# Review on Present Status and Future Potential of Renewable Energy in India

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*Abstract-* **The Sun has been worshiped as a life-giver to our planet since ancient times. The industrial ages gave us the understanding of sunlight as an energy source. India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar photovoltaics power can effectively be harnessed providing huge scalability in India. The primary objective for deploying renewable energy in India is to advance economic development, improve energy security, improve access to energy, and mitigate climate change. Sustainable development is possible by use of sustainable energy and by ensuring access to affordable, reliable, sustainable, and modern energy for citizens. Strong government support and the increasingly opportune economic situation have pushed India to be one of the top leaders in the world's most attractive renewable energy markets. Presently, most of India's energy demands are fulfilled by fossil fuels like coal, petroleum, natural gas, etc. Due to such high demand for fossil fuels, these fossil fuels will soon get depleted. India is increasingly adopting responsible renewable energy techniques and taking positive steps towards carbon emissions, cleaning the air and ensuring a more sustainable future. Recently, India achieved 5$^{th}$ global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March,2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.**

*Keywords:* **Renewable energy, Solar energy, Energy**

## Introduction

The sources of electricity production such as coal, oil, and natural gas have contributed to one-third of global greenhouse gas emissions. It is essential to raise the standard of living by providing cleaner and more reliable electricity. India has an increasing energy demand to fulfil the economic development plans that are being implemented. The provision of increasing quanta of energy is a vital pre-requisite for the economic growth of a country. The National Electricity Plan (NEP) framed by the Ministry of Power (MoP) has developed a 10-year detailed action plan with the objective to provide electricity across the country, and has prepared a further plan to ensure that power is supplied to the citizens efficiently and at a reasonable cost. According to the World Resource Institute Report 2017, India is responsible for nearly 6.65% of total global carbon emissions, ranked fourth next to China (26.83%), the USA (14.36%), and the EU (9.66%). Climate change might also change the ecological balance in the world. Intended Nationally Determined Contributions (INDCs) have been submitted to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. The latter has hoped to achieve the goal of limiting the rise in global temperature to well below 2 °C. According to a World Energy Council prediction, global electricity demand will peak in 2030. India is one of the largest coal consumers in the world and imports costly fossil fuel. Close to 74% of the energy demand is supplied by coal and oil. According to a report from the Centre for monitoring Indian economy, the country imported 171 million tons of coal in 2013–2014, 215 million tons in 2014–2015, 207 million tons in 2015–2016, 195 million tons in 2016–2017, and 213 million tons in 2017–2018. Therefore, there is an urgent need to find alternate sources for generating electricity. Awareness of saving energy has been promoted among citizens to increase the use of solar, wind, biomass, waste, and hydropower energies. It is evident that clean energy is less harmful and often cheaper. Recent estimates show that in 2047, solar potential will be more than 750 GW and wind potential will be 410 GW. A mixture of push policies and pull mechanisms, accompanied by particular strategies should promote the development of renewable energy technologies. The Indian Government has been at work, making a comprehensive policy for compulsory use of renewable energy resources through biomass, hydropower, wind, solar and municipal waste in the country, particularly for commercial establishments, as well as Government establishments. The financial allocation for renewable energy sources vis-a` - vis total allocation, however, remains in the range of 0.1% during Tenth Plan period. The Indian government has also set specific targets for renewable energy by 2012 it expects renewable energy to contribute 10% of total power generation capacity and have a 4–5% share in the electricity mix. This implies that growth in renewable energy will occur at a much faster pace than traditional power generation, with renewables making up 20% of the 70,000MW of total additional energy planned from 2008 to 2012. From 2002 to 2007, there was 3075MW of renewable grid-tied power planned, but the actual capacity addition exceeded 6000MW by 2006. A large share of this was the result of exceptional growth of wind energy in India. Wind energy is expected to add more than 10,000MW of additional capacity by 2012, followed by small hydro (1400 MW), cogeneration (1200 MW) and biomass (500 MW). Ministry of Nonconventional Energy Sources is focused on nation-wide resource assessment, setting up of commercial projects, renovation and modernization, development and up-gradation of water mills and industry-based research and development. The Ministry of New and Renewable Energy has identified renewable energy R&D as an important factor for developing this sector. R&D subsidy is 100% of a project's cost in government R&D institutions, and 50% in the private sector. The R&D subsidy for the

