Development of Wind Energy in India

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Abstract- Wind energy has been the fastest growing renewable energy sector in India. Energy is vital for the country's economic growth and improving the life standard of its citizen. India has spent lots of resources on increasing its energy capacity since independence. As a result, country's generation capacity has increased considerably. Nevertheless, meeting growing energy needs through conventional sources such as coal, gas, etc. creates environmental problems. Hence, the government embarked on exploring new and clean energy sources. Development and promotion of these new and renewable energy sources such as wind, solar and biomass has gotten considerable attention in India, although coal and natural gas are still major sources of electricity. The use of various sustainable, renewable energy technologies has been rising, as it develops rapidly and can be scaled up easily. Wind energy is a clean and eco-friendly energy source and increasingly accepted as a major complementary energy source for securing a sustainable and clean energy future in India. The Indian government has aimed to fully utilize the abundant resources of this energy, which India has. The official assessment shows this country has potential to generate over 100,000 MW of wind energy. Till May 2014, generation capacity of 21,268.3 MW has been created through wind, which places India in the fifth place globally. This paper provides a detailed description of Indian wind energy industry and discuss several developments which accelerated its growth. The paper presents current status, major achievements and future of wind energy in India.

Keywords- Renewable energy, Wind energy, India, Wind energy potential, Wind energy development

1. Introduction

Energy is a vital input in all sectors of any country's economy [1]. It is crucial for human development index as human development is positively correalated to energy consumption [2]. Till late 1980s energy has been generated largely by burning coal, hydrocarbon oil and natural gas leading to huge carbon emissions. Hence, environmental crisis has become a critical concern for the world today. Emission of greenhouse gases, limited coal availability, environment distortion, rising prices of fossil fuels and pressure on foreign exchange reserves have created hindrance in the prolongation of these resources [3]. Due to this, new energy economy is developing. This new energy economy generates energy from wind, sun and through heat within earth itself. Energy generated by burning fossil fuels damages the environment and causes climate change. However, energy based on renewable sources in general and wind energy specifically, does not affect the environment that adversely, which conventional energy sources do.

Due to the geographic conditions of India, plenty of renewable energy sources such as solar, wind, biomass, hydro and tidal are available to it [4]. India has strongly maintained fifth place in the world in installing wind energy, after China, U.S., Germany and Spain. India is one of the fastest growing, developing nation in the world and is considered as a favourable investment destination. India has come a long way from having mere 1350 MW generation capacity at the time of independence in 1947 to 249,488 MW in 2014. Indian government had embarked on giving attention to renewable energy in 1970s. Today, various plans are operating in India for promotion of renewable energy. Numerous renewable energy equipments are commercially available in the country. An Indian wind energy program which was initiated in the second half of the 1980s has increased the installation of wind energy substantially in the last few years.

Wind energy policies issued by the Indian government are very investor friendly and offer attractive tariff and regulation that provides healthy growth to this sector.

Government of India has set up a separate ministry for renewable energy called Ministry of New and Renewable Energy (MNRE) which is responsible for planning and carrying out of the policy framework for renewable energy. Recently, MNRE has introduced generation based incentive scheme to provide financial incentive for every unit of generation up to ten years [5]. This policy of providing incentive linked to generation will attract huge investment from domestic independent power producer and foreign investor as this has created a level playing field between domestic investor and foreign investor.

Table 1. Top 10 Cumulative installed capacity 2009-2013 (in MW) [7]

Country	2009	2010	2011	2012	2013
China	25,805	44,733	62,364	75,324	91,424
United States	35,086	40,298	46,919	60,007	61,091
Germany	25,777	27,191	29,060	31,270	34,250
Spain	19,160	20,623	21,674	22,784	22,959
India	10,926	13,065	16,084	18,421	20,150
United Kingdom	4,245	5,248	6,540	8,649	10,531
Italy	4,849	5,797	6,737	8,118	8,552
France	4,574	5,970	6,800	7,623	8,254
Canada	3,319	4,008	5,265	6,204	7,803
Denmark	3,465	3,749	3,871	4,162	4,772

2. Wind Energy Status (Worldwide)

Wind energy is crucial to the energy economy, since it is abundant, less costly and widely distributed. It can be scaled up easily and develop rapidly. The limited resources of coal can be finished, oil wells go dry, but wind resources of earth can never be finished.

According to global wind energy council, China overtook U.S. in 2010 and became a world leader in wind energy. Wind energy installation of China has risen exponentially from mere 300 MW in 2000 to 91,424 MW in 2013. China alone contributes 28.7% of the world's wind energy. Since 2009, China has installed more turbines than any other country in the world.

Globally, wind energy installed capacity grew by 35,467 MW in 2013, which is an addition of 12.5% on 283,048 MW installed capacity at the end of 2012 [6]. This has brought total global wind energy capacity to 318,530 MW. India with an installed capacity of 21,268.3 MW is in fifth place preceded by China (91,424 MW), U.S. (61,091 MW), Germany (34,250 MW) and Spain (22,959 MW). Table 1 presents the total installed capacity of top 10 countries as on 31st March 2014.

As expressed in Fig 1, global wind energy capacity has reached to 318,137 MW in 2013, after 283,048 MW in 2012, 238,126 MW in 2011, 198,001 MW in 2010 [7].

