growing 4–6 times from today's 20,000 TWh to reach around 100,000 TWh by mid-century).
- Hydrogen use will almost certainly increase dramatically (7–11 times by mid-century), with two routes to zero-carbon hydrogen: electrolysis, which will likely dominate in the long term, and steam methane reforming plus carbon capture and storage.
- Bioenergy and bio-feedstock will be

required in several sectors, but will need to be tightly regulated to avoid adverse environmental impact (such as deforestation), and its use should be focused on priority sectors where alternatives are least available or more costly, such as aviation and plastics feedstocks.

- Carbon capture (combined with use or storage) will likely be required to capture process emissions from cement and may also be the most cost-competitive decarbonization option for other sectors in several geographies. However, it does not need to play a major role in power generation, with the storage needs required could be less than many scenarios suggest. Tight regulation of storage is essential to ensure safety and permanence.

The *Mission Possible* report concludes that the most challenging sectors to decarbonize are plastics, due to end-of-life emissions; cement, due to process emissions; and shipping because of the high cost of decarbonization and the fragmented structure of the industry.

The ETC supports the objective of limiting global warming ideally to 1.5 °C and, at the very least, well below 2 °C. In the wake of the IPCC's urgent call for action, the *Mission Possible* report sends a clear signal to policymakers, investors,



and businesses: full decarbonization is possible, making ambitious climate objectives achievable.

The key policy levers to accelerate the decarbonization of harder-to-abate sectors include:

- Tightening carbon-intensity mandates on industrial processes, heavy-duty transport, and the carbon content of consumer products.
- Introducing adequate carbon pricing, strongly pursuing the ideal objective of internationally agreed and comprehensive pricing systems, but recognizing the potential also to use prices which are differentiated by sector, applied to downstream consumer products and defined in advance.
- Encouraging the shift from a linear to a circular economy through appropriate regulation on materials' efficiency and recycling.
- Investing in the green industry, through R&D support, deployment support, and the use of public procurement to create initial demand for 'green' products and services.
- Accelerating public–private collaboration to build necessary energy and transport infrastructure.

Industries and investors can anticipate the profound transformation in industry and transport they will eventually face by innovating and investing in decarbonization technologies and low-carbon infrastructure. The ETC provides the fact base for industry groups and private companies to develop roadmaps, collaborations and projects aiming for net-zero carbon emissions in their sectors. It also encourages businesses across multiple sectors to question their procurement practices and make commitments to buying 'green' products and services.

The members of the ETC are committed to achieving the Paris objective of limiting the rise in global temperatures to well below 2 °C and as close as possible to 1.5 °C. They are convinced that succeeding in that historic endeavour would not only limit the harmful impact of climate change, but would also drive prosperity and deliver important local environmental benefits.

Adair Turner, co-chair of the ETC said, "This report sets out an optimistic but completely realistic message—we can build a zero-carbon economy with a minor cost to economic growth. We should now commit to achieving this by 2060 at the latest, and put in place the policies and investments required to deliver it." Dr Ajay Mathur, co-chair of the ETC added, "Climate change imperatives, underlined most recently in the IPCC Special Report to limit global warming to 1.5 °C, require the world to move to near-zero carbon emissions by the 2060s or so—when many of the investments we make today would still be operational. The ETC report provides pragmatic steps to move towards zero-carbon technology options in these harder-to-abate sectors, providing both hope as well as strategic directions in these sectors." AU

To read the full report, visit the ETC website www.energy-transitions.org

Power Stations Driven by Light

More Efficient Solar Cells Imitate Photosynthesis

The smallest building blocks within the power stations of organisms which get their energy directly from the sun are basically miniature reactors surrounded by collectors which capture photons and forward them to the centre. The close correlation between structure and interaction of the components boosts productivity, a strategy which an international team of researchers is using for increasing the efficiency of solar technology. At Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), research is being carried out in this area by the Chair of Physical Chemistry I, and the latest results have been published in the journal Nature Chemistry.

