Department of Mechanical and Aerospace Engineering

Analysis and recommendations for renewable energy scenario in India

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Abstract

India ranks second in population and third in energy consumption. By the year, the population has an increasing curve and due to this, rate energy consumption in India has been increasing too. To offer a solution to the ever-growing energy demand, renewable solutions like wind and solar energy have been implemented on large scale. India, as of 2021 ranks 5th in solar energy production . business is the world's fourth most appealing renewable energy market. As of 2019, India was rated fifth in wind energy, fifth in solar energy, and fourth in renewable energy installed capacity. India proposed to produce 175 GW of renewable energy by 2025 including solar energy, wind energy, or hydro energy or all 3 combined. This thesis analyses the current energy scenario of renewable in India and if at all, the goal of reaching 175 GW can be reached. Large scale wind farms, and solar parks were analysed individually to find out their outputs and checked what percentage of these outputs contribute to the overall supply demand match of renewable energy in India. Wind farms were analysed by finding out the specifications of the turbines used in them, the number of turbines used, weather data of the location across the year was included in the analysis. A total of 97 wind farms were analysed, and their total annual outputs were calculated. As for the solar plants, the areas of the panels used, their inclination, and the location-specific amount of radiations were taken into consideration. When the outputs were obtained, they were compared to the energy consumption in India.

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1. Introduction

India is among the largest renewable energy producers. India's renewable energy is about 36% of the entire energy capacity. The country has aimed to reach 60 GW renewable energy production in the form of solar energy by 2025 (1). The study highlights the goal of Indian solar energy production by keeping feasibility factors in account. Again to find out the approximate span to reach the target is the other focus of the study. With the current progress in solar energy production, the study will cover all the relevant points to fulfil the requirement of the topic. Renewable energy generation is increasingly recognised as playing a critical role in achieving a variety of primary and secondary energy policy goals, including increased energy diversity and security, reduction of local pollutant and global greenhouse gas emissions, regional and rural development, and exploitation of opportunities to foster social cohesion. This concentrates the answer to the energy issue on the efficient exploitation of plentiful renewable energy resources including biomass, solar, wind, geothermal, and ocean tidal energy. This study examines India's renewable energy situation as well as extrapolates future changes based on electricity consumption, output, and supply.

India is the world's second most populous country, with 1.368 billion people as of January 2019. The annual growth rate is 1.18 percent, and it accounts for almost 17.74 percent of the global population. By the end of 2020, 2030, 2040, and 2050, the country is anticipated to have 1.383 billion, 1.512 billion, 1.605 billion, and 1.658 billion inhabitants, respectively.(2)

The major reason for emphasising the move to renewables is that India's economic and industrial growth is being hampered by the energy crisis, dangerously growing levels of environmental pollution, and ever-increasing population, which adds to a rapid increase in per-capita consumption. However, owing to a lack of efforts, legislation, and regulation to encourage renewable energy intake, a few states do not have adequate generation from renwable energy compared to its potential. Solar and wind energy producing facilities have been constructed on agricultural fields in some circumstances, which is helpful. This trend of utilising agricultural land to produce renewable energy might result in a large increase in renewable energy output. (3)

1.1.India's energy goal

India proposed to produce 175 GW of renewable energy by 2025 including solar energy, wind energy, hydro energy and Biomass combined (4). An investment of approximately INR 75 thousand cores is expected in the sector to fulfil the expectation. On the other hand, the target of solar energy production is 280 GW by 2030 and 60 GW by 2025. To meet the targeted amount of energy production the country needs to reach the installation capacity of 25 GW per year. For the targeted process, India needs to import millions of solar modules from various nations.

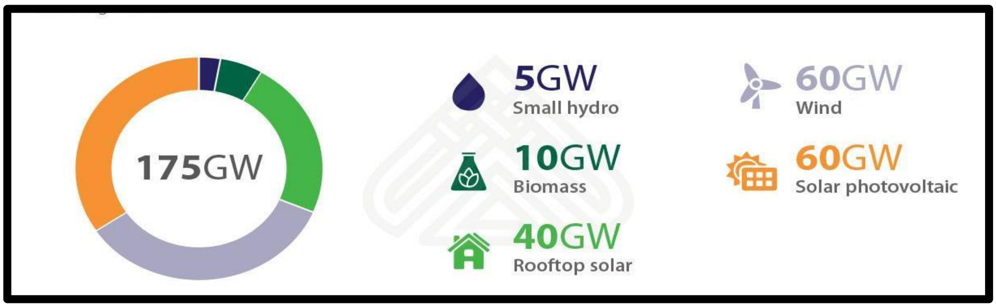

Figure 1: India's renewable energy target
(Source: indiatimes.com, 2020)

The estimated cost for the import is millions of dollars as the current domestic production of modules is not sufficient to fulfil the demand. As per the data of 2018 the installed capacity of solar energy in India has reached 25 GW. To reach the goal India needs to overcome the global supply chain operation issues.

Dependency on the other countries for the different solar energy-producing equipment is another reason for the cost implementation on the project. As per the data of 2019- 20 India's solar energy department spent 2.5 billion USD to import solar wafers, inverters, modules, and solar cells.

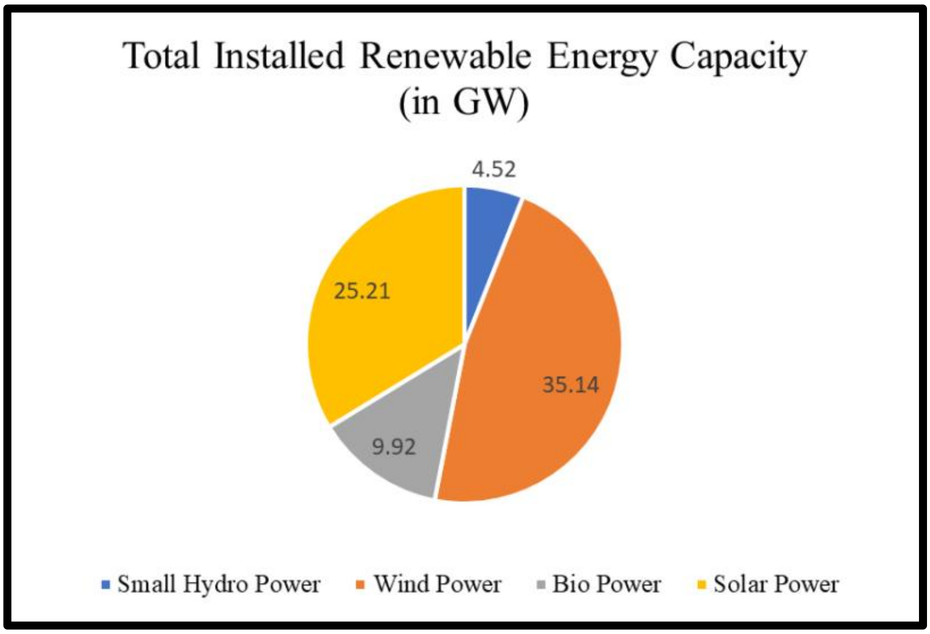

Figure 2: Total installed Renewable energy capacity
(Source: un.org, 2020)

According to the data, the current production capacity of the annual installation is solar PV cells of 3 GW, solar PV modules of 15 MW, and inverters of 5 MW. Companies like Fortune India, BTI are involved in the project of renewable energy production and predict the feasibility of the project. To achieve the targeted solar energy production India needs to double the production which is not a very easy job. Domestic production is not sufficient to reach the target so huge amounts of imports are involved.

Further, it is significant that India has failed to meet the demanded amount of solar energy production in the last few years. To reach the target consistency is the crucial thing that needs to be implemented. Again for the global pandemic the project of solar energy implementation is delayed which is another barrier to reach the target.

