A Review on Renewable Energy Sources, Potential and Policy in India

Arvind Kumar Tiwari

Abbreviations

ADB	Asian Development Bank
CASE	Commission for Additional Sources of Energy
CCGTs	Combined Cycle Gas Turbines
CPSUs	Central Public Sector Undertakings
DST	Department of Science and Technology
EPS	Electric Power Survey
GHG	Green House Gas
IAEA	International Atomic Energy Agency
IEPR	Integrated Energy Policy Report
IPPs	Independent Power Producers
MNERS	Ministry of New and Renewable Energy Sources
MNRE	Ministry of New and Renewable Energy
NPCIL	Nuclear Power Corporation India Limited
NSM	National Solar Mission
OWSC	Offshore Wind Steering Committee
PPP	Public-Private partnerships
RES	Renewable Energy Sources
SECI	Solar Energy Corporation of India
SHP	Small Hydro Power
UMWS	Union Ministry of Water Resources

A. K. Tiwari (✉)
Rajkiya Engineering College, Sonbhadra, India

S. Awasthi et al. (eds.), *Sustainable Computing*,
https://doi.org/10.1007/978-3-031-13577-4_1

1 Introduction

In India, the majority of the population lives in rural areas. As per the 2011 census, 68.84% of the Indian population lives in rural areas. India has nearly 0.638 million rural communities; thus, a proposal for electrification of the rural communities based on renewable energy such as biomass will be a powerful option. The "Ministry of New and Renewable Energy Sources" (MNERS) has a proposal to grasp a power of 4324.22 MW through biomass power [1–5, 7]. The MNRE has taken initiatives such as providing economic support and incentives for encouraging the optimal usage of RES [1]. The consumption of biomass as RES is in application in India since ancient eras as animal dung, wood, husk, and several existing usual feed stocks. In current scenario, global warming, decrease in conventional energy resources, and other global problems have directed to the growth of RES. Several nations have encouraged RES power generation through definite plans and financial incentives. Most of the Indian states are facing 3% to 21% energy shortages and 10.3% at the national level, while peak demand scarcity is 15.4% [2, 3]. In 1982, the Indian government set up a "Commission for Additional Sources of Energy" (CASE). The CASE is governed by the DST. In this review paper, various mode-wise RES potentials in India are discussed. The paper discusses the current position of conventional and RES progress and strategies to encourage RES. Forthcoming understanding of strategy on RES is also emphasized. The several types of RES and their potential in India are also discussed. Program regarding providing the grants on RES-founded power generation in India is stated. The remarkable share of this review paper is the policy adopted by the Indian government which is attentive to the development of RES-based power generation regions with tactical strategy and program. The basic reason for energy deficit is the decline in global resources of energy and the exponential growth in the rate of energy requirement [4, 5]. In India, electricity deficit is very common where most of the population has no contact to recent energy facilities. On a usual, for the next 25 years, the demand for electricity will probably see an upswing of 7.4% annually. To achieve the energy demand with a sustainable approach is the major issue and a suitable available option is RES in the present scenario. Hence, it is essential to strengthen the renewable energy program. With renewable power generation, we can achieve enriched energy security state, diminish the need to import, resolve fuel price instability problem, etc. By using 1 GW of renewable power, CO emission can be reduced up to 3.3 million tons annually; consequently, it will support to diminish the contrary effects of environment alteration [1, 6, 7]. The solar and wind renewable power are irregular in nature because of their dependency on solar radiation (or intensity of light) and wind speed, respectively, and also are hardly probable resources. Whereas, tidal wave power is also of intermittent nature but simply probable and trusts on the similar facts of wind turbine. Energy extraction from mixed resources is a challenging task. Under low solar emission circumstances, the photovoltaic panel cannot guarantee the essential solar power generation. Likewise, wind turbine will not operate unless the wind speed is equal to or greater than its cut-in value. Accordingly, to confirm an

Table 1 The common characteristics of RES [2]

Resource	Dispatchable generation	Variability	Predictability
Biofuel	High	Low	High
Biomass	High	Low	High
Geothermal	Medium	Low	High
Hydroelectricity	Medium	Medium	High
Solar	Low	High	Medium
Tidal	Low	High	High
Wave	Low	Medium	Medium
Wind	Low	High	Low

efficient, stable system operation and to avoid energy shortage in the grid, loads are the core aim of energy management. The common characteristics of various RES such as dispatchable generation, variability, and predictability have been shown in Table 1 [2].

The paper is organized as follows: Section 2 briefly overviews the available RES in. Section 3 describes the energy scenario during the 12th Five Year Plan. Extensively, a review on Added Capacity Adding Attained for the duration of the 12th Plan is mentioned in Sect. 4. Section 5 deals with comprehensive studies of Peak Demand and Energy Requisite Prediction. Section 6 discusses the Potential of Renewable Energy Sources in India. Section 7 deals with Capacity Addition from RES during the 12th Plan and Sect. 8 describes the Indian Policy on RES. Section 9 presents the Recent Renewable Energy Initiatives provided by the Indian Government. Section 10 deals with the other Programs for RES, while Sect. 11 focuses on Future Potential of RES in India. Section 12 mentions the Projection of RE generation in India. Finally, Sect. 13 mentions the conclusions of the paper.

2 Available Conventional Energy in India: Overview

India is a growing country in the world, and its population is growing much higher. Consequently, due to high population growth, economical and industrial growth is also high, which mandates high energy demand. The main sources that provide the energy supplies in India are natural fuels, i.e., oil and coal. The common fuel alternatives accessible for electricity generation are coal and lignite, hydro, nuclear, and natural gas as traditional sources, whereas solar, wind, biomass, small hydro, tidal, geothermal, waste, hydrogen/fuel cells are available as renewable energy sources. In India, the installed capacity, as on Sep 30, 2018, was 344,718.61 MW involving 221,802.59 MW thermal (which included 196,097.5 MW from Coal, 24,867.46 MW from Gas, 837.63 MW Diesel), 6780 MW from Nuclear, 45,487.42 MW hydro, while the installed capacity of renewable was 70,648.61 MW as on June 30, 2018, as illustrated in Fig. 1 [3–7]. India has a huge potential for RES

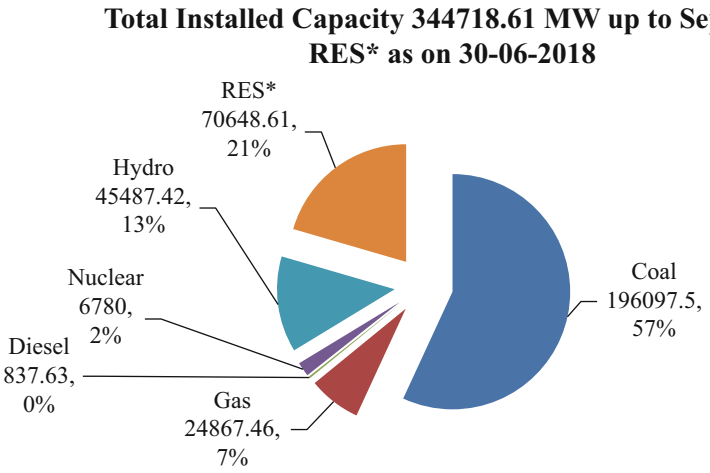


Fig. 1 All-India electrical power installed capacity as on Sep 30, 2018 [3–7]

for electricity generation and, after thermal power, India has achieved 2nd position in renewable power [3–7].

2.1 Generation From Traditional Sources in India

2.1.1 Coal/Lignite

In India, a prominent source for electricity generation is coal, and since low CO_2 emission approach has to be adopted, supplementary sources of electricity essential to be attached in optimum case which are other than coal. In the Indian power sector, coal-based generation of electricity is the pillar and will remain to govern generation of electricity. Supercritical method of processing the coal have been executed in view of environmental concerns. During the 12th Plan, based on supercritical approaches, a total volume of nearly 35,230 MW has been commissioned. In India, lignite is present at a limited number of places such as Neyveli, Surat, and Akrimota and Barsingsar, Palana, and Bithnok. The coal-based installed capacity of electricity generation was 196,097.50 MW as on Sep 30, 2018, approximately 57% of the overall installed capacity in India [1, 3]. The all-India annual coal consumption for electricity generation since 2004–2005 to 2017–18 is exhibited in Fig. 2 [1, 4–7]. This shows that all-India annual coal expenditure for electricity production is increasing exponentially and has doubled within the last decade. It means more coal is required per year due to greater demand for electricity, which can be fulfilled by the expansion of the existing capacity or the installation of new coal-based power plants.