private sector may be enhanced for initial stages of technologies that have longer time-horizons. Renewable sources already contribute to about 5% of the total power generating capacity in the country. During the last two decades, several renewable energy technologies have been deployed in rural and urban areas. Some of the achievements are given in Table 1 along with the estimated potential. In 2016, India's overall energy consumption was 724 million tons of oil equivalent (Mtoe) and is expected to rise to 1921 Mtoe by 2040 with an average growth rate of 4.2% per annum. Energy consumption of various major countries comprises commercially traded fuels and modern renewables used to produce power. In 2016, India was the fourth largest energy consumer in the world after China, the USA, and the Organization for economic co-operation and development (OECD) in Europe. The projected estimation of global energy consumption demonstrates that energy consumption in India is continuously increasing and retains its position even in 2035/ 2040. The increase in India's energy consumption will push the country's share of global energy demand to 11% by 2040 from 5% in 2016. Emerging economies such as China, India, or Brazil have experienced a process of rapid industrialization, have increased their share in the global economy, and are exporting enormous volumes of manufactured products to developed countries. This shift of economic activities among nations has also had consequences concerning the country's energy use.

**Material and Method**

As it is a revive various books, research papers, Govt. publications, Websites etc. are used for comparative study.

**Discussion**

**How renewable energy sources contribute to the energy demand in India**

Energy is a basic requirement for economic development and in every sector of Indian economy. It is thus necessary that India quickly look towards new and emerging renewable energy and energy efficient technologies as well as implement energy conservation laws. Against this background, the country urgently needs to develop a sustainable path of energy development. Promotion of energy conservation and increased use of renewable energy sources are the twin planks of a sustainable energy supply. Fortunately, India is blessed with a variety of renewable energy sources, like biomass, the solar, wind, geothermal and small hydropower and implementing one of the world's largest programs in renewable energy. India is determined to becoming one of the world's leading clean energy producers. The Government of India has already made several provisions, and established many agencies that will help it to achieve its goal. Renewable energy, excluding large hydro projects already account for 9% of the total installed energy capacity, equivalent to 12,610MWof energy. In combination with large hydro, the capacity is more than 34%, i.e., 48,643 MW, in a total installed capacity of 144,980 MW. Fig. 4 is showing installed power capacity (MW) in India. The country has an estimated renewable energy potential of around 85,000MW from commercially exploitable sources, i.e., wind, 45,000 MW; small hydro, 15,000MW and biomass/bioenergy, 25,000 MW. In addition, India has the potential to generate 35MW per square kilometer using solar photovoltaic and solar thermal energy. By March 2007, renewable electricity, excluding hydro above 25MW installed capacity, has contributed 10,243MWrepresenting 7.7% of total electricity installed capacity. There has been phenomenal progress in wind power and, with an installed capacity of over 8757 MW, India occupies the fifth position globally (REN21, Renewables 2009; Varuna SK, Singal.2007; Planning Commission, Govt. of India). According to the 11th new and renewable energy five-year plan proposed by the government of India, from 2008 to 2012 the renewable energy market in India will reach an estimated US $19 billion. Investments of US $15 billion will be required in order to add the approximately 15,000 megawatts (MW) of renewable energy to the present installed capacity. The Indian government has also set specific targets for renewable energy by 2012 it expects renewable energy to contribute 10% of total power generation capacity and have a 4–5% share in the electricity mix. This implies that growth in renewable energy will occur at a much faster pace than traditional power generation, with renewables making up 20% of the 70,000MW of total additional energy planned from 2008 to 2012. From 2002 to 2007, there was 3075MW of renewable grid-tied power planned, but the actual capacity addition exceeded 6000MW by 2006. A large share of this was the result of exceptional growth of wind energy in India. Wind energy is expected to add more than 10,000MW of additional capacity by 2012, followed by small hydro (1400 MW), cogeneration (1200 MW) and biomass (500 MW). Ministry of Nonconventional Energy Sources is focused on nation-wide resource assessment, setting up of commercial projects, renovation and modernization, development and up-gradation of water mills and industry-based research and development. The Ministry of New and Renewable Energy has identified renewable energy R&D as an important factor for developing this sector. R&D subsidy is 100% of a project's cost in government R&D institutions, and 50% in the private sector. The R&D subsidy for the private sector may be enhanced for initial stages of technologies that have longer time-horizons. Renewable sources already contribute to about 5% of the total power generating capacity in the country. During the last two decades, several renewable energy technologies have been deployed in rural and urban areas. Some of the achievements are given in Table 1 along with the estimated potential (Urja Akshay 2008).