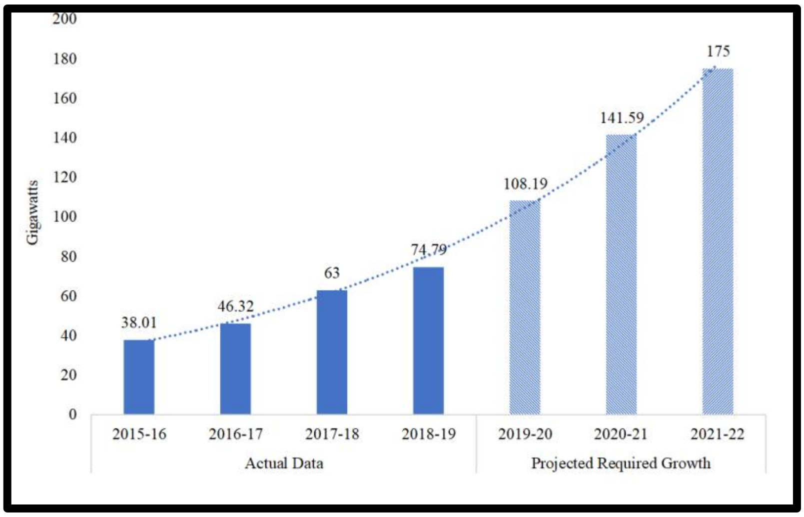

Figure 3: Progress needed to reach the total renewable energy target (Source: Madurai Elavarasan et al. 2020)

1.2.Years for implementation

According to the data of 2020, the Indian production capacity of solar energy has reached 20% of the targeted amount. The domestic solar power accumulation is 2.1 GW and that is 70% of the commercial amount. Current progress in the target indicates that 60% of the targeted amount can be reached in the given period of 2025. It may take another 5years to fulfil the goal of producing 60 GW of solar energy. The importation cost is the key factor that is delaying the project. The rise of the global pandemic causes a huge amount of cost cut off the project of domestic manufacturing of solar equipment. Another thirteen months will be required to complete the tender and all other formalities.

Completion of these factors in the given time will help the project to be completed by 2025. As per the data, the target of 2022 will be achieved by 65% which predicts that the goal of 2025 is hard to complete despite the feasibility of the project. The sustainability of the project depends on the import of the equipment which is not sufficient to achieve the goal within 2025.

1.3.Objective

The main objective of this thesis is to study upclose the renewable energy scenario in India and determine the contribution of renewable energy towards the overall energy consumption in India. This report finds out if the energy goal by the government of India can be fulfilled by their stated timeline.

2. Literature Review

In June 2021, Indian government set a target of installing 175 GW of renewable power. This comprised of 100 GW of solar energy, 60 GW of wind energy, 10 GW of bio-power, and 5 GW hydropower. As of March 2021, India has reached 40.9 GW (of 100 GW) solar, 38.7 GW (of 60 GW) wind, 8 GW (of 10 GW) bio energy, and 4.7 GW (of 5 GW) hydro energy (5).

Table 6: India installed capacity and target capacity

S. No.	Renewable energy source	Installed Capacity (GW)	Target Capacity (GW)
1	Solar	40.9	100
2	Wind	38.7	60
3	Bio-energy	8	10
4	Hydro energy	4.7	5

The extension of the solar energy capacity is predicted to be 15 to 20 GW which will help to reach the 60 GW target of solar energy installation by 2030. (6) The financial allocation of the projects needs to be done properly to complete the import of the required equipment to complete the installation of solar energy. The installation of the solar inverters, PV cells needs support from countries like China. Domestic production of the equipment will extend the time to reach the target. Solar energy is a key source of renewable energy along with wind energy in India. The target of the capacity can be reached in another 5 years from the previously targeted span

2.1.Wind energy

Wind turbines transforms the kinetic energy supplied by the wind into useable mechanical energy, which is then turned into electrical energy to generate electrical power, are used to harness wind power. The rotor and generator are the two most important components of a turbine system. The blades, which are placed in the rotor, are a crucial element of the system since they are responsible for harnessing the wind. The power industry will need to quadruple its generation capacity by 2030 due to fast development, increasing energy availability, and a constant increase in electricity as the end-use energy. Solar and wind energy should account for the majority of it, not only because it is environmentally friendly, but also because it has the lowest cost of generation. India is the world's largest open market, with enormous development potential. It has seen a significant infusion of cash and technological advancements. This will aid in the penetration of wind energy throughout the country (7). Offshore windfarms have traditionally dominated the market; however, technological advancements have prompted the wind industry to consider offshore wind farms as a viable option. With a capacity of 37.09002 GW as of October 2019, onshore wind plays a significant role in the generation of renewable energy in India; hence, offshore installed capacity will be a key addition to the Indian wind power sector. Offshore projects are more expensive than onshore projects, but they offer the advantages of more wind, greater wind density and speeds, a higher plant load factor (PLF), and no land acquisition issues. Offshore wind has a lot of promise, and in particular, it can give a lower cost of electricity, but it still has a long way to go. Techniques and equipment for analysing and forecasting coastal wind resources are getting considerably more expensive, and offshore wind is becoming increasingly unfeasible (7).

India is one of the world's fastest growing emerging countries and is seen as a promising investment opportunity. India has gone a long way since 1947, when it had only 1350 megawatts of generation capacity, to 249,488 megawatts in 2014. In the 1970s, the Indian government began to focus on renewable energy. In the 1970s, the government began to focus on renewable energy. Various programmes for the promotion of renewable energy are now in place in India.

In the nation, a wide range of renewable energy technology is commercially accessible. In the last several years, an Indian wind energy initiative that began in the second part of the 1980s has significantly boosted wind energy installation (8)

Wind energy is booming in India, and it's proving to be a viable alternative for addressing issues like meeting power demand, pollution, greenhouse gas emissions, and dwindling fossil fuels, among others. India is Asia's second-largest wind market after China, and the world's fourth-largest cumulative installed country after the United States and Germany (8).
Due to aerodynamic forces, the blades have different pressure on each side, and they function on the concept of "lift" and "drag," making the lift force greater and forcing the rotor to spin. The rotor is either directly linked to the generator or through a shaft that drives the gearbox. The turbines must operate between two speeds, known as the cut-in and cut-out speeds, which set the limitations. Any speed below the cut-in speed is too low to create any useful power, and any speed over the cut-off speed causes the turbine to shut down to avoid damage. The amount of power generated is proportional to the area swept by the blades, and the quantity of wind reaching the blades is determined by tower height. As a result, power is proportional to area.

2.1.1. Distribution of Wind farms

The distribution for wind energy projects through the states in India is given below:

Table 7:Distribution of wind installed capacity across India

S. No.	State	Installed Capacity (GW)
1	Tamil Nadu	9.23
2	Gujarat	7.2
3	Maharashtra	4.79
4	Karnataka	4.75
5	Rajasthan	4.3
6	Andhra Pradesh	4.07
7	Madhya Pradesh	2.51
8	Telangana	1.28
9	Kerala	0.62
10	Total	37.09

Tamil Nadu has the highest wind speeds throughout the year hence has more wind energy potential. Around 29% of wind capacity in India is contributed by Tamil Nadu international wind turbine manufacturers have made base in India and have unveiled new turbine models for the purpose of reaching the goal of 60 GW by 2022 (9). Some companies are Vestas, Suzlon, and Siemens- Gamessa. In 2020, Siemens Gamessa unveiled new models like SG 3.4 145 which is successor to SG 2.2 122 while Suzlon launched S97-2.1 and S88-2.1. According to the National Institute of Wind Energy (NIWE), total wind energy potential is 302 GW at 100 metre hub height and 695.50 GW at 120 metre hub height (11). More than 95 percent of economically exploitable wind resources are concentrated in seven states out of the entire projected potential (Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Tamil Nadu). Onshore wind projects require valuable land resources, which are rapidly becoming a serious restriction. With the finest windy locations becoming depleted, market-determined rates for onshore wind energy to rise in the future are expected.

