

Wind Energy Projects in India: Opportunities and Challenges

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ABSTRACT: Wind energy, with an average growth rate of 30%, is the fastest growing source of renewable energy in the world. India occupies the 4th place in the world in wind energy generation after Germany, the USA and Spain, and has an installed capacity of more than 7845 MW as of 31st December 2007. New technological developments in wind energy design have contributed for the significant advances in wind energy penetration and to get optimum power from available wind. In this study, wind energy scenario in the world in general and in India in particular is presented. Opportunities under the climate policy instruments and potential barriers for the large-scale dissemination of wind energy projects are explored. The future growth pattern to achieve the maximum utilization potential of wind energy projects in India is analyzed.

Key-words: renewable energy, wind energy scenario, logistic model, India

1. INTRODUCTION

Energy security and sustainable development are high in the global agenda due to: the impact of volatile energy prices; high demand for energy security; and concerns over environmental sustainability and the global climate change [1]. New and renewable energy technologies are considered to be one of the viable options to meet the challenge of achieving sustainable development while conserving natural resources that have been depleted due to the rapid growth in population, urbanization, and fossil fuel consumption [2-3]. Wind is commercially and operationally the most viable renewable energy resource and accordingly emerging as one of the largest source in this sector [4]. At the end of December 2007, worldwide capacity of wind-powered generators was 94 GW [5]. Wind currently produces just over 1% of world-wide electricity use [6]. It accounts for approximately 19% of electricity production in Denmark, 9% in Spain and Portugal, and 6% in Germany and the Republic of Ireland. Globally, wind power generation increased more than fivefold between 2000 and 2007 [5]. Fig 1 presents the world wide trend in global installations of wind power.

Wind energy sector observed phenomenal growth in the year 2007 however, in India, the industry failed to keep pace. Worldwide wind energy installations were 19.7 GW in 2007 up

from 15.1 GW in 2006. In contrast in India the installations in 2007 were 1.58 GW down from 1.73 GW in 2006. Though India ranks 4th globally, the country managed to register a growth rate of just 25.2% against the world average of 26.6%. This puts India far behind countries like the USA (45%), Spain (30.2%), France (56.7), and its neighbour China (127.5%). The time variation of the installed capacity of wind power in these countries is shown in Fig 2.

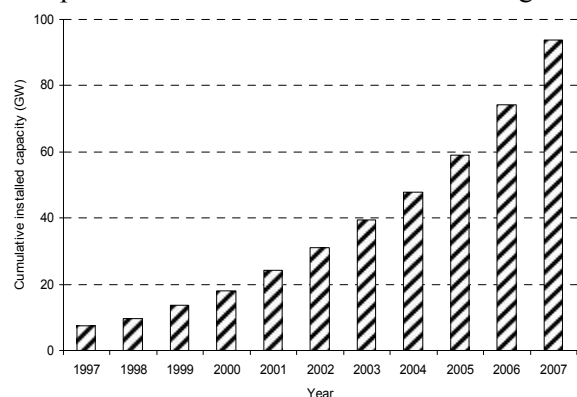


Fig 1. Global installed capacity of wind power projects (Source: www.wwindea.org)

India's total installed wind energy capacity now stands at 7.85 GW in comparison with 6.27 GW in 2006. In the year 2007, 19.7 GW of new wind energy capacity was added summing up to a global installed capacity of 94 MW by the end of December 2007. China with a growth rate of

127.5% showed the greatest performance of the top five wind countries. At this rate China is well set to overtake India in the next couple of years. In terms of continental distribution, Europe decreased its share in installed capacity from 65.5% in 2006 to 61% in 2007. However, Europe is still the strongest continent while North America and Asia are rapidly increasing their shares. In terms of new, additional capacity, Europe for the first time installed less than half of the new global capacity and counted for 43.6%, followed by North America (28.5%) and Asia (26.6%).

