

Evaluation of Wind Energy Potential alongside Motorways of Pakistan

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ABSTRACT

Presently world in general and Pakistan in particular is facing energy crisis despite the fact that Pakistan is blessed with natural resources required for its generation. There is a need to resolve the crises as they are directly affecting all spheres of life. The government is trying to explore economical renewable energy resources. One such renewable energy resource available in abundance is wind. Different potential sites for harnessing wind energy in Pakistan have already been identified by researchers. This paper aims at identifying the additional wind energy generation sites alongside the motorways due to natural wind and vehicular generated vortices due to heavy traffic. It aims at experimentally measuring the wind data and then calculating the available power potential at selected sites utilizing measured data. The most suitable sites for installation of the wind farm have also been identified and proposed with the estimate of total power potential.

Key words: Renewable Energy, Wind Energy, Experimental measurements, Vehicular vortices, Natural Energy Resource

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INTRODUCTION

Presently Pakistan is facing severe electricity crisis of its history. Recent statistics show a shortfall of above 7000 MW between energy supply and demand. If the situation is not addressed, the energy supply and demand gap would even widen in the future. Kessides analyzed the current energy demand and supply gap for Pakistan and also forecasted the future energy state under do nothing scenario (Kessides 2013). The study is depicted in Figure 1. Currently, conventional means of power generation in Pakistan are

being utilized which is mainly oil based generation. Total generation of electricity by different sector in Pakistan is presented in Figure 2 (Shah and Bhatti 2009). Power generation through conventional means has many disadvantages associated, out of which the most important is cost of power generation. Since, Pakistan does not have sufficient oil reserves, therefore, to meet oil requirement for power generation, Pakistan imports much of its oil from other countries. The fossil fuels being the highest contributor of world's primary energy; its reserves are diminishing rapidly (Muneer and Asif 2007). The increasing prices of the oil made this option difficult and in turn increased the power generation cost. Pakistan meets about 32.5% of its annual primary commercial energy needs from imported fuel by spending about US\$5 billion (Harijan et al. 2009). Another disadvantage associated with oil based power generation is air pollution. Renewable energy power generation sources instead reduce the carbon emissions considerably. Islam et al. has studied the reductions in carbon emissions by various energy sources as shown in Figure 3 (Islam, Mekhilef, and Saidur 2013). The trend of energy generation and its potential world over presented by different researchers (Şahin 2004; Kaldellis and Zafirakis 2012; Sun, Huang, and Wu 2012) shows that there is a need for an earlier move over from conventional to renewable energies that are naturally available in abundance and are capable to meet the current and projected global energy needs. Pakistan is fortunate to have a significant potential of such renewable energies. Farooq et al. studied the available and expected installed potential of renewable energies in Pakistan and same has been shown in Table 1 (Farooq and Kumar 2013). Amer et al. has also studied the renewable energy generation options from perspectives of technical, economic, social, environmental and political aspects for Pakistan (Amer and Daim 2011). Amongst the renewable energy resources, Pakistan has a potential of wind energy harvesting. Past, present and future utilization of wind energy has been elaborated by Bhutto et al. (Bhutto, Bazmi, and Zahedi 2013). They also discussed the efforts needed in this sector to effectively use this economical source. Isolated efforts are being made for utilization of wind energy both at Govt and commercial level. Mirza et al. summarized the wind energy development activities being pursued in Pakistan (Mirza et al. 2007), While researchers (Mirza, Khan, and Memon 2010; Ullah, Chaudhry, and Chipperfield 2010; Sheikh 2009, 2010; Aman et al. 2013; Nasir, Raza, and Abidi 1991) have identified potential sites in Pakistan for wind energy generations. The researchers in their work only focused on potential of Sindh and Baluchistan and did not consider the wind potential in locations at other provinces of the countries. Moreover, the wind potentials along the motorways were also neglected altogether. Importance of wind energy potential to convert it into other forms of energies has also been recognized at global level. The installed capacity of wind energy in the top 10 countries around the world is shown in Figure 4 (İlkılıç, Aydın, and Behçet 2011; Erdogdu 2009; Yaniktepe, Savrun, and Koroglu 2013; Lew 2000; Li, Hubacek, and Siu 2012). Wind energy due to its environmental friendly nature and competitive cost is making its way globally, and various countries have defined their wind energy policies (Saidur et al. 2010; Dincer 2011). It is estimated that coal-fired power stations typically emit around 800–1200 g of CO₂ for every unit (kWh) of electricity they produce. Therefore, each unit of electricity produced by wind energy avoids polluting the environment by an equivalent amount of emissions (Şahin 2004). While talking in terms of cost, it is observed that the energy generated by a wind mill could be twice as efficient as that obtained from a diesel generator (Bhutto, Bazmi, and Zahedi 2013). Wind phenomena along Highways and Motorways has been studied at global level (Rao et al. 2002; Kalthoff et al. 2005; Alonso-

Estébanez et al. 2012; Musa, Osman, and Hamat 2012) but same has neither been studied nor its potential was evaluated to enhance energy sector in Pakistan. The focus of this study is to evaluate the wind energy potential along motorways. Advantages due to use of such technology along motorways are not only limited to traffic noise suppression, but it also includes cost and environmental benefits. Pedersen et al. has shown that road traffic noise can provide a significant masking of wind farm noise (Pedersen et al. 2010).