2.2. Solar Energy

India's solar energy potential is vast. Most regions have 4-7 kWh/sq. m/day (12). Solar power plants have been increasing their capacities with new solar plants coming up in states of Gujarat, Maharashtra, Karnataka, Rajasthan, and Andhra Pradesh. India also holds the lead in Solar energy as of 2021, defeating Italy which ranks 5th now. Rural electrification and fulfilling other energy demand for electricity, heating, and cooling in both rural and urban regions would benefit from off-grid decentralised and low-temperature applications. Solar is the most secure of all energy sources in terms of energy security since it is readily accessible. A small percentage of total incident solar energy (if caught efficiently) might theoretically fulfil the entire country's electricity needs. Solar energy has had a noticeable influence on the Indian energy landscape in recent years. Millions of people in Indian communities have profited from solar energy-based decentralised and distributed applications that satisfy their cooking, lighting, and other energy demands in an environmentally responsible manner. The social and economic benefits include a reduction in drudgery among rural women and girls who collect fuel wood over long distances, a reduction in the risk of contracting lung and eye diseases, the creation of employment at the village level, and, ultimately, an improvement in the standard of living and the creation of economic opportunities at the village level. At the end of March 2019, India has 35.6 GW of wind energy capacity and 28.2 GW of solar energy capacity (solar and wind combined account for 17.9% of total installed capacity. Their combined output, however, only accounts for 7.3 percent of total energy generated (17).
In addition, India's solar energy sector has grown to become a key participant in grid-connected power generating capacity throughout the years. It promotes the government's objective of long-term prosperity while also establishing itself as an important contributor to meeting the country's energy demands and a key participant in ensuring energy security. The National Institute of Solar Energy estimated the country's solar potential to be at 748 GW, assuming that solar PV modules cover 3% of the waste land area Solar energy is one of the main missions of India's National Action Plan on Climate Change, with the National Solar Mission being one of them. On January 11th, 2010, the National Solar Mission (NSM) was launched.

India just surpassed Italy to take fifth place in the world for solar power installations. In the previous five years, solar power capacity has risen by more than 11 times, from 2.6 GW in March 2014 to 30 GW in July 2019 (14). Solar tariffs in India are now highly competitive and have reached grid parity.

India's average yearly temperature ranges from 25 to 27.5 degrees Celsius due to its position between the Tropic of Cancer and the Equator. As a result, India has enormous solar potential. India's theoretical solar power reception on solely its land area is around 5000 PW h/year, or about 600,000 GW, with about 300 clear, bright days each year. (15)

2.2.1 Distribution of solar energy

Table 8: Distribution of solar installed capacity across India

S. No.	State	Installed capacity (GW)
1	Rajasthan	5.732
2	Punjab	0.959
3	Uttar Pradesh	1.712
4	Uttarakhand	0.368
5	Haryana	0.407
6	Delhi	0.192
7	J&K	0.020
8	Chandigarh	0.045
9	Himachal Pradesh	0.042
10	Gujarat	4.430
11	Maharashtra	2.289
12	Chhatisgarh	0.252
13	Madhya Pradesh	2.463
14	Dadra and Nagar Haveli	0.005
15	Goa	0.007
16	Daman and Diu	0.040
17	Tamil Nadu	4.475
18	Andhra Pradesh	4.203
19	Telangana	3.953
20	Kerala	0.257
21	Karnataka	7.355
22	Puducherry	0.009
23	Bihar	0.159
24	Odisha	0.401
25	Jharkhand	0.052
26	West Bengal	0.149
27	Sikkim	0
28	Assam	0.042
29	Tripura	0.009
30	Arunanchalm Pradesh	0.005
31	Mizoram	0.001
32	Manipur	0.006
33	Meghalaya	0
34	Nagaland	0.001
35	Andaman and Nicobar	0.029
36	Lakshadweep	0.75
37	Others	-
	Total	40.0

2.3.Biomass Energy

The biomass scenario in India is nowhere near western countries. For comparison, biomass plants in Europe are 20 times the size of those in India. Grid based biomass power plants have a capacity of 8-15 MW. Also, there are challenges like the biomass is not available for the full year. Generally, in the 2-3 months after the harvesting period, biomass is available, which is again scarce in some region. States like Karnataka, Andhra Pradesh, and Maharashtra are the leading states that implement biomass for lighting homes and off-grid decentralized power. It is ironical that most agricultural regions do not use biomass energy in this day and age. When biomass is procured over a certain distance, processing in the form of shredding the biomass onsite before shipment is required to enhance its density. For a power plant of capacity 10-15MW, transportation in any manner from more than 50 kilometres becomes unviable. In the northern states, only Uttar Pradesh has implemented Biomass utilization on a large scale owing to its rich sugar cane industry. Roughly biomass plants exist in India which are capable of producing relatively high outputs to fulfil electrical needs. The paucity of investment in the biopower sector in states with significant biomass potential is mostly due to government policies. To encourage local businesses to take on the duty of delivering biomass to processing plants, a solid business model is required. To enable decentralisation of the biomass supply method, collection centres encompassing 2-3 villages can be established. In the event of crop failure, biomass power plant operators may look into employing energy crops as a substitute for crop waste. The scattered character of agricultural fields prevents significant automation, resulting in lower efficiency and higher procurement costs. As on 30th June 2021, India has reached 10.17 GW of installed capacity thus achieving the goal of 10 GW by 2022. Biofuels contain 10%–45% oxygen in their molecules, which explains why they burn more effectively and emit less greenhouse gases and particulates Fossil fuels, unlike biofuels, have no oxygen in their molecules yet have a larger energy content. As a result, in compared to fossil fuels, a greater quantity of biofuels is required to go the same distance. Biofuels' benefits promote their fast use, although their production is currently reliant on food crops. Conventional biofuels are the name given to these biofuels. Traditional biofuels have a well-developed logistics and supply chain, as well as a simple and established production technique. However, using food biomass for biofuel production indefinitely poses a danger to food security.(13)

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2.3.1. Biomass gasification plants in India