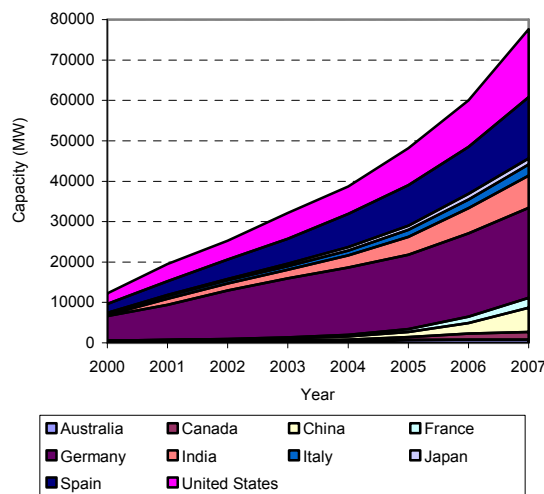


Fig 2. Installed capacity of wind power projects in top 10 countries (Source: www.wwindea.org)

The impetus behind wind power expansion has come increasingly from the urgent need to combat global climate change. Most countries now accept that GHG emissions must be drastically slashed in order to avoid environmental catastrophe. Wind energy offers both a power source that completely avoids the emission of carbon dioxide, the main GHG, but also produces none of the other pollutants associated with either fossil fuel or nuclear generation. Starting from the 1997 Kyoto Protocol, a series of GHG reduction targets has cascaded down to a regional and national level. These in turn have been translated into targets for increasing the proportion of renewable energy, including wind. In order to achieve these targets, countries in both Europe and elsewhere have adopted a variety of market support mechanisms. These range from premium payments per unit of output to more complex mechanisms based on an obligation on power suppliers to source a rising percentage of their supply from renewables.

As the market has grown, wind power has shown a dramatic fall in cost. The production cost of a kilowatt-hour of wind power is one fifth of what it was 20 years ago. 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. The successful wind energy business has attracted the serious attention of the banking and investment market, with new players such as oil companies entering the market. Hays and Attwood [7] concluded that Asia is playing an increasingly important role in the global wind industry as the region prepares to invest over \$12 billion in wind power generation capacity in the second half of this decade. India is the 4th largest wind market in the world however, the total installed capacity of wind power projects still remains far below from their respective potential (i. e. <20%). One of the barriers to the large-scale penetration of wind projects in India is the high upfront cost of these systems [8]. Other barriers to wind projects are low plant load factors, unstable policies of the state governments and poor institutional framework. As per Indian Wind Energy Association (INWEA) study, the actual installations in 2006-07 could have been much more but many constraints such as the lack of power evacuation infrastructure, availability of sites, logistics and even shortage of wind turbine supply could have somewhat slowed down the process of windfarm capacity additions. There have also been regulatory issues in some states that needed to be resolved. In this study, wind energy scenario in the world in general and in India in particular has been presented. Opportunities under the climate policy instruments and potential barriers for the large-scale dissemination of wind energy projects are explored. The future growth pattern to achieve the maximum utilization potential of wind energy projects in India is also analyzed.

2. WIND ENERGY TECHNOLOGY

Wind has considerable amount of kinetic energy when blowing at high speeds [9]. This kinetic energy when passing through the blades of the wind turbines is converted into mechanical energy and rotates the wind blades [10] and the connected generator, thereby producing electricity. A wind turbine primarily consists of a main tower, blades, nacelle, hub, main shaft, gearbox, bearing and housing, brake, and

generator [11]. 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 [9]. 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 [10]; 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. Fig 3 presents a schematic of a wind turbine.