Green plants, algae, and some bacteria use sunlight to convert energy. The pigments in chlorophyll absorb electromagnetic radiation which induces chemical reactions in electrons. These reactions take place in the nucleus of complex protein structures, referred to by experts as photosystems I and II. The processes which take place in these photosystems are induced by catalysts in a certain order. In the first step, oxygen is released from water. The next reaction prepares the production of carbohydrates for which no further source of energy is needed.

The reaction centres of the photosystems are encircled by light-absorbing pigments grouped into consolidated complexes. These antennae increase the area available for light rays to hit and extend the spectrum of usable wavelengths, both prerequisites for a favourable energy balance. Each reactor core is surrounded by approximately 30 antennae. Experiments conducted by scientists are still far from replicating the complexity of nature. In general, a ratio of 1:1 is the best that can be achieved: one light-absorbing molecule in combination with one catalyst for oxidizing water. The group of researchers led by Prof. Dr Dirk Guldi hope to revolutionize solar technology by synthesizing modules based on the correlation between structure and function in photosystem II. In the newly developed systems, light-absorbing crystals such as those which are already used in LEDs, transistors, and solar cells are layered into a network of hexagonal honeycombs around a water-oxidizing catalyst with four ruthenium metal atoms in the centre. When shown in a rather simplified manner, the compact, stable units made up of two components with a common long axis are reminiscent of cylindrical batteries. In the self-assembling chemical process, such 'miniature power stations' create two-dimensional slats. Like layers in a gateau, they form a common block which collects the energy won from the sun's rays.

This is not an entirely accurate reproduction of the ideal arrangement found in the natural photosystem, but the principle is the same. Five macromolecules in the shape of a honeycomb with the ability to capture light create a sheath around each reactor core, and it has been shown that these small power stations are efficient and successful at harvesting solar energy. They have an efficiency of over 40% and losses are minimal. Wavelengths from the green portion of the colour spectrum, which plants reflect, can also be used. These research results nourish the hope that solar technology can one day make use of the sun's energy as efficiently as nature. AU

Source: www.sciencedaily.com

» Shri Venkaiah Naidu, Hon'ble Vice President of India, along with other dignitaries, during the inauguration ceremony of the WSDS 2019

World Sustainable Development Summit (WSDS) 2019

The World Sustainable Development Summit (WSDS) is the annual flagship event of The Energy and Resources Institute (TERI). It has, in its journey of 18 years, become a focal point for global leaders and practitioners to congregate at a single platform to discuss and deliberate over climatic issues of universal importance. The Summit series has emerged as the premier international event on sustainability which focusses on the global future, but with an eye on the actions in the developing world which could bend our common future. The Summit series has, over the years, brought together 47 heads of state and government, 13 Nobel laureates, ministers from 76 countries, 1600 business leaders, 1800+ speakers and over 12,000 delegates from across the world. WSDS now strives to provide long-term solutions for the benefit of the global community by assembling the world's most enlightened leaders and thinkers on a single platform.

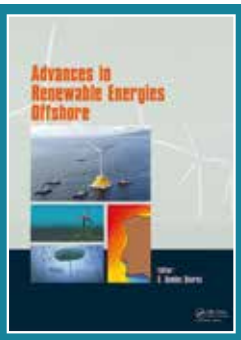
The summit was inaugurated by Shri M Venkaiah Naidu, Hon'ble Vice President of India, at Vigyan Bhawan today in New Delhi on February 11, 2019. Mr Nitin Desai, Chairman, TERI, delivered the welcome address. This year, TERI honoured Hon'ble Prime Minister of Fiji Frank Bainimarama with the Sustainable Development Leadership Award 2019 in recognition of his outstanding contributions towards sustainable development in Fiji. Delivering the inaugural address, Hon'ble Vice President of India Shri Venkaiah Naidu spoke about the many facets of sustainable development such as inclusive development, sustainable mobility and urbanization, energy security, waste management and green innovation. Dr Harsh Vardhan, Hon'ble Minister for Environment, Forest & Climate Change, Government of India, said, "Climate change and environmental problems are amongst the biggest challenges today. It goes without saying that these issues need to be addressed collectively by all of us before it is too late."

