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Growth Rate Analysis of Wind Turbine Industry in India

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Abstract: This study examines the relationship between the technology policy and industrial development of the wind turbine Industry in various Indian states and India. The electric power sector will be a primary target for deep reductions in CO_2 emissions because electric power plants are among the largest and most manageable point sources of emissions. With respect to new capacity, wind power is currently one of the most inexpensive ways to produce electricity without CO_2 emissions and it may have a significant role to play in a carbon constrained world. Yet, most research in the wind industry remains focused on near term issues, while energy system models that focus on century-long time horizons undervalue wind by imposing exogenous limits on growth. This study fills a critical gap in the literature by taking a closer look at the importance, growth and tariff of large-scale wind power.

Key words: Wind power, wind energy, wind turbine technology, wind, industry, India

INTRODUCTION

The wind energy boom includes more and more countries, with nearly 74,000 MW installed all over the world by the end of 2006. In 2005-06, the annual capacity addition in worldwide was nearly 14,900 MW, assuming the global rate of growth to 31.66% in the year 2006, with this growth rate continuing, it is expected that wind farms with a total capacity of 1,60,000 MW will be installed worldwide by the year 2010 (In Wind Chronicle, 2007). Over the last 3 years or so India has added more than 4,500 MW of wind power generation capacity accounting for more than 60% of the total installed capacity of 7,280 MW.Due to this growth, India ranked fourth in the world, has more wind power generation capacity than Denmark and has almost more than double the capacity of nuclear power in the country itself. Per capita consumption of energy in India is one of the lowest in the world. India consumes 520 kg of oil equivalent (kgoe) per person of primary energy compared to 1090 kgoe in china and worldwide average of 1,688 kgoe (In Wind Chronicle, 2007). The cumulative installed capacity of wind power projects in India is far below their gross potential (15%) despite very high level of policy support, tax benefits, long term financing schemes etc., for more than 10 years. One of the major barriers is the high costs of investments in these systems. The Clean Development Mechanism (CDM) of the Kyoto Protocol provides industrialized countries with an incentive to invest in emission reduction projects in developing countries to achieve a reduction in CO_2 emissions at lowest cost that also promotes sustainable development in the host country. Wind power projects could be of interest under the CDM because they directly displace greenhouse gas emissions while contributing to sustainable rural development, if developed suitably.

Wind resource: Ever since the days of sailing ships, it has been recognized that some areas of the earth's surface have higher wind speeds than others. Terms like doldrums, horse latitudes and trade winds are well established. A very general picture of prevailing winds over the surface of the earth is shown in Fig. 1. In some areas and some seasons, the actual pattern differs strongly from this idealized picture. These variations are due primarily to the irregular heating of the earth's surface in both time and position. The equatorial calms or doldrums are due to a belt of low pressure, which surrounds the earth in the equatorial zone as a result of the average overheating of the earth in this region. The warm air here rises in a strong convection flow. Late afternoon showers are common from the resulting

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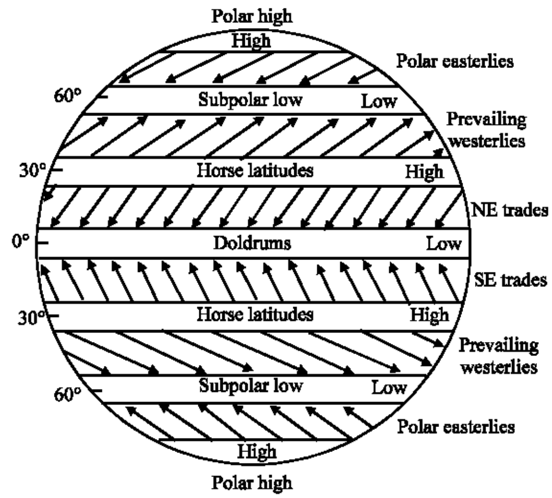