**Table 1. Renewable energy in India at a glance**

| Sl. no. | Source/system | Estimated potential | Achievements (as on 30 September 2008) |
|---|---|---|---|
| I | A power from renewables | | |
| A. | Grid interactive renewable power | (MW) | (MW) |
| 1. | Wind power | 45,195 | 9521.80 |
| 2. | Biopower (agroresidues and plantations) | 16,881 | 656.60 |
| 3. | Bagasse cogeneration | 5000 | 993.83 |
| 4. | Small hydro (up to 25 MW) | 15,000 | 2220.99 |
| 5. | Energy recovery from waste (MW) | 2700 | 55.25 |
| 6. | Solar photovoltaic power | – | 2.12 MW |
| | Sub total (A) | **84.776** | **13,450.59** |
| B. | Captive/combined heat and power/distributed renewable power | | |
| 7. | Biomass/cogeneration (non-baggase) | – | 136.70 |
| 8. | Biomass gasifiers | – | 102.21 |
| 9. | Energy recovery from waste | – | 31.07 |
| | Sub total (B) | – | **269.98** |
| | Total (A+B) | **84.776** | **13,720.57** |
| II | Remote village electrification | | **5379 villages/hamlets** |
| III | Decentralized energy systems | | |
| 10. | Family-type biogas plants | 120 lakh | 40.32 lakh |
| 11. | Solar photovoltaic systems | 50 MW/km$^2$ | 120 MWp |
| | i. Solar street lighting systems | – | 70,474 nos. |
| | ii. Home lighting systems | – | 434,692 nos. |
| | iii. Solar lanterns | – | 697,419 nos. |
| | iv. Solar power plant | – | 8.01 MWp |
| | v. Solar photovoltaic pumps | – | 7148 nos. |
| 12. | Solar thermal systems | | 4,78,058 nos. |
| | i. Solar water heating systems | 140 million m$^2$ of collector area | 2.45 million m$^2$ of collector area |
| | ii. Solar cookers | – | 6.37 lakhs |
| 13. | Wind pumps | – | 1342 nos. |
| 14. | Aero generators/hybrid systems | | 723.00 kW |
| IV | Awareness programs | | |
| 15. | Energy parks | – | 516 nos. |
| 16. | Aditya Solar Shops | – | 269 nos. |
| 17. | Renewable Energy Clubs | – | 521 nos. |
| 18. | Distric Advisory Committees | – | 560 nos. |

MW = mega-watt; m$^2$ = square meter; km$^2$ = kilowatt; MWp = mega watt peak

MNRE (www.mnre.gov.in).

**Biomass**

India is very rich in biomass and has a potential of 16,881MW (agro-residues and plantations), 5000MW (bagasse cogeneration) and 2700MW (energy recovery from waste) (Subramanian V 2007). Biomass power generation in India is an industry that attracts investments of over Rs. 600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas.

**Hydropower**

In India, hydropower projects with a station capacity of up to 25 megawatts (MW) fall under the category of small hydropower (SHP). India has an estimated SHP potential of about 15,000 MW, of which about 11% has been tapped so far. The Ministry of New and Renewable Energy (MNRE) supports SHP project development throughout the country. So far, 523 SHP projects with an aggregate installed capacity of 1705MW have been installed. Besides these, 205 SHP projects with an aggregate capacity of 479MW are under implementation. With a capacity addition, on an average, of 100MW per year and gradual decrease in gestation periods and capital costs, the SHP sector is becoming increasingly competitive with other alternatives.

**Wind energy**

The availability of wind varies for different regions. Wind resources can be exploited mainly in areas where wind power density is at least 400 W/m2 at 30 m above the ground. The Wind Resource Assessment Program is being implemented by C-WET (Centre for Wind Energy Technology) in coordination with state nodal agencies. An annual mean wind power density greater than 200 W/m2 (watts per square meter) at 50-m height has been recorded at 211 wind monitoring stations, covering 13 states and union territories, namely Andaman and Nicobar Islands, Andhra Pradesh, Gujarat, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttaranchal, and West Bengal. India's wind power potential has been assessed at 45,000 MW. A capacity of 8757MWup to 31 March 2008 has so far been added through wind (REN21, Renewables 2009). India is surpassed only by Germany as one of the world's fastest growing markets for wind energy. By the mid-1990s, the subcontinent was installing more wind generating capacity than North America, Denmark, Britain, and the Netherlands. The ten machines near Okha in the province of Gujarat were some of the first wind turbines installed in India. These 15-m Vestas wind turbines overlook the Arabian Sea. Now, in 2008, there is an installed capacity of 5310 MW; however, ten times that potential, or 45,000 MW, exists. Different types of Wind Power Generators used in India for Off grip Power generation, i.e., water-pumping windmills, aero-generators (a small wind electric generator having a capacity of up to 30 kW) and wind–solar hybrid systems [Urja Akshay 2007-8).