Table 9: Distribution of biomass plants across India

S. No.	State	Location of plant	Nominal capacity	Developer
1	New Delhi	UNIDO	1kW	CGPL
2	Gujarat	Speri,Vallabha Vidyanagar	1kW	CGPL
3	Maharashtra	IIT Bombay	1kW	CGPL
4	West Bengal	Tezpur University	1kW	CGPL
5	West Bengal	Banahut	1kW	CGPL
6	Bihar	Vaishal	1kW	OVN
7	Uttar Pradesh	Janak Puri	1kW	OVN
8	West Bengal	Dimapur	1kW	Synergy
9	West Bengal	Kolkata	1kW	Synergy
10	-	NTPC	5 kW	Aruna
11	Tamil Nadu	Dharmapuri	7.5 kW	Aruna
12	Tamil Nadu	Kanchipuram	7.5 kW	Aruna
13	Arunachal Pradesh	Arunachal Pradesh	7.5 kW	CGPL
14	Tamil Nadu	Dharmapuri	10kW	Aruna
15	Madhya Pradesh	Kasai	15kW	Aruna
16	Madhya Pradesh	Debrabandi	15kW	Aruna
17	Assam	Assam	20kW	BETEL
18	Karnataka	Astra - CGPL	20kW	BETEL
19	Karnataka	Hosahalli	20kW	CGPL
20	Arunachal Pradesh	Bomdila	20kW	OVN
21	Bihar	Drishtee Foundation, Sarut, Madhubani	20kW	OVN
22	Nagaland	Kohima	20kW	OVN
23	West Bengal	WBREDA	20kW	OVN
24	Karnataka	BAnglore	25 kW	BETEL
25	Assam	Guwahati	25 kW	OVN
26	Manipur	Manipur	25 kW	OVN
27	Karnataka	Bethmangala	35 Kw	NETPRO
28	Rajasthan	Sankalp	35 kW	NETPRO
29	Tripura	Katlamara	35 kW	OVN
30	Tripura	Don Bosco Training School, Bishram Ganj	35 kW	OVN
31	Tripura	Rubber Producer Society, Rangmala	35 kW	OVN
32	Tripura	Rubber Producer Society, Laxmandepa	35 kW	OVN
33	Tamil Nadu	Javalgiri, Hosur	45 kW	ARUNA
34	Karnataka	JNNCE, Shimoga	45 kW	BETEL
35	Bihar	DESI Power Bharbari	50 kW	NETPRO
36	Karnataka	WSD, Varlakonda	50 kW	NETPRO
37	Karnataka	Gem & Sons, Chitradurga	60 kW	BETEL

38	Tamil Nadu	Aruna	75 kW	ARUNA
39	Kerala	Ideal Crumb, Palakkad	75 kW	BETEL
40	Mizoram	Malson Bamboo Pvt. Ltd, Bairabi	75 kW	CGPL
41	Karnataka	NIE, Mysore	75 kW	ENERGREEN
42	Tamil Nadu	Bhagavathi Bio-Power, Mettupalyam	75 kW	ENERGREEN
43	Tamil Nadu	Kongu	75 kW	ENERGREEN
44	Tamil Nadu	G.B.Engineering Enterprises	75 kW	NETPRO
45	Karnataka	Elite Crumb Rubber, Mangalore	100 kW	BETEL
46		Synergy	100 kW	BETEL
47	Karnataka	MVIT– II	100 kW	NETPRO
48	Madhya Pradesh	DESI Power Orchha (P) Ltd.	100 kW	NETPRO
49	Tamil Nadu	Dev Power Corporation	100 kW	NETPRO
50	Tamil Nadu	Vellore Institute of Technol-ogy	100 kW	NETPRO
51	Tamil Nadu	VIT, Vellore	100 kW	NETPRO
52	Tamil Nadu	G.B Food oils	100 kW	NETPRO
53		Edathala Polymers	125 kW	BETEL
54	Karnataka	BERI, Kabbegiri Village, Tumkur	150 kW	ENERGREEN
55	Sagar Island	Sagar Island	150 kW	SYNERGY
56	West Bengal	WBREDA	150 kW	SYNERGY
57	Karnataka	BERI, Kabbegiri Village, Tumkur	225 kW	NETPRO
58	Tamil Nadu	Pointech	300 kW	ARRYA
59	Jammu	Hindustan Pencils	415 kW	BETEL
60	Tamil Nadu	Tahafet	415 kW	BETEL
61	Jammu	Sanghvi Woods	415 kW	BETEL
62	Jammu	Hindustan Pencils	415 kW	
63	Karnataka	Bethmangala	500 kW	ENERGREEN
64	Tamil Nadu	Arashi, Tamil Nadu	1 MW	ENERGREEN
65	Tamil Nadu	Gomathy	1 MW	ENERGREEN
66	Tamil Nadu	BMC, Kuttam	1.5 MW	ARRYA

(Source: https://www.eai.in)

Biomass materials that are used in India for the purpose of bioenergy are straws, rice husk, stock, and groundnut shells. The amounts of material are given in the table below:

Table 10: Materials for bioenergy in India

S. No.	Material used	Amount (Million Tonnes)
1	Straws	225.50
2	Bagasse	31.00
3	Rice husk	10.00
4	Groundnut shell	11.10
5	Stalks	2.00
6	Various oil stalks	4.50
7	Others	65.90
	Total	350.00

2.4. Hydro energy

India ranks 5th in the world for total installed hydroelectric capacity. As of 30 June 2021, India has reached 4.8 GW of the 5 GW goal which was to be attained by the year 2022. The total potential of India to produce hydro energy was calculated in 2021 by Indian Institute of Technology Roorkee. The study concluded with a total potential of 21.135 GW energy over 7135 sites all across India. Arunanchal Pradesh, Uttarakhand, Jammu and Kashmir, and Himachal Pradesh are hilly regions and these alone contribute above 50% of this potential. On a worldwide scale, India is endowed with enormous hydro-electric potential, ranking fifth in terms of usable hydro-potential. The first source of energy is tiny hydro. It is the most dependable renewable energy source. Small-scale hydropower development in India began roughly simultaneously with the world's first hydroelectric plant in Appleton, Wisconsin, in 1882. (Dhillon and Sastry, 1992). The first installation in India was a 130 KW plant at Sidrapong (Darjeeling) in 1897. (14)

The Ministry of Power oversees big hydropower, whereas the Ministry of New and Renewable Energy oversees minor hydropower up to 25 MW. As can be seen, fossil fuels including coal, natural gas, and oil account for 62.7 percent of total power generation. Energy consumption is expected to more than quadruple by 2030, while electricity demand is expected to almost treble. As a result, modest hydropower might be viewed as a more viable option for generating energy. Because most SHPs are canal-based or run-of-river types that use moving water to operate the turbine, small hydropower is typically clean, sustainable, and environmentally benign. For fear of floods, desertification, relocation difficulties, and other issues, big hydropower is frequently opposed by societies, environmentalists, and non-governmental groups. (15)

The weir or barrage is tiny, and no water is stowed; it is devoid of issues like relocating local residents or deforestation, which are common with major hydroelectric projects. SHPs are immune from forest and land clearance and public sitting/plenary enquiry in several countries, including India, since they are sustainable. According to the CEA, India has 1,48,700 MW of installed hydropower capacity that may be profitably used (15).

2.4.1. Distribution of hydroelectric plants in India

Table.6: Distribution of hydroelectric plants in India

S. No.	Name	River	Location	Capacity (MW)
1	Tehri Dam	Bhagirathi	Uttarakhand	2400 MW
2	Srisailam Dam	Krishna	Andhra Pradesh	1670 MW
3	Nagarjunasagar	Krishna	Andhra Pradesh	965 MW
4	Sardar Sarovar	Narmada	Gujarat	1450 MW
5	Baspa-II	Baspa	Himachal Pradesh	300 MW
6	Nathpa Jhakri	Satluj	Himachal Pradesh	1500 MW
7	Bhakra Dam	Satluj	Punjab	1325 MW
8	Pandoh Dam	Beas	Himachal Pradesh	990 MW
9	Baira Siul	Ravi	Himachal Pradesh	198 MW
10	Chamera-I	Ravi	Himachal Pradesh	540 MW
11	Chamera-II	Ravi	Himachal Pradesh	300 MW
12	Pong	Beas	Himachal Pradesh	396 MW
13	Uri Hydroelectric Dam	Jhelum	Jammu & Kashmir	480 MW
14	Dulhasti	Chenab	Jammu & Kashmir	390 MW
15	Salal	Chenab	Jammu & Kashmir	690 MW
16	Sharavathi	Sharavati	Karnataka	1035 MW
17	Kalinadi	Kalinadi	Karnataka	955 MW
18	Idukki	Periyar	Kerala	780 MW
19	Bansagar Dam	Sone	Madhya Pradesh	425 MW
20	Bargi Dam	Narmada	Madhya Pradesh	105 MW
21	Omkareshwar	Narmada	Madhya Pradesh	520 MW
22	Indira Sagar	Narmada	Madhya Pradesh	1000 MW
23	Loktak	Manipur	Manipur	105 MW
24	Koyna	Koyna	Maharashtra	1960 MW
25	Bhira Hydroelectric Project	Mulshi Dam	Maharashtra	150 MW
26	Teesta VI	Teesta	Sikkim	510 MW
27	Tanakpur	Sharda	Uttarakhand	120 MW
28	Dhauliganga-I	Dhauliganga	Uttarakhand	280 MW
29	Loharinag Pala	Bhagirathi	Uttarakhand	600 MW