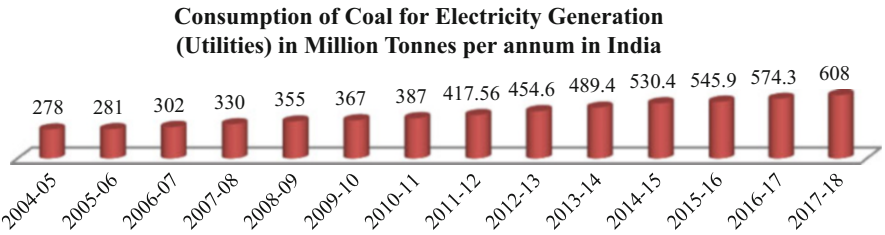


Fig. 2 All-India annual coal consumption for electricity generation [1]

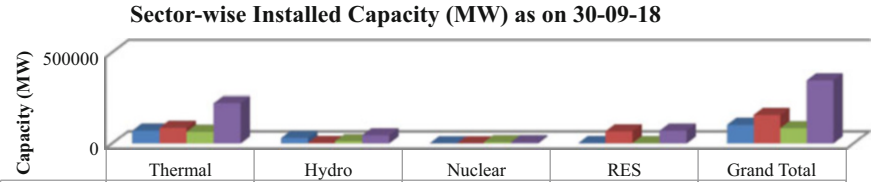
In 2017–18, the coal production was 675.40 million tons, with a maturation of 2.66% ended the preceding year. Although, production of lignite was 46.26 million metric tons in the same year with a growth of 2.27% ended in the preceding year. In world coal production, India is in 2nd position. In India, Andhra Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Orissa, Jharkhand, and West Bengal are the largest coal-producing states [1].

2.1.2 Hydro

The installed capacity for hydro-based electricity generation was 45,487.42 MW as on Sep 30, 2018, which was approximately 13% of the overall installed capacity in India [3, 6, 7]. Hydro-based power plant is utilized to meet its capacity for obtaining heavy loads and entirely fresh plans need to be considered bearing this goal in mind. However, the complete growth of hydro-electric potential, though strictly realistic, encounters many problems, with issues regarding water privileges, relocation of project-affected population, and environmental concerns, etc.

2.1.3 Nuclear

In September 1987, the Indian government formed Nuclear Power Corporation India Limited (NPCIL) under the Companies Act 1956, the Atomic Energy Act 1962 was set up with the objective of electricity generation from atomic power stations [1, 6, 7]. All nuclear power plants functioning through NPCIL are ISO-14001 approved (Environment Management System). At global level, International Atomic Energy Agency (IAEA) was established as a self-governing organization on July 29, 1957 [8]. To encourage peaceful usage of nuclear energy is the core goal of IAEA, and to avoid any military purpose use, composed of nuclear weapons. As per NPCIL, currently, 21 reactors of 6680 MW capacity are installed in India [1, 4–6]. Currently 13 out of 21 reactors are installed for electricity generation of 4280 MW capacities under the supervision of IAEA, which are based on imported oil. However, eight reactors of installed capacity of 2400 MW use native fuel for electricity generation.



	Thermal	Hydro	Nuclear	RES	Grand Total
State	71009.38	29942	0	2004.87	102956.25
Private	86600.3	3394	0	67141.44	157135.74
Central	64192.91	12151.42	6780	1502.3	84626.63
All India	221802.59	45487.42	6780	70648.61	344718.61

Fig. 3 Sector-wise installed capacity as on Sep 30, 2018 [3]

The nuclear-based electricity generation installed capacity was 6780 MW as on Sep 30, 2018, which was almost 2.1% of the overall installed capacity in India [3, 5, 6].

2.1.4 Gas

India has insufficient gas-based power plants and is facing huge generation loss due to lack of appropriate gas supply. Currently, surviving gas power plants are operational at a much small plant load factor (PLF) of approximately 23%, whereas some gas power plants are running inactive due to unobtainability of domiciliary natural gas. The gas-based electricity generation installed capacity was 24867.46 MW as on Sep 30, 2018, which was almost 7% of the overall installed capacity in India [3, 5, 6]. For less CO2 release and with the ability of gas to its fast increase, and decrease nature related problems, gas-based electricity generation is vital. In vision of bulky incorporation of renewable energy sources the benefit of fast ramping ability added significantly. Modern CCGTs have high efficiency of nearly 55% compared to gross efficiency of 40% of coal power plants. The sector-wise installed capacity as on Sep 30, 2018, is shown in Fig. 3 [3]. From this figure, we can observe that the contribution of private sector is more than central as well as state sector, while there is no contribution of private sector in nuclear-based power plant. The contribution of private sector in renewable areas is also more than that compared to the central as well as state sectors.

Figure 4 [1] exhibits annual per capita consumption of electricity since 2005–2006 to 2017–18. This shows that consumption of electricity increased exponentially and doubled within last one decade. Thus, due to industrialization, urbanization, villages' electrification, and development in other fields which require electricity, more power is required day by day and so, expansion of existing capacity or installation of new power plants is needed. Figure 5 shows the growth of rural electrification and pump sets' energization since the 9th Plan to the end of the 12th Plan [1]. From Fig. 5, it is observed that there are wonderful changes in pump sets' energizations from the 11th to the end of the 12th Plan.

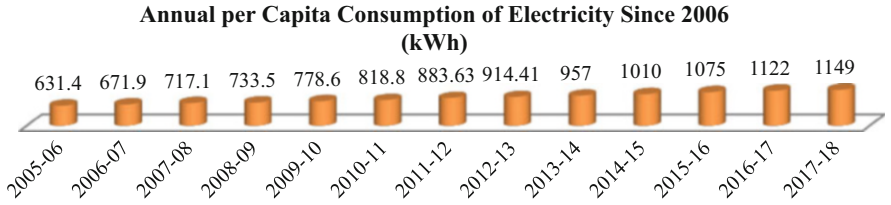


Fig. 4 Annual per capita consumption of electricity since 2005–2006 to 2017–18 [1]

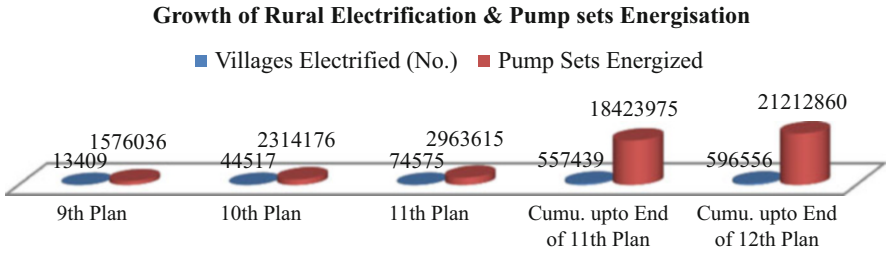
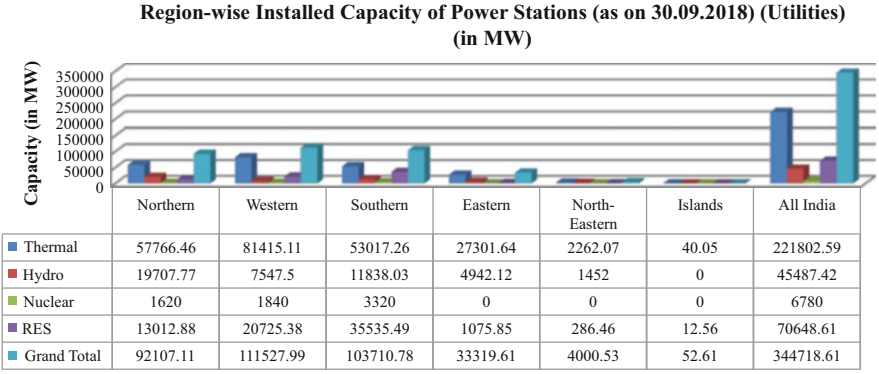


Fig. 5 Growth of rural electrification and pump sets energizations [1]

The region-wise installed capacity of power station as on Sep 30, 2018 is exhibited in Fig. 6 [3–5]. More installed capacity of power (111,527.99 MW) is positioned in the western region than in the southern (103,710.78 MW) and northern regions (92,107.11 MW). From Fig. 6, it is perceived that most of the power stations are based on thermal (221,802.59 MW), and RESs-(70,648.61 MW) based installed capacity in second position out of 3, 44,718.61 MW at all-India status. The hydro-based installed capacity is more in the northern region (19,707.77 MW), while 11,838.03 MW is in the southern region and total capacity at all-India level is 45,487.42 MW. The huge amount of installed capacity of power based on RES is positioned in the southern region (35,535.49 MW). The RES-based installed capacity of power is 20,725.38 MW in western, 13,012.88 MW in northern, 1075.85 MW eastern and 286.46 MW, 12.56 MW in the northeastern region and islands, respectively.

3 Energy Scenario During 12th Five-Year Plan (2012–2017) [1]

The National Electricity Policy, 2005 was decided with the supreme goal to completely attain the entitlement of electricity up to 2012, but the goal achieved successfully by the year 2017. For the 12th plan capacity of 88,537 MW was decided as addition target. Particulars of capacity addition targets and achievements as per sector and mode-wise in the 12th Plans are specified in Table 2 [1, 4, 5].