The three-day Summit brought together over 2000 delegates including global leaders, policy makers, government top officials and thinkers in the fields of sustainable development, energy, and environment sectors. Themed on 'Attaining the 2030 Agenda: delivering on our promise', WSDS 2019 created action frameworks to resolve some of the most urgent challenges facing developing economies in the backdrop of climate change, including – clean oceans, transport and mobility, sustainable agriculture, climate finance, and energy transition. Its main aim is to fast-track solutions to financing development, renewable energy, sustainable value chains and other far-reaching, systemic challenges represented by the United Nations' Sustainable Development Goals (SDGs). Dr Ajay Mathur, Director General, TERI said, "Platforms such as these are crucial for building on global best practices and ensuring that policy enables an environment that translates into tangible benefits for the world at large. We look forward to a world that is clean, green and yet viable. We need products, business models and policies to make this happen."

WSDS 2019 saw several thematic tracks and plenary sessions covering the five key themes of Climate, Environment, Habitat, Energy, and Resource Management. Discussions focussed on, inter alia:

- Cleaning the Air in India and its Cities
- Moving Towards Cleaner Oceans
- India's Renewable Revolution: Towards a Cleaner, Cheaper Electricity System
- Innovations in Climate Finance to Achieve Scale, Speed and Impact
- Rural Electricity Access in India: Taking a Leap from Grid Availability to Customer Service AU

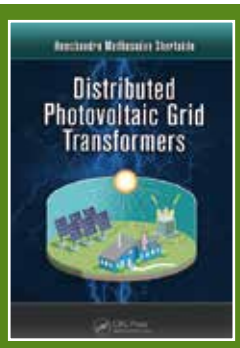
Source: http://www.teriin.org/



ADVANCES IN RENEWABLE ENERGIES OFFSHORE: PROCEEDINGS OF THE 3RD INTERNATIONAL CONFERENCE ON RENEWABLE ENERGIES OFFSHORE (RENEW 2018), OCTOBER 8-10, 2018, LISBON, PORTUGAL

Carlos Guedes Soares; CRC Press, 918 pages

Advances in Renewable Energies Offshore is a collection of the papers presented at the 3rd International Conference on Renewable Energies Offshore (RENEW 2018) held in Lisbon, Portugal, on October 8–10, 2018. The 104 contributions were written by a diverse international group of authors and have been reviewed by an International Scientific Committee. The book is organized in the following main subject areas: Modelling tidal currents; modelling waves; tidal energy devices (design, applications, and experiments); tidal energy arrays; wave energy devices (point absorber, multibody, applications, control, experiments, CFD, coastal OWC, OWC and turbines); wave energy arrays; wind energy devices; wind energy arrays; maintenance and reliability; combined platforms; moorings, and flexible materials. *Advances in Renewable Energies Offshore* collects recent developments in these fields, and will be of interest to academics and professionals involved in the above mentioned areas..