(Source: www.tutorialspoint.com)

3. Analysis of wind farms

3.1.Structure of calculations

An Excel tool was put together to get an idea of annual output of wind stations in India. The weather data that is the wind speeds in the regions of wind stations were taken into account. Each wind station was looked into and the models of turbines, their cut-in seeds, cut-out speeds, rated speeds were taken in account. Number of turbines was one of the main part of calculations and that was considered too for the total output. The power coefficient for wind turbines usually is in the range of 0.40 to 0.53. In this case, 0.42 was assumed for all turbines. The air density for all parts of India was taken as 1.225 kg/m^3 for all turbines in all regions. The formula used for calculations for hourly power produced is given below:

$$P = {}^{1}/_{2} \times C_p \times \rho \times A \times V^3$$

Where P is power output in kW

C_p is power co-efficient,

A is the swept area, m^2

ρ is the air density, kg/m^3

V is the wind speed perpendicular to turbine, m/s

Parameters entered in the Excel can be changed according to the location and the turbine. Power output across the year can be gained through this Excel. The Excel works such that weather data of location of each wind farm is added. Wind speeds for each hour across the whole year are added, and wind speeds which are below the cut-in speed and above cut-out speed are filtered out. Therefore 24 hours for 365 days, that is 8736 hours are added. And an output for each output is gained in kW. The formula which is given above is used where the air density is taken as common for all the wind speeds (1.21 kg/m3). The power co-efficient is also taken as common for all hours, which is 0.42 in this case as it is supposed to be between 0.40 and 0.53.

Swept area is the area covered by the rotors of the turbine. Hence if ‘d’ is the diameter of the rotor, the swept area is $\pi \times {}^{d^2}/_{4}$

Since a wind farm contains multiple turbines, the output is also multiplied to the number of turbines in the end. Finally, all the hourly outputs are added, and a final total output is gained in GWh.

A total of 97 windfarms were assessed in the Excel and their outputs sorted according to their regions are given below.

3.2.Analysis of wind farms in Maharashtra

Maharashtra has abundance of in habituated regions in rural areas with wind speeds as high as 18 m/s in some places which make it ideal location for wind farms. Places like Brahmanvel, Dhalgaon, Dhule, and Khandke boast of large scale wind farms which contribute to a major chunk of wind energy production in Maharashtra state. Implementation of multiple wind farms can be observed in some places where wind speeds and large spaces are vastly available. Companies which have manufactured turbines in this region are Suzlon, Enercon, Vestas, Neg Micon, and GE-Suzlon being the leading company manufacturing turbines for major wind projects in Maharashtra. The total annual energy production from major wind farms in Maharashtra totals to 1182 GWh with the district of Brahmanvel accommodating 7 wind farms alone producing roughly 570 GWh annually.

Small scale wind farms contribute to a total of 140 GWh which makes the total wind energy production of Maharashtra to 1322 GWh. Parakh Agro Industries created the 528MW Brahmanvel wind farm, which is located in Maharashtra's Dhule district. Apart from Dhule, Satara, Sangli, and Panchgani are other Maharashtra cities with a considerable number of power generation facilities. After Tamil Nadu, Maharashtra has the most wind energy installed capacity in India, with 4098MW.The Andhra lake was commissioned in 2012, while the construction phase started in 2009. It is located near Pune district in Western Maharashtra (20).

The 278 MW Dhalgaon wind farm in Sangli, Maharashtra, was built by Gadre Marine Exports. Suzlon and Enercon turbines are used in the wind farm, which was completed in 2005. Maharashtra is one of the greatest states to invest in wind energy because of its investor-friendly legislation (20)

Table 7: Calculated outputs of wind farms in Maharashtra

S. No.	Location	No. of Wind turbines	Total Nominal power (MW)	Turbine used	Manufacturer of turbines	Total annual output (GWh)
1	Andhra Lake I	70	56	E53/0.8	Enercon	1.42
2	Andhra Lake II	72	244.8	E103/3.4	Enercon	5.54
3	Aundhewadi	13	10.4	E48/0.8	Enercon	9.8
4	Brahmanvel I	2	3.3	V82-1.65	Vestas	4.40
5	Brahmanvel II	32	40	S66-1.25	Suzlon	45.61
6	Brahmanvel III	4	3	NM44/0.75	Neg Micon	2.53
7	Brahmanvel IV	20	25	NM44/0.75	Neg Micon	12.67
8	Brahmanvel V	16	3.6	S52-0.6	Suzlon	14.16
9	Brahmanvel VI	345	431.25	S64-1.25	Suzlon	462.39
10	Brahmanvel VII	4	6	S82-1.5	Suzlon	8.8
11	Brahmanvel VIII	18	14.4	E53/0.8	Enercon	16.48
12	Chakala I	64	80	S146-1.25	Suzlon	70.83
13	Chakala II	20	30	S82-1.5	Suzlon	6.98
14	Chakala III	2	4.2	S82-1.5	Suzlon	0.80
15	Dhalgaon I	2	2.5	S66-1.25	Suzlon	0.01
16	Dhalgaon II	14	22.4	S48-0.6	Suzlon	0.04
17	Dhalgaon III	51	30.6	S52-0.6	Suzlon	0.17
18	Dhalgaon IV	130	162.5	S64-1.25	Suzlon	0.64
19	Dhule I	2	2.5	S66-1.25	Suzlon	2.85
20	Dhule II	14	22.4	E48-0.6	Enercon	10.55
21	Dhule III	51	30.6	S52-0.6	Suzlon	45.10
22	Dhule IV	130	162.5	S64-1.25	Suzlon	174.15
23	Dhule V	49	73.5	S82-1.5	Suzlon	107.76
24	Khandke I	48	108	E48-0.8	Enercon	101.47
25	Khandke II	63	40.32	E53/0.8	Enercon	57.52
26	Panchpatta	65	338	E48/5.2	Enercon	1.09
27	Ratnagiri I	41	65.6	GE100/1.6	GE	8.44
28	Ratnagiri II	22	35.2	GE100/1.6	GE	4.53
29	Satara	35	52.5	S82-1.5	Suzlon	1.71
30	Sidhpur	35	52.5	S82-1.5	Suzlon	1.71
31	Welturi I	24	50.4	S97-2.1	Suzlon	1.64

3.3. Analysis of wind farms in Madhya Pradesh

Madhya Pradesh is in the centre of India and regions like Bhopal, and Indore are the main textile commerce hubs in India so the energy consumption is high in these regions. There are large scale wind farms located in this region. Some of the places where large scale wind farms can be found are Badnawar, Chandgarh, Lahori, Mamatkheda, and Ratlam. Turbine manufacturing market is dominated by Suzlon in Inox in Madhya Pradesh. The highest energy producing region is Ratlam where a single wind farm accommodates 85 wind turbines manufactured by Inox and generates total of 314.44 GWh wind energy. Unlike the other wind farms in Madhya Pradesh, Mamatkheda uses turbines manufactured by Regen Powertech and contributes the second highest amount of wind energy- 217.67 GWh.

