India's Spectacular Progress in Renewable Energy Generation

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Abstract: In Paris environmental meet 2016, the target to India is set to achieve 50 % of total capacity non-fossil power generation up to the year 2030. As of July 2024 India's fossil power generation is 54.5% and non-fossil power generation including hydro and nuclear power is 45.5% of its total power generation. India will definitely achieve the target of renewable energy power generation before 2030.In this mission of renewable energy power generation people's acceptance is for solar energy power generation. As of July 2024 India's solar energy power generation is nearly 87 GW among around 200 GW total renewable energy (RE) power generation. This paper is presented for the review of "spectacular Renewable Energy (RE) Power Generation" in last decade.

Key words: RE: Renewable Energy, Solar Energy, Wind Energy, Tidal Energy, Fossil and Non-Fossil Energy, Nuclear Power Generation, Hydro Power generation. [1]

Introduction: Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion's share of emissions, to renewable energy is key to addressing the climate crisis.

India's installed non-fossil fuel capacity is more than 205 GW. This include the hydro-electric and nuclear power generation. India has planned for a goal of 500 GW renewable energy capacity by 2030. In 2016 Paris agreement India made commitment of producing 50 % of its total electricity from non-fossil fuel. As of July 2024 Country's installed non-fossil fuel capacity is about 45.8%. With the help of increasing hydroelectric, nuclear and green hydrogen along-with solar and other non-fossil energy the installed renewable energy generation can be increased up-to 75% within next ten years.

What is renewable energy

Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us.

Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide.

Solar power is, contributing a substantial 87.20 GW to the total capacity.

India's ascent in the realm of renewable energy has been nothing short of spectacular. The government has undertaken a series of strategic initiatives and policy reforms in recent years to bolster the adoption of renewable energy technologies, with a particular emphasis on solar power. India is the world's third largest generator of solar energy, behind only the Chaina and US.

1. **Various Sources of Renewable Energy:**

1. Solar energy, 2. Wind energy, 3. Geothermal energy, 4. Hydropower, 5.Ocean energy or Tidal energy,6.Bioenergy,7 Green hydrogen,8.Gravitational energy,9. Nuclear energy.

Among the renewable energy sources Solar, Hydropower and Nuclear energy sources shares the major part in the total power generation in India.

As of 2024, hydroelectric power accounts for approximately 12% of the total installed electricity generation capacity in India.

1.1 SOLAR ENERGY

Solar energy is the most abundant of all energy resources and can even be harnessed in cloudy weather. The rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy.

1.2 WIND ENERGY

Wind energy harnesses the kinetic energy of moving air by using large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Wind energy has been used for millennia, but onshore and offshore wind energy technologies have evolved over the last few years to maximize the electricity produced - with taller turbines and larger rotor diameters.

Though average wind speeds vary considerably by location, the world's technical potential for wind energy exceeds global electricity production, and ample potential exists in most regions of the world to enable significant wind energy deployment.

Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential.

1.3 GEOTHERMAL ENERGY

Geothermal energy utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means.

Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but that are improved with hydraulic stimulation are called enhanced geothermal systems.

Once at the surface, fluids of various temperatures can be used to generate electricity. The technology for electricity generation from hydrothermal reservoirs is mature and reliable, and has been operating for more than 100 years.

1.4 HYDROELECTRIC POWER

India, blessed with numerous rivers and mountainous terrains, has vast potential for hydroelectric power generation. Over the years, the country has harnessed a significant portion of this potential, making hydroelectric power one of the key contributors to its energy mix. As of 2024, hydroelectric power accounts for approximately 12% of the total installed electricity generation capacity in India

***Table : Major Hydroelectric Plants Of India:**

S.No.	Name of Hydroelectric Power Plant	Location	River	Installed Capacity
1	Bhakra Nagal	Himachal Pradesh & Panjab	Satlaj	1325 MW
2	Tehari	Uttarakhand	Bhagirathi	1000 MW

				(Stage 1)
3	Nathpa Jhakri	Himachal Pradesh	Satlaj	1500 MW
4	Srisailam	Andhra Pradesh & Telangana	Krishna	1670 MW
5	Indira Sagar	Madhya Pradesh	Narmada	1000 MW
6	Koyana	Maharashtra	Koyana	1960 MW
7	Saradar Sarovar	Gujarat	Naramada	1450 MW
8	Uri	Jammu & Kashmir	Jhelum	480 MW
9	Dhauliganga	Uttarakhand	Dhauliganga	280 MW
10	Salal	Jammu & Kashmir	Chenab	690

1.5 OCEAN ENERGY (Tidal Energy)

Ocean energy derives from technologies that use the kinetic and thermal energy of seawater - waves or currents for instance - to produce electricity or heat.