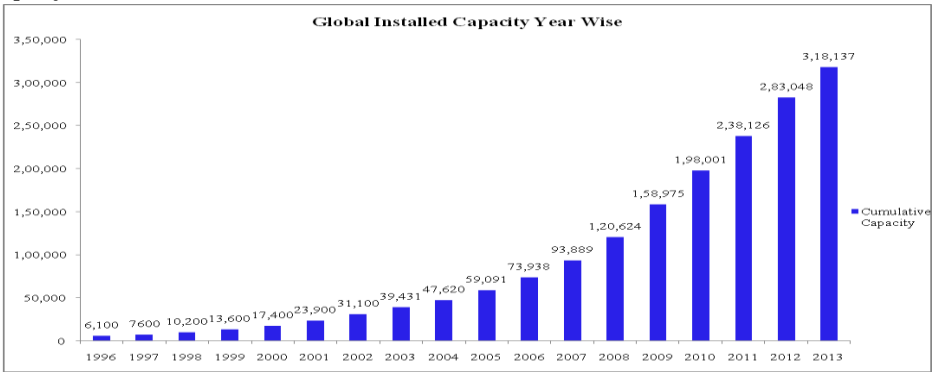

Figure 1. Global wind energy installation year wise [7]

In 2009, a new trend was started when more than half of global installation has started coming from outside of traditional European and North American market. This change was primarily driven by China, which installed 16,000 MW in 2013 and has leadership status with 91,424 MW wind energy installed capacity. Nevertheless, the global wind energy market witnessed a 22 % fall in annual capacity addition of 45,169 MW of 2012, due to the dramatic drop in the U.S. market. U.S has just added 1 GW wind energy in 2013, far below from 13 GW in 2012. In 2013, all the countries in the world have added 35,389 MW to total wind energy capacity.

3. Indian Wind Energy Potential

MNRE has incorporated Centre for Wind Energy Technology (C-WET) as technical focal point for development of wind energy in India [8]. This agency is responsible for wind resource assessment in the country. Till the recent past, the official estimate of onshore wind potential in India was 49.13 GW, but now it has been revised by C-WET to 102 GW, at 80 meter hub height [9]. The C-WET has established country – wide network of 790 wind monitoring stations in 31 states and union territories for wind resource mapping.

According to C-WET estimation, Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra are leading states in wind energy potential [10]. Wind resource assessment done by C-WET has made a vital contribution to wind energy industry as it identified suitable sites for commercial use. State wise potential and installation till 31st May 2014 has been provided in Table 2a and Table 2b respectively.

Table 2(a). State wise wind energy potential [9]

States / UTs	Estimated Potential	States / UTs	Estimated Potential
Andaman & Nicobar	365	Lakshadweep	16
Andhra Pradesh	14497	Madhya Pradesh	2931
Arunachal Pradesh	236	Maharashtra	5961
Assam	112	Manipur	56
Bihar	144	Meghalaya	82
Chhattisgarh	314	Nagaland	16
Dieu Damn	4	Orissa	1384
Gujarat	35071	Pondicherry	120
Haryana	93	Rajasthan	5050
Himachal Pradesh	64	Sikkim	98
Jharkhand	91	Tamil Nadu	14152
Jammu & Kashmir	5685	Uttarakhand	534
Karnataka	13593	Uttar Pradesh	1260
Kerala	837	West Bengal	22
Total			102788

Table 2(b). State wise wind energy installation [12,13]

States / UTs	Installed Capacity	Percentage of Total Installation
Andhra Pradesh	753	3.5%
Gujarat	3414	16.1%
Karnataka	2409	11.3%
Kerala	55	0.3%
Madhya Pradesh	439	2.1%
Maharashtra	4098	19.3%
Rajasthan	2820	13.3%
Tamil Nadu	7276	34.2%
West Bengal	1.1	0..1%
Others	3.2	0.02%
Total	21268.3	100%

However, wind resource assessment programme of C-WET estimation does not consider repowering of old wind energy sites by replacing with new higher capacity bigger turbines. Wind resource assessment done by another leading research institute, World Institute of Sustainable Energy, India (WISE) shows similar results as CWET. It

has projected 100 GW of wind energy is possible in India with larger turbines.

4. Indian Wind Energy Programme

The oil shock of the late 1970s had prompted energy planners all over the world to look for alternative sources of energy [11]. The sudden increase in the price of oil had affected the balance of payment situation adversely. Hence, Indian government started to concentrate on renewable energy with the missionary work of becoming self-sufficient in energy. In 1981, Indian government had instituted the Commission for Additional Sources of Energy (CASE) with the purpose of formulation and implementation of policies for development of new and renewable energy and increasing R&D activities in the sector for technical progress [12]. In 1982, a new department, Department of Non-Conventional Energy (DNES) was created in the then Ministry of Energy and given the responsibility of taking care of CASE. In 1992, this DNES was transformed into the separate ministry, Ministry of Non-Conventional Energy Sources (MNES) and became world's first ministry dedicated to renewable energy [13]. This ministry has been re-named to Ministry of New and Renewable Energy (MNRE) in October 2006 [14].