Fig. 1: Ideal terrestrial pressure and wind systems

adiabatic cooling which is most pronounced at the time of highest daily temperature. These showers keep the humidity very high without providing much surface cooling. The atmosphere tends to be oppressive, hot and sticky with calm winds and slick glassy seas. Ideally, there are two belts of high pressure and relatively light winds, which occur symmetrically around the equator at 30°N and 30°S latitude. The high-pressure pattern is maintained by vertically descending air inside the pattern. There are two more belts of low pressure, which occur at perhaps 60°S latitude and 60°N latitude. In the Southern Hemisphere, this low is fairly stable and does not change much from summer to winter. This would be expected because of the global encirclement by the oceans at these latitudes. In the Northern Hemisphere, however, there are large landmasses and strong temperature differences between land and water. These cause the lows to reverse and become highs over land in the winter. The intensities and locations of these highs may vary widely, with the center of the high only rarely located at the geographic pole. The combination of these high and low-pressure areas with the Coriolis force produces the prevailing winds shown in Fig. 1. Wind speeds are quite steady and strong during the year, with an average speed of 8-14 m sec^{-1}. The wind speeds tend to increase with increasing southerly latitude, leading to the descriptive terms roaring 40, furious 50 and screaming 60. This means that islands in these latitudes, such as New Zealand, should be prime candidates for wind power sites. In the Northern Hemisphere, the westerlies are quite variable and may be masked or completely reversed by more prominent circulation about moving low and high-pressure areas. This is particularly true over the large landmasses (Johnson, 2001).

Table 1: Mean wind speed at various levels

Mean wind speed (m sec^{-1})	No. of sites			
Height above ground level	50	75	100	125
>6	182	278	323	346
>7	54	108	150	199
>8	16	38	65	86
>9	6	16	25	36

India has not been regarded as a high wind country. It is only after the demonstration of first wind farms in India, that greater attention was paid to identification of wind resource areas in the country under the wind-mapping programme of the government of India. Identification of high corridors in Tamil Nadu and Karnataka with exceptionally high wind speeds led to setting up large wind farms in theses areas. In connection with the wind-mapping programme, it needs to be said that the states that have been forthcoming with policies and mechanisms for wind power development such as Tamil Nadu, Gujarat, Maharastra andra Pradesh and Karnataka received greater attention of this government driven programmes as well as private sector.

Based on the wind resource assessment report, there are some regions and sites subject to high wind speeds; by and large vast areas of the country are subject to mediocre wind speeds. There are very few areas having annual average wind speeds of more than 8 m sec^{-1} and vast areas that experience average wind speeds higher than 5.5 m sec^{-1} at about 20 m above the ground. Generally wind speed increases with height above the ground level, at a height of about 60-80 m, the average wind speeds of these vast areas could be in the range of 6-7 m sec^{-1}. Examination of data from 555 monitoring stations from all over India and extrapolation, wind speeds at 50-125 m heights above ground level are shown in Table 1.

At 75 m above ground level more than 50% of the monitored sites experience wind speeds greater than 6 m sec^{-1} and at 100 m, 68% of the sites experience wind speeds higher than 6 m sec^{-1}. Twenty percent sites experience wind speeds more than 7 m sec^{-1} at 75 m height and 27% at 50 m height. Vast areas of Gujarat, Maharastra, Karnataka, Orissa andra Pradesh and Tamil Nadu are subject to such wind speeds. Compilation of wind speed data at different heights shows that in many parts of the country wind speeds at 100-125 m levels are high (Mani and Mooli, 1983).

Importance of wind energy: With more and more evidence coming to light about the adverse effects of increasing presence of CO_2 in the atmosphere, we need to change the way in which we produce the majority of our energy, i.e., burning of fossil fuels. This need for change led to introduction of the Kyoto accord; a legally binding agreement dedicated to reduction of CO_2 emissions. With respect to the geographic location, for instance there doesn't seem to be many places where hydro dams and reservoirs can be installed, the same goes for solar power where the northern European climate will limit its usage. As for wave power; well it hasn't proved itself yet despite the fact that it has been around for some time now. That reacts to wind; wind has been seen as the fastest way, to make an impact on increasing a countries share of renewable energy and reducing emissions, making wind the renewable energy of choice. Solving many of the environmental and energy problems in industrialized countries, the growth of wind energy has been fuelled by this increased awareness of both public and private parties in environmentally friendly energy technology. Nationally, there have been increasing efforts to promote wind energy as a response to the awareness of the limited supply of fossil fuels and also to meet the growing energy demand. The Central and State governments have realized that not only can wind energy be a way to meet future energy demands but also could promote economic growth in rural communities, some of the hardest areas with hit job losses and declining population in recent years.