	Northern	Western	Southern	Eastern	North-Eastern	Islands	All India
Thermal	57766.46	81415.11	53017.26	27301.64	2262.07	40.05	221802.59
Hydro	19707.77	7547.5	11838.03	4942.12	1452	0	45487.42
Nuclear	1620	1840	3320	0	0	0	6780
RES	13012.88	20725.38	35535.49	1075.85	286.46	12.56	70648.61
Grand Total	92107.11	111527.99	103710.78	33319.61	4000.53	52.61	344718.61

Fig. 6 Region-wise installed capacity of power stations as on Sep 30, 2018 [3]

Table 2 Targets and achievements of capacity addition in the 12th Plan (in MW) [1]

	Thermal		Hydro		Nuclear		Total	
Sector	Target	Ach.	Target	Ach.	Target	Ach.	Target	Ach.
Central	14,878	15,869	6004	2584	5300	2000	26,182	**20,453**
State	13,922	22,201	1608	2276	0	0	15,530	**20,453**
Private	43,540	53,661	3285	619	0	0	46,825	**54,280**
All India	**72,340**	**91,730**	**10,897**	**5479**	**5300**	**2000**	**88,537**	**99,209**

Table 3 Target and achievement of capacity addition for 2017–2018 (in MW) [1, 3]

	Thermal		Hydro		Nuclear		Total		%
Sector	Target	Ach.	Target	Ach.	Target	Ach.	Target	Ach.	
Central	4880	3170	800	390	500	0	6180	**3560**	**57.61**
State	3546	1760	300	200	0	0	3846	**1960**	**50.96**
Private	2940	3780	205	205	0	0	3145	**3985**	**126.71**
Total	**11,366**	**8710**	**1305**	**795**	**500**	**0**	**13,171**	**9505**	**72.17**

Table 2 shows the capacity addition achievement was 99,209 MW in the 12th Five-year Plan against the target set of 88,537 MW capacities from traditional energy sources. The private sector's achievement was 54,280 MW against the target set by 46,825 MW, which is more than that of central and state sectors' achievement, i.e., 26,182 MW and 15,530 MW, respectively, against the target set of 26,182 MW and 15,530 MW, respectively. For the thermal, capacity, the additional target set was 72,340 MW, while for hydro and nuclear, it was 10,897 MW and 5300 MW, respectively. The target and achievement of capacity addition for 2017–2018 and capacity addition targets/achievements during Sep-2018 from conventional energy sources for different sectors are exhibited in Table 3 [1, 3] and Table 4, respectively [3].

Table 4 Targets/achievements of capacity addition during Sept. 2018 (in MW) [3]

Schemes	Sector	Target 2018–2019	Sep-18		April 2018– Sept 2018		Deviation
			Target	Ach.	Target	Ach.	(+) / (−)
Thermal	Central	2760	0	0	0	0	0
	State	4506.15	0	0	0	0	0
	Private	0	0	0	0	0	0
	Total	**7266.15**	**0**	**0**	**0**	**0**	**0**
Hydro	Central	710	0	0	110	110	0
	State	130	63.33	30	129.99	30	−99.99
	Private	0	0	0	0	0	0
	Total	**840**	**63.33**	**30**	**239.99**	**140**	**−99.99**
Nuclear	Central	**0**	**0**	**0**	**0**	**0**	**0**
All India	Central	3470	0	0	110	110	0
	State	4636.15	63.33	30	129.99	30	−99.99
	Private	0	0	0	0	0	0
	Total	**8106.15**	**63.33**	**30**	**239.99**	**140**	**−99.99**

Table 5 Generation of electricity for Sept. 2018 (in BU) [3]

Type	Achievement Sept. 2017	Targets Sept. 2018	Achievement Sept. 2018	% Change w.r.t. 2017
Thermal	84.87	88.21	87.18	2.72
Nuclear	2.67	2.617	2.56	−4.16
Hydro	14.10	15.741	17.42	23.54
Bhutan Import	0.855	0.674	0.884	3.39
All India	102.494	107.239	108.044	5.41

Table 6 Generation of electricity for the duration of April 2017–Sept. 2017 and April 2018–Sept. 2018 (in BU) [3]

Type	April 2017– Sept 2017	April 2018– Sept. 2018	% Change w.r.t April 2017– Sept 2017
Thermal	509.00	529.43	4.01
Nuclear	17.06	18.911	10.85
Hydro	81.36	83.370	2.44
Bhutan Import	3.805	3.805	0.00
All India	611.25	635.517	3.97

The attainment of electricity generation was 108.044 BU against the target set of 107.239 BU from conventional energy sources for September 2018 as shown in Table 5 [3].The achievement of electricity generation for September 2017 was 102.494 BU and the percentage change for September 2018 was 5.41 with respect to 2017. Table 6 [3] exhibits the generation of electricity for the duration of April 2017–Sept. 2017 and April 2018–Sept. 2018, which exhibits that the percentage change for April 2018–Sept. 2018 was 3.97 with respect to April 2017–Sept. 2017.

Table 7 Generation capacity addition for Sept. 2018 (in MW) [3]

Type	Achievement Sept. 2017	Targets Sept. 2018	Achievement Sept. 2018	% Change w.r.t. Sept. 2017
Thermal	510	0	0	0
Hydro	100	63.33	30	47.37
Nuclear	0	0	0	0
All India	**510**	**63.33**	**30**	**47.37**

Table 8 Producing capacity addition for the duration of April 2017– Sept. 2017 and April 2018–Sept. 2018 (in MW) [3]

Type	April 2017–Sept. 2017	April 2018–Sept. 2018	% Change
Thermal	4300	0	−100
Hydro	278	140	−50
Nuclear	0	0	0
All India	**4578**	**140**	**−97**

The target and achievement of generation capacity addition for Sept. 2018 for the conventional energy sources is presented in Table 7 [3]. During this time, only hydro power was targeted for 63.33 MW and achievement was 30 MW. The achievement of generating capacity addition of hydro for Sept. 2017 was 100 MW and the percentage change for Sept. 2018 was 47.37 with respect to Sept. 2017. Table 8 [3] exhibits producing capacity addition for the duration of April 2017–Sept. 2017 and April 2018–Sept. 2018, which exhibits that the percentage change for April 2018– Sept 2018 was −97% with respect to April 2017– Sept. 2017.

Table 9 presents the region-wise power supply status (Energy & Peak) for Sept. 2017 and Sept. 2018 [3]. The availability of energy for Sept. 2018 was 109,099 MU against the requirement of energy of 109,640 MU, i.e., a deficit of 0.5%., while for Sept. 2017, the availability was 101,561 MU against the requirement of energy of 102,465 MU, i.e., a deficit of 0.9%. The peak met of power for Sept. 2018 was 175,528 MW against the peak demand of power of 176,538 MW, i.e., a deficit of 0.6%., while for Sept. 2017, the peak supply of power was 158,550 MW against peak demand of power of 162,452 MW, i.e., a deficit of 2.4%.

4 Added Capacity Attained for the Duration of 12th Plan (Not Involved in the Targeted Capacity of 88,537 MW) [1, 3]

For effortlessly, the establishment of coal-based power plants has been relicensed according to Electricity Act, 2003. Consequently, a capacity of 35,296.6 MW not included in the 12th Plan goal has returned profits in the 12th Plan. Table 10 [1,

Table 9 Status of power supply (energy & peak) in Sept. 2018 [3]

	Energy (MU)					
	Requirement		Availability		Surplus(+)/Deficit (−) in %	
Region	Sep-2017	Sept. 2018	Sept. 2017	Sept. 2018	Sept. 2017	Sept. 2018
Northern	34,454	33,357	33,824	32,957	−1.8	−1.2
Western	29,344	32,764	29,232	32,745	−0.4	−0.1
Southern	24,727	28,691	24,685	28,631	−0.2	−0.2
Eastern	12,414	13,291	12,345	13,278	−0.6	−0.1
North-Eastern	1526	1536	1475	1489	−3.3	−3.1
All India	**102,465**	**109,640**	**101,561**	**109,099**	**−0.9**	**−0.5**
Region	**Power (MW)**				Surplus(+)/Deficit (−) in %	
	Peak demand		Peak met			
	Sept. 2017	Sept. 2018	Sept. 2017	Sept. 2018	Sept. 2017	Sept. 2018
Northern	57,203	56,409	54,649	55,650	−4.5	−1.3
Western	46,382	52,933	45,710	52,895	−1.4	−0.1
Southern	41,071	45,587	40,852	45,428	−0.5	−0.3
Eastern	20,274	21,781	20,208	21,781	−0.3	0.0
North-Eastern	2629	2921	2520	2850	−4.1	−2.4
All India	**162,452**	**1,76,538**	**158,550**	**1,75,528**	**−2.4**	**−0.6**

Table 10 Added capacity attained for the duration of 12th Plan (in MW) [1, 3]

		Thermal				
Sector	Hydro	Coal	Gas/LNG	Total	Nuclear	Total
State	0.0	3920.0	51	3971	0.0	**3971.0**
Private	9.0	8520.0	397.1	8917.1	0.0	**8926.1**
Central	24.0	18,445.0	3930.5	22,375.5	0.0	**22,399.5**
Total	**33.0**	**30,885.0**	**4378.6**	**35,263.6**	**0.0**	**35,296.6**

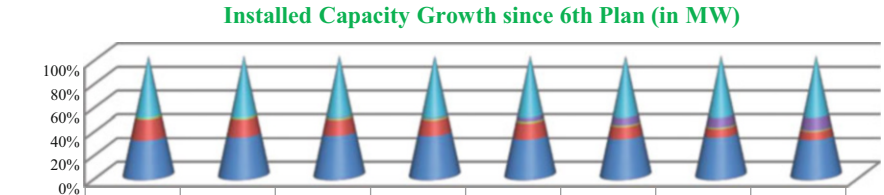
3] presents the sectorwise and modewise added capacity attained for the duration of the 12th Plan. This comprises involvements from the private sector of 22,399.5 MW, around 63.5% of overall capacity addition, which is exterior to the goal.