India has always been a frontrunner in the development of renewable energy in Asia. MNRE's objective is to increase the contribution of all grid connected renewable energy sources in the energy mix of India. Grid connected renewable sources include wind power, bio power (including Biomass power and waste to energy), small hydro power (up to 25 MW generating capacity) and solar power [15]. MNRE supervises autonomous energy development institutes like National institute of solar energy for solar energy, C-WET for wind energy, SSS NIRE for biomass energy, AHEC for hydropower and IREDA for financial support and lending to renewable energy projects [14]. There are some other departments also under various ministries such as Ministry of Power, Planning commission and Prime Minister Council for Climate Change to oversee renewable energy projects. Wind energy has received maximum investment among all the renewable energy technologies due to its short gestation period, lower investment and better commercial viability of the projects. As a result, wind energy has largest share in the total renewable energy installation in India with 67%. In recent years, wind energy industry has started growing at a fast pace.

Worldwide, governments started giving attention to wind energy projects in the 1960s, when the National Aeronautical Laboratory (NAL) of U.S.A developed multi vane wind turbine. In 1976–77 it had gone one step further and developed sail type wind turbines. In India wind energy programme was started in 1983-84 with the aim of carrying out resource assessment survey, setting of demonstration projects and incentivizing wind energy to make it more competitive. As Indian constitution directs electricity to be combined responsibility of federal and state government both, hence wind energy programme was executed with the support of state nodal agencies by MNRE [16]. Indian Wind Turbine Manufacturer Association (IWTMA) had also played vital role in the development and execution of this programme.

As on May 2014, India has 31,833 MW of installed renewable energy capacity, out of which wind energy accounts 21,268.23 MW. Wind energy has been distantly followed by small hydro power and solar power with 3,803.65 MW and 2,647 MW respectively [17]. Last year (From April 2013 to March 2014), India added 2,085 MW of wind energy with a growth rate of 11%. According to IWTMA, Wind energy growth rate has come down in 2012, due to the negative impact of removal of accelerated depreciation benefit from domestic investor. However, the Indian government has realised importance of accelerated depreciation and restored this benefit in the recent annual budget on July 2014. From 2002 to 2011, the average growth rate of wind energy was 26.87%. Figure 2 shows year wise installation of wind energy in India from 2002 to 2014.

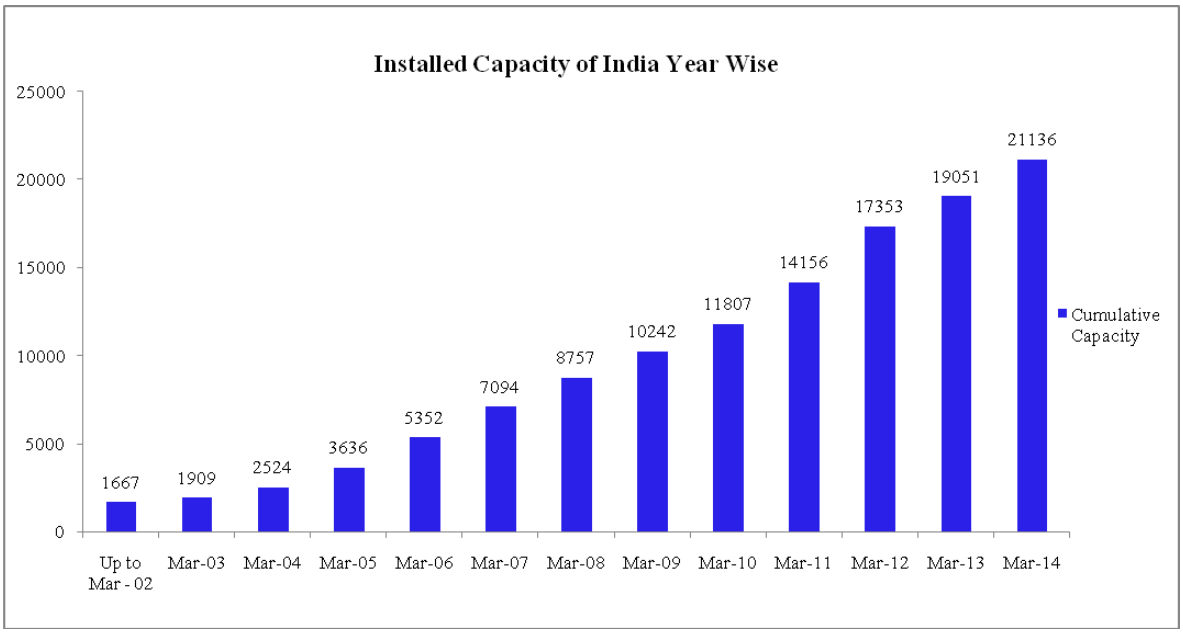

Figure 2. India wind energy installation year wise [22.23]

5. Wind Energy Status in India

Demand for energy in India has grown considerably after 1991 due to the speeding up of economic development. This demand will continue to grow as the speedy development of economy gets coupled with the growth in population [18]. According to International Energy Agencey (IEA), by 2020 India needs 327 GW of power generation capacity, which means additional capacity of 13 GW should be created every year. This pressing need for energy has also been contemplated in the national grid be set at 5% in 2009/10, subsequently to be increased by 1% every year to reach 15% by 2019/20 [20].