Carbon emission reduction from electric generation to the level required to stabilize atmospheric carbon concentration is most effectively achieved through a combination of natural gas, energy efficiency and renewable energy (Table 2).

Wind energy is a clean source that generates electricity with virtually no CO_2 emissions. Wind along with displacement of carbon dioxide, also displaces other harmful emissions contributing to smog, acid rain and airborne particulates. Though the combustion of natural gas produces no sulphur oxide emissions, it does produce significant amounts of nitrogen oxides and particulates as well as about 40% of carbon emissions produced by coal. Wind technology provides an outstanding opportunity to out carbon dioxide output at an extremely reasonable cost. In addition to helping the various countries to meet its greenhouse goals, setting up of wind turbines will result in healthier air and water for millions of people and in the creation of new jobs.

Wind has considerable amount of kinetic energy when blowing at high speeds. This kinetic Energy when passing through the blades of the wind turbines is converted into mechanical energy and rotates the blades and the connected generator, thereby producing electricity. A wind turbine primarily consists of a main tower, blades, nacelle, hub, main shaft, gearbox, bearing

Table 2: Emissions factors of gas, coal and wind technologies (lb Mwh^{-1})

Pollutant	Advanced coal	Advanced gas	Wind
Sulphur oxides	0.83	0.00	0
Nitrogen oxides	1.82	0.61	0
Particulates	0.14	0.10	0

and housing, brake and generator. The main tower is 50-100 m high. Generally, three blades made up of Fiber Reinforced Polyester are mounted on the hub, while in the nacelle the major parts are housed. Under normal operating conditions the nacelle would be facing the upstream wind direction (Patel, 1999). The hub connects the gearbox and the blades. Solid high carbon steel bars or cylinders are used as main shaft. The gearbox is used to increase the speed ratio so that the rotor speed is increased to the rated generator speed (Burton *et al.*, 2001), it is the most critical component and needs regular maintenance. Oil cooling is employed to control the heating of the gearbox. Gearboxes are mounted over dampers to minimize vibration. Failure of gearbox may put the plant out of operation for an entire season, as spares are often not available. Thus, new gearless configurations have become attractive for wind plant operators. Modern turbines fall into two basic groups: horizontal axis turbines and vertical axis turbines. Horizontal axis turbines resemble airplane propellers, with two to three rotor blades fixed at the top of the tower and facing the wind. This is the most common design found today, making up most of the large utility-scale turbines on the global market. Vertical axis turbines resemble a large eggbeater with rotor blades attached vertically at the top and near the bottom of the tower and bulging out in the middle (Purohit and Michaelowa, 2007).

As a result of this changing attitude towards renewable energy, wind power has been most rapidly growing renewable energy source over the last decade. Despite this high growth, established energy incumbents have obstructed wind energy development with high investment cost, market failures and substantial opposition. The levelized cost of power from wind project is now about 4.5 Rs KWh^{-1}. Compared with levelized coal plant cost of 3.9 Rs KWh^{-1}. The cost of avoiding carbon dioxide emissions with technology is currently about 237.6 Rs t^{-1}. The goal for wind technology is to have winds total costs equal to the variable cost (i.e., the fuel cost and O and M costs) of its fossil fuel.

Significant areas of the world have mean annual wind speeds of above 6-7 m sec^{-1} which makes small-scale wind powered electricity generation an attractive option (Gipe, 1999). It is important to obtain accurate wind speed data for the site in mind before any calculation can be made.

The power in the wind is proportional to:

- The area being swept by the wind turbine blade.
- The cube of the wind speed.
- The air density-which varies with altitude.

The formula used for calculating the power is

$$P = 0.5\times\rho\times A\times C^3$$

Where:

P : Power in watts (W).
ρ : Air density in kilograms per cubic meter (kg m^{-3}), (about 1.225 kg m^{-3} at sea level, less higher up).
A : Swept rotor area in square meter (m^2).
C : Wind speed in meter per second (m sec^{-1}).

The fact that the power is proportional to the cube of the wind speed is very significant. This can be demonstrated by pointing out that if the wind speed doubles then the power in the wind increases by a factor of eight. It is therefore, worthwhile finding a site, which has a relatively high mean wind speed.