4.1 A Cooperative Analysis of 12th Plan with Earlier Five-Year Plans

Table 11 [1, 3] exhibits the target and achievement capacity addition for the duration of earlier five-year plans. It is observed that, during the 9th Plan capacity addition, achievement was less than the 8th plan. It also exhibited that for earlier five-year plans, capacity addition achievement was little of the target; however, the capacity addition achievement was 112% of the target during 12th Plan.

Table 11 Target and achievement of capacity addition in previous five-year Plans (in MW) [1, 3]

	8th plan		9th plan		10th plan		11th plan		12th plan	
Plan/sector	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
State	14,870	6835	10,748	9353	11,157	6245	26,783	16,732	15,530	23,277.4
Private	2810	1430	17,589	5262	7121	1930	15,043	23,012	46,825	55,479.5
Central	12,858	8157	11,909	4504	22,832	13,005	36,874	15,220	26,182	20,452.6
Total	30,538	16,423	40,245	19,119	41,110	21,180	78,700	54,964	88,537	99,209.5
% Achievement	**53.7**		**47.5**		**51.5**		**69.84**		**112.1**	



	End of 6th Plan	End of 7th Plan	End of 8th Plan	End of 9th Plan	End of 10th Plan	End of 11th Plan	End of 12th Plan	Up to Sep-2018
Total	42584.72	63636.34	85795.37	105045.96	132329.21	199877.03	319606.3	344718.61
RES	0	18.14	902.01	1628.39	7760.6	24503.45	50018	70648.61
Nuclear	1095	1565	2225	2720	3900	4780	6780	6780
Hydro	14460.02	18307.63	21658.08	26268.76	34653.77	38990.4	44478.42	45487.42
Thermal	27029.7	43745.57	61010.28	74428.81	86014.84	131603.18	218329.88	221802.59

Fig. 7 Installed capacity growth since the 6th Plan (in MW) [1]

Figure 7 exhibits the growth of installed capacity during the previous eight-year plans, i.e., since the 6th Plan [1]. It is observed that installed capacity of thermal, hydro, and nuclear increases in each five-year plan, but the installed capacity of RES increases very fast in comparison to conventional sources.

4.2 Slipped Projects and Causes of Slippage from 12th Plan Capacity Addition Target [1]

From the 12th Plan, a total of 24,613.8 MW capacities (29% of 88,537 MW, i.e., the targeted capacity addition) have slipped. Table 12 exhibits the sectorwise and modewise particulars of capacity slipped [1]. It is observed that the maximum projects slipped from private sector (56%), while lowest in state sector (5%) and 39% from central sector. The modewise maximum slipped projects were in thermal sector (65%), whereas the lowest was in the nuclear sector (13%) and 22% from the hydro sector. The detail of statewise capacity slipped and the power projects slipped from 12th Plan capacity addition target is given in [1].

Table 12 During the 12th Plan, capacity slipped from capacity target of 88,537 MW (in MW) [1]

Sector	Hydro	Thermal			Nuclear	Total
		Coal	Gas/LNG	Total		
State	541.0	600.0	37.8	637.8	0.0	**1178.8 (5%)**
Private	1490.0	12,245.0	0.0	12,245.0	0.0	**13,735.0 (56%)**
Central	3420.0	2980.0	0.0	2980.0	3300.0	**9700.0 (39%)**
Total	**5451.0(22%)**	**15,825.0**	**37.8**	**15,862.8(65%)**	**3300.0(13%)**	**24,613.8**

[a]Excludes 10 MW downward capacity revision in respect of Hinduja TPP [1]

Table 13 Regionwise electrical energy requirement (utilities) (MU) [1, 3]

Region	2016–17	2021–22	2026–27
Northern	356,521	468,196	616,345
Western	352,304	481,501	627,624
Southern	307,047	420,753	550,992
Eastern	128,300	171,228	217,468
North- Eastern	15,876	23,809	34,301
Islands	381	537	705
All-India (Electrical Energy Requirement)	**1160,429**	**1566,023**	**2047,434**

The sluggish growth of civil works, poor geology, and unfavorable weather conditions are the main causes of slippage for hydro projects. Some other issues are concerned with law and order, funds' limitations, agreement, environmental, local difficulties, resettlement and rehabilitation that contributed to capacity slippage during the 12th plan. The main problems which concern with slippage of thermal projects are different from those in hydro projects, such as problems in land acquisition, which is required for establishing of plants, transmission lines, etc. The other causes also responsible for slippage of the plants such as state policies; availability of startup power at site, lack of natural gas, issues with rate invades on account of interruption in well-timed end of projects, problems in fund from banks and financial institutions, poor performance of main contractor, contractual disputes, natural calamities, and extreme weather conditions, etc.

5 Peak Demand and Energy Requisite Prediction

Based on the 19th report of Electric Power Survey (EPS), assessment of electricity demand has been carried out by generation expansion planning studies. The regionwise expected necessity of peak demand and energy are given in Tables 13 and Table 14, respectively [1, 3].

Table 14 Regionwise peak demand of electricity (utilities) (MW) [1, 3]

Region	2016–17	2021–22	2026–27
Northern	55,596	73,770	97,182
Western	50,141	71,020	94,825
Southern	44,782	62,975	83,652
Eastern	20,883	28,046	35,674
North-Eastern	2810	4499	6710
Islands	77	108	142
All-India (Electrical energy requirement)	**161,834**	**225,751**	**298,774**

6 Renewable Energy Sources: Potential in India

Renewable sources that are frequently restocked by nature are sun, wind, hydro, biomass, geothermal, idal energy, etc. This comprises heat and electricity produced from the above-mentioned resources. India is the fourth leading electricity user country at global level after the USA, China, and Russia. At present, India has more programs for RESs in the world. For research and development expertise and for manpower advancement in renewable energy sector, the MNRE has been loyal. Huge potential of RES is available in different forms such as solar, SHP, wind, biomass, etc. An overall capacity of 310 GW has been set up, which involves 69.4%, 13.9%, 14.8%, and 1.9% power generation from thermal, hydro, renewable, and nuclear plants, respectively [1, 5, 6]. After thermal power, India has attained 2nd position in renewable power and renewable power scattering speedily [1]. The Indian government has decided on a goal for renewable power of 175 GW capacity. This comprises 100 GW solar power, 60 GW wind power, 10 GW bio-power, and 5 GW small hydro power targeted for 2022 [1, 5, 6]. The MNRE is implementing extensive schemes with monetary and economic backing and open-minded programs to attain this goal. The Ministry has taken quite a lot of steps to achieve visualization of clean energy. The principal goals of usage of renewable energy in India have been electricity unavailability, energy access, climate variation, energy security, etc.

6.1 Solar Energy

India has a huge potential of solar power owing to its promising solar region from 400 S to 400 N positions in world map. Normally, most regions of India receive an average solar radiation of 4–7 kWh/m^2/day, since there are nearly 300 strong sunny days in a year. Among all accessible different RES in India, solar energy has the maximum potential. Solar powers with a total capacity of 70,648.61 MW were installed as on Sep 30, 2018 against probable potential of about 100,000 MW in India [3, 9]. When the sun hits the atmosphere, it is at 1017 W, and on the earth's

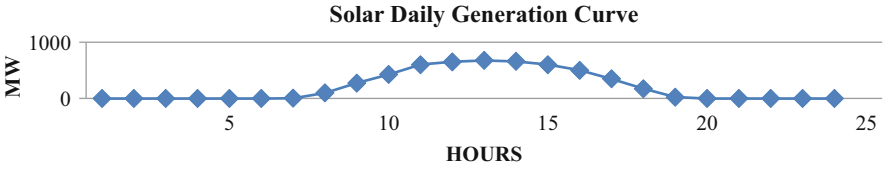


Fig. 8 Typical daily profile of a solar power generation [1]

surface, it is at 1016 W, then solar power can be easily harnessed. For all needs of civilization, a total demand for power is 1013 W at global prominence. However, sun provides 1000 times more power than total demand of civilization in the world. If only 5% of solar energy is used, then 50 times world energy requirement will be fulfilled. In a year, the corresponding energy potential is around 6000 million GWh of energy. National Solar Mission (NSM) has goal for grid solar power at 20,000 MW and off-grid capacity 2000 MW for which solar thermal collector areas of 20 million square meter and solar lighting of 20 million is under execution by 2022 [1, 9]. In January 2010, NSM has given an excessive enhancement to solar power development in the country. As on March 31, 2017, a capacity of 12,288.83 MW solar power was installed in India, which is around 21.5% of total capacity installed of renewable energy [1, 3]. This installed capacity of solar power is mostly spread in the following states in descending order of installed capacity such as: Andhra Pradesh (1867.23 MW), Rajasthan (1812.93 MW), Tamil Nadu (1691.83 MW), Telengana (1286.98 MW), Gujarat (1249.37 MW), Madhya Pradesh (857.04 MW), Punjab (793.95 MW), etc. [1, 9]. Figure 8 exhibits the typical daily profile of solar power generation [1]. This exhibited that the solar power generation slowly rises once begin, extents an extreme position approximate in noon and then slowly falls down in evening.