MNRE estimates show that 90 GW of capacity is possible through different renewable energy sources. This includes 48.6 GW of wind power at 50 meter hub height, 14.3 GW from small hydro power and 26.4 GW from biomass [21]. However, Indian government still does not have official estimates of solar energy potential in the country, but various private agencies claim India is having huge potential of solar energy. Table 2a shows that draft of 12th five year program in which, government targeting to reach 100 GW of additional capability (including carry forward of 28 GW capacity from 11th five year program). There are plans to add additional renewable capacity of 30 GW in this 12th five year plan (2012-17) with an investment of USD 53.1 billion. This includes 15 GW of wind, 10 GW of solar, 2.7 GW of biomass and 2.1 GW of small hydro [19]. The National Action Plan for Climate Change (NAPCC) set up by the Indian government has recommended that the minimum share of renewable energy in the

Gujarat, Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu are having a large potential of wind energy. These states are having areas with good and consistent wind, suitable for commercial use of wind energy. Hence, India's wind energy capacity of 21,264 MW, mainly executed in Tamil Nadu (7276 MW), Maharashtra (4098 MW), Gujarat (3414 MW), Rajasthan (2820 MW) and Karnataka (2409 MW) as shown in Table 2b. Table 3 shows state wise annual wind energy capacity addition from April 2005 to May 2014 and Table 4 provide state wise installed capacity from 2005 to May 2013 [22,23].

Table 3. State wise annual capacity addition (22,23)

State	Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Rajasthan	Tamil Nadu	West Bengal	Others
Up to March'2002	93.2	181.4	69.3	2	23.2	400.3	16.1	877	1.1	3.2
2002-03	0	6.2	55.6	0	0	2	44.6	133.6	0	0
2003-04	6.2	28.9	84.9	0	0	6.2	117.8	371.2	0	0
2004-05	21.8	51.5	201.5	0	6.3	48.8	106.3	675.5	0	0
2005-06	0.45	84.6	143.8	0	11.4	545.1	73.27	857.55	0	0
2006-07	0.8	283.95	265.95	0	16.4	485.3	111.9	577.9	0	0
2007-08	0	616.36	190.3	8.5	130.39	268.15	68.95	380.67	0	0
2008-09	0	313.6	316	16.5	25.1	183	199.6	431.1	0	0
2009-10	13.6	297.1	145.4	0.8	16.6	138.9	350	602.2	0	0
2010-11	55.4	312.8	254.1	7.4	46.5	239.1	436.7	997.4	0	0
2011-12	54.1	789.9	206.7	0	100.5	416.5	545.7	1083.5	0	0
2012-13	202.1	208.3	201.7	0	9.6	288.5	614	174.6	0	0
2013- May 14	305.4	239.4	273.8	19.8	53.0	1076.2	135.1	113.8	0	0
Total	753	3414	2409	55	439	4098	2820	7276	1.1	3.2

unemployment problem, in an environment friendly way.

Table 4. State wise installed capacity (22,23)

State	Up to Mar - 02	Mar-03	Mar-04	Mar-05	Mar-06	Mar-07	Mar-08	Mar-09	Mar-10	Mar-11	Mar-12	Mar-13	May-14
Andhra Pradesh	93.2	93.2	99.4	121.2	121.7	122.5	122.5	122.5	136.1	191.5	245.6	447.7	753.0
Gujarat	181.4	187.6	216.5	268.0	352.6	636.6	1252.9	1566.5	1863.6	2176.4	2966.3	3174.6	3414.0
Karnataka	69.3	124.9	209.8	411.3	555.1	821.1	1011.4	1327.4	1472.8	1726.9	1933.6	2135.3	2409.0
Kerala	2.0	2.0	2.0	2.0	2.0	2.0	10.5	27.0	27.8	35.2	35.2	35.2	55.0
Madhya Pradesh	23.2	23.2	23.2	29.5	40.9	57.3	187.7	212.8	229.4	275.9	376.4	386.0	439.0
Maharashtra	400.3	402.3	408.5	457.3	1002.4	1487.7	1755.9	1938.9	2077.8	2316.9	2733.4	3021.9	4098.0
Rajasthan	16.1	60.7	178.5	284.8	358.1	470.0	538.9	738.5	1088.5	1525.2	2070.9	2684.9	2820.0
Tamil Nadu	877.0	1010.6	1381.8	2057.3	2914.9	3492.8	3873.4	4304.5	4906.7	5904.1	6987.6	7162.2	7276.0
West Bengal	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Others	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Total	1666.8	1908.8	2524	3635.7	5351.9	7094.1	8757.4	10242.3	11806.9	14156	17353.2	19052	21268.3

Role of wind energy is not only limited to energy generation, but it also contributes to the country by generating employment, reducing adverse effects of greenhouse gases and increasing size of GDP. According Global Wind Energy Council (GWEC), wind energy can create 213,000 green collar jobs every year in manufacturing, project development, installation, performance, maintenance, consulting, and so on [24].

Hence, wind energy can assist in solving longstanding

Along with reducing hazardous effects of greenhouse gases, it will generate additional revenue by selling carbon credits through clean development mechanism (CDM). Global wind energy council estimated that by 2030 wind energy can supply up to 24% of India's power needs, while bringing additional investment of $10637.12 million investment every year.

