Wind Energy Potential Estimation in India

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ABSTRACT

The most daunting problem of today's world is the global climate change, which is predominantly due to the Greenhouse Gas (GHG) emissions. Major contribution of GHG is by the burning of fossil fuels such as coal and oil. Apart from being the major contributors to GHG emissions, fossil fuels are exhaustible resources. Increasing negative effects of fossil fuel combustion on the environment in addition to limited stock have forced many countries to explore and change to environmentally friendly alternatives that are renewable to sustain the increasing energy demand. Changing to renewable sources and implementation of effective conservation measures would ensure sustainability. Of the three Kyoto agendas, Clean Development Mechanism (CDM) is widely accepted. Harnessing the inexhaustible, renewable and naturally available sources of energy like solar, wind, ocean, geothermal, etc would help the world overcome the existing energy crisis. . Currently, wind energy is one of the fastest developing renewable energy source technologies across the globe. It is high time to assess the wind energy potential of the countries to supplement the growing energy needs. This paper presents the results of the analysis of wind speed data for one calendar year (2009) at 15 important stations in India and the wind energy potential of each site is also presented. The sites where wind energy can be profitably harnessed and the months in which maximum energy can be obtained are briefly discussed.
Keywords: Global climate change, GHG Emission, fossil fuels, CDM, Wind energy, Potential Estimation.

1 INTRODUCTION

For more than 50 years, the Earth's climate has been changing because of increasing greenhouse gas emissions from the burning of fossil fuels such as coal and oil, as well as deforestation and other human activities [1]. Greenhouse gas (GHG) emissions, largely carbon dioxide (CO2) from the combustion of fossil fuels, have risen dramatically since the start of the Industrial Revolution. Globally, energy related CO2 emissions have risen 145-fold since 1850—from 200 million tons to 29 billion tons a year and are projected to rise another 54 percent by 2030 [2]. Increasing energy demands and decreasing fossil fuel reserves and its negative ecological implications force us to unearth the renewable and non-polluting sources of energy like solar, wind, ocean, geothermal, etc. Wind energy is one of the significant and potential sources of energy recognized by world countries a few decades back. Wind energy is ultimately a solar resource. Large scale wind systems are created mainly because of temperature differences between the earth's latitudes and deflection caused by the earth's rotation. Dry air in the vicinity of 30^o N and 30^o S sinks and flows towards the equator, where it replaces rising hot air (often referred to as Hadley circulation). At mid latitudes, between 30 ^{o} and 70 ^{o} north and south, air flows towards the pole and is deflected westwards [3]. Wind speed, air density, latitudes, surface roughness, terrain, atmospheric pressure, average temperature, land use pattern etc. will significantly influence wind velocity. The kinetic energy of the wind is a promising source of renewable energy with significant potential in many parts of the world. The total annual kinetic energy of air movement in the atmosphere is estimated to be around 3×10^{15} kWh or about 0.2% of the solar energy reaching the earth. The maximum technically usable potential is estimated theoretically to be 30×10^{12} kWh/year or about 35% of the current world total energy consumption [4]. Windmills are used to harness wind energy. The power of wind blowing at 25.6km/h is about 200W/m2 of the area swept by a windmill. Approximately 36% of this power can be captured by the windmill and converted to electricity [5]. Wind energy has lot of advantages. It is freely available. It is a clean energy in the sense that it causes negligible pollution. The technology behind harnessing this energy is quite easy and well known.

Importance of this alternate source was recognized quite early in India and efforts have been made to tap this source at many places by installing wind energy systems but site selection is the most important aspect before the installation of a wind energy system. This calls for the estimation of available wind energy at a certain place. This paper presents the results of the analysis of wind speed data for one calendar year (2009) at 15 important stations in India namely Chennai, Trichy, Mumbai, Hyderabad, Ahmedabad, Patna, Lucknow, Agartala, Jaipur, Delhi, Nagpur, Varanasi and Amritsar. The wind energy potential of each site is also estimated using three different methods. The sites where wind energy can be profitably harnessed and the months in which maximum energy can be obtained are briefly discussed with the obtained results.

2 WIND ENERGY PARAMETERS

Wind cannot be transported and, therefore, wind turbines must be located where the wind resource is present. The energy content of the wind, being related to the cube of the wind speed, varies significantly with only small changes in wind speed. This fact demands the importance of having accurate wind speed data when the wind energy resource is being evaluated. Since wind speed is a continuously varying parameter, it is customary to average the wind speeds during each hour and to use the hourly mean wind speed as the basic parameter in calculations of wind power.

3 WIND SPEED AND ENERGY RESOURCE

The annual wind speed at a location is useful as an initial indicator of the value of the wind resource. The relationships between the annual mean wind speed and the potential value of the wind energy resource are listed in Table 1 [6].