6.2 Wind Energy

In India, wind-based power schemes are mostly spread in regions such as southern, western, and northern states, whereas there is no grid link of wind power plant in the eastern and northeastern states. The electricity generation based on wind in India is extremely affected by the monsoon. In the context of Indian monsoon, strong monsoon starts in the month of May–June from the southwest, and moist air travels in the direction of the land when cool, whereas a weaker monsoon starts in the month of October from the northeast and dry air travels in the direction of the ocean when cool [10–12, 14]. Wind speed is comparatively weak in the month of November to March. Wind power generation is at the mercy of wind speed which is influenced by daily and seasonal weather patterns. Figure 9 exhibits the profile of a typical daily wind power generation [1]. In India, wind-based power generation program was initiated since 2010–11, i.e., finish of the 6th five yearly

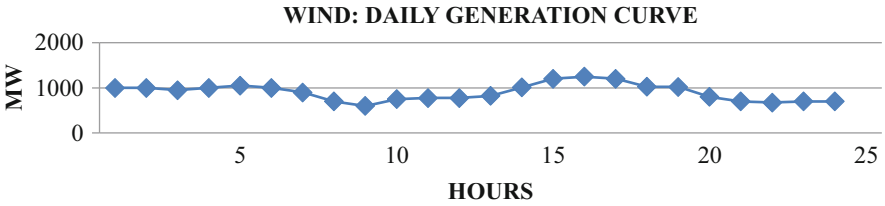


Fig. 9 Profile of typical daily wind power generation [1]

plans and substantial growth can be seen in the last few years. The main objectives of program were to commercialization of wind power generation, supporting for research and development, afford assistance on wind projects and also to create attentiveness in citizens. In connection with this program, MNRE has done several amendments concerning policies, schemes, and incentives towards the development of wind energy [13, 15]. Compared to Denmark or the USA, India is a beginner in the wind energy sector. Due to interest of the Indian government in wind energy sector, it is rated fifth with leading wind power installed capacity. Presently, after the USA, China, Spain, and Germany, India has fifth rank in installed wind power capacity of 34,293.48 MW as on June 30, 2018 [3]. In India, wind power plants are mostly positioned in the southern, western, and northern regions and the installed capacity was 32,279.77 MW as on March 31, 2017, which is around 56.4% of total installed capacity of renewable [1, 3]. In India the wind power installed capacity is mostly spread in following states in descending order of installed capacity such as: Tamil Nadu (8631 MW), Gujarat (6044 MW), Maharashtra (4789 MW), Rajasthan (4300 MW), Karnataka (4544 MW), Andhra Pradesh (4007 MW), Madhya Pradesh (2520 MW), Telangana (128 MW), Kerala (53 MW) [1]. Muppandal wind farm located in Tamil Nadu is the biggest in the country with a total capacity of 1500 MW [1]. Under MNRE, Indian Renewable Energy Development Agency (IREDA) offers several incentives in order to rapidly grow wind power plants. In National Electricity Plan (2012), the target of total power generation capacity of about 350–360 GW by the year 2022 was stated by the Central Electricity Authority. In August 2012, MNRE established Offshore Wind Steering Committee (OWSC) and, in 2013, OWSC released a draft on National Offshore Wind Energy Policy. As on March 31, 2017, grid-connected installed capacity of wind power was 32,279.77 MW [1].

6.3 Biomass Energy

Other sources of RESs are the usage of living and lifeless forms of biological material for energy generation as biomass. Biomass can be used as energy either as heat, which is produced directly via combustion, or after transforming it to different forms of biofuel indirectly. Presently, direct-fired approach-based biomass plants

are mostly used, which are similar to most fossil-fuel-fired power plants. India is a country with an agriculture-based economy and has massive potential for biomass. The main objective of biomass power/cogeneration program implementation is encouraging expertise for optimal use of wastes, cotton stalk, soya husk, rice husk, bagasse, groundnut/coconut shells, saw dust, de-oiled cakes, straw, etc., as biomass resources. Presently, the contribution of biomass is about 14% of the total energy amount globally, and 38% of this energy is spent in developing nations mostly in the rural and traditional areas of the economy [1, 5, 16]. In India, from agriculture, forestry, plantations, and agro-industrial residues, around 540 million tons yearly is the assessed availability of biomass. With current existing expertise assessment, the grid class power of over 16,000 MW can be produced by using surplus agricultural residues [1, 5]. In addition, it is the assessment that if entirely 550 sugar mills shift over to recent procedures of co-generation, then almost 5000 MW of power can be produced. Consequently, it is reflected that India has about 21,000 MW power potential through biomass. Ever since the mid-1990s, the Indian government has been executing programs on biomass power/cogeneration. In India, through 167 projects on biomass powers and cogeneration of capacity, 1650 MW have been fitted for serving power to the grid [1, 5]. Additionally, a capacity of 1850 MW electric power is under various stages of execution through nearly 171 projects based on biomass and cogeneration. From sugar mills, which comprise 82 projects based on cogeneration projects with fitted capacity adding to 690 MW. Additional 107 projects of 1280 MW capacity are under execution [1, 5, 16]. In India, some states are at top position in cogeneration projects implementation such as Andhra Pradesh, Tamil Nadu, Karnataka, and Uttar Pradesh. However, for biomass-based power projects, the topmost states are Andhra Pradesh, Karnataka, Chhattisgarh, Maharashtra, and Tamil Nadu. As on June 30, 2018, a capacity of 8839.10 MW biomass power was installed, this is almost 14.5% of whole fitted capacity of renewable, whereas installed capacity of biomass for grid-connected was 8295.78 MW as on March 31, 2017 [1, 3, 16]. Bagasse is known as waste from sugar mills which is used in bagasse cogeneration [1, 16]. Consistent with MNRE, via biomass and bagasse cogeneration it is projected that 73,000 MW power will be produced by 2032 [1, 16].

6.4 Small Hydro Power (SHP)

Hydro-based power plants below 25 MW capacities are characterized as small hydro power plants (SHP). In India, the assessed potential is approximately 20,000 MW for power generation from such plants, out of which about 2.5 GW has been developed [1, 5, 17]. According to the potential available river-based projects are situated in Himalayan states and irrigation waterways based situated in other states. In these plants, the water flow is utilized to rotate the turbine blades which drive the mechanically coupled rotor of generator for generating electrical power. Generated electricity through hydro-based system is the function of turbine size and the amount

Table 15 RESs installed capacity as on June 30, 2018 (in MW) [1, 3, 5]

Small hydro power	Wind power	Bio-power		Solar power	Total capacity
		BM power/Cogen.	Waste to energy		
4493.20	34293.48	8700.80	138.30	23022.83	70648.61

of water flowing through the turbine. In remote regions, SHP plants are mostly used as separate power systems. In India, installed capacity of SHP was 4493.20 MW as on June 30, 2018, which is about 7.17% of overall installed capacity of renewable [1, 3, 5, 16]. Ambition of country for grid interactive power generation capacity is that the 2% of total power should come from SHP. The Indian government has currently fixed a goal of 60,000 MW from SHP projects by 2022 [1, 3, 16]. For existing SHP projects under the public sector, only the government has provided grant for its overhaul and modernization. Grid-connected installed capacity of SHP plants was 4379.86 MW as on March 31, 2017 [1, 5, 16].

6.5 Ocean Surface Waves and Tidal Power

There is a method to harness energy of ocean surface waves as wave power and energy of tides as tidal power. These are two types of hydro power with future potential. Nevertheless, they are not broadly working commercially [1, 5].

6.6 Installed RES Potential in India

Table 15 exhibits RESs installed capacity of 70,648.61 MW as on June 30, 2018 [1, 3, 5, 16]. Figure 10 represents the growth of RES since the 6th Plan [1, 3, 5, 16]. It is observed that at the end of the 10th Plan, installed capacity of RES was 7760.6 MW, whereas at the end of the 11th Plan, what was achieved was 24,503.45 MW. At the end of the 12th Plan, it was 50,018 MW, and up to Sept. 2018, total installed capacity achieved was 70,648.61 MW [3, 5].

Generation of electricity through conventional and renewable sources in Sept. 2017 and Sept. 2018 is given in Fig. 11 [3]. Total growth of electricity generation is achieved by 8.24%, while 46.9% in renewable generation and 5.41% in conventional generation has been achieved.