**Solar energy**

The total annual solar radiation falling on the earth is more than 7500 times the world's total annual primary energy consumption of 450 EJ. The annual solar radiation reaching the earth's surface, approximately 3,400,000 EJ, is an order of magnitude greater than all the estimated (discovered and undiscovered) non-renewable energy resources, including fossil fuels and nuclear. However, 80% of the present worldwide energy use is based on fossil fuels. Most parts of India receive 4–7 kWh of solar radiation per square

meter per day with 250–300 sunny days in a year. The highest annual radiation energy is received in Western Rajasthan while the North- Eastern region of the country receives the lowest annual radiation India has a good level of solar radiation, receiving the solar energy equivalent of more than 5000 trillion kWh/yr. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m2, with the hours of sunshine ranging from 2300 to 3200 per year.

**Geothermal energy**

Biofuel program in the country is at nascent stage. The policy measures currently in place include an excise tax reduction for E-5, the obligation to blend all petrol with 5% ethanol in certain regions since January 2003 and government regulation of the ethanol selling price on the basis of ethanol production costs. Subsequently the percentage of ethanol mixture in petrol is planned to be increase to 10%. A new biofuel policy for the country is under construction.

**Estimated renewable energy potential in India**

The estimated potential of wind power in the country during 1995 (BSK Naidu 1996) was found to be 20,000 MW (20 GW), solar energy was 5 × 1015 kWh/pa, bioenergy was 17,000 MW, bagasse cogeneration was 8000 MW, and small hydropower was 10,000 MW. For 2006, the renewable potential was estimated as 85,000 MW with wind 4500 MW, solar 35 MW, biomass/bioenergy 25,000 MW, and small hydropower of 15,000 MW (Ashwani Kumar et al 2010). According to the annual report of the Ministry of New and Renewable Energy (MNRE) for 2017–2018, the estimated potential of wind power was 302.251 GW (at 100-m mast height), of small hydropower 19.749 GW, biomass power 17.536 GW, bagasse cogeneration 5 GW, waste to energy (WTE) 2.554 GW, and solar 748.990 GW. The estimated total renewable potential amounted to 1096.080 GW [39] assuming 3% wasteland, which is shown in Table 2.