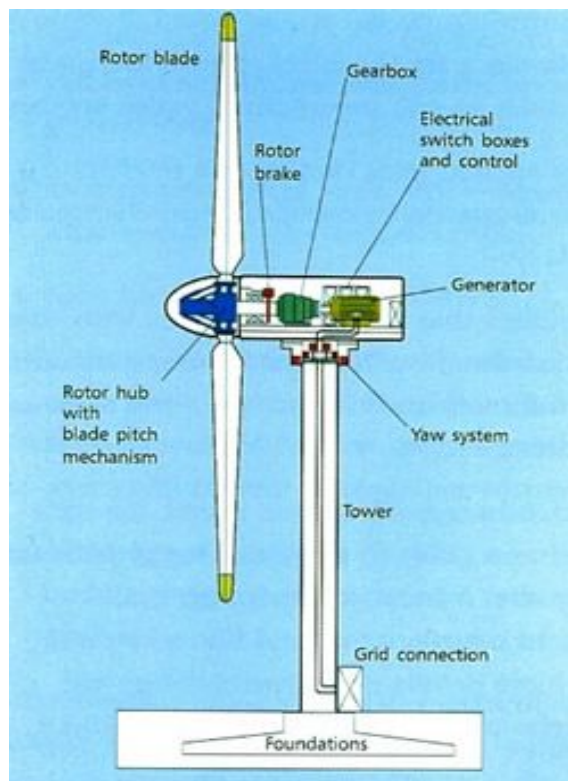


Fig 3. Schematic of wind turbine

The most dramatic improvement has been in the increasing size and performance of wind turbines. From machines of just 25 kW twenty years ago, the commercial size range sold today is typically from 600 up to 2.5 MW, with 80 m diameter rotors placed on 70-100 m high towers. In 2003, the German company Enercon erected

the first prototype of a 4.5 MW turbine with a rotor diameter of 112 m. Wind turbines have a design lifetime of 20-25 years, with their operation and maintenance costs typically about 3-5% of the cost of the turbine. At present, efforts are being made to develop a low cost, indigenous, horizontal axis Wind Energy Generator (WEG) of 500 kW rating. The WEG will have a two bladed rotor and the tower will be a tubular tower with guys. The organizations contributing in the development of the WEG are (i) National Aerospace Laboratory, (ii) Structural Engineering Research Centre, (iii) Sangeet Group of Companies, and (iv) Center for Wind Energy Technology. It will be specially suited for Indian wind conditions i.e. relatively low wind speeds and dusty environment. It is further learnt that this WEG may cost almost 50% as compared to the other WEGs of the same rating commercially available in India.

3. WIND ENERGY POTENTIAL IN INDIA

Wind in India are influenced by the strong south-west summer monsoon, which starts in May-June, when cool, humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when cool, dry air moves towards the ocean. During the period March to August, the wind is uniformly strong over the whole Indian Peninsula, except the eastern peninsular coast. Wind speeds during the period November to March are relatively weak, though higher winds are available during a part of the period on the Tamil Nadu coastline. In order to tap the potential of wind energy sources, there is a need to assess the availability of the resources spatially. A Wind Resource Assessment Programme was taken up in India in 1985 [8]. Around 1150 wind monitoring/mapping stations were set up in 25 states and Union Territories (UTs) for this purpose. Over 200 stations in 13 States and UTs with annual mean wind power density greater than 200 W/m^2 at a height of 50 m above the ground level show wind speeds suitable for wind power generation [11]. The wind power density at a height of 50 m above the ground level is depicted in Fig 4.

On a regional basis, more detailed assessments have been done. Ramachandra and Shruthi [12] employed a GIS system to map the wind energy resources of Karnataka state and analyzed their variability considering spatial and

seasonal aspects. Onshore wind power potential in the country has been assessed at 45 GW assuming 1% of land availability for wind power generation in the potential areas [13]. It is estimated that a penetration (supply fraction) of wind power on a large grid can be as much as 15–20% without affecting grid stability due to requirement of reactive power [14]. Therefore, at present, it is not technically feasible to exploit the full wind potential in view of total installed power-generating capacities from conventional power generating methods including hydro-electric power plants in different states.