Ocean energy systems are still at an early stage of development, with a number of prototype wave and tidal current devices being explored. The theoretical potential for ocean energy easily exceeds present human energy requirements.

1.6 BIOENERGY

Bioenergy is produced from a variety of organic materials, called biomass, such as wood, charcoal, dung and other manures for heat and power production, and agricultural crops for liquid biofuels. Most biomass is used in rural areas for cooking, lighting and space heating, generally by poorer populations in developing countries.

Modern biomass systems include dedicated crops or trees, residues from agriculture and forestry, and various organic waste streams.

1.7 GREEN HYDROGEN

Green hydrogen: an alternative that reduces emissions and cares for our planet

This technology is based on **the generation of hydrogen — a universal, light and highly reactive fuel — through a chemical process known as electrolysis.** This method uses an electrical current to separate the hydrogen from the oxygen in water. If this electricity is obtained from renewable sources we will, therefore, produce energy without emitting carbon dioxide into the atmosphere.

1.8 GRAVITATIONAL ENERGY

In a gravity battery, a mass is displaced, or lifted, to generate gravitational potential energy that is transformed into electricity. Gravity batteries store gravitational potential energy by lifting a mass to a certain height using a pump, crane, or motor. After the mass is lifted, it now stores a certain gravitational potential energy based on the mass of the object and how high it was lifted. The stored gravitational potential energy is then transferred into electricity. The mass is lowered to fall back to its original height, which causes a generator to spin and create electricity.

1.9 NUCLEAR ENERGY:

Nuclear power has emerged as a key component of India's energy strategy, providing a significant share of the country's electricity. India's nuclear power journey began with the establishment of the Tarapur Atomic Power Station (TAPS) in Maharashtra, in 1969.As of 2024, India operates 22 nuclear reactors across 7 nuclear power plants, with an installed capacity of around 6780 MW.

Major Nuclear Power Plants in India:

1. Tarapur Atomic Power Station (TAPS), Maharashtra, capacity: 1400 MW. Radioactive Material used : Uranium
2. Rajasthan Atomic Power Station (RAPS), Rajasthan, capacity: 1180 MW. Radioactive Material used : Uranium
3. Madras Atomic Power Station (MAPS), Tamil Nadu, capacity 440 MW. Radioactive Material used : Uranium
4. Kudanakulam Nuclear Power Plant (KKNPP) Tamil Nadu, capacity: 2000 MW. Radioactive Material used : Uranium
5. Kaiga Generating Station (KGS), Karnataka, capacity 880 MW. Radioactive Material used : Uranium
6. Narora Atomic Power Station, Uttarpradesh,capacity: 440 MW. Radioactive Material used : Uranium
7. Karapar Atomic Power Station (KAPS), Gujarat, capacity: 440 MW. Radioactive Material used : Uranium

Natural uranium contains about 0.7 % uranium-235, while the rest is mostly uranium-238.For use in reactors, uranium must be enriched to increase the concentration of uranium-235. Along with Uranium. Plutonium and Thorium is used in Indian nuclear reactors.

2. Review of Power generation:

As India progresses in its renewable energy journey, the focus must now shift toward the seamless integration of intermittent energy sources into the grid, the development of robust energy storage solutions, and addressing land and resource availability challenges. With innovation, dedication, and a resolute commitment to sustainability, India's renewable energy sector holds the promise of delivering a cleaner, more sustainable future for generations to come.