All India power generation from RESs achieved 62,659.401 MU from April 2018 to August 2018 as shown in Fig. 12 [3]. Out of which, wind power contributes 39,314.548 MU, solar power 14,702.788 MU, biomass power 1205.59 MU,

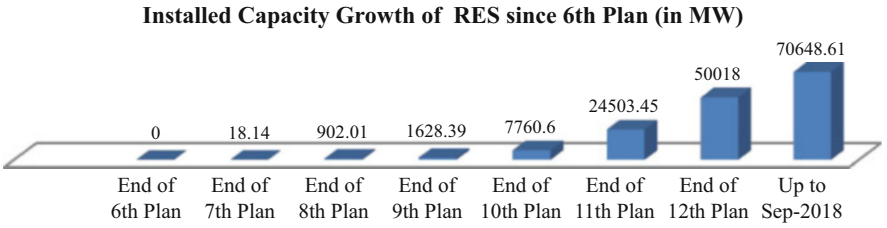


Fig. 10 Installed capacity growth of RES since the 6th Plan (in MW) [1, 3, 5]

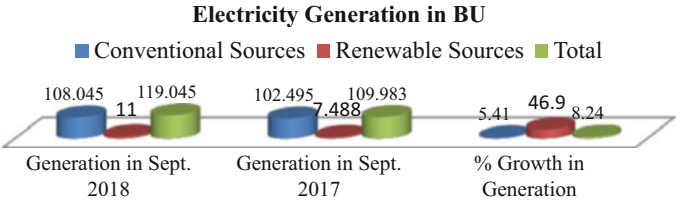
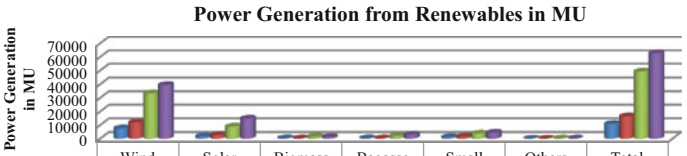


Fig. 11 Electricity generation in BU through conventional and renewable sources in Sept. 2017 and Sept. 2018 [3]



	Wind	Solar	Biomass	Bagasse	Small Hydro	Others	Total
Aug-17	7512.157	1660.26	264.182	281.647	1070.064	28.614	10816.924
Aug-18	11771.655	2635.793	185.61	218.277	1531.777	32.532	16375.645
Cumulative for April-2017-Aug-2017	33172.505	8808.937	1468.707	1814.848	3705.692	149.672	49120.361
Cumulative for April-2018-Aug-2018	39314.548	14702.788	1205.59	2923.271	4335.633	177.571	62659.401

Fig. 12 All India power generation from RESs [3]

Table 16 Grid-connected installed capacity of renewable power plants (as on Mar 31, 2017) [1]

Renewable energy source	Installed capacity (MW)
Solar power	12,288.83
Wind power	32,279.77
Bio-power & waste power	8295.78
Small hydro power	4379.86
Total	**57,244.24**

cogeneration bagasse 2923.271 MU, small hydro power 4335.633 MU, and others 177.571 MU. Table 16 exhibits grid-connected installed capacity of renewable power plants in India [1]. State-wise grid-connected installed capacity of renewable power plants as on Mar 31, 2017, has been given in [1].

Table 17 Capacity addition target of RES in 12th plan [1]

Source	Capacity (MW)
Solar	10,000
Wind	15,000
Other RES	5000
Total	**30,000**

Table 18 Installed capacity of RESs as on March 31, 2017 [1, 3]

Source	Capacity (MW)
Solar	12,288.83
Wind	32,279.77
Bio-power and waste power	8295.78
Small hydro	4379.86
Total	**57,244.24**

Table 19 Source-wise capacity addition reached from RESs during the 12th Plan [1]

Source	Capacity (MW)
Solar	11,347.53
Wind	15,383.17
Bio-power and waste power	5040.78
Small hydro	969.36
Total	**32,740.84**

7 Capacity Addition from RES in 12th Plan

During the 11th Plan, a capacity addition of 16,744 MW was achieved from RESs, although at the end of the 11th Plan (2007–12), the installed capacity of RESs was 24,503 MW. For the duration of the 12th Plan, capacity addition of 30,000 MW was targeted from RES; details are provided in Table 17 [1, 3, 5, 16].

Although, by 2021–22, the goal of installed capacity of RESs has been reviewed to 175 GW [1, 3]. Table 18 exhibits the installed capacity of RESs as 57,244.23 MW as on March 31, 2017 in India [1, 3]. From Table 18, present scenario of installed capacity of RES displays that although wind plants are leading nowadays but in forthcoming installed capacity of solar plants shall have more comparison to wind plants.

As on March 31, 2017, a capacity addition of 32,740.84 MW has been reached from RESs during the 12th Plan. Table 19 exhibits details of source-wise capacity added during the 12th Plan [1].

8 RES Policy of India

In current scenario of India, due to fast population and high economic growth, energy consumption has been growing very rapidly. Expected demand of electricity has increased due to fast development and improved human living status of millions

of Indian families. Consequently, Government of India is creating several plans and strategies in the energy sector at present. Subsequently, viable progress is now the significant goal of the world and RES are considered as the most favorable option for power generation. MNRE has implemented several schemes, policies, and strategies in the RESs' sector and is also encouraging adoption of these approaches by offering many grants and incentives [1, 5, 16]. MNRE is providing many kinds of grants for both sectors, private and the government [1, 5, 16].The renewable power sector has appeared, for instance, to play the major role in the grid connected power generation [16]. The Indian government has taken many steps for the development through RES such as the concept of solar parks, organizing RE-Invest 2015-a global investor's' meet, initiation on grid connected rooftop solar scheme, concept of Green Energy Corridor reserving amount of Rs.38,000crore for it, scheme of mounting 100,000 solar pumps and solar installations under the Surya Mitra scheme training 50,000 people, for solar and wind power free inter-state transmission charges etc. [1, 5, 16]. The Energy and Resources Institute (TERI) report on Pricing of power from Non-Conventional Sources is described in [18]. The Statewise Track of Power Scenario in India for 2018 is discussed in [19]. Annual report of 2017 reported by World Institute of Sustainable Energy, Pune is given in [20]. The Electricity Act 2003 and other guidelines for consumers are mentioned in detail in [21–28].

9 Recent Renewable Energy Initiatives

9.1 Solar Parks

In India, for quick growth of solar-based projects, the concept of solar parks model has been introduced. The Indian Government has sanctioned a total of 34 solar parks for 21 states with a capacity of 20,000 MW [1, 16]. In order to minimize the risks associated with the solar projects, the state governments or EPC developers have taken the initiatives for establishing their solar projects (SP). Charanka solar park is the first established solar park in the country in Gujarat. The cost of big size solar power projects hassles, therefore, capacity sizes of 500 MW (Ultra-Mega projects) or above are planned. For solar park growth, big portions of land are presented in a few states. The Indian Government has set a goal of mounting solar power plants of 100 GW by 2022. Table 20 shows the state-wise approved capacity of solar parks [1, 16].

9.2 Solar Cities

In India, development, economic growth, and increasing population are the main causes of rapid increase in energy demand, which boosted Green House Gas (GHG)

Table 20 State-wise approved capacity of 34 solar parks for 21 states [1, 16]

States	Approved capacity of solar parks (in MW)
Jammu Kashmir, Arunachal	100 (one solar park in each state)
Haryana, Chhattisgarh, West Bengal, Telengana, Tamil Nadu	500 (one solar park in each state)
Rajasthan	680 + 1000 + 500 + 750 + 321 (5 solar parks)
Gujarat	700
Madhya Pradesh	750 + 500 + 500 + 500 + 500 (5 solar parks)
Maharashtra	500 + 500 + 500 (3 solar parks)
Karnataka	2000
Kerala	200
Himachal Pradesh, Orissa	1000 (one solar park in each state)
Uttarakhand	50
Uttar Pradesh	600
Assam	69
Nagaland	60
Meghalaya	20
Andhra Pradesh	1500 + 1000 + 1000 + 500 (4 solar parks)

emissions. For encouraging use of RES and decreasing GHG emissions, several countries set a goal and also announced polices for developing solar cities like Australia and the USA. In India, quite a lot of cities and towns are sense fast growth in the peak demand of electricity [1, 3, 5–7]. At the local level, government bodies or electricity utilities are unable to handle fast growth during peak demand of electricity, thus most of the cities or towns are facing shortage in electricity supply. MNRE has taken initiation for the advancement of cities by means of solar power with certain objective as offer a structure and assistance to make a principal plan with valuation of existing energy position, forthcoming claim and action plans. Other objective of solar cities is to supervise the execution of viable energy opportunities through public–private partnerships (PPP). MNRE has set the goal of 60 solar city projects out of which 56 solar city projects are approved for development [5, 16]. Currently, for urban areas, MNRE has commenced several programs for encouraging solar water-heating systems in offices, industry, hospitals, hotels, and hostels.

9.3 Solar Pump

In 2016, a Water Aid report categorized India as the nastiest country for most people without safe water at global level. In India, more than 76 million people are away from the safe water supply and their living standard is more serious. As per expectations of the Asian Development Bank (ADB), India will have a water

shortage of 50% by 2030. However, as per expectation of Union Ministry of Water Resources (UMWS) country's present water necessities per year are estimated to be about 1100 billion cubic meters, although for the year 2025 and 2050 to be about 1200 and 1447 billion cubic meters, respectively [1, 5, 16]. With the increase in population, the claim for fresh water is also likely to increase, but the diminishing supply will make it difficult to meet the requirements. The population of India is approximately 18% of the world's population, but access to usable water sources is 4% only. As per 'Composite Water Management Index' report released by National Institution for Transforming India (NITI Ayog) in June 2018, Delhi and other 21 cities across the country will run out of groundwater by 2020 [1, 5, 16]. In urban areas, about 70.1% of the households require safe drinking water. Almost 18.7% of rural populations obtain drinking water through systematized pipe supply and others have to depend on unprocessed ground and surface water. The Indian Government has taken numerous initiatives for the irrigation and drinking water supply [1, 3–7, 16]. For irrigation and drinking water supply purpose, the Government of India has executed a system to set up 1 lakh solar pumps with funding of state nodal agencies and NABARD. The main purpose of these solar pumps would be to provide benefit to farmers for agriculture productions, revenue, and facilitating drinking water [5].

