Recent State Wise Statistical Review of Renewable Energy in India

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Abstract

The conventional energy sources such as fossil fuels increases pollutant level in the environment. The finite sources and non-generation of conventional energy force us to explore new sources of energy. The renewable energy is the most promising source of energy since it has no impacts on the environment and it is available at almost at places on the earth. The increasing demand of energy in the developing countries like India can only be fulfilled with development, in production and distribution of renewable energy. In this paper, we have reviewed the statistics of renewable energy from recent years in India. We found that India has very high potential in renewable energy, but the installed capacity of renewable sources is meager in almost every sector of renewable energies. State-wise picture is also very same. Some states have large potential of particular energy source, and also have good installed capacity. But some states have not good installed capacity, although their potential is high, hence the government policies has been working on the development of renewable energy at regional level.

Keywords: Renewable energy, potential of renewable energy, installed capacity of renewable energy, green energy.

Introduction

India has the second highest population in the world with an increasing demand of energy. The energy demand is increasing by a rate of 6.5% per annum in the field of commercial as well as human activities in India [1], The economic development of any country basically depends on the energy. Every sector of Indian economy, such as agriculture, industry, transport, commercial and domestic needs input of energy. The electricity power demands contain a major portion of this energy demand. Hence the energy production is one of the major factors for economic and social development. But with respect to the energy production, we must keep in mind about the environmental problems associated with the conversion of energy from various resources. This is due to the fact that, the increased pollution, population and industrialization cause the environmental degradation. After industrialization in Europe, in the late 18^{th} to early 19^{th} century, the conventional sources such as fossil fuels like coal, petroleum has increased tremendously in worldwide. These sources are readily available and easy to produce the energy from these sources. It has taken millions of years of formation. They are natural products and we don't have any artificial process for regenerating it. They will perish one day.

So, the fast depletion, high prices and pollution problems due to these conventional energy sources forces us to explore other sources which are clean and sustainable for energy generation. The use of renewable sources or non-conventional sources are the most valuable solutions to reduce the environmental problems associated with fossil fuels based energy generation. These renewable sources often termed as 'Green energy sources' due to their no impacts on the environment. In the past three decades, research and development of green energy have been increased, which caused hundreds of promising new technologies that can reduce our dependence on coal, oil, and natural gas. Green energy comes from natural sources such as sunlight, wind, rain, tides, plants, and geothermal heat. These energy resources are renewable, means they are self regenerated. On the contrary, the fossil fuels are a finite resource such as coal, natural gases, etc. and they are not regenerated, only one time use is possible in these conventional sources. The world energy forum (WEF) has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades [2]. Renewable energy sources have very small impact on the environment than that of fossil fuels. Burning of fossil fuels injects various pollutants in the atmosphere. About 70% of India's electricity generation is made from burning of fossil fuels. The greenhouse gases are emitted as a byproduct from fossil fuels burning. These greenhouse gases drive the climate changes. The carbon dioxide (CO_2) is the major greenhouse gas, which is responsible for the global increase in temperature called global warming. The major contributors in the CO_2 emission in 2014 [3] in the world are as shown in Figure 1.

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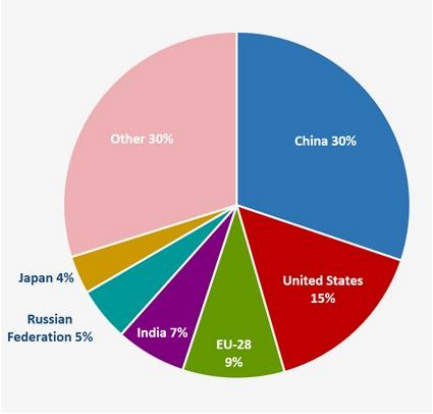