6. Development of Wind Energy

The growth of wind energy in India has been very consistent. This country's Cumulative Annual Growth Rate (CAGR) in wind energy since 2002 is 24.1%. This rate of growth is at par with the global rate for the same period. Table 2b also indicates that wind energy installation is primarily concentrated in Tamil Nadu, Gujarat, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh and Rajasthan. Tamil Nadu has always been the leader among Indian states in the installation of wind energy. It has installed capacity of 7,276 MW wind energy, which is 34% of India's total wind energy installation. Maharashtra is closely following Tamil Nadu with 4,098 MW of installed wind energy. Gujarat, Rajasthan and Karnataka as well handsomely contributed in increasing the share of wind energy in India. All these states have installed more than 2000 MW wind energy. Information on state wise installation of wind energy shows that wind farms have been built all across the nation, from the coastal region to sandy deserts and from the hilly country to the plains. Hence, Indian government envisages, wind energy will greatly aid in attaining its mission of increasing share of renewable energy in total energy. Since 2002, wind energy has contributed more than 19,500 MW in the total installation. This is the reason, now government has increased target of annual capacity addition to 2500 MW.

7. Wind Energy Policy in India

The Indian government is on the mission of increasing investment in the renewable energy sector by adopting an investor friendly approach. The government is adopting an alternate approach as it does not invest directly into a wind energy project, but invest in R&D by putting up small demonstration projects at remote locations. The Indian government had put up these demonstration projects in Tamil Nadu, Gujarat, Madhya Pradesh and Karnataka with the support of Danish International Development Agency (DANIDA). During 11th five year plan (2007-2012) Indian government has spent $44.79 million on R&D in wind energy.

Structure of economics of wind energy projects requires huge capital investment, but low recurring cost. Generally, initial capital outlay for one MW wind energy project in India is one million USD (1 USD = 60 Indian Rupees). Due to the requirement of high initial capital, payback period in this industry is very long. But advantage with this sector lies in its low recurring cost and consistent revenue flow as the wind pattern does not change dramatically.

Considering high initial cost, government has decided to offer inducements to individual investors for investing money in wind energy. Basket of incentives for this industry includes income tax holiday, accelerated depreciation, concessional excise and custom duty, provision of borrowing at low interest rates, etc. State governments also help investors by signing power purchase agreement for 20 years, allowing sale of energy to third parties and captive use of energy. Some state governments also provide subsidy for the initial investment in wind energy and sale tax benefits. The state governments of Tamil Nadu, Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Rajasthan, Haryana and West Bengal provide feed in tariff for purchasing wind energy. Feed in Tariff provides the minimum price at which wind energy based power must be sold to electricity distribution companies [25]. This tariff is higher in comparison to the other conventional energy sources. Table 5 provides a brief overview of wind energy policies of various states.

Apart from above mentioned incentives, state government also mandates distribution companies to buy a minimal percent of power from renewable energy sources. This policy is called as Renewable Purchase Obligation (RPO). This policy has its origin from Electricity Act 2003 in which it is mentioned a minimum percent of power to be procured from renewable energy sources by the obligated entities. Obligated entities are distribution companies, captive consumer and open access user, who is purchasing or generating energy by burning coal or gas [27]. RPO acts as a mandatory provision for procurement of energy from renewable energy sources.

8. State Level Wind Power Growth

Wind energy has received maximum investment among all renewable energy technologies. Totally, 445 wind farms that are installed in India, have come up across number of states [28]. Although Tamil Nadu has maximum number of installations, but Maharashtra, Gujarat, Karnataka and Rajasthan have also contributed well to wind energy. India's largest wind farm, Yermala Wind farm has been installed in Maharashtra. CLP owns this wind farm with 250 Enercon E53 800 KW wind turbines. More information about India's largest wind farm has been provided in Table 6.

Table 5. Incentives across different sates [15]

State	Feed In Tariff (In INR)	PPA Tenure (in Years)	Third Party Sale	Captive Usage
Andhra Pradesh	3.50	25	Permitted	Allowed
Gujarat	4.23	25	Permitted	Allowed
Haryana	6.14	25	Permitted	Allowed
Karnataka	3.70	10	Permitted	Allowed
Kerala	3.64	20	Permitted	Allowed
Madhya Pradesh	4.35	25	Permitted	Allowed
Maharashtra	Wind Zone I – 5.67 (w/o AD), 4.86 (with AD)	13	Permitted	Allowed
	Wind Zone II – 4.93 (w/o AD), 4.23 (with AD)			
	Wind Zone III – 4.20 (w/o AD), 3.60 (with AD)			
	Wind Zone IV – 3.78 (w/o AD), 3.24 (with AD)			
Odisha	5.31 (w/o AD) 4.48 (with AD)	13	Permitted	Allowed
Punjab	5.96 (w/o AD) 5.36 (with AD)	10	Permitted	Allowed
Rajasthan	5.18 (w/o AD) 4.90 (with AD)-for projects in Jaisalmer, Jodhpur and Barmer districts. 5.44 (w/o AD) 5.14 (AD)-for other districts	25	Permitted	Allowed
Tamil Nadu	3.51	20	Permitted	Allowed
Uttarakhand	Wind Zone I – 5.15 (w/o AD), 4.75 (with AD)	25	Permitted	Allowed
	Wind Zone II – 4.35 (w/o AD), 4.00 (with AD)			
	Wind Zone III – 3.65 (w/o AD), 3.35 (with AD)			
	Wind Zone IV – 3.20 (w/o AD), 2.90 (with AD)			
West Bengal	5.70	10	Permitted	Allowed