Table 8: Calculated outputs of wind farms in Madhya Pradesh

S. No.	Location	No. of wind turbines	Total nominal power (MW)	Turbine model	Manufacturer of turbines	Total annual output (GWh)
1	Badnawar	50	100	SG97-2.0	Siemens Gamesa	202.72
2	Chandgarh I	46	92	SG97-2.0	Siemens Gamesa	186.43
3	Chandgarh II	19	38	SG97-2.0	Siemens Gamesa	77
4	Lahori I	46	92	IN100/2.0	Inox	93.42
5	Lahori II	25	50	IN100/2.0	Inox	50.77
6	Lahori III	15	30	IN100/2.0	Inox	30.46
7	Mamatkhede	67	100.5	R87/1,5	Regen Powertech	217.67
8	Ratlam	85	170	IN93/2.0	Inox	314.44

3.4.Gujarat

Average wind speed in Gujarat is 5 m/s. The major factor that gives Gujarat an advantage is that it being close to the sea and getting high amounts of radiation, options of offshore wind and solar can be explored. There are 6 regions where major wind farms are situated- Dayapur, Rojmal, Samana, Jangi, Khambaliya, and Rajkot. The highest energy produced by a wind farm is 679.75 GWh in Dayapur. The turbines which are used in wind farms in Gujarat are manufactured by Vestas vastly with Inox, Gamessa, and Suzlon. Total energy consumption of Gujarat annually is 95,970 GWh, while the total wind energy produced from large scale wind farms comes to 1,879.77 GWh. Plus small scale wind farms account to 88.49 GWh of energy. This takes the total wind energy production in Gujarat to 1968.26 GWh.

Table 9: Calculated outputs of wind farms in Gujarat

S No	Location	No. of wind turbines	Total nominal power (MW)	Turbine Model	Manufacturer	Total annual output (GWh)
1	Dayapur	125	250	IN113/2.0	Inox	679.75
2	Janggi	55	140.25	V82-1.65	vestas	125.49
3	Khambaliya I	23	50.6	V120-2.2	Vestas	112.38
4	Khambaliya II	5	10	V110-2.0	Vestas	20.53
5	Khambaliya III	9	18	V100-2.0	Vestas	30.54
6	Rajkot I	35	52.5	S82-1.5	Vestas	79.80
7	Rajkot II	46`	101.2	V120-2.2	Vestas	109.3
8	Rajkot 2A	12	25.2	SG112-2.1	Siemens Gamesa	38.4
9	Rajkot 2B	14	28	IN113/2.0	Inox	44.3
10	Rojmal	165	330	IN100/2.0	Inox	559.48
11	Samana	35	52.5	S82-1.5	Siemens	79.80

3.5.Andhra Pradesh

Andhra Pradesh has abundance of inhabituated regions in rural areas with wind speeds as high as 18 m/s in some places which make it ideal location for wind farms. Places like Brahmanvel, Dhalgaon, Dhule, and Khandke boast of large-scale wind farms which contribute to a major chunk of wind energy production in Andhra Pradesh state. Implementation of multiple wind farms can be observed in some places where wind speeds and large spaces are vastly available. Companies which have manufactured turbines in this region are Suzlon, Enercon, Vestas, Neg Micon, and GE-Suzlon being the leading company manufacturing turbines for major wind projects in Maharahstra. The total annual energy production from major wind farms in Andhra Pradesh totals to 203.84 GWh with the district of Anantpur accommodating 7 wind farms alone producing roughly 193.091 GWh annually. Small scale wind farms contribute to a total of 40 GWh which makes the total wind 2energy production of Andhra Pradesh to 1322 GWh.

Table 10: Calculated outputs of wind farms in Andhra Pradesh

S No.	Location	No.of Turbines	Total nominal power (MW)	Model of turbine	Manufac-turer	Total annual output (GWh)
1	Anantpuram Orange	50	100	SG97-2.0	Siemens Gamesa	25.65
2	Anantpur Hero	60	120	SG114-2.0	Siemens Gamesa	42.51
3	Anantpur Adani	25	50	SG100-2.0	Siemens Gamesa	13.63
4	Anantpur Axis	50	34.07	S112-2.1	Suzlon	34.07
5	Anantpur Ostro	94	48.22	S97-2.1	Suzlon	48.22
6	Anantpur I	5	7.5	S82-1.5	Suzlon	1.83
7	Anantpur II	47	159.8	GE103/3.4	GE	27.18
8	Bellugappa	48	100.8	S112-2.1	Suzlon	6.08
9	Ellutale I	24	50.8	S97-2.1	Suzlon	2.29
10	Ellutale II	24	50.8	S97-2.1	Suzlon	2.38

3.6. Analysis of wind farms in Rajasthan

Average wind speed in Rajasthan is 7 m/s.. There are 6 regions where major wind farms are situated- Bhakrani, Jaipur, Devgarh, Mokal, Sipala, Tejuva. The highest energy produced by a wind farm is 109.67 GWh in Devgarhr.Total capacity of Rajasthan as of 2020 is 4337 MW. The turbines which are used in wind farms in Rajasthan are manufactured by Suzlon vastly with Enercon and Regan Powertech. Total energy consumption of Rajasthan annually is 60,151 GWh, while the total wind energy produced from large scale wind farms comes to 907.37 GWh. Plus small scale wind farms account to 38.49 GWh of energy. This takes the total wind energy production in Gujarat to 945.86 GWh. The Jaisalmer wind park, developed by Suzlon Energy, is the country's second-largest onshore wind farm. The 1,064MW project, which is located in Rajasthan's Jaisalmer region, includes a cluster of wind farm locations such as Amarsagar, Badabaug, Baramsar, Tejuva, and Soda Mada, among others. The wind park's construction began in 2001, and it reached its present capacity in April 2012. Suzlon's complete wind portfolio was employed in the project, from the oldest 350 kW model to the most recent S9X – 2.1MW series.

Suzlon, a developer of renewable energy solutions, developed the wind farms for a variety of clients, including private and public sector companies, independent power producers, and power utility companies.

Table 11: Calculated outputs of wind farms in Rajasthan

S No.	Location	No. of Turbines	Total nominal power (MW)	Model of turbine	Manufacturer	Total annual output (GWh)
1	Bhakrani I	27	21.6	E53-0.8	Enercon	3.05
2	Bhakrani II	103	206	E53-2.0	Siemens Gamessa	11.63
3	Bhakrani III	18	14.4	E53-0.8	Siemens Gamessa	2.03
4	Devgarh	59	88.5	R82-1.5	Regan Powertech	109.67
5	Mokal I	15	31.5	S88-2.1	Suzlon	31.76
6	Mokal II	20	42	S88-2.1	Suzlon	42.35
7	Mokal III	38	79.8	S88-2.1	Suzlon	80.47
8	Sipala	126	100.8	E53-0.8	Enercon	14.26
9	Tejuva	96	201.6	S97-2.1	Suzlon	9.15

3.7.Analysis of wind farms in Karnataka

Karnataka has abundance of in habituated regions in rural areas with wind speeds as high as 10 m/s in some places which make it ideal location for wind farms. Places like Banner, Taggupurti, Nimbagallu, and Herapanahalli boast of large-scale wind farms which contribute to a major chunk of wind energy production in Karnataka state. Implementation of multiple wind farms can be observed in some places where wind speeds and large spaces are vastly available. Companies which have manufactured turbines in this region are Suzlon, Enercon, Vestas, Neg Micon, and GE-Suzlon being the leading company manufacturing turbines for major wind projects in Karnataka. The total annual energy production from major wind farms in Karnatakatotals to 1182 GWh with the district of Brahmanvel accommodating 7 wind farms alone producing roughly 570 GWh annually. Small scale wind farms contribute to a total of 140 GWh which makes the total wind energy production of Karnataka to 1322 GWh. In Karnataka, India, the Tuppadahalli onshore wind farm is a 56.1MW power plant. The wind farm is 55 kilometres from Chitradurga and 260 kilometres from Bangalore, Karnataka's capital.