Table 2. The estimated renewable potential in India

| State-wise Renewable Energy Potential (in MW) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sl. No. | States/UTs | Wind power (MW) | Small hydro power | Bio-energy | | | Solar | Total |
| | | | | Biomass power | Bagasse cogeneration | Waste to energy | | |
| 1 | Andhra Pradesh | 44.229 | 0.978 | 0.578 | 0.3 | 0.123 | 38.44 | 84.648 |
| 2 | Arunachal Pradesh | 0 | 1.341 | 0.008 | 0 | 0 | 8.65 | 9.999 |
| 3 | Assam | 0 | 0.239 | 0.212 | 0 | 0.008 | 13.76 | 14.219 |
| 4 | Bihar | 0 | 0.223 | 0.619 | 0.3 | 0.073 | 11.2 | 12.415 |
| 5 | Chhattisgarh | 0.077 | 1.107 | 0.236 | 0 | 0.024 | 18.27 | 19.714 |
| 6 | Goa | 0.001 | 0.007 | 0.026 | 0 | 0 | 0.88 | 0.914 |
| 7 | Gujarat | 84.431 | 0.202 | 1.221 | 0.35 | 0.112 | 35.77 | 122.086 |
| 8 | Haryana | 0 | 0.11 | 1.333 | 0.35 | 0.024 | 4.56 | 6.377 |
| 9 | Himachal Pradesh | 0 | 2.398 | 0.142 | 0 | 0.002 | 33.84 | 36.382 |
| 10 | Jammu & Kashmir | 0 | 1.431 | 0.043 | 0 | 0 | 111.05 | 112.524 |
| 11 | Jharkhand | 0 | 0.209 | 0.09 | 0 | 0.01 | 18.18 | 18.489 |
| 12 | Karnataka | 55.857 | 4.141 | 1.131 | 0.45 | 0 | 24.7 | 86.279 |
| 13 | Kerala | 1.7 | 0.704 | 1.044 | 0 | 0.036 | 6.11 | 9.594 |
| 14 | Madhya Pradesh | 10.484 | 0.82 | 1.364 | 0 | 0.078 | 61.66 | 74.406 |
| 15 | Maharashtra | 45.394 | 0.794 | 1.887 | 1.25 | 0.287 | 64.32 | 113.932 |
| 16 | Manipur | 0 | 0.109 | 0.013 | 0 | 0.002 | 10.63 | 10.754 |
| 17 | Meghalaya | 0 | 0.23 | 0.011 | 0 | 0.002 | 5.86 | 6.103 |
| 18 | Mizoram | 0 | 0.169 | 0.001 | 0 | 0.002 | 9.09 | 9.262 |
| 19 | Nagaland | 0 | 0.197 | 0.01 | 0 | 0 | 7.29 | 7.497 |
| 20 | Odisha | 3.093 | 0.295 | 0.246 | 0 | 0.022 | 25.78 | 29.436 |
| 21 | Punjab | 0 | 0.441 | 3.172 | 0.3 | 0.045 | 2.81 | 6.768 |
| 22 | Rajasthan | 18.77 | 0.057 | 1.039 | 0 | 0.062 | 142.31 | 162.238 |
| 23 | Sikkim | 0 | 0.267 | 0.002 | 0 | 0 | 4.94 | 5.209 |
| 24 | Tamil Nadu | 33.8 | 0.66 | 1.07 | 0.45 | 0.151 | 17.67 | 53.801 |
| 25 | Telangana | 4.244 | 0 | 0 | 0 | 0 | 20.41 | 24.654 |
| 26 | Tripura | 0 | 0.047 | 0.003 | 0 | 0.002 | 2.08 | 2.132 |
| 27 | Uttar Pradesh | 0 | 0.461 | 1.617 | 1.25 | 0.176 | 22.83 | 26.334 |
| 28 | Uttarakhand | 0 | 1.708 | 0.024 | 0 | 0.005 | 16.8 | 18.537 |
| 29 | West Bengal | 0.002 | 0.396 | 0.396 | 0 | 0.148 | 6.26 | 7.202 |
| 30 | Andaman & Nicobar | 0.008 | 0.008 | 0 | 0 | 0 | 0 | 0.016 |
| 31 | Chandigarh | 0 | 0 | 0 | 0 | 0.006 | 0 | 0.006 |
| 32 | Dadra & Nagar Haveli | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | Daman & Diu | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | Delhi | 0 | 0 | 0 | 0 | 0.131 | 2.05 | 2.181 |
| 35 | Lakshadweep | 0.008 | 0 | 0 | 0 | 0 | 0 | 0.008 |
| 36 | Puducherry | 0.153 | 0 | 0 | 0 | 0.003 | 0 | 0.156 |
| 37 | Others | 0 | 0 | 0 | 0 | 1.022 | 0.79 | 1.812 |
| | Total | 302.251 | 19.749 | 17.536 | 5 | 2.554 | 748.99 | 1096.08 |

(***Source:*** **Ministry of New and Renewable Energy (2017)**

**Current achievements in renewable energy 2017– 2018**

1. India doubled its renewable power capacity in the last 4 years. The cumulative renewable power capacity in 2013–2014 reached 35,500 MW and rose to 70,000 MW in 2017–2018.
2. India stands in the fourth and sixth position regarding the cumulative installed capacity in the wind and solar sector, respectively. Furthermore, its cumulative installed renewable capacity stands in fifth position globally as of the 31st of December 2018.
3. As said above, the cumulative renewable energy capacity target for 2022 is given as 175 GW. For 2017 2018, the cumulative installed capacity amounted to 70 GW, the capacity under implementation is 15 GW and the tendered capacity was 25 GW. The target, the installed capacity, the capacity under implementation, and the tendered capacity are shown in Fig. 1.

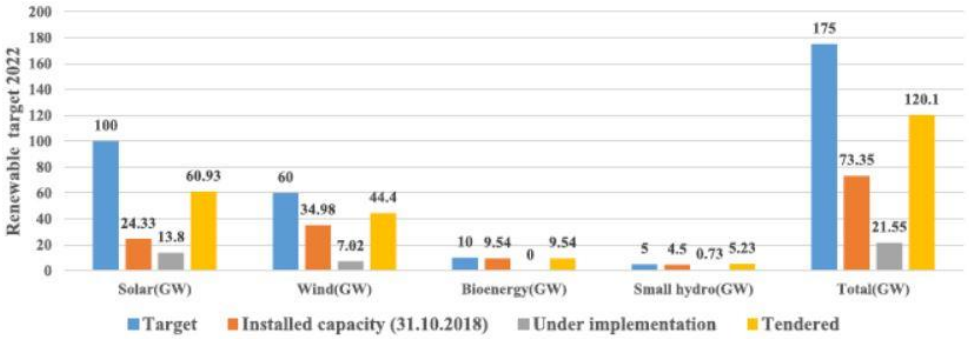


**Fig. 1** Renewable energy target, installed capacity, under implementation and tendered (*Source:* Initiatives and achievements, MNRE (2018).)