Table 6. Largest wind farm in India [28]

Power Plant	Developer	Location		Total Capacity
		City	State	
Yermala Wind Farm	Enercon	Solapur	Maharashtra	200 MW
Vankusawade Wind Farm	Suzlon	Satara	Maharashtra	189 MW
Abdasa Wind Farm	Suzlon	Kutch	Gujarat	150 MW
Muppandal Wind Farm	Many developers including Suzlon, Enercon and Vestas	Kanyakumari	Tamil Nadu	150 MW
Andhra Lake Wind Farm	Enercon	Pune	Maharashtra	114 MW
Khandke Wind Farm	Enercon	Ahmednagar	Maharashtra	108.4 MW

Bhakrani Wind Farm	Enercon	Jaisalmer	Rajasthan	104 MW
Sipla Wind Farm	Enercon	Jaisalmer	Rajasthan	102 MW
Savalsung Wind Farm	Gamesa	Bijapur	Karnataka	100 MW
Sadawaghpur Wind Farm	Suzlon	Satara	Maharashtra	74 MW

The following section provides the growth form of wind energy in different Indian states.

8.1. Tamil Nadu

Tamil Nadu is pioneer of wind energy in India. Due to its encouraging policies for wind energy, this state has always been preferred by the wind energy industry for installing the projects since the commencement of Indian wind energy programme. Wind farm developed by M/s. Pandian Chemicals at Kanyakumari on March 28, 1990 with 250 KW wind turbine, had been the first wind farm developed by any private company in India. Not only wind farm development, also manufacturing of wind turbines was started in this state by a joint venture between NEPC of India and Micon of Denmark. Since then, number of renowned manufactures such as Vestas, Gamesa, Suzlon and RRB have set up their manufacturing facilities in the state and Tamil Nadu has become manufacturing hub of wind turbines in the country. As wind farm sites in Tamil Nadu are not located on complex terrain, it is easy to transport wind turbine equipment to the site that makes project development comparatively easy [29]. Muppandal wind farm of the state, which is located on Aralvaimozhi mountain pass, is the largest wind farm in Asia with a generation capacity of 1500 MW [30]. It has large number of wind turbines of various sizes from 200 KW to 1650 KW.

Tamil Nadu is the leading producer of wind energy with a total installed capacity of 7,276 MW, accounting 34% of India's total wind capacity [23]. Except 2007, Tamil Nadu's annual capacity addition has been highest among all the states since 2002. In 2011, Tamil Nadu has achieved another success by installing 1,083 MW wind energy in a single year, which is highest annual installation by any Indian state in single year. In the recent past, districts of Coimbatore, Tirruppur and Theni are the locations where the maximum numbers of wind turbines are getting installed. The spectacular growth of wind energy in Tamil Nadu is attributed to consistent effort of government to assess wind resource potential and set up conductive policies to attract private investment.

8.2. Maharashtra

Investor-friendly policies of Government of Maharashtra and technical viability of the demonstration projects have attracted huge investment in the wind sector. Maharashtra is having largest installed capacity of wind energy after Tamil Nadu with 4098 MW, covering about 19% of India's total wind capacity [23]. When the Indian government started wind energy programme in 1980s, this state also decided to set up some agency that would cater to energy development in Maharashtra on the same line. Thus Maharashtra Energy Development Agency (MEDA) had been formed to undertake development of renewable energy as a state nodal agency under umbrella of MNRE. Due to the long- term certainty provided by the regulatory framework and several other policy initiatives, there has been significant development of installed capacity based on renewable energy sources especially wind energy. Maharashtra has been seen as one of the best state to invest in wind energy due to investor friendly policies. Satara, Sangli, Dhule and Panchgani are places in Maharashtra those have a good number of wind power generating facilities.

8.3. Gujarat

The state of Gujarat is blessed with a long coastline of 1600 KM where the wind speeds are adequate for conversion into electrical energy. Just like MEDA, Government of Gujarat has setup Gujarat Energy Development Agency (GEDA) in 1979 to tackle the oil crisis of 1970s. This is a state nodal agency developed to foster the development of sustainable energy systems suitable for a country like India, which relies heavily on imported oil for meeting energy needs. Due to government efforts, in 1985 India's first joint sector 1.10 MW wind farm came at Mandvi in Gujarat. This State's government is always keen to promote investment in wind energy, hence it has introduced a number of incentives like higher feed in tariff, wheeling and banking of energy. Due to this, big energy companies like China Light and Power (CLP), Tata Power and ONGC have setup wind energy production facilities in this state. ONGC has installed 51 MW wind power project for its captive purpose in Kutch district of state, whose energy is getting wheeled to its manufacturing plants at Vadodara, Ahmedabad and Mehsana. The Gujarat government, along with the need of the hour has revised its wind energy policy to boost wind generation in the country. Of late, on July 25th, 2013, the state government had pronounced a new wind power policy known as Wind

Power Policy - 2013. Under this new policy, wind energy tariff has been increased and captive use of wind energy made more easily accessible. The Gujarat government has provided a big relief to developers by providing land on lease basis for wind power projects.