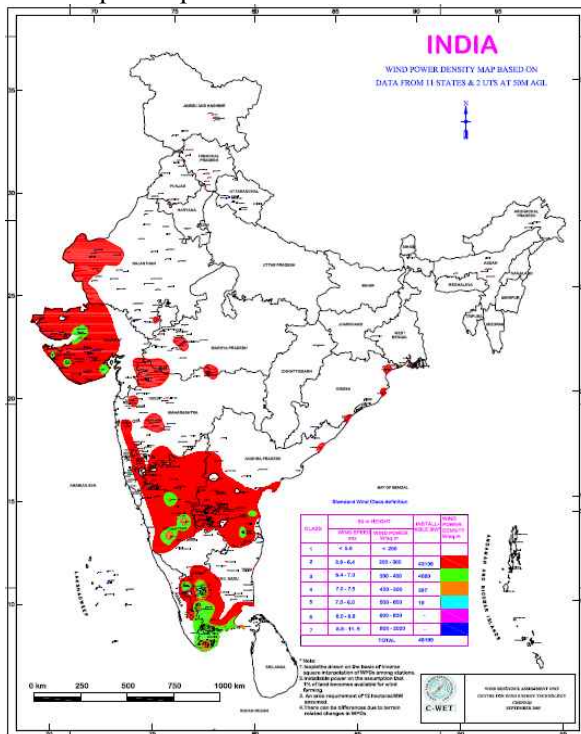


Fig 4. Wind power density map

Considering a maximum of 20% penetration of existing capacities of the grids through wind power in the potential states, technical potential for grid interactive wind power is presently limited to only 13 GW [11] that is expected to increase with augmentation of grid capacity in potential states. Table 1 presents a state wise break-up of the estimated technical potential along with wind power installed capacity until December 2007. Tamil Nadu has already surpassed the presumed technical potential, indicating that it may be underestimated for India as a whole. IWEA has estimated that with the current level of technology, the 'on-shore' potential for utilization of wind energy in India is of the order of 65 GW however; the annual

reports of the MNRE mentioned that the gross potential is 45 GW only [11].

4. WIND ENERGY PROGRAMME IN INDIA

The original impetus to develop wind energy in India came in the early 1980s from the government, when the Commission for Additional Sources of Energy had been set up in 1981 and upgraded to the Department of Non-Conventional Energy Sources in 1982. The setup of these institutions was due to the wish to encourage a diversification of fuel sources away from the growing demand for coal, oil and gas required to meet the demand of the country's rapid economic growth [15]. A market-oriented strategy was adopted from inception, which has led to the successful commercial development of the technology. The broad based national programme included wind resource assessment; R&D support; implementation of demonstration projects to create awareness and opening up of new sites; involvement of utilities and industry; development of infrastructure capability and capacity for manufacture, installation, O&M of wind power plants; and policy support.

The Ministry of New and Renewable Energy (MNRE) is providing support for research and development, survey and assessment of wind resources, demonstration of wind energy technologies and has also taken fiscal and promotional measures for implementation of private sector projects [16-17]. Wind turbines up to 2 MW are presently manufactured in India [11]. Fig 5 presents the cumulative capacity of wind power installed in India over time. A notable feature of the Indian programme has been the interest among private investors/developers in setting up of commercial wind power projects. This is due to a range of fiscal incentives provided by the Government of India such as 80% accelerated depreciation, tax holiday for power projects, concessional customs and excise duty as well as liberalized foreign investment as liberalized foreign investment procedures. The Indian Renewable Energy Development Agency (IREDA) provides concessional loans. Current interest rates are 9.5% for a maximum repayment period of 10 years and 9.0% for a maximum repayment period of 8 years [11].

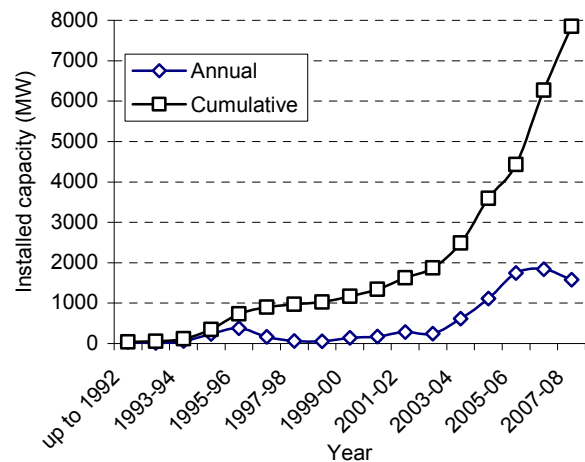
Table 1. State-wise wind power installed capacity in India

