# Recapitulation of Renewable Energy Generation in India

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**ABSTRACT**

***R****enewable energy sources and technologies are the eco-friendly keys to the sustainable growth of a country. India has abundant supply of renewable resources. It has one of the leading programs in the world for deploying and developing renewable energy products and markets. An exclusive ministry, the Ministry of New and Renewable Energy (MNRE) launched as one of the world's largest and ambitious programs on renewable energy developments in the year 1992. Since then, the government designed policies/schemes for conducive environment to furnish foreign investments and ramp up the renewable energy market at a rapid rate. India has an estimated potential of 900 GW for electricity generation from renewable energy (RE). The goal set by the government for capacity addition from RE-based electricity generation is 175 GW by 2022. This paper is an attempt to provide an overview of India's renewable power sector at a glance. Efforts have been made to highlight the current status, major achievements, ongoing and future plans of renewable expansions in the country.*

***Keywords-*** *Sustainable development, renewable energy, solar energy, wind energy, bio-energy, hydropower, installed capacity*

## I. INTRODUCTION

Energy is the indispensible ingredient for the socio-economical development and a key aspect influencing the sustainable development of a nation.

The Indian economy has unprecedented economic growth over the last decade. The economy of India is the sixth largest in the world by nominal GDP (behind United States, China, Japan, Germany, United Kingdom) and the third-largest by purchasing power parity (PPP) behind China and United States, as per International Monetary Fund World Economic Outlook (IMF-WEO). India ranks at 9 as per the real GDP growth (%change) and reported a real GDP growth of to 7.04% in 2016-17. Despite having large coal reserves and overall growth in coal and natural gas production over the past two decades, India is increasingly dependent on import of fossil fuels, crude and petroleum oil. These conventional sources of energy have environmental impacts

such as Ozone depletion, Global warming and Acid rain. Also waste disposal is another problem associated with coal and nuclear plants. These factors drive to research the alternative sources of energies that can be implemented to meet the power demands as well have no adverse environment impacts. Renewable energy resources are regenerative in nature and present in abundance.

The energy crisis in 1970s led to the establishment of the many constitutional bodies world-wide that supports countries in their transition to a sustainable energy future. The International Energy Agency (IEA- 1973), Renewable Energy Policy Network for the 21st Century (REN21-2004), The UN Secretary General's Sustainable Energy for All (SE4ALL-2012), International Renewable Energy Agency (IRENA-2014),

India is the first country to establish a separate Commission for Additional Sources of Energy (CASE) in the Department of Science & Technology (India) in March 1981. The CASE was responsible for the formulation of policies and their implementation for developing new and renewable energy. In 1982, a new Department of Non-conventional Energy Sources (DNES) under the ministry of energy was constituted and incorporated CASE under its

umbrella. The ministry was established as the Ministry of Non-Conventional Energy Sources in 1992. It adopted its current name Ministry of New and Renewable Energy (MNRE) in October 2006.

The objective of this paper is to provide an overall scenario of renewable energy potentials in India. Section-2 outlines the Indian power sector. Renewable energy sources-Solar, Wind, Bio, Hydro, Geo-thermal and Ocean are discussed in detail with the perspective of current developments and opportunities in section-3. Section-4 concludes the future scope of renewable energy in India.

## II. INDIAN POWER SECTOR OVERVIEW

India is the world's second- largest producer, consumer and importer of thermal coal and third largest electricity user in the world behind only China and the U.S. [1].

India's electricity demand is anticipated to be twofold over the upcoming decade. Therefore, government is focusing on economic use of coal and strongly supporting green energy transition. The pie chart in Fig 1 shows the percentage share of various sources in overall installed generating capacity of India by the year 2017 [2][14]. India's total gross power capacity will more than double from 284 GW in 2015 to an estimated 670 GW by 2030 [3].