10 Other Programs/Policies/Schemes

The Indian Government has launched other useful programs, policies, and schemes based on RES such as (i) National Solar Mission for Solar projects; (ii) Wind and Solar Resources Atlas 2015 of India; (iii) Offshore Wind Energy Policy; (iv) Remote Village Electrification Program (RVEP); (v) Rural and Decentralized Renewable Power Schemes; (vi) Renewable Energy Park Scheme; (vii) Aswayuja Shops policy; (viii) Hybrid Vehicles schemes; (ix) Alternative Fuels schemes; (x) Policies on Geothermal & Tidal Energy. Details about above programs, policies, and schemes are mentioned in [16].

11 Future Potential of Renewable Energy in India

11.1 Renewable Energy Target by 2022

In India, RES is evolving to a major role in the electrical power system with and without grid. It is predictable that RES has to show an abundant greater part in reaching energy security also to be an essential fragment of the energy scheduling. In India, due to huge potential of RES, as India has reorganized a goal to an installed capacity of 175 GW by 2022 [1, 5–7, 16]. Table 21 shows that India has currently fixed a goal to an installed capacity of 175 GW from RESs by 2022, which

Table 21 Installed capacity target of from RESs by 2022 [1, 3, 5, 16]

Renewable energy sources	Installed capacity target
Solar	1,00,000 MW
Wind	60,000 MW
Biomass	10,000 MW
Small hydro	5000 MW
Total	**1,75,000 MW**

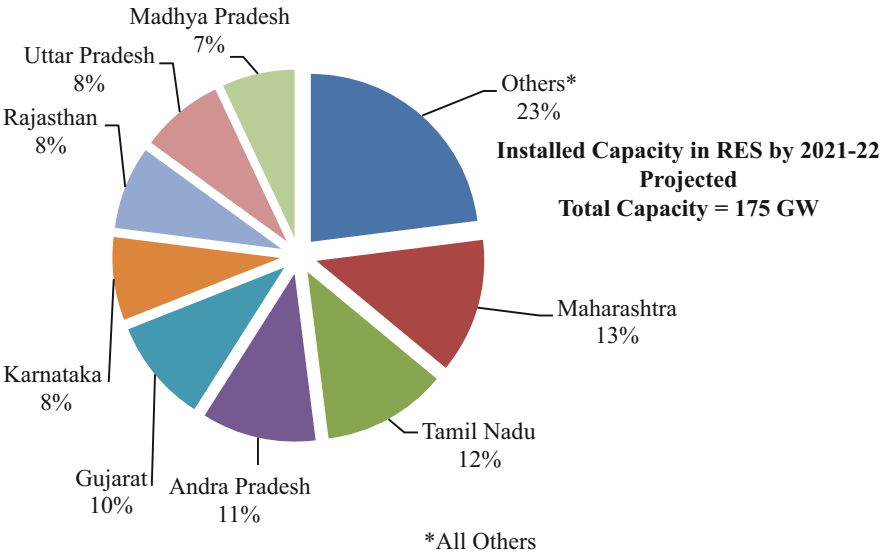


Fig. 13 Statewise target to installed renewable power of 175 GW capacities by 2022 [1, 3]

comprises 100 GW from solar, 60 GW from wind, 10 GW from biomass and 5 GW from SHP [1, 5–7, 16]. The goal of solar energy of capacity 100 GW is set under the National Solar Mission (NSM), out of which 40 GW is from solar roof tops and 60 GW from grid-connected projects of large and medium scale category. The above projects are implemented through the state Governments as well as other authorized bodies such as Solar Energy Corporation of India (SECI), Independent Power Producers (IPPs), Central Public Sector Undertakings (CPSUs), etc. [5]. The extensive higher capacity goal of renewable energy will guarantee superior energy security, upgraded energy access, and boosted employment chances.

Figure 13 exhibits the state-wise goal to fitted renewable power of 175 GW capacities by 2022 [1, 3, 5, 16]. From mentioned data, we have observed that about 13% of target will be installed in Maharashtra, after that about 12% in Tamil Nadu and about 11% in Andhra Pradesh. It also shows that these regions are most favorable for RESs. From Fig. 13, we have observed that eight states in India shall give approximately 77% of the renewable installed capacity by 2022. From Fig. 14, if we have seen region-wise, we observe that about 34% (100 GW) of total capacity will be installed in the southern region, after that, about 31% in the western region,

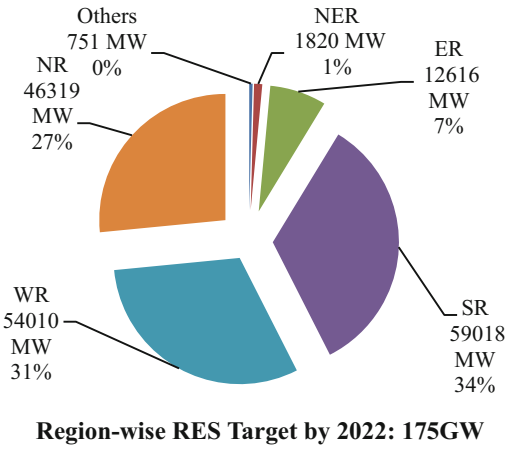


Fig. 14 Regionwise target to installed renewable power of 175 GW capacities by 2022 [1, 3]

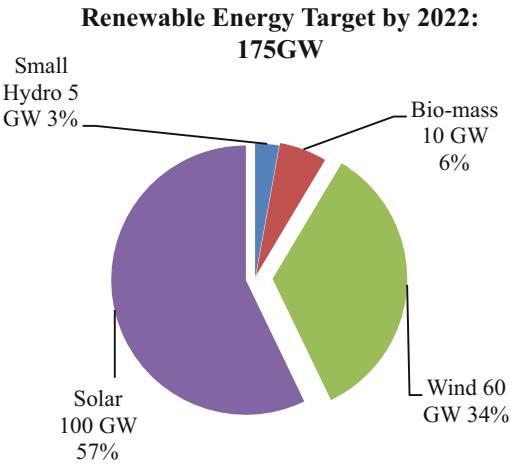


Fig. 15 Modewise target to installed renewable power of 175 GW capacities by 2022 [1, 3]

and about 27% in the northern region, while about 1% in northeastern region [1, 5, 16]. Figure 15 shows modewise goal to be fitted renewable power of 175 GW capacity by 2022 [1, 5, 16]. From this figure, we have seen that target to installed capacity from RESs are as 57% (100 GW) from solar, 34% (60 GW) from wind, 6% (10 GW) from Bio-mass, and 3% (5 GW) from SHP. From mentioned data, we observe that eight states shall give approximately 77% of entire installed capacity of renewable by 2022 [1, 5–7, 16].

Table 22 represents the year-wise goals fixed by MNRE for installation of renewables to attain the objective of 175 GW capacities by 2022 [1, 3]. From the table, we have seen that total solar target is 18,711 MW which comprises 10,311 MW from rooftop solar, 8400 MW from ground-mounted solar by 2022. The targets for other RES are 5720 MW wind power, 304 MW Biomass power, and 220 MW power from SHP by 2022.

Table 22 Targets of RES (2017–22) [1, 3]

Category	Capacity addition[a] (in MW)				
	2017–18	2018–19	2019–20	2020–21	2021–22
Rooftop solar	5000	6000	9000	9000	10,311
Ground-mounted solar	10,000	10,000	10,000	10,000	8400
Total solar	15,000	16,000	19,000	19,000	18,711
Wind	4700	5300	6000	6000	5720
Biomass	350	350	350	350	304
Small hydro power	100	100	100	100	220
TOTAL	**20,150**	**21,750**	**25,450**	**25,450**	**24,955**

[a]The capacity has been used to reach at entire RES capacity of 175 GW by 2021–22

Table 23 Projected electricity generation from RES for the years of 2021–22 and 2026–27 [1, 3, 5, 16]

Year	Installed capacity of RES (GW)	Expected generation in (BU)					Contribution of RES to total energy demand (%)
		Solar	Wind	Biomass	SHP	Total	
2021–22	175	162	112	37	15	326	20.1%
2026–27	275	243	188	63	24	518	24.4%

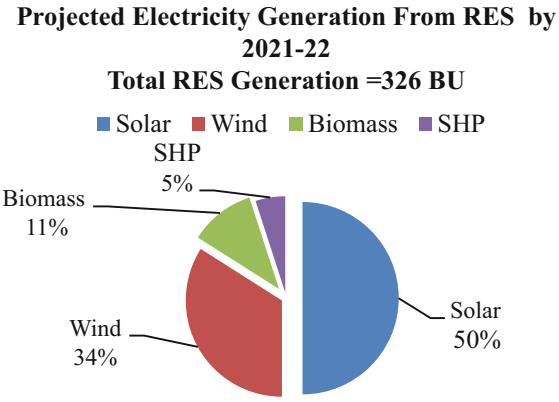


Fig. 16 Projected electricity generation from RES by 2021–22 [1, 3, 5, 16]

12 Projection of Renewable Energy Generation

According to MNRE, as per capacity addition targets predictions of RES by the year 2021–22 and in view of an RES capacity summation of 100,000 MW for the duration of 2022–27, predicted electricity generation from several RESs has been assessed as mentioned in Table 23 and Fig. 16 [1, 3, 5, 16]. From Table 23, we have found that participation of RES will be approximately 21% of the overall energy for the duration of 2021–22, whereas 24% by 2026–27 in India.