DISTRIBUTED PHOTOVOLTAIC GRID TRANSFORMERS 1ST EDITIONN

Hemchandra Madhusudan Shertukde; CRC Press, 293 pages

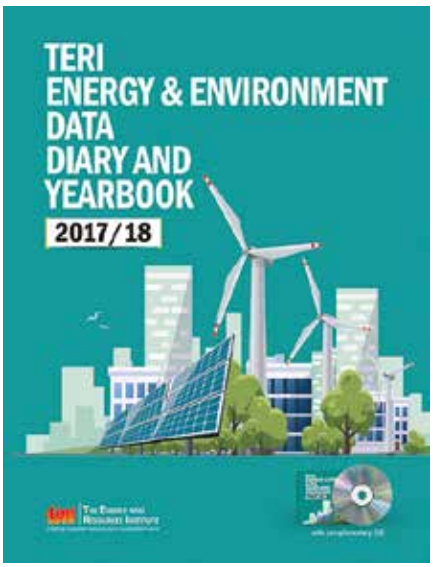
The demand for alternative energy sources fuels the need for electric power and controls engineers to possess a practical understanding of transformers suitable for solar energy. Meeting that need, *Distributed Photovoltaic Grid Transformers* begins by explaining the basic theory behind transformers in the solar power arena, and then progresses to describe the development, manufacture, and sale of distributed photovoltaic (PV) grid transformers, which help boost the electric DC voltage (generally at 30 volts) harnessed by a PV panel to a higher level (generally at 115 volts or higher) once it is inverted to the AC voltage form by the inverter circuit. Packed with real-life scenarios and case studies from around the globe, the book covers the key design, operation, and maintenance aspects of transformers suitable for solar energy. Topics include islanding, voltage flicker, voltage operating range, frequency and power factor variation, and waveform distortion. Multiple homework questions are featured in each chapter. A solutions manual and downloadable content, such as illustrated examples, are available with qualifying course adoption.

ENGINEERING TECHNOLOGIES FOR RENEWABLE AND RECYCLABLE MATERIALS: PHYSICAL-CHEMICAL PROPERTIES AND FUNCTIONAL ASPECTS 1ST EDITION

Jithin Joy, Maciej Jaroszewski, Praveen K M, Sabu Thomas, and Reza Haghi; Apple Academic Press, 324 pages

Engineering Technologies for Renewable and Recyclable Materials focusses on many recent advances in recycling and reuse of materials, outlining basic tools and novel approaches. It covers important issues, such as e-waste recycling, bio-mass recycling, vermitechnology, recovery of metals, polymer recycling, environmental remediation, waste management, recycling of nanostructured materials, and more. Also included is coverage of new research in the use of laser spectroscopy, pyrolysis, and recycled biomaterials for biomedical applications.

TERI ENERGY & ENVIRONMENT DATA DIARY AND YEARBOOK (TEDDY 2017/18)



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 that 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, household, and commercial), and environment (local and global). It also provides a review of the government policies that have implications on energy and environment in India.

Each edition of TEDDY contains India's commercial energy balances for the last four years that provide comprehensive information on energy flows within different sectors of the economy and how they have been changing over time. These energy balances and conversion factors are a valuable reference for researchers, scholars, and organizations working on energy and related sectors. After the introductory chapter, TEDDY is divided into sections on energy supply, energy demand, and local and global environment. The overall structure of this year's TEDDY is different from the previous editions, with certain improvisations. One of the main highlights of TEDDY 2017/18 is the addition of four new chapters under the environment section. Thirty-third edition of TEDDY has been restructured to make it less prose intensive. Graphs, figures, maps, and tables have been used in all chapters to explain facts, which make the book an interesting read. The publication is accompanied by a complimentary CD containing full text. The publication is often cited in international peer-reviewed journals and policy documents.

Key Features

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

Target Audience

Researchers and professionals from industries, government organizations, and public sector undertakings. Research scholars from different NGOs, bilateral and multilateral institutions, and academic institutions. AU

Source: http://www.teriin.org/

RENEWABLE ENERGY DATA PORTAL

Prayas (Energy Group), Renewable Energy Data Portal (http://www.prayaspune.org/peg/re.html)

The Indian renewable energy sector has been in an extremely dynamic phase of evolution in the last few years, especially with regard to capacity addition and prices. India has set itself an ambitious renewable energy target of 175 GW by 2022. In spite of the several social, economic and environmental benefits of renewable energy, such a high target has profound implications and can throw up myriad challenges for the Indian power sector, especially in the medium term. Hence it is very important for the electricity sector actors to objectively look at the growth of renewables. A lot of data is already available to understand the renewable energy sector, but more granular and comprehensive up-to-date data, publicly accessible in a user friendly manner, can aid better understanding of the renewable energy evolution in the country.