Table 2.1.Total Installed Capacity (As on 30.06.2024)- Source : Central Electricity Authority (CEA) ¬

Installed Generation Capacity (Sectorwise) as on 30.06.2024 :in (MW)

Sector	Installed Generation Capacity (MW)	% Share in Total
Central Sector	1,04,453	23.4%
State Sector	1,07,671	24.1%
Private Sector	2,34,065	52.5%

Total Installed Capacity	4,46,189 = 4,46,190	

Table 2.2 Installed Generation Capacity (Fuel wise)as on 30-06-2024 (Fossil Fuel)

Category	Installed Generation Capacity (MW)	% Share in Total
Coal	2,10,970	47.3%
Lignite	6,620	1.5%
Gas	24,818	5.6%
Diesel	589	0.1%
Total Fossil Fuel	2,42,997	54.5%

Table 2.3 Installed Generation Capacity (Fuel wise) as on 30-06-2024 (Non-Fossil Fuel)

Category	Installed Generation Capacity (MW)	% Share in Total
RES Including Hydro	1,95,013	43.7 %
Hydro : 46,928		10.5%
Wind,Solar and other RE: 1,48,085 Wind: 46,656 Solar: 85,474 BM Power/Cogen:10,355 Waste to Energy : 593 Small Hydro Power: 5,005		33.2% 10.5% 19.2% 2.3% 0.1% 11%
Nuclear	8,180	1.8%
Total Non-Fossil Fuel	2,03,193	45.5%
Total Installed Capacity (Fossil & Non-Fossil Fuel)	4,46,190	100%

Table 2.4 The annual growth in generation during recent years is as under:

Year	Growth in Fossil Fuel (Thermal Generation) %	Growth in Renewable Energy (RE) Generation (Including Large Hydro) %	Growth in Non-Fossil Fuel Generation RE + Nuclear Generation %	Growth in Total Generation %
2011-12	6.6	17.5	18.30	9.14
2012-13	7.3	-5.9	-4.78	4.46
2013-14	4.2	10.0	9.05	5.23
2014-15	10.8	1.3	1.91	8.84
20115-16	7.5	-1.8	-0.97	5.69
2016-17	5.3	8.9	7.68	5.80
2017-18	4.3	11.1	9.55	5.35
20118-19	3.4	14.3	12.09	5.19
2019-20	-2.7	12.7	13.99	0.95
20120-21	-1.0	2.1	0.86	-0.52
20121-22	7.96	7.74	7.96	7.96
2022-23	8.21	12.84	10.90	8.89
2023-24	9.98	-2.09	-1.37	7.06
2024-25*	12.03	3.49	5.85	10.54

- Provisional up to June 2024

Table 2.5: Electricity Generation through Conventional and Renewable sources of Energy with Annual Increase:.

SR.NO.	Year	Total Generation Including Renewable Sources (BU)	% Growth
1	2009-10	808.498	7.56
2	2010-11	850.387	5.59
3	2011-12	928.113	9.14
4	2012-13	969.506	4.46
5	2013-14	1020.200	5.23
1	2014-15	1110.392	8.84
2	2015-16	1173.603	5.69
3	2016-17	1241.689	5.80
4	2017-18	1308.146a	5.35
5	2018-19	1376.095	5.19
6	2019-20	1389.102	0.95
7	2020-21	1381.855	- 0.52
8	2021-22	1491.859	7.96
9	2022-23	1624.158	8.89
10	2023-24	1739.091	7.06
*11	2024-25	481.001	10.54

Upto June 2024,(Provisional) Source : CEA , India

The electricity generation target (Including RE) for the year 2023-24 has been fixed as 1750 Billion Unit (BU). i.e. growth of around 7.2% over actual generation of 1624.158 BU for the previous year (2022-23). The generation during 2022-23 was 1624.158 BU as compared to 1491.859 BU generated during 2021-22, representing a growth of about 8.87%.

India's total installed renewable energy capacity is 197.20 GW.This include:

Wind power: 47.07 GW,Solar power: 87.20 GW,Biomass generation: 10.35 GW,Waste to energy :0.60 GW,Small hydro power: 5.03 GW,Large hydro power: 46.92 GW.India is the third largest in renewable power generation.

Maharashtra Government has decided to set up 9200 MW solar projects to provide electricity for irrigation in day time to farmers.

Conclusion: In renewable power generation solar, wind, and hydro power share is 186.22 GW out of total 197.20 GW. Along with these three major sectors of renewable power generation, Green liquid hydrogen and Nuclear power can play the important role to enhance the India's renewable power generation up to 50 to 60 % of its total power generation by the year 2030.

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