Figure 1: The major contributors in the CO2 emission in 2014 in

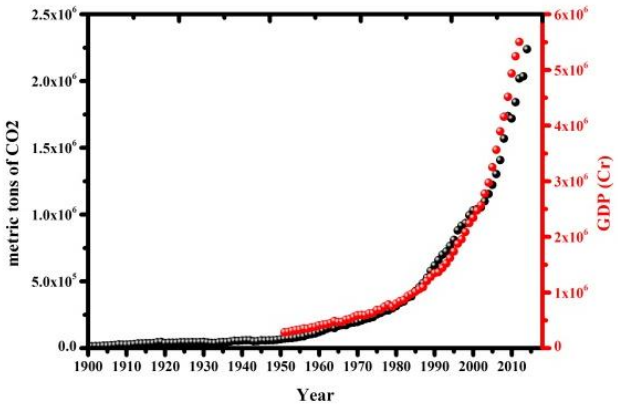

Figure 2: The CO_2 emission of India from 1900 to 2014 along with GDP in (Rs. Cr.) from 1952 to 2014. (Boden et. al., (2017) and data.gov.in) [4]

The China (30%), the United States (15%), the European Union (9%), India (7%), the Russian Federation (5%), and Japan (4%) with other countries contributed 30% in CO_2 emission during 2014. India is at 3th position on emission of CO_2, if we look at its country wise contribution. The CO_2 emission has been maximized in China over the world. This data includes the CO_2 emissions from fossil fuel combustion, as well as other industrial processes.

Figure 2 indicates the CO_2 emission of India in metric tons from 1900 to 2014. The exponential increase in CO_2 emissions can be observed after the 1980. Before 1980, the CO_2 emission was very small and almost negligible. But after industrialization in India, during 1980 to 1990 a steep increase in CO_2 emission has observed. This is only due to the increased the fossil fuel, petroleum consummations after 1980 in India. If we look at the gross domestic product (GDP) of India from 1951 to 2014 (it is also plotted along with CO_2 emission), it is clearly seen that the CO_2 emission been increasing with GDP of India. This shows that the economic growth also causes pollution. This increase in pollution causes long term effects on the environment. Hence the green energy is the only way to produce the energy without any emissions of pollutants in the atmosphere. The green energy is easily available at all places on the earth, whether it is a rural area or urban area. But the fossil fuels are available at particular places and to obtain it, heavy mining and drilling is required. Most of such sources are at ecologically sensitive locations. The renewable energy has potential to generate pure energy such as electricity from solar radiation, from wind turbines and hydrothermal sources. The advanced technologies in the material sciences have decreased the cost of solar panels, wind turbines and other sources of green energy. In recent decades green energy can replace fossil fuels in all major areas of use, including electricity, fuel for motor vehicles, etc. In this paper, the state wise renewable energy potential of India is studied. This paper has discussed the introduction of Green energy, status of renewable energy in India.

Types of green energy

There are many types of green energy which have been developed with fast rate. The most common types of green energy are solar power, wind power, Bioenergy and hydropower, geothermal etc.

Solar Power

All the energy sources on the earth are based on the sun, directly as solar insolation or indirectly as wind, rain and tides. We are literally wasted the pure energy coming from the sun, but this may due to the lack of efficient technologies in this field. The solar power is used to produce electricity using photovoltaic cells, which capture sunlight and turn it into electricity. Solar energy is also used to heat water, provide natural lighting and cook food. Solar technologies have become inexpensive enough to supply power to everything from small handheld gadgets such as mobiles to entire villages.

India as a tropical country is gifted with rich solar energy resources. The average intensity of solar radiation received on India is 200 MW/km square (megawatt per kilometre square). This amounts to 657.4 million MW with total geographical area of India is ~ 3.29 million km square [5] (http://www.indiaenergyportal.org). But, only 12% of the total land area which is 0.413 million km square can be used for solar power generation. Because about 88% of the

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total land is covered by agriculture, forest etc. Cities and villages, industry takes 6% and 6 % is inhabitable region containing snow, desert etc. The solar insolation is largely depends on the climate such as in the monsoon season where the solar energy is very less.