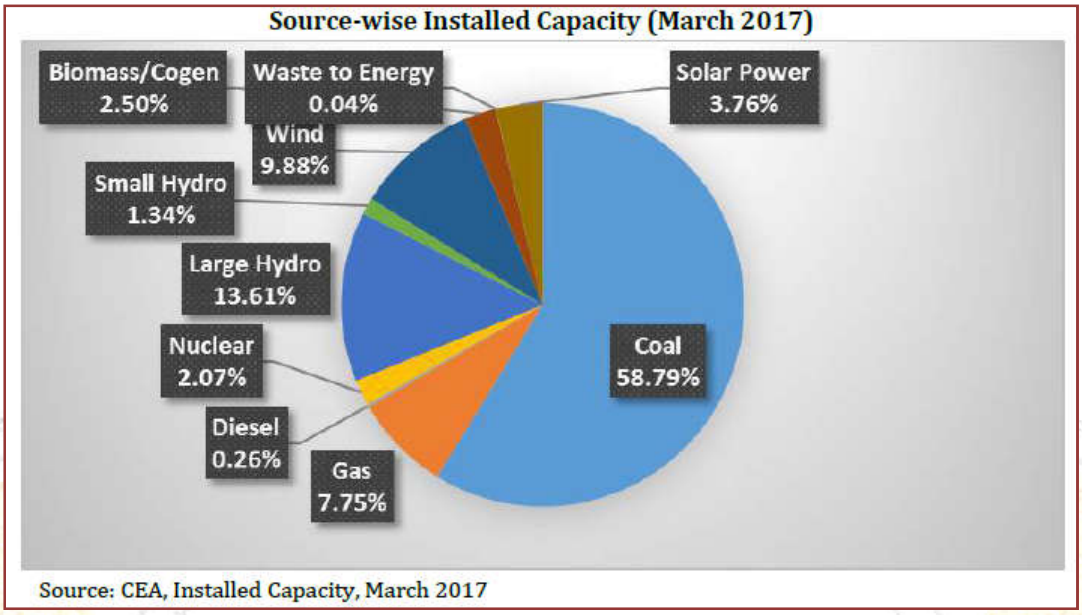


Figure 1: Source wise installed capacity (Current Status-March 2017)

Table 1shows the overall installed capacity till March 2017 is 326.832 GW from various sources [14].

Table 1: Source wise installed capacity as on March-2017

| Source | Total Thermal | | | Nuclear | Hydro | Small Hydro | Solar Power | Wind | Biomass/ Cogen | Waste to Energy | Total Renewable |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coal | Gas | Diesel | | | | | | | | |
| Installed Capacity (GW) | 192.16 | 25.33 | 0.84 | 6.78 | 44.478 | 4.379 | 12.288 | 32.28 | 8.1817 | 0.114 | 57.244 |
| | 218.33 | | | | | | | | | | |
| **Grand Total: 326.832 GW** | | | | | | | | | | | |

## III. PRESENT STATUS OF RES IN INDIA

India is at sixth position in the world in total installed renewable power generation capacity after China, the US, Germany, Spain and Italy. India could become the fourth largest renewable energy market worldwide by 2030. It could account for 9% of all global final renewable energy use, after China, the United States and the European Union [3-4].

The maximum addition in renewable capacity was observed in the year 2016-17 as shown in Fig. 2. It made a record in Indian history in which renewable capacity installs (15.7 GW, 2.5 times the 6.5 GW of renewable installs in the year 2015-16) exceeded net thermal power installs (7.7 GW, down 65% year on year).

IEEFA forecasts 14 GW of renewable capacity additions in 2017-18, a slight slowdown on 2016-17 but more than double the 5.8 GW of net thermal capacity additions [1].