8.4. Karnataka

Karnataka is one of the leading states in potential of renewable energy in India. At present, thermal and hydro is the primary source of energy in this state. Nevertheless, renewable energy contributes about 24% to state's installed capacity. The renewable energy potential of the state is estimated at 28 GW, mainly from wind, small hydro, co-generation and biomass sectors. According to C-WET, Wind energy potential of the state at 80 meter hub height is 13.6 GW. Karnataka has formulated Karnataka Renewable Energy Policy in 2009 under the supervision of Karnataka Renewable Energy Development Limited (KREDL) to establish 4,300 MW from renewable energy sources by 2014. Through this policy, state government has made provision for easy financing for renewable energy projects, establishment of special renewable energy economic zones and provide time bound clearances from various departments to ensure speedy project execution. Out of state's total capacity of 2409 MW, 1089 MW projects are set up after implementation of this policy. Since, Karnataka is having complex terrain, there are a number of small wind farms in the state, located on small hills. This makes this state of having the highest number of wind farms. Chirtadurga, Dharwad, Gadag and Belgaum are prominent areas for wind energy in the state. Chitradurga with more than 20,000 wind turbines is considered as a location with highest Plant Load Factor (PLF) of India. Average PLF in Chitradurga is noted as 34%, which is much better than sites in other states. Due to favourable energy policies, Karnataka is home for major IPPs. In this state IPPs have invested heavily in all energy sources. Out of total energy installation of 13.94GW, 32% energy projects are established by private investment. In fact, world leader in renewable energy, Acciona Energy of Spain has installed three wind farms in the state with a total capacity of 85.8 MW. All three projects have already been registered with United Nations under Clean Development Mechanism (CDM) of Kyoto Protocol.

8.5. Rajasthan

Rajasthan is emerging as the most favoured destination for setting up wind power projects. This state has reached to installation of 2,820 MW on March 2014 from just 16.1 MW in 2002. The prime reason for this growth is the attention given by state government to develop clean energy sources. Wind energy development programme in Rajasthan was started in 1999, when MNRE launched a scheme to install 2 MW demonstration projects. Subsequent to the overwhelming success of these demonstration projects, commercial activity of wind energy had started. 25 MW Wind energy project development by Rajasthan Renewable Energy Corporation Limited (RRECL) in 2004 was the first commercial project of the state. Thenceforth, numbers of IPPs like CLP, IL&FS, NALCO etc. have invested in wind energy programme of state. IL&FS has implemented 38.4 MW project with 63 Enercon E-53 wind turbines of 800 KW size at Jaisalmer. On the basis of weather data of meteorological department this site is one of the best position for wind energy projects. CLP India has proposed to plant up 100.8 MW wind energy project at Tejuva with 48 units of Suzlon S-97 – 2.1 MW wind turbine. With the target to increase the share of wind energy in the energy mix, on June 17, 2014 state government has approved an amendment in the Wind Energy Act, 2012 to attract investment for 400 MW wind energy project. Rajasthan is fully committed to promote all renewable energy technologies, hence it is one of the leading state in the field of solar energy with total solar installation of 500 MW.

8.6. Andhra Pradesh

According to the studies conducted by C-WET, Andhra Pradesh is having second highest potential for wind energy with 14.5 GW of generation potential at 80 meter hub height. During the last two years, this state has witnessed a big surge in wind energy installation. In 2012, Andhra Pradesh had seen a sudden jump in installation when it installed more than 200 MW of wind energy projects, while before 2012, its annual installation had never extended beyond 60 MW. In 2013 also, 305.35 MW wind energy has been established [23]. This growth of wind energy in the state has been credited to the interest shown by IPPs especially Mytrah Energy and Greenko Group. Mytrah Energy Limited is an India focussed subsidiary of the Mytrah Group of United Kingdom. This wind power generation company is based in Hyderabad and listed on the Alternative Investment Market of (AIM) of the London Stock Exchange. This company has set up 100.4 MW wind energy project in two different locations, namely Burgula and Vajrakarur [31]. In January 2014, Mytrah Energy has signed MoU with Andhra Pradesh government to install 2850 MW wind energy project in the state [32]. In July 2014, this company has become leading wind IPP in India with operational wind assets of 524.85

MW. Another big IPP, Greenko group is having 100.2 MW wind farm operational at Rayala site in Anantapur district in Andhra Pradesh [33]. This project has been implemented in two phases, first was completed in November 2013 while the second phase in February 2014. Andhra Pradesh will soon become one of leading state in India in wind energy with the backing of these big IPPs. In the current year (2014), Andhra Pradesh in targeting to install 500 MW wind energy and it has already signed power purchase agreement (PPA) with the investors for this.

8.7. Madhya Pradesh

The government of Madhya Pradesh has been at the forefront in promoting various renewable energy sources including wind energy through its policy initiatives and incentives for renewable energy investor. Although Madhya Pradesh is not among the leading states in wind energy potential as it is having the potential of generating only 2931 MW energy from wind. But state government is always keen to raise the contribution of wind energy for sustainable growth. In October 1994, this state had formed a joint sector company called M.P Windfarms Ltd by an MoU between Madhya Pradesh UrjaVikas Nigam, IREDA and Consolidated Energy Consultants Limited (CECL) to develop wind energy projects in the state. Between 1995 and 1999 this company implemented 13 MW wind power project in Dewas to set a platform for commercial wind energy projects. Since then, 439 MW wind energy projects have been installed in the state at different locations like Dewas, Ratlam etc. Dewas alone is having 139 MW installed capacity [34]. In July 2014, GE has announced plans to put up two separate wind energy projects of 50 MW each at Betul district. Both these projects are expected to start commercial operation by December 2014. The Madhya Pradesh government has made substantial modifications in its wind energy policy for achieving ambitious target of creating installed capacity of 1800 MW in the near future through the backup of the individual sector. Already 46 projects of approximately 1500 MW have been granted to the private sector.