The actual power that can be extracted from the wind is significantly less than what this figure suggests. The actual power will depend on several factors, such as the type of machine and rotor used, the sophistication of blade design, friction losses and the losses in the pump or other equipment connected to the wind machine. There are also physical limits to the amount of power that can be extracted realistically from the wind. It can be shown theoretically that any windmill can only possibly extract a maximum of 59.3% of the power from the wind. In reality, this figure is usually around 45% (maximum) for large electricity producing turbine and around 30-40% for a wind pump.

So, modifying the formula for 'Power in the wind' we can say that the power, which is produced by the wind machine, can be given by:

$$Pm = 0.5\times Cp\times\rho\times A\times C^3$$

Where:

Pm : Power (in watts) available from the machine.
Cp : Coefficient of performance of the wind machine (power efficiency).

Evolution of the wind turbine industry: The idea of harnessing wind energy to produce electricity is nearly as old as the electric Power system itself: 6 years after Edison built New York City's Pearl Street Station in 1882,

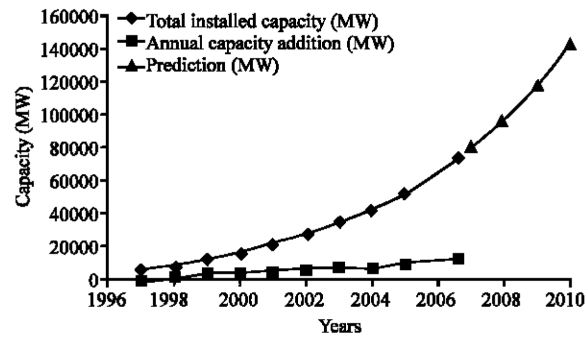


Fig. 2: Total installed capacity and prediction throughout the global

Charles Brush built the first windmill designed to produce electricity. Brush's Turbine consisted of 144 cedar planks with a diameter of 17 m, had an output of 12 kW and produced electricity for 20 years. For the next century, wind turbines remained a hobby for self-motivated engineers and resourceful farmers, who built small-scale wind turbines-less than 10 kW-to power remotely located homes and farms that remained untouched by the spread of transmission and distribution lines. According to the International Energy Agency (IEA, 2006), renewable energy sources excluding hydro, combustible renewable and waste contributed just 0.5% of the total primary energy supplies in 1999. This category includes wind energy, geothermal, solar and others. The phenomenal growth of this industry can be attributed, primarily, to the rapid progress made in wind turbine technology. Technological progress has led to the development of turbines with high power capture efficiency. However global installed wind capacity is increasing rapidly. Current global installed capacity exceeds 74000 MW with a projected growth rate of greater than 30% per year. Figure 2 shows the global annual addition, installed capacity and prediction in wind turbine industry up to 2010. If the same growth rate continues, at the end of 2010 throughout the global the installed capacity is nearby 160,000 MW.

Wind energy industry growth in India: The International Energy Agency predicts that the world's energy needs will be about 60% higher than they are now (International Energy Outlook, 2006). Over the last three years or so, India has added more than 4,500 MW of wind power generation capacity accounting for more than 60% of the total installed capacity of 7,280 MW. This, therefore has been a high growth period and today India is ranked fourth in the world, has more wind generation capacity than Denmark and has almost more than double the capacity based on nuclear power in the country itself. In 2006, the capacity of power plant in India was 124 GW, of which 66% thermal, 25% hydro, 3% nuclear and 5% new renewable (http//power.min.nic.in). Chinese power capacity reached over 600 GW (Peoples Daily, 2007), showing India's backlog. In the best locations, wind is already competitive with new coal-fired plants. Individual wind turbines have also increased in capacity, with the standard commercial machines reaching 2.5 MW and prototypes for offshore plants even 5 MW.

A notable feature of the Indian programme has been the interest among private investors/developers in setting up of commercial wind power projects. The gross potential is 46,000 MW (source MNES) and a total of about 7280 MW of commercial projects have been established until June 2007. Figure 3 represents state-wise trends in cumulative installations till June 2007.

Figure 4 represents the gross potential in all states of India. In particularly, the installed capacity is very close to Gross potential in Tamil Nadu.