State	Gross Potential (MW)	Total Capacity (MW) till 31.12.07	Technical Potential (MW)
Andhra Pradesh	8275	122.4	1750
Gujarat	9675	874.8	1780
Karnataka	6620	917.2	1120
Kerala	875	2.00	605
Madhya Pradesh	5500	70.3	825
Maharashtra	3650	1646.3	3020
Rajasthan	5400	495.7	895
Tamil Nadu	3050	3711.5	1750
West Bengal	450	1.10	450
Others	2990	3.2	-
Total (All India)	45195	7844.5	12875

Source: <http://www.inwea.org/>

Table 2 presents the summary of key central government incentives for wind energy projects in India. MNRE has issued guidelines to all state governments to create an attractive environment for the export, purchase, wheeling and banking of electricity generated by wind power projects. The guidelines include the promotion of renewables including wind energy through preferential tariffs and a minimum obligation on distribution companies to source a certain share of electricity from renewable energy. However, only a subset of states is actually complying with these guidelines. The SERC's of Andhra Pradesh, Madhya Pradesh, Karnataka and Maharashtra provide preferential tariffs for wind power. Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh and Orissa have enacted the renewables obligation on distributors. The problem with incentives on the state level is that

they vary erratically and thus cannot be taken for granted by project developers.

**Fig 5.** Installed capacity of wind energy projects in India**Table 2.** Financial and fiscal incentives for wind power projects in India

Type of incentive	Description	Rate
I. Indirect Taxes	i) Wind operated electricity generators upto 30 kW and wind operated battery chargers upto 30 kW.	5%
	ii) Parts of wind operated electricity generators for manufacturer of wind operated electricity generators, namely: Special bearing, Gear Box, Yaw components, Wind turbine controllers.	5%
	Sensors, Brake hydraulics, Flexible coupling, Brake callipers.	25%
	iii) Blades for rotor of wind operated electricity generators for the manufacturers or the manufacturers of wind operated electricity generators.	5%
	iv) Parts for the manufacturer or the maintenance of blades for rotor of wind operated electricity generation.	5%
II. Excise Duty	v) Raw materials for manufacturer of blades for rotor of wind operated electricity generators.	5%
	Devices/Systems exempted from Excise Duty:	
	i) Wind operated electricity generator, its components and parts thereof including rotor and wind turbine controller.	
	ii) Water pumping wind mills, wind aero-generators and battery chargers.	
	[Notification No.6/2002 dated 01/03/2002 (S.No.237 non-conventional devices/systems)]	
III. Sales Tax	Exemption/reduction in Central Sales Tax and General Sales Tax are available on sale of renewable energy equipment in various states.	
	i) 80% Accelerated Depreciation on specified Non-conventional Renewable Energy devices/systems (including wind power equipment) in the first year of installation of the projects.	
	ii) Tax Holiday on Power Projects.	

5. WIND POWER UNDER CLEAN DEVELOPMENT MECHANISM

The Clean Development Mechanism (CDM) of the Kyoto Protocol provides industrialized countries (Annex-I) with an incentive to invest in emission reduction projects in developing countries (non-Annex-I) to achieve a reduction in CO₂ emissions at lowest cost that also promotes sustainable development in the host country. The sale of CERs (certified emissions reductions) could help to accelerate wind power development in India. The CDM was slow to take off as after the Marrakech Accords of 2001 it took another three years to define the bulk of the rules. The CDM Executive Board (EB) surprised many observers by taking a rigorous stance on critical issues such as baseline and additionality determination. Once the key rules were in place, a “gold rush” happened in 2005 and 2006. Over 1500 projects were submitted with an estimated CER volume of about 1.5 billion [18]. However, the volume share of renewable energy projects was less than expected due to the high attractiveness of projects reducing industrial gases and CH₄ from waste.