Wind Power

The changes in the atmospheric pressures at different locations cause air to flow, low air pressure to high pressure. This air flow can be used to drive the turbines and as resultant production of the electricity. High altitude sites and areas near the seashore provide the best conditions for capturing the strongest winds. Global level India is at fifth position in wind power generation after China, U.S. Germany and Spain. The government policies, since 1990, is been leads to the growth of wind power in India. Sharma et al., (2012) [6] reviewed the state wise status of wind energy in India. They have studied that the India have large potential in wind power, it is been increasing in India from 1990. They concluded that if the wind turbine will produced wit cost effective, then wind power plant will be increased in India.

Hydropower

Hydro power also called as hydroelectric power is generated by forcing the running water through a turbine system to generate electricity. India receives very high rain, hence the hydropower is one of the major energy sources in India. Among all renewable sources the small hydropower (SHP) is one of the promising sources for sustainable water and energy development and the geography of India supports the development of small hydro projects [7]. The rivers are the major sources of water. The monsoon and snow at Himalaya are the major fed the water to the rivers in India. The SHP plants has more advantages than the large hydro power (LHP) plants. LHP leads deforestation, changed water flow, disrupts aquatic ecosystems, earthquakes. Small hydro power projects (SHP) are the stations with capacity of up to 25 megawatts (MW). India has SHP potential about 15000 MW.

Geothermal Energy

Just below the earth's crust, there is a huge source of heat energy, this heat energy is from the formation of the planet and the radioactive decay of minerals at the core of the earth. This heat energy is called geothermal energy. When water comes in contact with this extreme heat causes evaporation and ejects from the crust in the form of hot springs. The vapors from these springs are used to drive turbines to generate electricity. North America has large potential in this source.

Bio-energy

There are two major technologies used to convert biomass into energy; thermo-chemical and bio-chemical technology. India is still being vastly depends on the agricultures area, this renewable energy source has high importance. The natural wastes or agriculture wastes are about 500 million metric tons per year in India [8]. About 70% of population of India resides in rural areas which is largely depends on the conventional energy sources for their primary energy demands. They use the biomass burning as source of heat for the cooking. This leads to the smoke formation and increase in aerosol in the atmosphere. But this biomass can be used for the formation of the energy without harming the environment. The biodiesel is one form of bio-energy. The biodiesel is a green liquid fuel, it is inexpensive, energy efficient and stable, pure and clear, can be produced locally and vehicle performs better with this diesel [1]. It can be used as substitute for the traditional transportation fuels e.g. petrol and diesel. The oil from Jathropa curcus can be used for such purposes. It can grow in less water and poor soil. India has large potential in the cultivating of such plants, we have to increase the productivity of such plants. Biogas is also promising sources of energy for cooking particularly in rural areas. The manure from farm, agricultural waste, municipal waste, green waste and food waste can be used for biogas formation. Ejecting material from biogas plant can be used as fertilizers in farm.

Energy status in India.

India has tremendous potential for generating clean electricity through Renewable Energy Sources (RES) namely Hydro, wind and Solar [9]. India is emerging as one of the fastest growing countries in the world. The Indian economy has been vastly expanded with annual Growth Rate in India averaged 6.13 % from 1951 to 2017 [10] (https://tradingeconomics.com). India is the third after China and USA with 5.5% global share of energy consumption in 2016 [11]. The per capita electricity consumption is about 1020 Kwh which is very less compare to the other countries.

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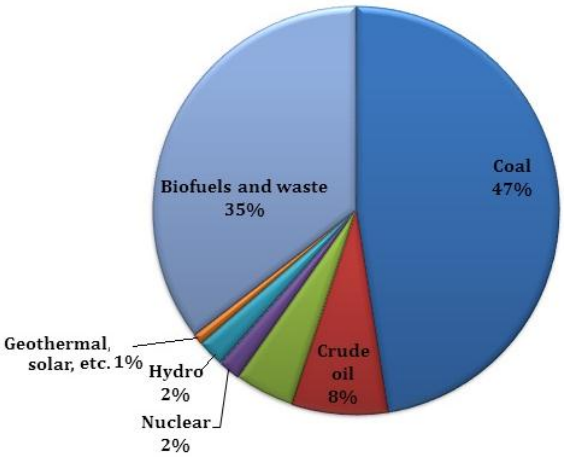