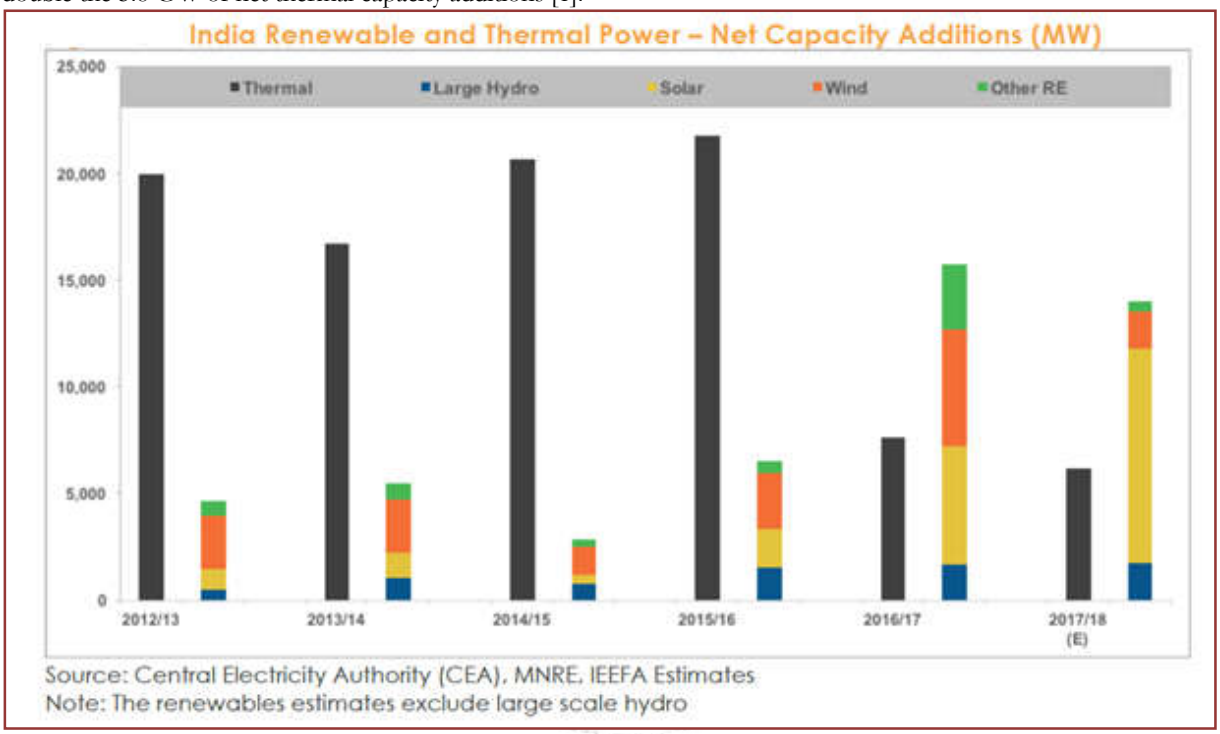


Figure 2: Year-wise capacity addition in MW

The cost of renewable is declining and will be the cheapest source with advancements in technologies in near future [5-6]. The potential for renewable across India in the 2017-2022 plan is highlighted in Table 2 as obtained from MNRE-wind energy mission rural electrification. It shows that India has a large scope for cumulative renewable installs to go up six-times.

Table 2: India's scope for RE addition

Indian Renewable Energy Capacity Potential (GW)

| Sources | 2022 Total (GW) | Potential | Potential (%) |
|---|---|---|---|
| Wind (onshore) | 60 | 103 | 10% |
| Solar | 100 | 749 | 73% |
| Small Hydro | 7 | 20 | 2% |
| Biomass | 11 | 23 | 2% |
| Wind (offshore) | 2 | 127 | 12% |
| **Grand Total** | **180** | **1,022** | **100%** |

**3.1 Solar energy**

Solar energy is the most profuse everlasting energy resource on earth and it is available for use in its direct form as solar radiations. Solar energy as heat is utilized for applications like cooking, drying, water purification, power generation, water heating and similar applications. Solar energy as light is converted into electricity via photovoltaic cell. Electricity generated by photovoltaic is utilized for many applications like lighting, pumping, communications, and power supply in inaccessible areas. Most parts of India receive 4 to7 kWh of solar radiation per square meter per day with 250–300 sunny days in a year with highest annual radiation in western Rajasthan [7]. The solar energy potential is equivalent to 6,000 million GWh annually [MNRE]. Former initiative under India's National Action Plan on Climate Change (NAPCC) had been taken in 2008 as Jawaharlal Nehru National Solar Mission (JNNSM) intended to establish India as a worldwide leader in solar energy in phase-wise manner. In 2015, the government revised the earlier target of the scheme from 20 GW to 100 GW by the year 2022. The scheme for "Development of Solar Parks and Ultra Mega Solar Power Projects"

was initiated by MNRE on 12/12/2014. It aimed to set up Solar Parks and Ultra Mega Solar Power Projects of capacity 20,000 MW within a span of 5 years from 2014-15 onwards. The capacity of the Scheme has been enhanced from 20 GW to 40 GW in the year 2017.