4. There is tremendous growth in solar power. The cumulative installed solar capacity increased by more than eight times in the last 4 years from 2.630 GW (2013– 2014) to 22 GW (2017–2018). As of the 31st of December 2018, the installed capacity amounted to 25.2122 GW.
5. The renewable electricity generated in 2017–2018 was 101839 BUs. 6. The country published competitive bidding guidelines for the production of renewable power. It also discovered the lowest tariff and transparent bidding method and resulted in a notable decrease in per unit cost of renewable energy.
7. In 21 states, there are 41 solar parks with a cumulative capacity of more than 26,144 MW that have already been approved by the MNRE. The Kurnool solar park was set up with 1000 MW; and with 2000 MW the largest solar park of Pavagada (Karnataka) is currently under installation.
8. The target for solar power (ground mounted) for 2018–2019 is given as 10 GW, and solar power (Rooftop) as 1 GW.
9. MNRE doubled the target for solar parks (projects of 500 MW or more) from 20 to 40 GW.
10. The cumulative installed capacity of wind power increased by 1.6 times in the last 4 years. In 2013–2014, it amounted to 21 GW, from 2017 to 2018 it amounted to 34 GW, and as of 31st of December 2018, it reached 35.138 GW. This shows that achievements were completed in wind power use.
11. An offshore wind policy was announced. Thirty-four companies (most significant global and domestic wind power players) competed in the "expression of interest" (EoI) floated on the plan to set up India's first mega offshore wind farm with a capacity of 1 GW.
12. 682 MW small hydropower projects were installed during the last 4 years along with 600 watermills (mechanical applications) and 132 projects still under development.
13. MNRE is implementing green energy corridors to expand the transmission system. 9400 km of green energy corridors are completed or under implementation. The cost spent on it was INR 10141 crore (101,410 Million INR = 1425.01 USD). Furthermore, the total capacity of 19,000 MVA substations is now planned to be complete by March 2020.
14. MNRE is setting up solar pumps (off-grid application), where 90% of pumps have been set up as of today and between 2014–2015 and 2017–2018. Solar street lights were more than doubled. Solar home lighting systems have been improved by around 1.5 times. More than 2,575,000 solar lamps have been distributed to students. The details are illustrated in Fig. 2.

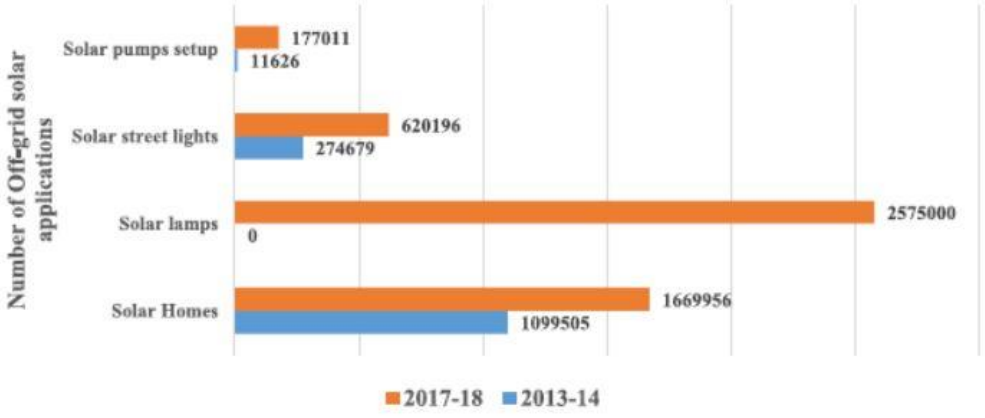


**Fig. 2** Off-grid solar applications (*Source:* Initiatives and achievements, MNRE (2018).)

15. From 2014–2015 to 2017–2018, more than 2.5 lakh (0.25 million) biogas plants were set up for cooking in rural homes to enable families by providing them access to clean fuel.
16. New policy initiatives revised the tariff policy mandating purchase and generation obligations (RPO and RGO). Four wind and solar inter-state transmission were waived; charges were planned, the RPO trajectory for 2022 and renewable energy policy was finalized.
17. Expressions of interest (EoI) were invited for installing solar photovoltaic manufacturing capacities associated with the guaranteed off-take of 20 GW. EoI indicated 10 GW floating solar energy plants.