Annual mean wind speed at 10m height	Indicated value of wind resource
< 4.5 m/s	Poor
4.5 – 5.4 m/s	Marginal
5.4 – 6.7 m/s	Good to very good
> 6.7 m/s	Excellent (or exceptional)

Table 1: Annual mean wind speed and potential value of the wind energy resource

4 OBJECTIVE

The main objectives of the study are to:

- ✓ Assess the availability of wind energy resources in India based on season wise and location wise data of wind velocity
- ✓ Analyze wind energy potential according to the climatic zones

5 STUDY AREA

The study was conducted for fifteen places in India, based on data compiled from various sources for various locations. The country lies to the north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude, with a total land area of 3,287,263 square km. India is bounded to the southwest by the Arabian Sea, to the southeast by the Bay of Bengal and the Indian Ocean to the south. Cape Comorin constitutes the southern tip of the Indian peninsula, which narrows before ending in the Indian Ocean. The Maldives, Sri Lanka and Indonesia are island nations to the south of India with Sri Lanka separated from India by a narrow channel of sea formed by Palk Strait and the Gulf of Mannar. The northern frontiers of India are defined largely by the Himalayan mountain range where its political boundaries with China, Bhutan, and Nepal lie. Its western borders with Pakistan lie in the Punjab Plain and the Thar desert. In the far northeast, the Chin Hills and Kachin Hills, deeply forested mountainous regions, separate India from Burma while its political border with Bangladesh is defined by the watershed region of the Indo-Gangetic Plain, the Khasi hills and Mizo Hills. Climate across India ranges from equatorial in the far south, to Alpine in the upper reaches of the Himalayas.

The climate of India defies easy generalisation, comprising a wide range of weather conditions across a large geographic scale and varied topography. Analysed according to the Köppen system, India hosts six major climatic subtypes, ranging from desert in the west, to alpine tundra and glaciers in the north, to humid tropical regions supporting rainforests in the southwest and the island territories. Many regions have starkly different microclimates. The nation has four seasons: winter (January and February), summer (March to May), a monsoon (rainy) season (June to September), and a post-monsoon period (October to December).

India's unique geography and geology strongly influence its climate; this is particularly true of the Himalayas in the north and the Thar Desert in the northwest. The Himalayas act as a barrier to the frigid katabatic winds flowing down from Central Asia. Thus, North India is kept warm or only mildly cold during winter; in summer, the same phenomenon makes India relatively hot. Although the Tropic of Cancer, the boundary between the tropics and subtropics, passes through the middle of India, the whole country is considered to be tropical.

The India Meteorological Department (IMD) designates four official seasons:

- **Winter**, occurring between January and March. The year's coldest months are December and January, when temperatures average around 10–15 °C (50–59 °F) in the northwest; temperatures rise as one proceeds towards the equator, peaking around 20–25 °C (68–77 °F) in mainland India's southeast.
- **Summer** or **pre-monsoon** season, lasting from March to June (April to July in northwestern India). In western and southern regions, the hottest month is April; for northern regions, May is the hottest month. Temperatures average around 32–40 °C (90–104 °F) in most of the interior.
- **Monsoon** or **rainy** season, lasting from June to September. The season is dominated by the humid

southwest summer monsoon, which slowly sweeps across the country beginning in late May or early June. Monsoon rains begin to recede from North India at the beginning of October.

- **Post-monsoon** season, lasting from October to December. South India typically receives more precipitation. Monsoon rains begin to recede from North India at the beginning of October. In northwestern India, October and November are usually cloudless. Parts of the country experience the dry northeast monsoon.

The Himalayan states, being more temperate, experience an additional two seasons: autumn and spring. Traditionally, Indians note six seasons, each about two months long. These are the spring, summer, monsoon season, early autumn, late autumn, and winter. These are based on the astronomical division of the twelve months into six parts.

India has six different climatic zones namely:

1) Tropical wet
2) Tropical wet and dry
3) Semi arid
4) Humid sub-tropical
5) Mountainous (Hill type)
6) Desert or Arid

On comparison with the above classification, the 15 places under study may be grouped as:

1) Tropical wet
   Trivandrum
2) Tropical wet and dry
   Chennai, Kolkata, Mumbai, Hyderabad, Ahmedabad, Nagpur
3) Semi arid
   Jaipur, Amritsar
4) Humid sub-tropical
   Patna, Lucknow, Agartala, Tiruchirapalli, New Delhi, Varanasi

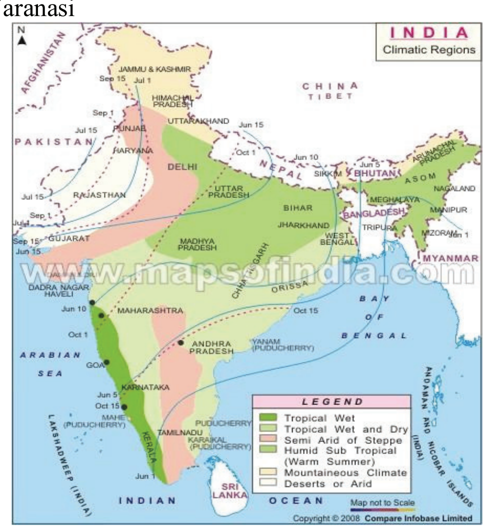

Figure 1: Climatic regions of India

6 ESTIMATION OF AVAILABLE WIND ENERGY

There are many methods by which the available energy can be estimated [7].