Fig 6 presents the distribution of 3324 CDM projects in each sector till April 2008. Out of 2061 projects (on renewables) currently at an advanced stage of the CDM project cycle hydro projects (including large hydro) make up the largest share accounting for 41%, followed by biomass projects at 26% and wind energy at 20%. In total, renewable energy projects constitute 61% of the project portfolio (Fig 6).

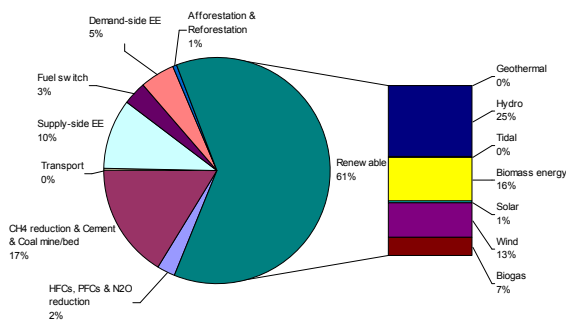


Fig 6. Number (%) of CDM projects in each category (Source: www.uneprisoe.org)

However, when the expected CERs are broken down by project type as a product of how much carbon financing each project type receives, renewable energy projects accounts for only 33%

of all expected CERs. The main reasons attributed to low CERs are renewable energy projects typically reduce emissions of CO₂, which has a global warming potential of “1” and many renewable energy projects are relatively small scale. Out of the 3324 CDM projects submitted to the EB, 1033 projects had been registered by the EB till April 2008 (www.cd4cdm.org). 426 CDM projects related to wind energy of which 138 have been registered, 10 requested registrations, 3 projects requested review, 259 were at the validation stage, 11 projects need correction and 5 projects had been rejected by the CDM EB (<http://cdm.unfccc.int>). Fig 7 presents the status of the wind energy projects from India till April 2008. Out of the 187 projects submitted to the UNFCCC, 53 projects had been registered, 12 projects need correction and 3 projects request for review. 115 projects were at the validation stage whereas 4 projects had been rejected by the EB.

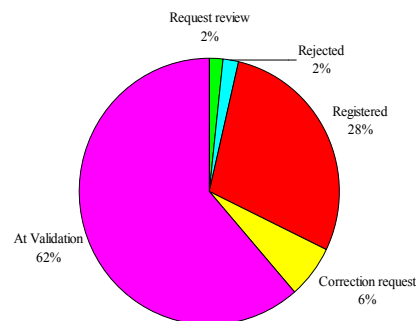


Fig 7. Status of Indian wind energy projects

Purohit and Michaelowa [4] assessed the theoretical CDM potential of wind energy projects in India. It is observed that the gross annual CER potential of wind energy in India reaches 86 million. Similarly, based on the technical potential of wind power projects in India the CDM potential has been estimated as 25 million tonne. Table 3 presents the state-wise CDM potential of wind energy projects in India, Gujarat has the largest CO₂ emissions mitigation potential through wind power (19 million tonne) followed by Andhra Pradesh (16 million tonne), Madhya Pradesh (11 million tonne), and so on. The annual electricity generation by wind power projects based on the gross and technical potential is also given in Table 3. With 25% PLF of wind power projects the annual gross electricity generation potential has been estimated at 99 TWh whereas the annual

technical electricity generation potential has been estimated at 28 TWh.

Table 3. Annual gross and technical CO₂ emissions mitigation potential through wind projects in India

State	Region	Baseline (kg CO ₂ /kWh)	Annual electricity generation (TWh)		Annual CO ₂ mitigation potential (million tonnes)	
			Gross	Technical	Gross	Technical
Andhra Pradesh	Southern	0.86	18.1	3.8	15.6	3.3
Gujarat	Western	0.89	21.2	3.9	19.0	3.5
Karnataka	Southern	0.86	14.5	2.5	12.5	2.1
Kerala	Southern	0.86	1.9	1.3	1.6	1.1
Madhya Pradesh	Western	0.89	12.0	1.8	10.8	1.6
Maharashtra	Western	0.89	8.0	6.6	7.2	5.9
Orissa	Eastern	1.04	3.7	1.5	3.9	1.5
Rajasthan	Northern	0.75	11.8	2.0	8.9	1.5
Tamilnadu	Southern	0.86	6.7	3.8	5.8	3.3
West Bengal	Eastern	1.04	1.0	1.0	1.0	1.0
All India			99.0	28.2	86.2	24.9