India has planned to achieve energy required by increasing renewable energy sources. The total domestic energy production is estimated to achieve 844 MTOE by 2021–22. This will catch about 69% of probable energy, as it is expected to be almost 375.6 MTOE by 2021–22, and the rest to be gained from imports. The Wind Energy Department is scheduled to reseat 10–15% in order to catch the power demand. With the help of weighty and significant incentives, solar power is also scheduled to catch energy capacity of 20 GW by 2022 [5]. As, by 2017–18, in India, the private sector has played a significant role in the production of electricity and the credit goes to the private sector for more than 35% of electricity production. In order to brand India as independent in electricity, a huge number of power projects based on solar are to be set up. RESs-based power projects are also to help indirectly diminish CO_2 in the atmosphere as well as decrease pollution.

12.1 Perspective Plan 2022

The Indian Planning commission has prepared an Integrated Energy Policy Report (IEPR) and point out that RES remains essential to the energy sector in India. RESs would not be out of place to note that RES may possibly be a major competitor achieving energy freedom for the lengthy time. Regarding plan 2022 as per planning commission, the Indian Government has decided viable aim for the country. Figure 17 shows the renewable energy potential vs. 2022 target [5, 6, 16]. Figure 18 exhibits all-India load duration curve for 2021–22 [1].

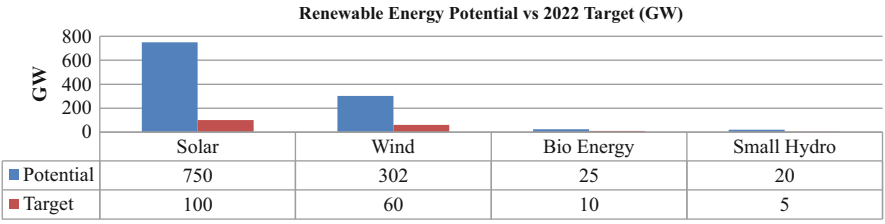


Fig. 17 Renewable energy potential vs. 2022 target (GW) [5, 6, 16]. (Source: WISE, 2017 (compiled from MNRE Annual Report 2017))

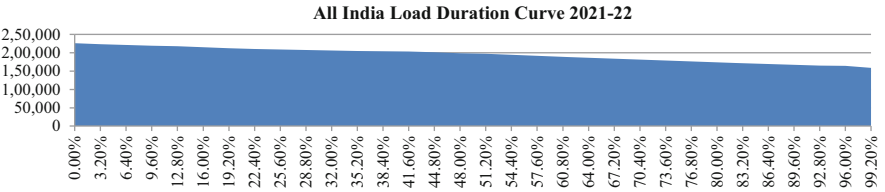


Fig. 18 All-India load duration curve for 2021–22 [1]

12.2 Perspective Plan for Grid-Interactive Renewable Power

India has also planned for Grid-interactive Renewable Power based on solar energy with the ambition to set up grid-interactive rooftop solar plant of capacity 40 GW by 2022 [5, 16]. The rooftop solar plants would be installed in several sites such as government and state-owned sector buildings, institutional, commercial, industrial, and residential buildings. The rooftop solar capacity of 656 MW was installed in India on March 31, 2017. Indian Government provided subsidies or incentives on rooftop projects that is 30% in institutional buildings, residential and social, whereas 15–25% for projects in government and state-owned enterprises. However, there are no subsidies or incentives provided in the industrial and commercial sectors for setting up of rooftop solar projects. Up to the 13th Plan, capacity of renewable power is projected to catch 54,000 MW, consisting of wind power of 40,000 MW, SHP of 6500 MW, and biomass-power of 7500 MW. According to MNRE, statewise and year-wise capacity addition target to attain the cumulative capacity of 40 GW by 2022 is presented in [5, 16].

12.3 Perspective Plan for Renewable Power for Urban, Industrial, and Commercial Applications

The main objectives comprise solar collector area of 50 million square meter for thermal uses, mostly solar water heating and from bio-source grid/captive power of 7500 MW, together with wastes of urban and industrial. As per the position in 2017, there is a gigantic capacity which needs solid attention across all. The symbolic aims for 2022 and 2032 are given in Table VII of [5, 7, 16].

12.4 Medium Term (2032) Deployment Goals

The Indian government has targets of 15% grid-connected renewable power by 2032 and substitute fuels such as hydrogen, bio fuels, and synthetic fuels replacement up to 10% by 2032 [6]. The Indian government has also made plans in various sectors by 2032 [5, 16] such as (a) energy recovery using suitable waste in 423 cities from municipal together with 107 municipal corporations; (b) solar water heating systems; (c) solar sensors-based controlled street lighting in all cities to 100% exposure; (d) energy retrieval from suitable industrial wastes across the country; (e) cogeneration with 100% recovery of potential of sugar and biomass-based industries; and (f) expansion of motive power and cooking in electrified villages. The status of renewables at global level is reported in [29, 30].

13 Conclusion

A vital study of the existing and upcoming scenario of energy resources and its potential in India has been highlighted. Several energy resources in widespread diversity and different forms of RES are obtainable in India. In this paper, the installed capacity of conventional and non-conventional power and future plans for RES as per MNRE is also described in detail. Discussions also reflect the huge potential of RESs for electricity generation in different regions in India. As per GOI plans, policies, and programs on utilization of RES to achieve the increasing energy requirements, fulfilling of energy scarcity and energy security has been the focus in this paper. As per MNRE dreams, the present status and future demand of electricity reflect that although right now the involvement of RES is less but upcoming growth will influence brand RES technique more modern to shift conventional sources of energy. The approach for realizing superior aims regarding huge application of RES will mostly be influenced by the active contribution of all performers such as government agencies, NGOs, manufacturers, research and development institutions, financial institutions, developers among the new breed of energy tycoons. It is imagined that this paper will assist as an appreciated resource to any further work carried out in this important area of research.

14 Future Work

This paper presents a wide range of renewable energy potential and policy in India through which researchers can compare the potential and policy with other countries. Future work shall focus on the comparison of data of renewable energy potential of European countries.

References

1. National Electricity Plan Volume-I (Generation), Government of India Ministry of Power Central Electricity Authority January, 2018
2. Variable renewable energy, https://en.wikipedia.org/wiki/Variable-_Renewable-Energy
3. Executive Summary on Power Sector, Government of India Ministry of Power Central Electricity Authority, Jan. 2017, March-2018, September-18
4. Energy statistics report, Govt. of India; March, 2018
5. Ministry of New and Renewable Energy, Government of India. Available: http://www.mnes.nic.in/
6. Indian Energy Portal, [Online] https://www.re3data.org/repository/r3d100011024
7. Ministry of Power, Government of India. [Online] Available: http://powerminp.nic.in/
8. International Atomic Energy Agency (IAEA). Available: https://www.iaea.org/about
9. G. Sandeep, S.A. Raghubir, "Development of Solar Electricity Supply System in India: An Overview", Hindawi Publishing Corporation. J. Solar Energy (2013). https://doi.org/10.1155/2013/632364

10. Wind Power Development in India: An Overview. Available: https://mnre.gov.in/file-manager/akshay-urja/october-2017/Images/20-25.pdf
11. Centre for Wind Energy Technology. [Online] Available: http://www.cwet.tn.nic.in/default.htm
12. L.G. Lee, Wind energy developments: Incentives in selected countries, Available: http://tonto.eia.doe.gov/ftproot/features/wind.pdf
13. Indian Renewable Energy Development Agency (IREDA). [Online] Available: http://www.ireda.in
14. Suzlon Energy. [Online] Available: https://www.suzlon.com/
15. Indian Wind Energy Association (IWEA). [Online] Available: http://www.inwea.org/index.htm
16. S.N. Singh, B. Singh, O. Jacob, Renewable Energy Generation in India: Present Scenario and Future Prospects. (2009). https://doi.org/10.1109/PES.2009.5275448, Published in IEEE PES General Meeting, 2009
17. Review of Performance of Hydro Power Stations 2017–18, Hydro Project Planning & Investigation Division, Central Electricity Authority
18. TERI Report to CERC on "Pricing of power from Non-Conventional Sources" [Online] Available: http://cercind.gov.in/index.html
19. Power Scenario in India 2018 – State Wise Track. Available: https://enincon.com/report/power-scenario-in-india-2018
20. Annual report 2017–18, reported by World Institute of Sustainable Energy, Pune
21. The Electricity Act 2003
22. Report on Short-term Power Market in India: 2017–18, Economics Division Central Electricity Regulatory Commission. Available: www.cercind.gov.in/2018/MMC/AR18.pdf
23. Annual report 2018-Central Electricity Authority. Available: http://www.cea.nic.in/reports/annual/annualreports/annual-report-2018.pdf
24. A consumer's guide to electricity tariff determination. Available: https://www.karnataka.gov.in/kerc/.../Electricity-Tariff-Determination.pdf
25. Power Distribution Tariffs in India 2018
26. India's Electricity Sector Transformation report of Institute of Energy Economics and Financial Analysis November, 2017, IEFE.org
27. Load Generation Balance Report 2017–18. Available: www.cea.nic.in/reports/annual/lgbr/lgbr-2018.pdf
28. Report of the Working Group on, "NEW AND RENEWABLE ENERGY" for XIth Five Year Plan (2007–12), Planning commission, Government of India, 2006, Available: http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_renewable.pdf
29. Renewables 2018 Global Status Report, REN21. Available: https://www.ren21.net
30. World Energy Council Annual Report 2017. Available: https://www.worldenergy.org/wp-content/uploads/2018/09/WEC-2017-Signed.pdf