8.8. Kerala

Kerala government had set up The Agency for Non - Conventional Energy and Rural Technology (ANERT) in 1986 as an independent body for conducting surveys to acquire renewable energy projects. ANERT has conducted studies in association with MNRE of the wind potential of the state and estimated it to be 605 MW. This agency is also in the process of putting a 2MW demonstration project at the Rammakalmedu site in Idukki district. Rammakalmedu site is identified as most potential site in the state for developing wind power with an estimated potential of 80 MW. Totally in Kerala, 16 potential sites have been identified for the exploration of wind energy. These sites include 10 locations in Idukki district, five in Palakkad district and one in Thiruvananthapuram. This state has been very slow in the process of executing of wind energy project, which can be seen in its only 55 MW installed capacity so far. Since 2002, there have been seven years, when not a single wind energy project had been installed in the state. In 2013 also, Kerala has installed only 19.8 MW. But Kerala government is trying very hard to break this jinx with the support of big energy companies of India. Recently, Kerala has signed an agreement with National Hydroelectric Power Corporation (NHPC) to set up a wind power project in Palakkad district. In the first phase, the plan is to have a wind farm of 82 MW in Kottathara and Nallasingam areas of Palakkad district [35]. Cost of this project is estimated to be about USD 80.3 million. One of the leading energy companies of India, National Thermal Power Corporation (NTPC) has also signed MoU with the state government to set up 200 MW wind power project in the state. This project will come in Idukki and Palakkad district of state [36].

8.9. West Bengal

West Bengal Renewable Energy Development Agency (WNREDA), state nodal agency was set up in 1993 for implementation of non-conventional energy programmes in the state. This agency had given mandate to promote renewable energy projects in the state and create a conducive environment for commercialisation of these projects. This agency has implemented several programmes for various renewable energy technologies like Wind Turbines, Wind Diesel Hybrid, Small Hydro, Solar Thermal, Solar Photovoltaic, Biogas Plants, Biomass Gasifier, Tidal Power etc. [37]. Nevertheless, wind energy installed capacity of the state is only 1.1 MW.To improve share of wind energy in energy mix,in 2009, West Bengal Green Energy Development Corporation (WBGEDC) proposed a 40-50 MW facility on 1,400 acres in the backwaters of Bay of Bengal at Dadanpatra, approximately 150 km from Kolkata, in PurbaMedinipur district. Suzlon had instantly showedinterest in this project, but this project could not beexecuted due to the problem in land execution [38]. At present, four wind energy units of 250KW are working in state at Frazerganj. A composite

wind – diesel plant of 1 MW capacity is also working at Sagar Island. State government encourage power companies to buy energy generated by renewable energy equipment to increase share of renewable energy in state energy capacity.

9. Conclusion

Due to liberalisation and change in lifestyle of consumer, demand for energy has increased. This growth of demand can be effectively tackled by better energy management. Development of energy sources is vital to meet the growing energy demand. India has huge potential of renewable energy sources especially solar and wind. Realizing this potential, Government of India has been actively putting efforts to promote renewable energy. Growth in the installed capacity of wind energy shows that investors are positively participating in Indian wind energy programme. Wind energy has become more of business propositions for investors and contributing to development of economy as well. Wind energy positively affects a country's economy by providing three fold returns i.e. economic, social and environmental. However, high cost of generating energy from wind is a cause of concern. Total Cost of installing an onshore wind power system in India is 1300 to 1450 USD /KW [39]. Wind turbine cost including tower and installation can be as much as 84% of the total project cost. Similar to other renewable energy technologies, high upfront cost of wind power is barrier to their uptake, despite the fact there is no fuel price risk after its installation. Hence, it is important to concentrate on development of new, technically advanced, state of art wind turbines which are cost effective and reduces per unit cost of wind power. It is vital for Indian government to increase investment in the R&D of wind turbines and wind resources assessment programme. With a high quality wind resource assessment, efficiency of wind farm can be increased which can subsequently reduce per unit cost of generation.

India's global position in wind energy can be bettered, since nature has provided it abundant resources of wind energy. Indian government has laid the foundation of comprehensive renewable energy programme which can meet this growing energy demand by increasing energy capacity of country. Over the period, Indian government has taken many steps to promote renewable energy in the country. However, in recent years, China has unsettled position of many leading countries including India by its enormous installation every year. China's implementation of countrywide renewable energy law is the main factor behind this rise in wind energy. Hence it is important for Indian government to introduce revolutionary changes in its wind energy programme to compete with China at international forum and to become global leader in wind energy. These changes can include starting offshore wind energy installation, repowering of old turbines with new higher capacity wind turbines, increasing R&D budget in wind energy technology and enhancing regulatory and tariff regime to bring wind energy into national power system. This paper has made modest attempt to discuss the journey of wind energy in India since 1985 till date and highlighted the contribution of central government and various state governments in the development of this industry.

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