Figure 3:The primary energy sources in India during 2015

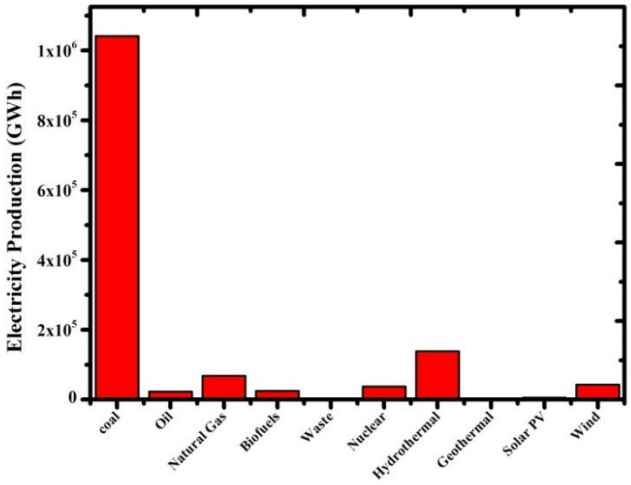

Figure 4:The electricity production in India during 2015 from different sources.

ng y is from coal with biofuels and waste are at second. Crude oil contributes 8% and remaining energy sources such as geothermal, hydropower, nuclear together gives only 5% of energy. Figure 4 illustrates the electricity production from different sources in India during 2015. Total electricity production in India during 2015 was about $13*10^5$ GWh. The most of the electricity production was from coal, others contributed nothing comparable to it. The conventional sources (coal, oil, natural gases etc.) contribute all energy than the renewable energy sources. This shows that the India is largely depends on the conventional sources for the energy production than the green energy sources.

The total electricity energy consumption during 2015 in India was about 10^6 GWh. Figure 4 indicates that about 45% electricity is used for the Industry, 25% for residential area, 19% for agriculture, 10 % for public service and remaining 2% for transportation [12](http://www.iea.org/).

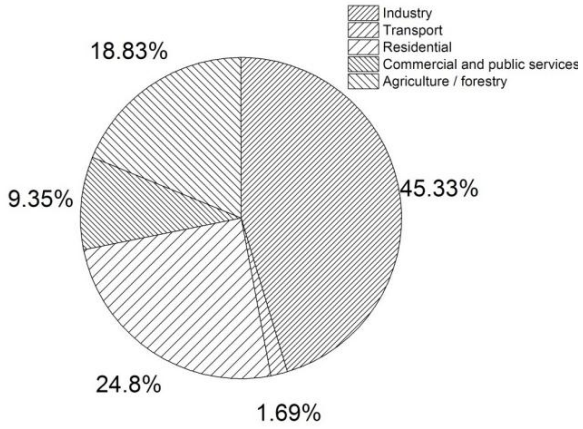

Figure 5: the electricity energy consumption in GWh in different sectors during 2015.

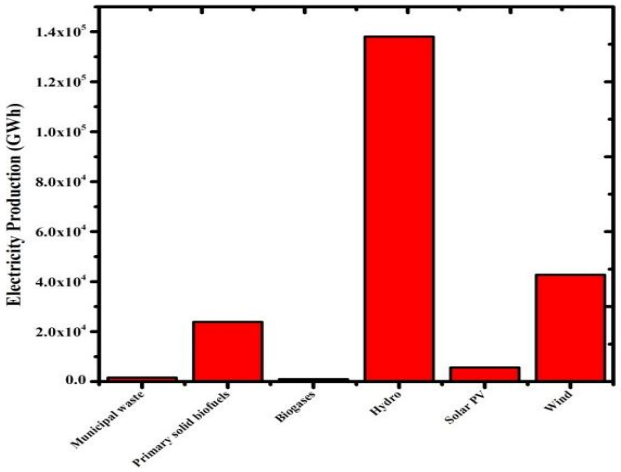

Figure 6: the electricity production from renewable energy sources in India during 2015.