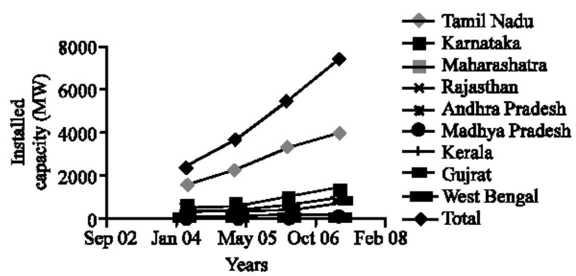
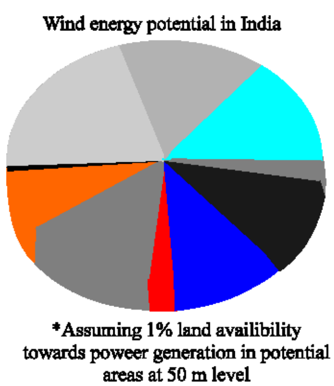


Fig. 3: Installed capacity of all regions in India



State	Gross potential* (MW)
Andhra Pradesh	9,063
Gujrat	7,362
Karnataka	7,161
Kerala	1,026
Madhya Pradesh	4,978
Maharashatra	4,519
Orissa	1,120
Rajasthan	6,672
Tamil Nadu	4,159
West Bengal	32
Total	46,092

Fig. 4: Wind energy potential in India

Based on the available data, it is seen that the total wind electric generators installed by Suzlon Energy Ltd. in Aralvaimozhi, Kanyakumari District is 420 and in its growth rate is tabulated in Table 3 since 2002.At the end of 2008, the company has planned to install 408 wind Turbines.

The trends at national level are presented in Fig. 5 and it indicates the installed capacity up to June 07. In India, one of the major actors in the development is government and its wind energy friendly policies.

We take the case of the government intervention in Tamil Nadu, India. The first wind farm with 10 of the 55 kW of Wind Electricity Generators (WEGs) was operated on January 18, 1986 at Mullakkadu, Tuticorin. Since then Tamil Nadu has made rapid progress with major funding assistance from MNES and with the local cost shared by Tamil Nadu Energy Development Agency (TEDA) and Tamil Nadu Electricity Board (TNEB) equally. As on 31-12-2001 these demonstration wind farms in Tamil Nadu with 117 wind electric generators have cumulatively generated and fed into electricity board grid a total of 312.5 million units of electricity. The Tamil Nadu Energy Development Agency (TEDA), nodal agency of the Ministry of Non-Conventional Energy Sources (MNES) is a Tamil Nadu government undertaking to promote renewable sources of energy and energy conservation activities. It has been a major catalyst for the tremendous growth Tamil Nadu has made in the development of wind power (Dime, 2006). TEDA has undertaken statewide wind resource assessment programme right from 1986 with the funding assistance of Government of India (MNES) and Government of Tamil Nadu and with the Technical Assistance of Indian Institute of Tropical Meteorology, Bangalore. The first private sector wind farm of the country was set up in TamilNadu during 1990 with two wind electricity generators of 250 KW each at Muppandal. The NAL has been involved in the development of wind turbine development programmes which being largely funded by the New Millennium Indian Technology Leadership Initiative (NMITLI) of the Council of Scientific and Industrial Research (CSIR), the Centre for Wind Energy Technology (C-WET), Chennai and the Sangeeth Group of Companies, Coimbatore as the industrial partner. Wind speeds in India, for instance, are much lower than wind speeds in European countries and it is known that the power generated is proportional to the

Table 3: Growth rate of Wind Turbines in Aralvaimozhi by Suzlon Energy Ltd

Categories	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	Up to till now
Total machines	32	82	220	325	399	408	420
Total generation	6,554,812	157,372,390	411,853,599	568,491,716	874,894,829	472,099,150	2,471,743,406
Average generation	468,201	3,814,682	3,156,441	2,384,354	2,721,134	1,255,535	7,671,597
Average M/C avail	96.08%	96.87%	97.68%	96.39%	97.77%	98.42%	97.32%
Average grid avail	91.86%	96.38%	92.84%	91.05%	92.87%	92.13%	90.35%