The Renewable Energy Data Portal is Prayas (Energy Group)'s effort to collate important data, already available in the public domain, at one place and present it so as to underline the rapidly growing renewable energy. Another feature of this effort is the interactive nature of the data portal which allows users to look at specific information, across renewable energy sources/years/states, etc. The resulting graphs can be downloaded using the 'Download' button at the bottom.

The portal was inaugurated by Mr Anil Jain, Adviser (Energy), NITI Aayog on December 1, 2016. The first revision took place in November 2017. A second revision took place in June 2018 to include more data and improved visualization. A new tab has added on rooftop solar, mostly containing data on prices discovered through bidding. Along with it, the RE capacity, RE prices, and renewable energy certificates were expanded to include more data. A third revision is due soon. AU

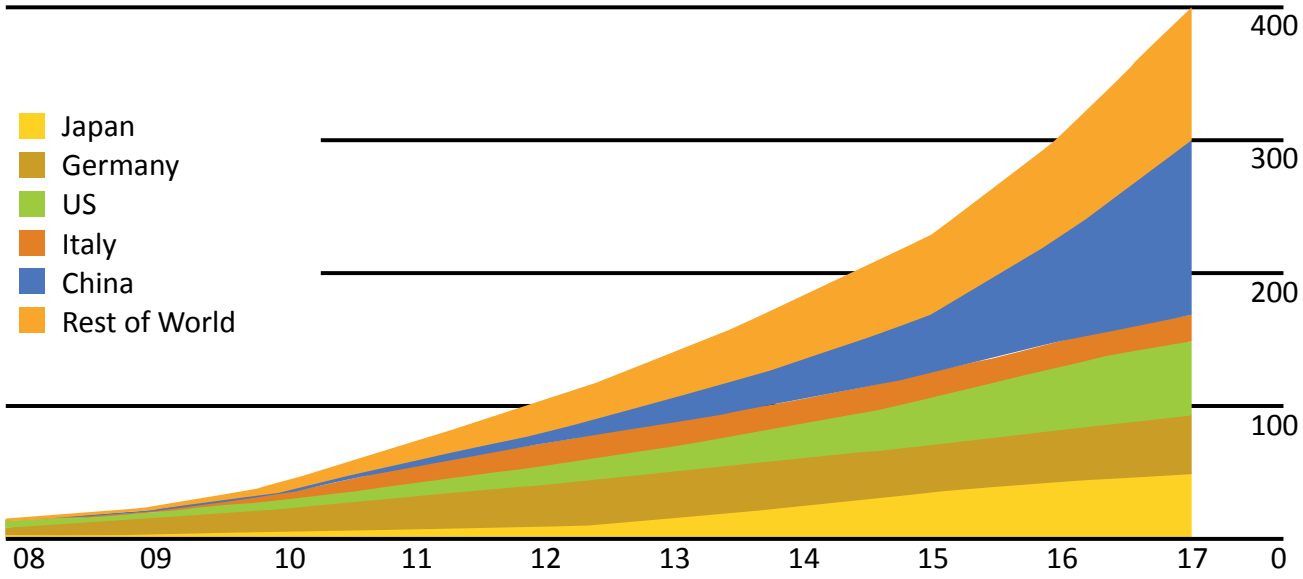

NATIONAL
April 4–5, 2019 | Mumbai, India
Intersolar India West
Website: https://www.intersolar.in/en/home.html
April 20–21, 2019 | Bengaluru, India
Electric, Hybrid, Solar Vehicle & Eco Green: EHSE 2019
Website: https://www.energysector.in/events/electric-hybrid-solar-vehicle-eco-green-ehse
April 26–27, 2019 | Hyderabad, India
RenewX
Website: https://www.renewx.in/
May 9, 2019 | Kolkata, India
SolarRoofs West Bengal 2019
Website: https://www.solarquarter.com/index.php/events4/all-events/business-events/41-solarroofs-west-bengal-2019
May 22–24, 2019 | New Delhi, India
Smart Cities India Expo
Website: http://www.smartcitiesindia.com/