The electricity production from renewable energy sources in India during 2015 is as shown in Figure 6. The most of the electricity production was from Hydrothermal. The wind and primary solid biofuels is the second and third in the electricity production .The solar PV, biogases and wastes are contributing to the very small electricity production. There is ample solar power in India, but we are wasting it. [12] (http://www.iea.org/).

Potential of India in renewable energy.

According to annual report 2016-2017 of the ministry of New and Renewable Energy, Government of India [13] (https://mnre.gov.in) the renewable energy potential and installed capacity in India during 2016-2017 is as shown in

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Table 1.

Table 1: The estimated renewable potential and installed capacity in India during 2016-2017.

Source	Potential (GW)	Capacity (GW)
Wind	102	28.70
Small Hydro	20	4.33
solar power	750	9.01
Bioenergy	25	7.91
Total	897	50.07

The total installed potential of India is about 900 GW. Solar power shows very high potential compare to the other sources. Energy from wind has also very good potential. Although the small hydro power (SHP) source and bioenergy sources has less potential compares to other, but their importance cannot be neglected. Because of large water and bioenergy (agriculture and forest) sources available in India.

The total installed capacity of renewable energy as on 2016 -2017 is about 50 GW. Wind power capacity is largest about 29 GW. The solar power has large potential in India (750 GW), but the installed capacity is just 9 GW. As compared to the potentials of SHP and bioenergy has satisfactory capacity of energy production. Overall in India the potential of renewable energy sources is about 900 GW with different sector has different potential. Solar power has maximum potential. But as India has very diverse geographical and climatic conditions, the renewable potential is largely varies with different states.

State wise potential of different sources of renewable energy

Table 2 shows the state wise potential and installed capacity of different sources of renewable energy in India during 2016-2017[1]. (https://mnre.gov.in). Rajasthan state (148.51 GW) has the maximum renewable potential contributing about 17 % of the total potential of renewable energy. Jammu Kashmir in second position with a 13 % contribution and Maharashtra, Madhya-Pradesh and Gujarat contributing about 8% each in the total potential. These five states have collective 54% of total potential of country. These states are with larger areas, only Uttar Pradesh (4 %) showing less potential as compared to the area.

Wind power potential

The total wind power potential in India is about 103 GW, Gujarat state contributes maximum about 34% of wind power potential, Tamil Nadu, Andhra Pradesh and Karnataka contributes about 14 % of wind power potential. These states contributes about 74 % of total potential of wind power. These states have large costal area with ample wind power which can be used to generate the energy.

SHP potential

The total SHP power potential in India is about 20 GW, Karnataka state contributes maximum about 18% of total SHP power potential. The northern part of India which contains rivers live Ganga, Sindhu etc has large potential in SHP. Punjab (14%), Himachal Pradesh (11 %) and Uttarakhand (8 %), Jammu Kashmir (6 %) and Arunachal Pradesh (6%) contribute collectively about 45 % of total contribution in SHP potential. Tamil Nadu, Andhra Pradesh and Karnataka contribute about 14 % of SHP power potential.

Bio energy potential

The bioenergy potential in India is about 25 GW. Bio-energy contains biomass, bagasse and waste to enrgy. The natural carbon resources which are easily renewable are known as biomass [14]. The baggage is the residue which left after the extraction of juice from sugar cane. The process of generating electricity or heat energy from the treatment and processing of waste is known as waste to energy. Maharashtra (14%), Punjab (13 %) and UttarPradesh (12 %) contributes maximum in bioenergy potential of India. These state are with large agriculture areas.