Table 12: Calculated outputs of wind farms in Karnataka

S. No.	Location	No. of turbines	Total nominal power (MW)	Model of turbine	Manufacturer	Total annual output (GWh)
1	Banner	20	42	S88-2.1	Suzlon	42.35
2	Taggupaurti	38	79.8	S88-2.1	Suzlon	20.47
3	Nimbagallu	20	48	S97-2.1	Suzlon	48.57
4	Ralle	76	39.5	S97-2.1	Suzlon	2.95
5	Gadag !	49	73.5	S82-1.5	Suzlon	3.34
6	Gadag II	2	0.450	N29.5-.225	NEPC	0.02
7	Gadag III	59	88.5	R82-1.5	Regan Powertech	3.34
8	Gadag IV	24	65.5	S97-2.1	Suzlon	7.69
9	Gadag V	18	45.1	S88-2.1	Suzlon	4.28
10	Chitrudugh	96	201.6	S97-2.1	Suzlon	9.15
11	Herapanahalli I	18	14.4	S53-0.8	Suzlon	2.03
12	Herapanahalli II	103	206	SG53-2.0	Siemens Gamessa	9.15
13	Herpanahalli III	96	201.6	SG3-0.8	Siemens Gamessa	2.03
14	Herapanahalli IV	18	45.1	SG97-2.1	Siemens Gamessa	4.28

4. Analysis of Solar parks

4.1.Calculations strategy of solar parks

An excel was made where the location of the solar park was entered including the longitude and latitude of the region. The direct and diffused solar radiations are entered for each hour for a day across the year. Thus, a total of 8076 inputs on radiations are gained and input in the Excel. Specifications of the solar panel like Orientation and tilt are set which apply to all the 8076 inputs. The orientation is set to South east in tis case as the most output is obtained at angle of 45 degrees. The tilt is taken as 12 degrees. The area of the panel including all the phases is set. The window transmission coefficient can also be entered and is set at 87% The efficiency of PV and inverter are set and an output for each hour is gained across the year. These outputs are totalled to calculate an overall annual output for each solar park.

4.2.Analysis of solar parks in Rajasthan

Rajasthan is the leading state in India in terms of solar power. It is home to Dhirubhai Ambani Solar park which is Fresnel type 125 MW CSP plant. Jodhpur alone contributes to 1500 MW of the total 2489 MW in Rajasthan state. Along with Jodhpur, Jaisalmer and Bikaner also have large scale solar plants.

Table 13: Calculated outputs of solar parks in Rajasthan

S No.	Solar Power Plant	Nominal Capacity	Total output (GWh)
1	Bhadla Solar Park I	680	7.61
2	Bhadla Solar Park II	1000	7.01
3	Bhadla Solar Park III	500	3.80
4	Bhadla Solar Park IV	750	5.71
5	Pokran Solar Park	750	12.06
6	Phatehgarg Solar Park	421	7.11
7	Nokh Solar Park	925	18.69

4.2.1. Bhadla Solar Park

The world's largest solar power plant, the Bhadla Solar Park, is located in the Bhadla hamlet in Rajasthan's Jodhpur region. The fully operational power plant, with a capacity of 2,250MW and a 14,000-acre footprint, has been erected. The Bhadla solar park is a 2.25 GW solar complex under construction in the Bhadla hamlet in Rajasthan's Jodhpur area (24). Bhadla solar park is the largest solar plant in the world. It has a total of 37 sections divided in 4 phases. A total of 14000 acres is covered by the solar park and the name plate capacity is 2245 MW. The capacity is divided among the four phases of the park. Phase I has a capacity of 680 MW, Phase II has a capacity of 1000 MW, Phase III has a capacity of 500 MW, and Phase IV has capacity of 750 MW.

4.2.2. Pokhran solar park

Also known as Dhirubhai Ambani Solar Park, it is situated near the village of Pokhran which is based near Jaiselmer city. When it was commissioned it was supposed to be forty mega watt solar power facility. One phase of the solar park which is 35 thousand sq. km. is is planned in the Thar desert as that area gets maximum radiations in Rajasthan and still remains to be habituated (25).

4.2.3. Fatehgarh Solar Park

The Fatehgarh Solar Park, which is located in Rajasthan's Jaisalmer district, spans 9,981 acres and have a total capacity of 1,500 megawatts.

4.2.4. Nokh Solar Park

Nokh Solar Park is a 925 megawatt (MW) solar project under construction in Rajasthan's Jaisalmer area. The project is being developed by Rajasthan Solar park Development Company Limited (RSDCL), a subsidiary of Rajasthan Renewable Energy Corporation (RREC), in collaboration with National Thermal Power Corporation (NTPC).
In February 2020, the businesses signed an implementation support agreement (ISA) under which RSDCL would construct the basic infrastructure and NTPC will develop the solar photovoltaic (PV) projects in the solar park (26).

4.3. Analysis of solar parks in Andhra Pradesh

Total installed capacity of Andhra Pradesh as of March 2010 is 4203 MW. Large scale power plants like Anathapuram-II contribute to vast majority of its total power output.

Andhra Pradesh has enough of pumped hydroelectric energy storage to convert solar electricity into a continuous power source to fulfil its long-term energy demands. To minimise the intermittency associated with renewable energy, the state plans to build 33,000 MW of pumped storage plants. Installed capacity of Ananthapuram-II alone is 1500 MW.

Other plants that are installed in Andhra Pradesh are Kurnool Solar plants, Kadappa Solar power Plant, Hybrid Solar Wind park, and Ananthapuram-I solar park.

Table 14: Calculated outputs of solar parks in Andhra Pradesh

S. No.	Solar Power Plant	Nominal Capacity (MW)	Total output (GWh)
1	Ananthapuram I	1500	21.80
2	Kurnool	1000	15.87
3	Kadappa	1000	19.59
4	Anathapuram II	500	8.72
5	Hybrid Solar Wind	160	2.65

4.3.1. Ananthapuram-I solar park

Anathapuram-I Ultra Mega Solar Park is a solar park based in north Andhra Pradesh, in the Anantpur district. Its size is around 7900 acres. A total of 1000 MW capacity has been commissioned in 2021 by private solar companies. Galivedu Solaar park is based near NP KunTa Solar park too, And is owned by companies like Tata. A total of 400 MW is commissioned in Galivedu Solar Park (27).

4.3.2. Kurnool solar park

The Kurnool Solar Park has a total area of 24 km2 (9.3 sq mi) in the Kurnool district's Gani and Sakunala villages. Aridity prevails throughout the area. Over 4 million solar panels with capacities of 315 and 320 watts are used in the park. Through approximately 2,000 circuit kilometres of cables, the panels are linked to four 250 MW 220/33 kV pooling stations and a 400/220 kV grid substation. The Kurnool Solar Park can generate more than 8 GWh of power on a bright day, which is enough to fulfil almost the entire electrical demand in the Kurnool area. By 2022, the Indian government hoped to have constructed a total capacity of 20 GW of solar PV power output. India, on the other hand, now has 29.41 GW of solar photovoltaic (PV) plants, indicating that the objective has been met three years ahead of schedule. (28)

When comparing the gain of modules using a single-axis tracking system to a fixed-tilt angle system, The single-axis tracking system is found to increase the plant's performance. Kurnool Solar Power Park is one of India's largest solar parks, with an average solar radiation of 5.5–6.0 kWh/m^2.