INTERNATIONAL
April 9–10, 2019 | Berlin, Germany
April 9–10, 2019 Berlin, Germany
Website: https://2019.energydialogue.berlin/
May 20–23, 2019 | Houston, USA
AWEA WindPower
Website: https://www.windpowerexpo.org/
May 29–30, 2019 | Atlanta, USA
Solar Power Southeast
Website: https://events.solar/southeast/
June 6–7, 2019 | London, UK
14th World Bioenergy Congress and Expo
Website: https://bioenergy.insightconferences.com/
June 13–14, 2019 | Sydney, Australia
Renewable Cities Australia
Website: https://renewablecities.com.au/#

RENEWABLE ENERGY AT A GLANCE: GLOBAL

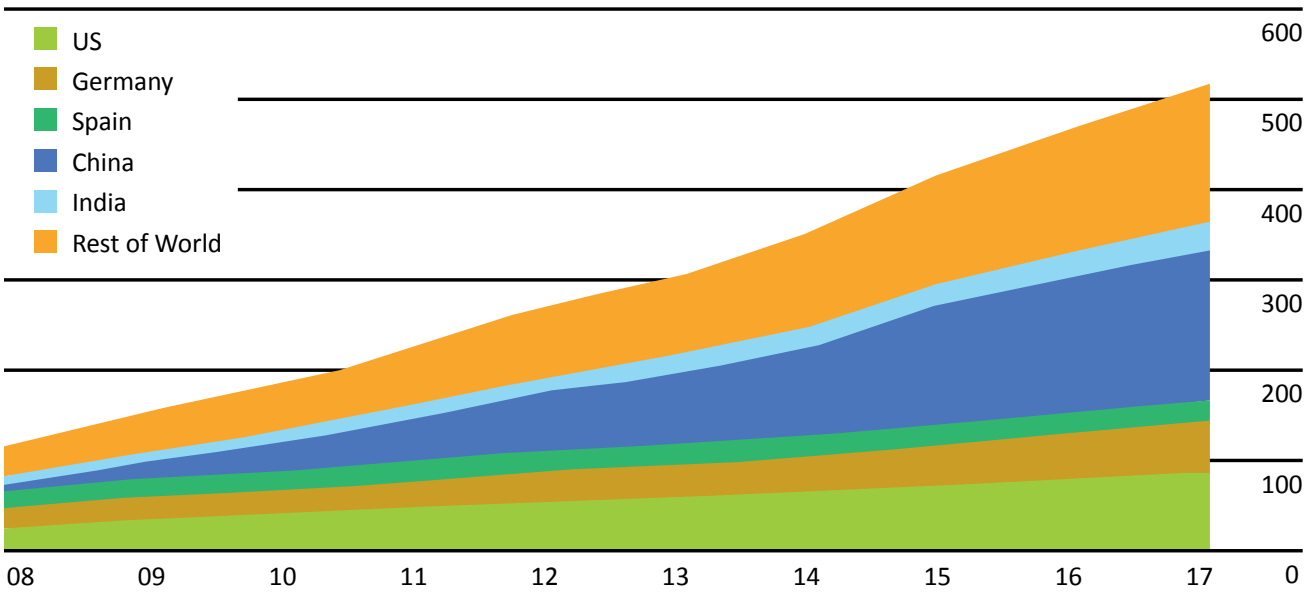
Solar PV generation capacity

Gigawatts, cumulative installed capacity



Wind generation capacity

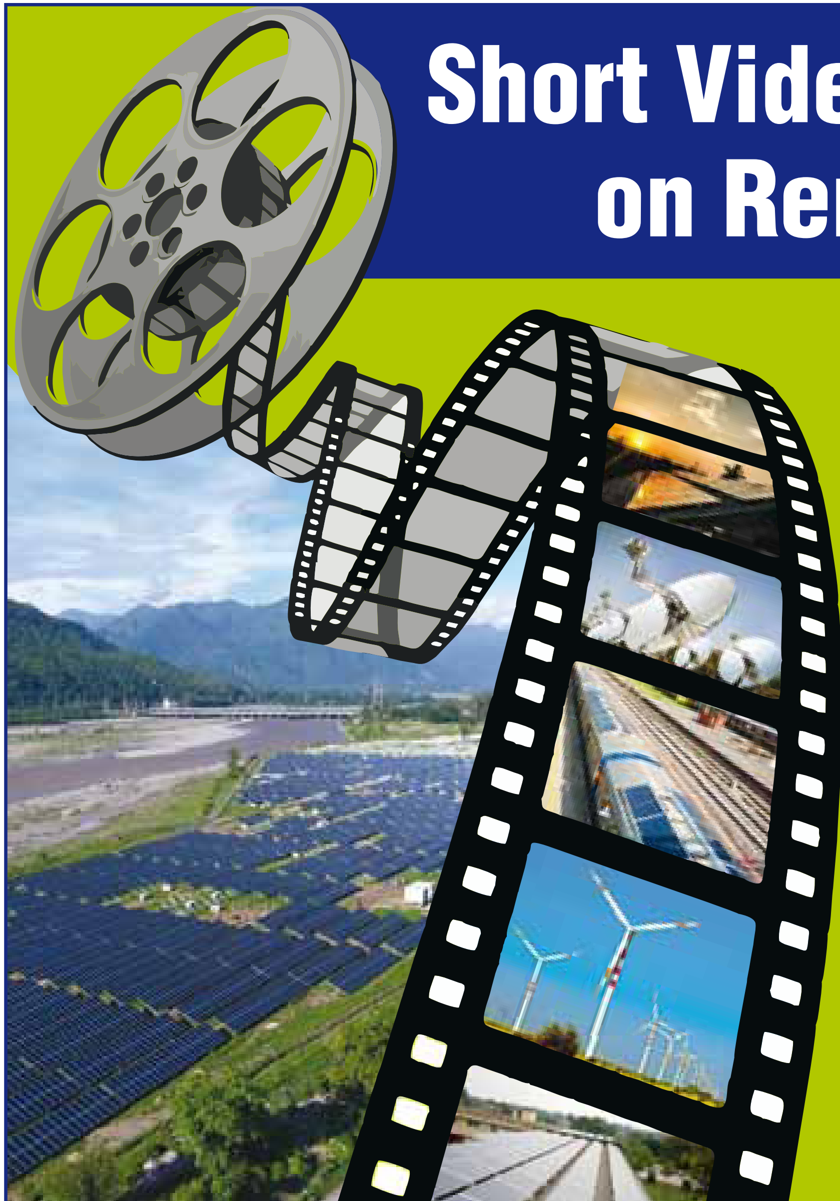
Gigawatts, cumulative installed capacity



Source: www.bp.com

RNI No. DELENG/2007/22701

Short Video Film Competition on Renewable Energy



Ministry of New and Renewable Energy, Government of India is organizing **Short Video Film Competition** (maximum 3 minute duration) on Renewable Energy. **The theme of the film is "Renewable Energy Powering India."** The competition will be for **two categories – one up to 18 years of age and the other between 18-30 years of age.** The film may be on any aspect of renewable energy including renewables in neighbourhood, far-flung places, islands, hills, plain areas for different applications of renewable energy. The film can be shot using smartphones, cameras or any other digital recorder. Animation films, mobile films and films of any other genre produced with telecast quality can participate in this contest. **The film (maximum 500 MB size) should be in MP4 format, HD quality and to be submitted directly through attachment or may share the link at vdofilmcompet.mnre@gov.in on or before 25th April 2019.**

There is no entry fee for participation in the competition. **The other details of the competition are available on MNRE's website www.mnre.gov.in.**