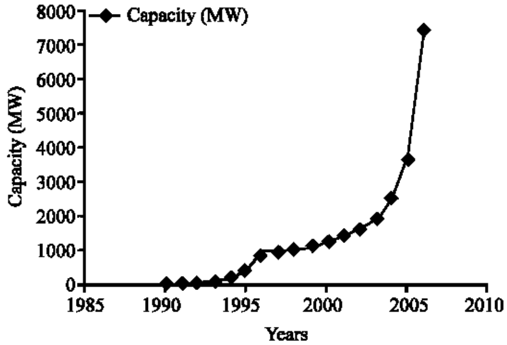


Fig.5: Wind power development in India

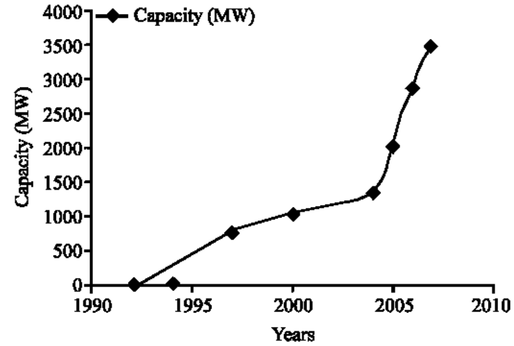


Fig. 6: Wind Power progress in Tamil Nadu

cube of the wind speed. Lower speeds, therefore, drastically affect the wind power output. Unless a turbine is properly designed to efficiently generate electricity at these lower speeds, it is not going to work well in India. And hence, NAL is involved in building wind turbine that are adapted to the Indian conditions (Johnson, 2005). The State Governments, State Nodal Agencies or State Electricity Boards, together with extremely favourable financial incentives, have created the conditions that have allowed the wind energy market to expand from just 32 MW of installed capacity in early-1990. The Indian Renewable Energy Development Agency (IREDA) has played a significant role in the promotion of wind energy, attracting bilateral and multilateral financial assistance from world institutions and the private sector. The Centre for Wind Energy Technology (C-WET) based in Tamil Nadu also acts as a technical focal point for wind power development in India. There are but few indigenous private players in this sector, which are actively pursing the process of innovation and adaptations of the foreign technology to meet the local needs and seek international accreditation. Initially, financing institutions other than IREDA were not willing to invest in wind power projects due to lack of exposure and experience in this sector. In 1993-94, the World Bank provided financial assistance of US $43 million for wind energy to IREDA. This opened the window for large-scale financing and catalyzed the growth of the industry in the mid-1990s. The growing interest among wind project sponsors encouraged other financial institutions to begin financing wind projects.

The total current wind capacity in India is 7.2 GW (as on June 07) growing at 40% per annum (the fastest among all sources of energy in the country, though from a lower base). The country ranks 4th in wind power capacity worldwide. India is estimated to have a theoretical potential of 65 GW and a technical potential of 15 GW. A target of 10.5 GW of capacity addition from wind has been set till 2012.

The wind power has seen rapid development in Tamil Nadu since 1992 as seen in Fig. 6. The wind energy production is also limited and it has been growing with very little speed up to March’03. Due to the continuous support given by Tamil Nadu Energy Development Agency and Tamil Nadu Electricity Board, majority of the investors came forward to invest Wind Turbine Industry since 2004. The installed capacity in TamilNadu is 1361.6 MW as on March 04. Later, the growth has been increased tremendously and reached 3249.6 MW in March 07. In districts with high wind energy potential *viz.* Jamnagar, Coimbatore, Tirunelveli, Satara, Dhule, Chitradurga, Kanyakumari and Jaisalmer, less than 0.2% area is under wind farms. All over the country the coverage is only about 300 km^2 area and less than 6.28 GW (Hossain, 2007), where there is a concentration of assets in some states (Tamil Nadu accounts for 50% of capacity, Maharastra 20% and Karnataka 12%) states like Kerala andra Pradesh.

The State Electricity Regulatory Commissions (SERCs) have been very active in the last 2 to 3 years in coming up with Tariffs for off-take of electricity from renewable energy projects and in setting renewable energy portfolio standards. Summarising details of tariffs for electricity from wind Industry as set by the State Electricity Regulatory Commissions, shows that (Table 4) tariffs vary from Rs.2.90 kWh^{-1} (Tamil Nadu) to Rs.3.97 kWh^{-1} (Madhya Pradesh).