To develop Carbon Free Islands under National Action Plan on Climate Change and Greening for setting up of grid connected solar PV power projects in Andaman & Nicobar and Lakshadweep was launched in 2016[ Report renewable India, MNRE]. In September 2016, Adani Green Power commissioned the world's largest single site solar project of 648MW at Kamuthi, Tamil Nadu. Then in July 2017, India made the record of having world's biggest single-site solar plant of 1 GW commissioned in Kurnool in Andhra Pradesh [8-9].

**3.2 Wind energy**

Wind energy is turning out to be potential alternative energy technology of the future because of technology advancement and government incentive policies for green energy [10-11]. The wind energy sector emerged in India in the early 1980s following a detailed assessment of wind resources by the Indian Institute of Tropical Metrology in 1983[8]. The National Institute for Wind Energy's (NIWE) latest estimate

for India's wind power potential is 302 GW at 100 meters. Over the past three decades, the sector has steadily grown to achieve a cumulative capacity of 31.175 GW at the end of March-2017, making India the fourth-largest market globally [14]. Installation rates have ranged from 1.5-3.0 GW annually over the past decade, with a significant increase to 5.5 GW in 2016-17 [1].States with high Wind Power Density like Tamil Nadu(7,694.3 MW), Gujarat(4,441.5 MW), Karnataka(3,154.2 MW), Maharashtra(4,666.1 MW), Rajasthan(4,216.6 MW), and Andhra Pradesh(2,092.5 MW) take the lead with a cumulative installed capacity (28,700.4 MW) that accounts for more than 90 per cent of the total wind capacity in the country[12]. India's Offshore Wind Policy had been announced by MNRE in Oct. 2015. India's National Institute for Wind Energy (NIWE) is the nodal agency for implementing the policies for creating ecosystem in renewable wind sector. The first comprehensive assessment of offshore wind potential in two key coastal states is being undertaken by the FOWIND (Facilitating Offshore Wind in India) project [13]. It is a four-year project implemented by a GWEC (Global Wind Energy Council)-led consortium. European Union and Gujarat Power Corporation Limited are the co-financers for this project.

**3.3 Bio energy**

Bio-energy is one of the key energy assets for worldwide sustainable advancements as it is clean and abundant source of energy. Biomass is organic matter that includes all plants and plant derived materials, including agricultural crops and trees, wood and wood residues, grasses, plants, animal compost, community residues, and other residue materials. India is a country having vast biodiversity from the tiny microalgae to massive banyan trees. Bio-energy programs and policies were initiated in 1970 and got momentum in mid 1990s especially to strengthen energy availability in rural areas.

The Government of India (GOI) initiated a program of blending ethanol with petrol (Ethanol Blended Petrol Program-EBPP) in January 2003. In 2009 National Policy on Biofuels had been formulated by the MNRE in 2009 with the recommendation of the blending at least 20% bio-fuels with diesel and petrol by 2017. Another program launched by GOI under MNRE - National Biogas and Manure Management Programme (NBMMP) installed around 4.96 million household size biogas plants in the country by 2016-17[MNRE-website-report]. A National Bio-fuel Coordination Committee (NBCC) had been set up to provide high-level coordination of multiple departments and agencies for policy guidance/review on different aspects of bio-fuel development, promotion, and utilization.

Table shows the state wise share of bio-mass and waste to energy status as on 31/03/16 [14].

Table 3: Top five states in share of Bio-mass and waste to energy

| Bio-Power (MW) | State | | | | | All India Total |
|---|---|---|---|---|---|---|
| | Maharashtra | Karnataka | Uttar Pradesh | Tamil Nadu | Andhra Pradesh | |
| Bio-mass | 1220.78 | 872.18 | 870.00 | 641.90 | 380.75 | **4831.33** |
| Waste to energy | 12.72 | 1.00 | 5.00 | 8.05 | 58.16 | **115.08** |

**3.4 Hydro energy**

Hydro energy is the largest renewable energy resource being used for the generation of electricity. It has many advantages over other sources such as high efficiency and reliability, established technology, low costs and ability of adjusting load variations easily. The first hydropower plant in India was of capacity 130 kW and installed in Sidrapong (Darjeeling) in the year 1897. Since then at the end of 12$^{th}$ five-year plan, the total installed capacity currently reached to 44.478 GW [1] out of which small hydro accounts for 4.378 GW. Hydro projects are categorized as large hydro, small hydro (2 - 25 MW), mini hydro (100 kW - 2 MW) and micro-hydro (up to 100 kW) power projects. It has been recognized that small hydropower projects can play a vital part in enhancing the overall energy state of the country. The