18. Policy for the solar-wind hybrid was announced. Tender for setting up 2 GW solar-wind hybrid systems in existing projects was invited.
19. To facilitate R&D in renewable power technology, a national lab policy on testing, standardization, and certification was announced by the MNRE.
20. The Surya Mitra program was conducted to train college graduates in the installation, commissioning, operations, and management of solar panels. The International Solar Alliance (ISA) headquarters in India (Gurgaon) will be a new commencement for solar energy improvement in India.
21. The renewable sector has become considerably more attractive for foreign and domestic investors, and the country expects to attract up to USD 80 billion in the next 4 years from 2018–2019 to 2021–2022.
22. The solar power capacity expanded by more than eight times from 2.63 GW in 2013–2014 to 22 GW in 2017–2018.
23. A bidding for 115 GW renewable energy projects up to March 2020 was announced.

**Current energy policies**

The ultimate objective of the renewable energy policy framework is to significantly increase the share of renewable energy source in India's energy mix (Maithani PC 2008). These energy policies are set by government.

**1. National Electricity Policy, 2005**

The National Electricity Policy aims at achieving the following objectives; access to electricity, availability of power demand (to be fully met by 2012), energy and peaking shortages to be overcome and spinning reserve to be available, supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates, per capita availability of electricity to be increased to over 1000 units by 2012, financial turn around and commercial viability of electricity sector and protection of consumers' interests.

**2. The Electricity Act 2003**

The Electricity Act contains the following provisions pertaining to non-conventional energy sources. Under Sections 3(1) and 3(2), it has been stated that the Central Government shall, from time to time, prepare and publish the National Electricity Policy and Tariff Policy, in consultation with the state governments and authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or material, hydro and renewable sources of energy. Section 4 states that the Central Government shall, after consultation with the state governments, prepare and notify a national policy, permitting stand-alone systems for rural areas. Section 61, 61(h) and 61(i) state that the appropriate commission shall, subject to the provision of this Act, specify the terms and conditions for the determination of tariff, and in doing so, shall be guided by the following, namely, the promotion, cogeneration and generation of electricity from renewable sources of energy; and the National Electricity Policy and Tariff Policy. Section 86(1) and 86(1)(e) state that the state commissions shall discharge the following functions, namely, promote cogeneration and generation of electricity from renewable sources of energy by providing, suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution license.

**3. Tariff Policy, 2006**

The Tariff Policy announced in January 2006 has the following provisions:
1. Pursuant to provisions of section 86 (1) (e) of the Act, the Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs.
2. It will take some time before non-conventional technologies can compete with conventional sources in terms of cost of electricity. Therefore, procurement by distribution companies shall be done at preferential tariffs determined by the Appropriate Commission.
3. Such procurement by Distribution Licensees for future requirements shall be done, as far as possible, through competitive bidding process under Section 63 of the Act within suppliers offering energy from same type of nonconventional sources.
4. The Central Commission should lay down guidelines within three months for pricing non-firm power, especially from nonconventional sources, to be followed in cases where such procurement is not through competitive bidding.

**4. National Rural Electrification Policies, 2006**

1. Goals include provision of access to electricity to all households by the year 2009, quality and reliable power supply at reasonable rates, and minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
2. For villages/habitations where grid connectivity would not be feasible or not cost effective, off-grid solutions based on standalone systems may be taken up for supply of electricity.
3. State government should, within 6 months, prepare and notify a rural electrification plan, which should map and detail the electrification delivery mechanism.
4. The Gram Panchayat shall certify and confirm the electrified status of the village as on 31st March each year.

**5. Integrated Energy Policy Report (Planning Commission) 2006**

Suggest a path to meet energy needs of the country in an integrated manner up to 2031–2032. It recommended special focus on renewable energy development.

**Initiatives and steps for delivery and outreach**

**1. District Advisory Committees (DACs)**

These Committees have led to the creation of an effective renewable energy promotion network at the grass-root level that will also help in integration of renewable energy schemes with those of other development departments. To date, 550 DACs have been setup in 550 districts of the country.

**2. Akshay Urja Shops (renewable energy shops)**

Akshay Urja Shops were launched to cover all districts of the country to ensure easy availability of such systems/devices. It is expected that the common man will embrace renewable energy technologies in a big way for augmenting energy needs of cooking, lighting and motive power from these shops.

**3. Energy parks**

With a view to integrating the activities of State and District Levels Energy Parks was set up at the national level.

**4. Rajiv Gandhi Akshay Urja Diwas (Rajiv Gandhi Renewable Energy Day)**

The birth anniversary of former Prime Minister, late Sh. Rajiv Gandhi on 20th August 2006 was observed as 'Rajiv Gandhi Akshay Urja Diwas' all over the country is organize to increase awareness on a mass-scale at National, State and District levels.