The first method is to calculate the available wind power P from the knowledge of u_m, the average of the monthly mean wind speeds at a site, using the equation

$$\mathbf{P = 0.5 \times \rho \times (u_m)^3} \qquad (1)$$

where ρ is the density of air at sea level at the site.

The second method revolves the average yearly wind speed u_y and the available wind power is given by

$$\mathbf{P = 0.5 \times \rho \times (u_y)^3} \qquad (2)$$

7 RESULTS

The wind power calculated using the first method is tabulated in Table 2 and that by second method is tabulated in Table 3.

Station	Mean monthly speed U_m (m/s)	Wind power (W/m^2)
CHENNAI	1.51	2.07
TIRUCHIRAPALLI	3.24	20.41
MUMBAI	2.50	9.38
HYDERABAD	2.85	13.89
TRIVANDRUM	1.04	0.67
KOLKATA	1.09	0.78
AHMEDABAD	2.48	9.15
PATNA	1.94	4.38
LUCKNOW	1.39	1.61
AGARTALA	0.83	0.34
JAIPUR	2.12	5.72
DELHI	1.78	3.38
NAGPUR	1.29	1.29
VARANASI	1.69	2.89
AMRITSAR	1.69	2.89

Table 2: Wind power by method 1

Station	Mean yearly speed (m/s)	Wind power (W/m^2)
CHENNAI	1.39	1.61
TIRUCHIRAPALLI	3.33	22.15
MUMBAI	2.50	9.38
HYDERABAD	2.78	12.89
TRIVANDRUM	1.11	0.82
KOLKATA	1.11	0.82
AHMEDABAD	2.50	9.38
PATNA	1.94	4.38
LUCKNOW	1.39	1.61
AGARTALA	2.22	6.56
JAIPUR	2.22	6.56
NEW DELHI	1.67	2.79
NAGPUR	1.39	1.61
VARANASI	1.67	2.79
AMRITSAR	1.67	2.79

Table 3: Wind power by method 2

8 DISCUSSION

The wind velocity patterns and the wind energy potential in India vary with respect to the geographical location and seasonal variation. As seen from the tables 2 and 3, the wind energy potential vary for different places and different seasons, which will be analyzed in detail.

8.1 Wind Energy potentials in various climatic zones

As defined earlier, there are six climatic zones in India. The fifteen places under study come under four zones and the remaining two zones namely Hill type and Desert are insignificant for setting up windmills. Accordingly one place comes under the tropical wet region, six under tropical wet and dry region, two under semi arid and six under humid sub-tropical region. Analyzing the wind energy potentials, the following important inferences can be made.

1) In the tropical wet region, the wind energy potential is found to be the least. As the number of places coming under this region is low (only Trivandrum), the prediction may be incorrect. However, referring to the wind velocities of certain other places in this region proves the fact that the wind energy potential is not appreciable.
2) In the tropical wet and dry region, come six places namely Chennai, Kolkata, Mumbai, Hyderabad, Ahmedabad and Nagpur. In this region, the wind energy potential varies from least to an appreciably high value, which is influenced by the wind velocity patterns and monsoonal changes. After careful exploitation, windmills can be profitably set up in this region.
3) In the semi arid region, the wind energy potential is moderate. The two places under study in this region are Jaipur and Amritsar.
4) In the humid sub-tropical region, the places under study are New Delhi, Patna, Lucknow, Agartala, Tiruchirapalli and Varanasi. The wind energy potential ranges from moderate to high values, the highest among all in Tiruchirapalli. Among the four regions, this region can be considered the best, with respect to the fifteen places of study.

8.2 Wind Energy potentials in various seasons

The potential of wind energy in a region depends not only on its geographical location but also on the seasonal variations and influence of monsoons. As said earlier, there are four seasons in India namely winter (Jan –Mar), summer or pre-monsoon (Mar-June), monsoon (Jun–Sep) and post-monsoon (Oct–Dec). The variations in wind energy potentials accordingly in these four seasons are given below.

1) During winter (Jan –Mar), the wind velocities and hence the wind energy potential is found to be the least among all the other seasons.
2) During the summer or pre-monsoon season (Mar-June), the wind velocity and the wind energy potentials of the chosen sites are found to be high.
3) During the monsoon season (Jun–Sep), the wind energy potential varies from high to moderate values.
4) During the post-monsoon season (Oct–Dec), the wind energy potential of the assessed sites is found to be low.

9 CONCLUSION

The wind energy potentials of fifteen different places in India is chosen at random spread widely across the country are estimated and analyzed. The following conclusions are made:

1) The tropical wet and dry region (places like Chennai, Kolkata, Mumbai) and humid sub-tropical region (places like NewDelhi, Patna, Tiruchirapalli), the wind energy potential is found to be high.

2) During the summer or pre-monsoon season and the monsoon season (March – September), the wind energy potential is found to be appreciably higher than that in other seasons.

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