Ministry's aim is to achieve the SHP installed capacity of about 7000 MW by the end of 12th Plan [MNRE]. The focus of the SHP programme is to lower the cost of equipment, increase its reliability and set up projects in areas which give the maximum advantage in terms of capacity utilization [Renewable energy scen]. The hilly States of India mainly Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand, and constitute around half of this potential. Other potential States are Maharashtra, Chhattisgarh, Karnataka and Kerala [MNRE site]. India stands at fifth in the world in terms of usable hydropower potential. Despite significant hydropower potential, till now, only 30% of India's total economically feasible hydropower potential has been harnessed [15].

**3.5 Geothermal energy**

Geothermal energy is the heat energy available within the earth that can be used directly for heating or transformed into electricity. In 2016, the global geothermal installed capacity was 12.7 GW; United States (2.5 GW), Philippines (1.9 GW) and Indonesia (1.5 GW) lead in installed geothermal power capacity. Global installed capacity additions in 2016 amounted to 901 megawatts (MW), the highest number in 10 years, which were installed in Kenya (518 MW), Turkey (197 MW) and Indonesia (95 MW) (IRENA, 2017a)[16]. According to the Geothermal Energy Association, the global geothermal industry is expected to reach about 18.4 GW by 2021 (GEA, 2016) and planned capacity addition in India is 98 MW [16-17].

The Geological Survey of India (GSI) has identified about 340 geothermal hot springs in the country. These springs are grouped into seven geothermal provinces, that is, the Himalayan (Puga, Chhumathang), Sohana belt in Haryana, Cambay Graben basin, Son-Narmada-Tapi (SONATA) lineament belt, West Coast, Godavari basin, and Mahanadi basin. Some of the prominent geothermal resources include the Puga valley and Chhumathang in Jammu and Kashmir, Manikaran in Himachal Pradesh, Ratnagiri in Maharashtra, and Tapovan in Uttarakhand. A new location of geothermal power energy has also been found in Tattapani in Chhattisgarh. In addition, Gujarat is set to tap geothermal electricity through resources which are available in Cambay between the rivers Narmada and Tapi. MNRE is targeting for the deployment of geothermal capacity of 1,000 MW in the initial phase till 2022.

**3.6 Ocean energy**

More than 70 percent of earth's surface is covered by ocean and represents an inexhaustible source of energy. Ocean energy is used in the form of tidal, wave, stream and Ocean thermal Energy. Currently, the United Kingdom (UK) and United States of America (USA) are at top in developing wave and tidal conversion technologies followed by Norway and Canada. Technologies in tidal and wave are still under nascent and pre-commercial phase. There are about four tidal power plants in operation with capacity varying from 1 MW to 254 MW. Four countries have utilized tidal barrage technology to harness tidal energy. These are Shiwa Lake Tidal plant-254 MW ( South Korea), La Rance Tidal power plant-240 MW (France), Annapolis Royal tidal plant- 20 MW ( Canada), The Jiangxia Tidal power station 3.2 MW( China)and The Kislaya Guba Tidal facility-0.4 MW (Russia)[18].

Ocean Energy Systems (OES) is the international technology collaboration programme on Ocean Energy Systems under the International Energy Agency (IEA) with 25 country members. Tidal current deployments have increased to over 17 MW in 2017. The major projects behind this development are MeyGen/Inner Sound Phase 1A in the UK, Paimpol-Bréhat in France and the LHD Tidal Current Energy Demonstration Project in China. Wave energy deployments have also doubled to 8 MW in 2017[18].

As per the report in [19], ocean energy potential in India assessed to 53 GW with a capacity utilization factor in the range of 15-20% for wave energy and 25%-30% for tidal energy. Theoretical Potential for tidal Energy in India is 12500 MW and ideal locations are Gulf of Khambhat & Gulf of Kutch (GJ), Sunderbans (WB),Western Ghats (MH). Most of the extractable potential of 41000 MW in wave energy exists on the western coastline of India along Maharashtra, Goa, Karnataka, Kerala, Kanyakumari and Southern tip. A systematic approach for identification of suitable site and technology for potential site for tidal energy conversion has been proposed in [20]. The total estimated power that could be harvested in the regions identified is about 11,555 MW, with the lowest capacity factor. the Indian Navy is investigating the feasibility of an OTEC plant in Andamans in the Bay of Bengal, with the technical support of National Institute of Ocean Technology (NIOT).