**5. Akshay Urja Newsletter (Renewable Energy Newsletter)**

A bi-monthly newsletter titled 'Akshay Urja' was started with a focus on national/international renewable energy developments, technological developments, manufacturer's details, renewable energy education, etc.

**6. Renewable Energy Clubs**

A scheme has been evolved to promote the study of renewable energy through the setting up of RE Clubs in AICTE recognized/ approved Engineering Colleges/Technology Institutions all over the country to educate and sensitize young and future scientists on various aspects of new and renewable energy.

**Future of renewable energy in India**

India, faced with twin challenges on energy and environmental front, has no option but to work towards increasing the role of renewable in the future energy systems. Renewable energy technologies vary widely in their technological maturity and commercial status. In India, renewable energy is at the take-off stage and businesses, industry, government and customers have a large number of issues to address before these technologies could make a real penetration. India with large renewable energy resources (solar PV, wind, solar heating, small hydro and biomass) is to set to have large-scale development and deployment of renewable energy projects (Maithani PC 2008). The aim of meeting 10% of the country power supply through renewable by 2012 and also ambitious plans for the distribution of biogas plants, solar PV applications and solar city appears to be within reach. Moreover, introduction of tradable renewable energy certificates (REC) could overcome the existing gap that is hindering the application of quota for renewables and thereby creates a vibrant market. India would also have to look for international cooperation in renewable energy through well-defined R&D projects with proper division of labour and responsibilities for specific tasks with equitable financial burden and credit sharing arrangements.

Renewable energy development is considered in India to be of great importance from the point of view of long-term energy supply security, environmental benefits and climate change mitigation. The Integrated Energy Policy report has recognized the need to maximally develop domestic supply options as well as the need to diversify energy sources. The Committee has placed emphasis on higher use of renewables in all forms of services. It is expected that the contribution from renewables in power generation alone can be of the extent of 60,000MW in the year 2031–2032. By 2031–2032 renewables will be the key driver in social inclusion of the poor in the development process. A modest assessment of investments in the renewable energy sector will be about Rs. 300,000 crores over the next 25 years. MNRE has included in its mission: energy security; increase in the share of clean power; energy availability and access; energy affordability; and energy equity (Chaturvedi P, Garg HP. 2008). A number of government and private organizations such as MNRE, Centre for Wind Energy Technology, Universities, IITs, NITs, Indian Oil Corporation Ltd. (IOCL) and The Energy Resource Institute (TERI) are involved in R&D of renewable energy sources.

**Conclusion**

The renewable sector suffers notable obstacles. Some of them are inherent in every renewable technology; others are the outcome of a skewed regulative structure and marketplace. The absence of comprehensive policies and regulation frameworks prevent the adoption of renewable technologies. The renewable energy market requires explicit policies and legal procedures to enhance the attention of investors. There is a delay in the authorization of private sector projects because of a lack of clear policies. The country should take measures to attract private investors. Inadequate technology and the absence of infrastructure required to establish renewable technologies should be overcome by R&D. The government should allow more funds to support research and innovation activities in this sector. There are insufficiently competent personnel to train, demonstrate, maintain, and operate renewable energy structures and therefore, the institutions should be proactive in preparing the workforce. Imported equipment is costly compared to that of locally; therefore, generation of renewable energy becomes expensive and even unaffordable. Hence, to decrease the cost of renewable products, the country should become involve in the manufacturing of renewable products. Another significant infrastructural obstacle to the development of renewable energy technologies is unreliable connectivity to the grid. As a consequence, many investors lose their faith in renewable energy technologies and are not ready to invest in them for fear of failing. India should work on transmission and evacuation plans. Inadequate servicing and maintenance of facilities and low reliability in technology decreases customer trust in some renewable energy technologies and hence prevent their selection. Adequate skills to repair/service the as par parts/equipment are required to avoid equipment failures that halt the supply of energy. Awareness of renewable energy among communities should be fostered, and a significant focus on their socio-cultural practices should be considered. Governments should support investments in the expansion of renewable energy to speed up the commercialization of such technologies. The Indian government should declare a well-established fiscal assistance plan, such as the provision of credit, deduction on loans, and tariffs. The government should improve regulations making obligations under power purchase agreements (PPAs) statutorily binding to guarantee that all power DISCOMs have PPAs to cover a hundred percent of their RPO obligation. To accomplish a reliable system, it is strongly suggested that renewables must be used in a hybrid configuration of two or more resources along with conventional source and storage devices. Regulatory authorities should formulate the necessary standards and

regulations for hybrid systems. Making investments economically possible with effective policies and tax incentives will result in social benefits above and beyond the economic advantages.

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