7. PROSPECTS OF WIND ENERGY IN INDIA

Empirical studies have shown that in a variety of situations the growth of a technology over time may conform to an S-shaped curve, which is a combination of simple and modified exponential curves. The S-shaped curves are characterized by a slow initial growth, followed by rapid growth after a certain take-off point and then again a slow growth towards a finite upper limit to the dissemination. Fig 8 represents the projected time variation of the cumulative capacity of wind power using the logistic model considered in the study.

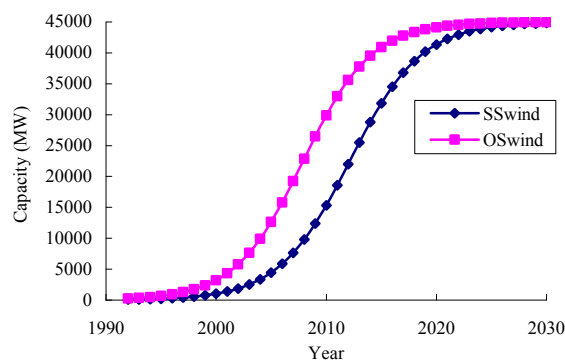


Fig 8. Time variation of wind energy projects in India using logistic model

Two cases such as business as usual or standard scenario (SS) and optimistic scenario (OS) are presented. The values of the regression coefficients using a logistic model have been estimated by regression of the time series data for the installation of wind power (Fig 5). In the optimistic scenario it is assumed that, in the past, if the diffusion of wind power would have been driven by the market forces instead of subsidies then the cumulative capacity of installation of wind power would be three times more than the actual level [18]. Our results indicate that in India, even with highly favourable assumptions, the dissemination of wind power projects is not likely to reach its maximum estimated potential in another 15 years however, all these time periods are not relevant for the CDM whose current endpoint is 2012 and which may only be able to live longer if post-2012 negotiations retain an emission target based policy regime. CDM could be used as a tool to foster the dissemination of wind power projects in the country and accelerate the diffusion process. Table 4 presents the projected values of the cumulative capacity of wind power and likely CER generation using the logistic model.

Table 4. Projected values of the cumulative capacity of wind power and associated CER generation

Year	Projected values of cumulative capacity (GW)		Projected values of the annual electricity generation (TWh)		Projected values of the annual CER generation (million CERs)	
	SS	OS	SS	OS	SS	OS
2012	22	36	48	78	41	67
2016	35	42	76	92	65	79
2020	41	44	91	97	78	83

It may be noted that with the current trend of dissemination of wind power projects in the country, around 22 GW capacity could be installed up to the end of first crediting period in the SS scenario whereas in the OS scenario 36 GW capacity could be installed. Up to the year 2020, more than 44 GW capacity of the wind power projects are expected to be installed that would generate 87 million CERs.

8. CONCLUSIONS

Wind energy scenario in the world in general and in India in particular is presented. Opportunities under the clean development mechanism and potential barriers for the large-scale penetration of wind energy projects are highlighted. The future growth pattern to achieve the maximum utilization potential of wind energy projects in India is also analyzed. The preliminary results indicate that there is a vast theoretical potential of CO₂ mitigation by the use of wind energy in India. On the basis of available literature, the gross potential of wind power is more than 45 GW. It is surmised that the annual CO₂ mitigation potential of wind energy projects in India under the opportunities through CDM could theoretically reach 86 million tonnes. The projections based on the past diffusion trend indicate that in India, even with highly favorable assumptions, the dissemination of wind power projects is not likely to reach its maximum estimated potential in another 15 years. Therefore, if India has to match the growth rate in the global wind energy sector, outstanding regulatory and policy issues need to be urgently addressed.

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