Solar power potential

Solar power (750 GW) has maximum potential in renewable energy. Rajasthan (19%) and Jammu Kashmir (15 %) has large potential in solar power, since theses states are mostly barren lands. The most of the areas in these states are not being used for cultivation. Rajasthan receives highest solar insolation and north eastern part of India receives Very less insolation [2]. Rajasthan has large potential in solar power generation, since it is mostly desert, receives a

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very small amount of rain. The sky is clear through the year and receives large solar insolation. Jammu Kashmir has good potential in solar power, but due to geographical condition in this state imparts abstraction on the solar power generation in this state.

Table 2 : State wise Renewable Energy Potential and installed capacity during 2016-2017 (in MW).

States/Union 103territories	Wind Power (MW)		SHP (MW)		Bioenergy (MW)		Solar (MW)		Total (MW)	
	P	IC	P	IC	P	IC	P	IC	P	IC
Andhra 103Pradesh	14497	1450.35	978	232.98	1001	1200.41	38440		54916	3001.21
Arunachal Pradesh	236		1341	104.61	8		8650	0.27	10236	104.87
Assam	112		239	34.11	220		13760		14330	34.11
Bihar	144		223	70.7	992	130.26	11200	45.1	12559	159.22
Chhattisgarh	314		1107	76	260	839.7	18270	93.78	19951	449.68
Goa			7	0.05	26	0	880	0	912	0.05
Gujarat	35071	4104.46	202	16.6	1683	168.9	35770	1123.363	72726	5300.72
Haryana	93		110	73.5	1707	135.9	4560	15.39	6470	134.19
Himachal Pradesh	64		2398	793.81	144		33840	0.2	36446	794.01
Jammu & Kashmir	5685		1431	156.53	43		111050	1	118208	157.53
Jharkhand	91		209	4.05	100		18180	16.19	18580	20.24
Karnataka	13593	2871.15	4141	1217.73	1581	2617.54	24700	153.32	44015	5115.38
Kerala	837	43.5	704	198.92	1080	0	6110	13.045	8732	255.47
Madhya Pradesh	2931	2288.6	820	86.16	1442	108.9	61660	790.37	66853	3204.03
Maharashtra	5961	4664.08	794	346.18	3424	3750.06	64320	385.756	74500	6654.51
Manipur	56		109	5.45	15		10630		10811	5.45
Meghalaya	82		230	31.03	13		5860		6185	31.03
Mizoram			169	36.47	3		9090	0.1	9261	36.57
Nagaland	16		197	30.67	10		7290		7513	30.67
Orissa	1384		295	64.63	268	60	25780	66.92	27728	151.55
Punjab			441	170.9	3517	476.75	2810	520.7	6768	857.35
Rajasthan	5050	3993.95	57	23.85	1101	338.4	142310	1294.6	148518	5425.2
Sikkim	98		267	52.11	2		4940		5307	52.11
TamilNadu	14152	7632.31	660	123.05	1671	1933.75	17670	1267.414	34152	9672.72
Telangana		98.7			0		20410	796.59	20410	895.29
Tripura			47	16.01	5		2080	5	2131	21.01
Uttar-Pradesh	1260		461	25.1	3043	2615	22830	143.5	27593	1043.6
Uttarakhand	534		1708	209.33	29	228	16800	41.15	19071	326.48
West Bengal	22		396	98.5	544	78	6260	11.77	7222	136.27
Andaman and Nicobar	365		8	5.25	0		0	5.1	373	10.35
Chandigarh					6		0	6.81	6	6.81
Dadra and Nagar Haveli					0		0		0	0

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Daman and Diu	4				0		0	4	4	4
Delhi					131	16	2050	23.87	2181	39.87
Lakshadweep					0		0	0.75	0	0.75
Puducherry	120				3		0	0.025	123	0.03
Others		4.3			1022		790	100.31	1812	104.61
Total	**102772**	**27151.4**	**19749**	**4304.27**	**25090**	**14697.57**	**748990**	**7805.34**	**896602**	**44236.92**

P- Potential.
IC-Installed Capacity.

State-wise Installed Capacity of Renewable energy in India during 2016-2017 .