High capital cost (ranging from Rs. 30 crore to Rs. 60 crore per MW), Lack of experience, unpredictable environmental conditions and difficulty to assess environmental impacts are the major barriers in harnessing ocean energy [20].

Despite the inclusive policy and regulatory frameworks for the aspired quantum leap, the inadequacies in institutional mechanisms are hampering the progression of policy implementation. Many researchers are focusing on exploring the issues and challenges that have been impeding the process of clean energy consumption [21]. The pie chart in Fig. 3 represents the state-wise estimated potential of RE in India.

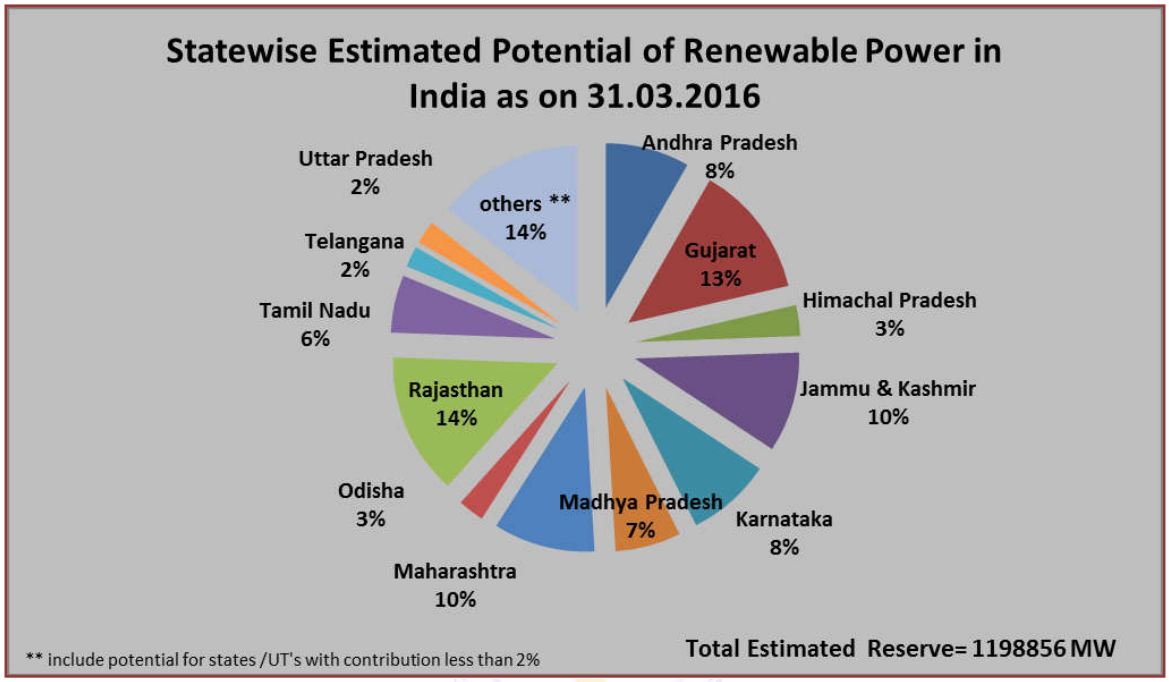


Figure 3: State-wise estimated potential of Renewable Energy.

## IV.CONCLUSIONS AND FUTURE SCOPE

India has abundance resources of Renewable Energy and harnessing these adequately with innovative technologies, government policies/ schemes and financial support. The year 2016-17 proved to be landmark in electricity sector transition. It is the first time this year that total clean energy capacity additions exceeded new thermal generation. It also made the record of low solar PV electricity tariff as compared to coal fired energy generation. Similar, rapid reduction in price of wind power has also been observed. India's target is to reduce GHG emission by 30-35% and increase renewable capacity to 40% by the year 2030. Growth in renewable like solar and wind has a vast prospect of rapid job creation. Few measures like improvement in enforcement of RE purchase, outreach to banks, land acquisition policies, incentives to energy project developers, and promoting energy storage and monitoring technologies for stable power systems are the need of the hour for further developments and keeping pace at international level.

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