Windmills in Tamil Nadu were reported to have been shut down due to drop in demand. The supply from wind mills had been cut off from the grid after the frequency of the Tamil Nadu Electricity Board grid crossed 50.3 Hz.Tamil Nadu has an installed wind capacity of 3400 MW and they work mostly in season. The shut down resulted in substantial loss to wind farm owners.

Table 4: Tariff per state

	Andra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pardesh	Maharashtra	Rajesthan	Tamil Nadu	West Bengal
Wheeling	2% of energy+ transmission charges	4% of energy	7.5% of energy	5% of energy	2% of energy+ transmission charges as per ERC	2% of energy+ 5% transmission loss	10% of energy	5% of energy	2% energy
Banking	12 Months	*Energy accounting and commercial settlement	2% per month for	9 months (June-Feb)	Not allowed	12 months	6 monthly i.e., April to Sept. and October to March	5% (12 months)	6 months
Buy-back rate	Rs. 3.37 kwh^{-1} for FY 04-05 wef 1.4.2004, freezed for 5 years	Rs. 3.37 kwh^{-1} levelised for 20 years	Rs.3.40 kwh^{-1} fixed for 10 years	Rs 3.14 kwh^{-1} fixed for 20 years	Rs. 3.97 (with decrease of 17 paisa up to 4 th year) then fixed at Rs. 3.30/U from 5th for 20 year (wef. 11.6.04)	Rs 3.50 kwh^{-1} escalation of Rs 0.15/U per year for 13 years from DOC of the project	Rs 3.59 for 1st year escal of 2 paisa up to 12th year and escal of 1 paisa up to 20th year	Rs 2.90 Kwh^{-1} (levlised)	Upper cap of Rs 4 per unit
QA Trans.	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed

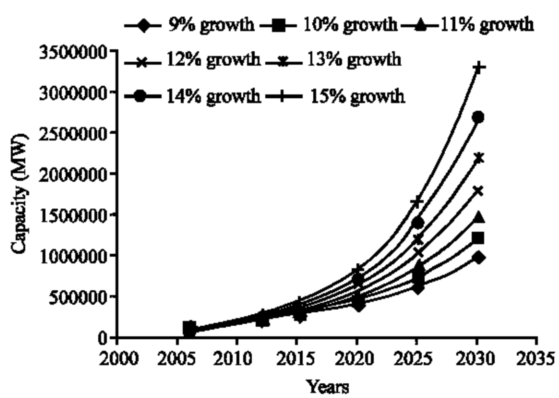


Fig. 7: Projections of installed capacity (MW)

DISCUSSION

In India the total current wind capacity has been growing at 40% per annum (the fastest among all sources of energy in the country, though from a lower base) and in Tamil Nadu the growth has been increased tremendously and reached the installed capacity as 3249.6 MW in March 07. In terms of the market for wind energy in the United States, while as much as 100% of the entire nation s power consumption needs could be met by wind energy discounting transmission issues, the primary factor wind energy must overcome in order to be economically competitive is simply cost. The Fig. 7 presents the total installed capacity needed in India assuming at different growth rates. Even if we go by the lower growth rate 9% situation becomes rather alarming by 2020. Based on calculations if we go by the growth rate of 15% at the end of 2030, the installed capacity becomes 3285672 MW. The currently installed wind power capacity generates more than 1% of the global electricity consumption. Based on the accelerated development, it is predicted that by 2010, 160,000 MW will be installed.

CONCLUSION

The different technology policy and industrial development of the wind turbine industry in India and various Indian states, emphasizes India's unique strategy of interactive learning for developing wind turbine industry. It clearly indicates as solution to meet the Global requirements through wind turbine industry. The growth clearly shows that how the Indian Government, Non renewable energy sectors and Tamil Nadu helps the private sectors to increase the production of wind turbine industry. Knowledge of the wind velocity at different sites could be used to estimate the wind power production, average machine generation and grid availability. This attempts to assess the India's gross potential, position in the world market, wind resource and variation of wind speed with respect to site, different growth rate. This sectoral innovation systems framework is especially useful tool for analyzing the growth of wind turbine industry and in its essence to preserve the environment with reduction in carbon dioxide emissions.

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