Table 2 gives the State-wise Installed Capacity of Renewable energy as on 30-06-2016 from Ministry of New and Renewable Energy, Government of India [13]. As stated earlier the varying geographical condition and climate at different states in India, renewable energy have limitations. The state wise total capacity of renewable energy in India is varying. Total installed capacity of India is about 44 GW of renewable energy. Tamil Nadu (22%) has maximum installed capacity of renewable energy, Maharashtra (15 %) in second position. Gujarat, Karnataka and Rajasthan have 12 % each contribution in the total renewable energy. Comparing to the potential of renewable Jammu Kashmir (1 %) has very less installed renewable energy.

Wind power

The total installed capacity of wind power in India is about 27.5 GW. Tamil Nadu has maximum installed capacity with a 28% contribution of total installed capacity of renewable energy. Maharashtra, Gujarat and Karnataka contribute 17% and 15% and 11 % respectively. Tamil Nadu has become a center of wind power generation in India. Many wind power plants have been developed at different part of Tamil Nadu. Muppandhal wind power station in Tamil Nadu is the largest in Asia. Maharashtra has 23 MW power plant in Satara district near to Pachgani.

SHP

The total installed capacity of SHP in India is about 4.3 GW. Karnataka and Himachal pradesh contributed 28% and 18% in total SHP installed capacity, while Maharashtra contributed just 8 %.

Bioenergy

The total installed capacity of SHP in India is about 14.69 GW. Maharashtra contributes maximum 26% while Karnataka, Uttar Pradesh and Tamil Nadu contributes 18%,1%and 13 % respectively in Total installed capacity of bioenergy.

Solar energy

The total installed capacity of solar power in India is about 7.9 GW. Rajasthan with maximum capacity about 17% Tamil Nadu and Gujarat has installed capacity 16 %, 14 % respectively. Andhra Pradesh, Telangana and Madhya Pradesh contributes each by 10 % in total installed capacity of solar power. Maharashtra and Punjab has just 7% and 5 % installed capacity. Solar Photovolatic is largely used for the electricity production from the sun power. But the lack of high efficiency and he cost of solar cell impose limitaions in the development of solar energy. In India a advanced research in material science is been going on to increase the solar cell efficiency [15,16]. Kapoor et al., [9](2014) reviewed the evolution of solar energy in India since 1950 along with government national five year plans (FYP). They find positive result in the development of solar energy in India from independence and concluded that the solar energy solar energy is contributing to the development of India in three fold economically, socially and environmentally.

Percentage installed capacity of than the potential.

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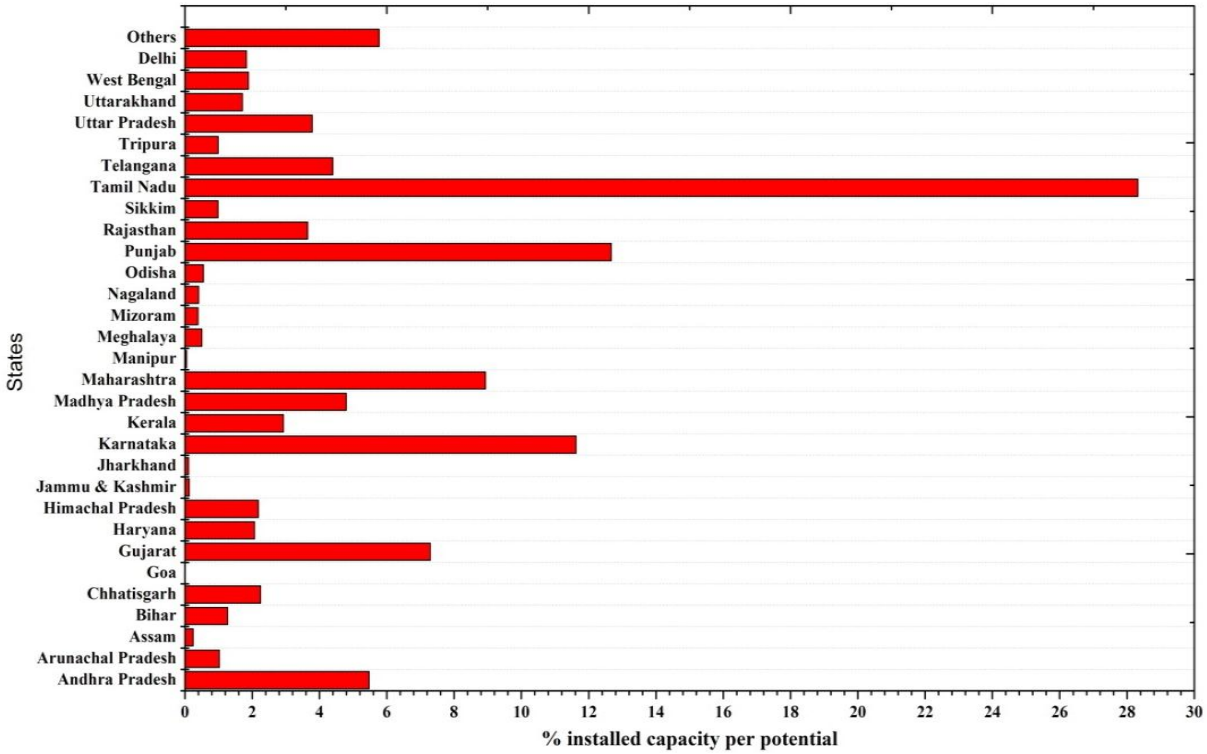