A 50 MW solar photovoltaic system has been built in Kurnool as part of this project. The performance parameters for analysis are specified in this article. From April 2018 to March 2019, the system was monitored. The performance ratio ranged from 75% to 83 percent, resulting in an annual average performance ratio of 79.94%. (28)

4.3.3. Kadappa solar park

A total of 500 MW has been commissioned for the adapa Solar park which is based in Mylavaram Mandal district and roughly covers 25 sq. kms. Companies which have commissioned this solar park are Andhra Pradesh Solar Power Corporation Private Limited and Solar Energy Corporation of India Limited. (29)

4.4. Analysis of solar parks in Gujarat

Gujarat has a total installled capacity of 4430 MW as of March 2021. Power plants like Dholera solar plant are situated here. Dholera has two phases. Dholera Solar power plant Phase I has a capacity of 4000 MW (which still has to be operational), while Dholera power plant phase 2 has a capacity of 1000 MW. The goal of Gujarat Government is to take the total installed capacity to 22, 922 MW. Rajkot, Surendranagar, and Kutch are districts where major solar power plants are situated.

Table 15: Calculated outputs of solar parks in Gujarat

S No.	Solar Power Plant	Nominal Capacity (MW)	Total output (GWh)
1	Radhnaseda	700	11.42
2	Harsad	350	17.06
3	Dholera I	1000	18.41
4	Dholera II	4000	33.10

4.4.1. Dholera solar park

Dholera solar park is a two-phase solar project in Dholera hamlet, around 80 kilometres from Ahmedabad, Gujarat, India. Dholera Solar Park will be built on Coastal Regulation Zone (CRZ) type 1B property inside the Dholera Special Investment Region (DSIR) in Gujarat, near the Gulf of Khambhat. The 920km2 DSIR will be built by the government created Dholera Special Investment Regional Development Authority and will include 22 Gujarat villages (DSIRDA). (30)

4.5.Analysis of solar parks in Madhya Pradesh

Madhya Pradesh is another state where large scale solar power plants are situated. Power plants like Rewa solar power plant, Omkaresar Floating Solar Park, Chhattarpur Solar Park, and Agar power park are located in Madhya Pradesh. Chhattarpur has the most installed capacity of them which is 950 MW. It is located in the city of Barethi.

Table 16: Calculated outputs of solar parks in Madhya Pradesh

S. No.	Solar Power Plant	Nominal Capacity (MW)	Total power output (GWh)
1	Rewa	750	15.39
2	Mandsaur	250	5.73
3	Neemuch	500	8.32
4	Agar	550	15.13
5	Shajapur	450	7.96
6	Omkareswar Floating Solar Park	600	16.54
7	Chhattarpur Solar Park	950	17.71
8	Barethi Solar Park	550	9.20

4.5.1. Rewa solar park

On January 3rd, 2020, the 750 MW Rewa Solar Project, one of the world's largest solar projects, was completely operational. Since then, it has been supplying the state-owned Madhya Pradesh Power Management Company (MPPMCL) and the Delhi Metro Corporation Limited with inexpensive and clean power (DMRC). (31)

Rewa solar project is the first project in India in which the energy produced is used for railway traction. There are a total of three phases each having a nameplate capacity of 250 MW. (32)

4.5.2. Neemuch solar park

The Neemuch solar power plant will have three units: Unit 1 (160MW), Unit 2 (170MW), and Unit 3. (170MW). The projected Neemuch Solar Park would span an area of roughly 1065.7ha and will be located in the villages of Badi, Kawai, and Bardawada within the Singoli division of the Neemuch District in Madhya Pradesh, India.

The project site is roughly 70 kilometres from Neemuch town, near the state borders of Madhya Pradesh and Rajasthan. It is linked to the State Highway – 9A by village roads. The nearest train station is at Mandalgarh, Rajasthan, some 25 kilometres to the north of the site. (22)

4.5.3. Agar solar park

Due to land restrictions, the projected 550MW Agar Solar Park will be constructed in two divisions (tehsils) in the Agar district, with two units. The total acreage required for the solar park's development is 1108.63ha.

The Agar Solar Park's 200MW Agar unit (unit four) will be located around 12.7 kilometres from the town of Agar. The planned location is accessible through State Highway 27 and has a 5m wide approach road. The Agar Solar Park will employ solar photovoltaic modules of various rated capacities based on poly / monocrystalline and / or thin film (CdTe). The solar panels will have a fixed tilt and a single axis tracking module mounting system fitted. (21)

4.6.Analysis of solar parks in Maharashtra

As of March 2021, the total installed capacity in Maharashtra is 2280 MW. Power plants like Saiguru, Dondaicha, and Patoda are situated in Maharashtra. Sai Guru power plant is the largest solar plant in Maharashtra with a capacity of 500 MW. It is situated in Sakri, and the head office is located in the city of Mumbai.

Table 17: Calculated outputs of solar parks in Maharshtra

S. No.	Solar Power Plant	Nominal Capacity (MW)	Total power output (GWh)
1	Sai Guru	750	10.49
2	Dondaicha	250	4.98
3	Patoda	500	6.94

4.7. Analysis of solar parks in Uttar Pradesh

BSNU is located there. It has a capacity of 1,200 MW, compared to just 440 MW of UP solar park owned by Lucknow Solar Power. Towns like Bijnor are where upcoming solar projects are taking place.

Table 11: Calculated outputs of solar parks in Uttar Pradesh

S. No.	Solar Power Plant	Nominal Capacity (MW)	Total power output (GWh)
1	Solar Park in UP	440	9.22
2	Jalaun Solar park	1200	19.58

4.7.1. Jalaun Solar Park

The Jalaun Solar Power Project is a solar photovoltaic power producing facility that spans two villages in Uttar Pradesh's Jalaun district, Kuhana and Shajahanpur. Essel Infraprojects Limited, a subsidiary of the Essel Group, designed the plant. The facility, which is situated across 250 acres, is projected to generate 85 million units per year and is linked to 132 KV Sarsela-Kalpi substations.

5. Discussion and conclusion

The goal set by the government of India for biomass energy has been reached in 2021.While hydro energy will soon reach its goal of 5 GW before 2022, just 0.2 GW short.

Areas which are lagging behind are solar and wind energy. Going by calculations it can be seen that the total energy production through wind is 62,757 GWh and energy production through solar is 50,700 GWh. As compared to population increase in India, and hence the energy consumption in India, these figures prove to be insufficient. The energy consumption of India in 2009 was 771 TWh and in 2019 was 1249 TWh

Most regions in India receive 4-7 kWH per sq. meter per day. A solar potential of 280 GW was calculated in a recent study done by IBEF. Wind energy still remains to be harnessed on the offshore front in India. Construction and operation of off shore wind farms may change the situation and prove as a game changer.

127 GW of installed wind capacity can be obtained if offshore wind energy is harnessed, taking the total potential of wind to 302 GW at just 100 meter hub height. This goes on to show that, even though a rapid growth in the past 11 years can be seen, India still needs the infrastructure and resources to tap renewable energy sources.

As can be seen in the tables above, wind turbines in most regions have to be imported. Waiving of GST and excise duties can help private organizations like Adani, Tata, and Reliance to take obligatory part in renewable production much faster. As was stated before, potential for hydro energy still needs to tapped in northern regions like Himachal Pradesh, Arunanchal Pradesh, and Uttarakhand. The hydro power potential of India is calculated to be 145,320 MW compared to only an installed capacity of 45,700 MW.

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