Figure 8 : Percentage of installed capacity per potential of state during 2016-2017 in India

Figure 8 shows that Tamil Nadu has maximum installed capacity with respect their potential of renewable energy. Most of the energy of Tamil Nadu came from wind power and solar power. Punjab is at second with high installed capacity in SHP and solar power. Karnataka with energy production form SHP, bioenergy it is situated third. Maharashtra is in fourth position with energy production from bioenergy, SHP and wind power. Gujarat and Rajasthan although has high energy production from solar power, as compare to their potential they are lacking in renewable energy. Andhra Pradesh, Bihar and Uttar Pradesh contribute very less in renewable energy production compare to their potential. The other renewable sources such as tidal energy, geothermal energy etc not been used extensively in India. They are meager as compare to the solar, SHP and wind power.

Government of India policies on Renewable energy

Government of India first stepped in march 1981 in renewable energy and started commission for additional sources of energy (CASE) under the department of science and technology (DST). In 1982 it is changed to Department of Nonconventional Energy Sources (DNES) working under the Ministry of Energy. Then the world's first ministry for the energy is established in 1992 named Ministry of Non-conventional Energy Sources (MNES) which changed to Ministry of New and Renewable Energy (MNRE) in 2006. National Wind-Solar Hybrid Policy for the wind solar energy, Strategic plan for new and renewable energy sector for the period of 2011-2017 and national policy on biofuels are the policies is being implemented by MNRE [13] (https://mnre.gov.in/policies). Along with these various government bodies is been working in adevelopment renewable energy source such as India renewable energy development agency (IREDA), Ministry of power (MOP), Centre for Wind Energy Technology (CWET) etc. In next five decades, India's power generation requirements will be increased to one terawatt. We will have to develop and increase our energy sources in future. We have to see this as chance because development of new technology in renewable energy can increase the jobs in the future also.

Conclusions

The uses of conventional sources have very potential impact on the environment. The high prices, finite quantity and no regeneration in case of conventional sources force us to explore new technologies in renewable energy. India has large potential in every sector of renewable energy sources. But we have not been used these developed the renewable energy sources as their potential. The different states in India have different potential of renewable energy, but the installed capacity is also been varying. There are some geographical limitations are also to develop the renewable energy sources as per potential. Tamil Nadu, Maharashtra, Punjab and Gujarat are being successful in the generation of renewable energy. But the states like Uttar Pradesh, Rajasthan and Andhra Pradesh are not

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being satisfactory development in renewable energy. The installed capacity with respect to potential in different sector of renewable energy sources such as wind, solar, SHP and bioenergy is varying with states in India.

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