WIND POTENTIAL ALONG MOTORWAYS

Currently, there are two major motorway sectors in Pakistan i.e., M-1 and M-2. M-1; starts from Peshawar and ends at Islamabad, while M-2; starts from Islamabad and ends at Lahore. Wind map of Pakistan shown in Figure 5 was utilized to identify the potential sites for wind speed measurements on motorways. Based upon the wind map, four potential sites, Burhan Interchange, Katti Hills Corridor, Ghazi Barotha and Chakri Corridors were selected for measurements and evaluation of the wind potential. Wind speeds were measured at these sites using anemometer with capability to measure from 0.3 - 40 m/s.

Around 30 measurements were taken at each selected location over a period of twelve months to calculate average wind speed over the year. Chakri corridor had the highest wind potential with an average wind speed of 7.5 m/s, while Ghazi Barotha Canal corridor had the lowest wind potential with an average wind speed of 1.2 m/s. The wind speed at Katti Hill corridor and Burhan interchange were measured as 4 m/s and 2.5 m/s respectively. The recorded readings are tabulated in Table 2.

In addition to natural wind potential, vehicular induced wind turbulence and increase in the wind speed due to vehicular turbulence were also measured. The vehicle passing rate on M-1 was 12 vehicles per minute and that on M-2 was 22 vehicles per minute with heavier vehicles using outer lanes on both sides. The effect of traffic disturbance on the natural wind speed was also observed which was significant with heavier traffic movement in the external lanes. The vehicular movement had a positive effect of 0.6 to 0.9 m/s for light traffic vehicles and from 0.8 to 1.1 m/s for heavy traffic vehicles.

Based upon the data collected through measurements at different sites on motorway, theoretical power potential of these sites was calculated using analytical equations. The result of this analysis is the basis for selection of sites suitable for installation of windmills along the motorways. The reference turbine used for these calculations has 5m diameter. Following equation was used for theoretical power calculations:

$$P = 1/2 C_p A V^3 \quad (1)$$

The procedure followed for calculation of power is illustrated as follows:

- The distance in meters from the center of the central shaft to one of the blades was measured and then the rotor swept area was calculated.
- The wind speed of the site was measured using a wind anemometer, and the altitude of that site was measured using altimeter.
- The air density of the site was determined using atmospheric tables.

The power potential with a single wind turbine of the type specified earlier at selected sites is tabulated in table 3. Chakri corridor had a highest potential of 1982 watts per turbine, while Ghazi Barotha corridor had a lowest potential of 37.36 watts per turbine. The power potential at Katti Hill corridor and Burhan interchange were 564.3 and 155.3 watts per turbine respectively.

CONCLUSION

Electricity production through wind is one of the economical sources of electricity, and if seriously explored, it can be useful in improving the energy crisis in Pakistan. Based on the calculated and measured data, it is relatively safe to say that Chakri wind corridor is one of the suitable sites along the motorway for generation of electricity through wind mills. Chakri wind corridor is spread over an area of 4 kilometers. Keeping the safe distance between the two turbines to avoid flow disturbance, 200 wind turbines can be installed on each side. So a total of 400 wind turbines on both sides of the road at a safer distance of 4km corridor can be installed. These 400 wind turbines can produce an average of 0.8 MW of electricity that can subsequently be added to the national grid or used for localized purposes. These wind turbines can generate substantial revenue annually.

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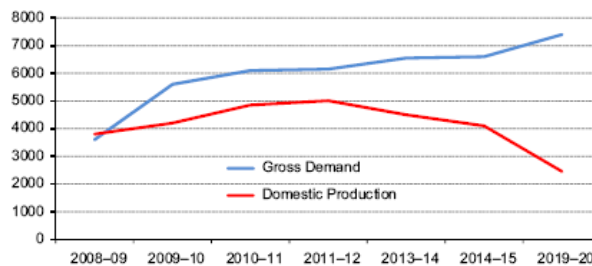


Figure 1: Energy Supply and Demand Gap Pakistan [1]

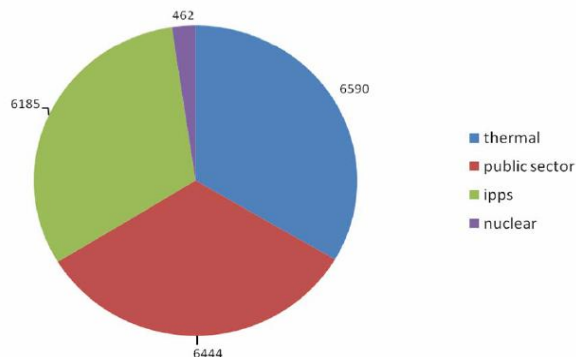


Figure 2: Power generation in Pakistan by different sectors [2]

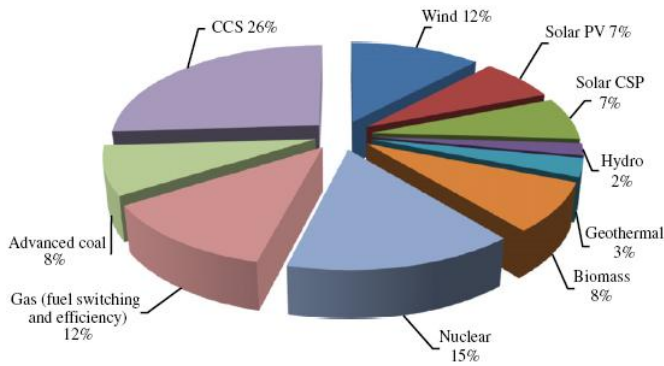


Figure 3: Contribution of CO2 emissions reductions in various power sectors [4]

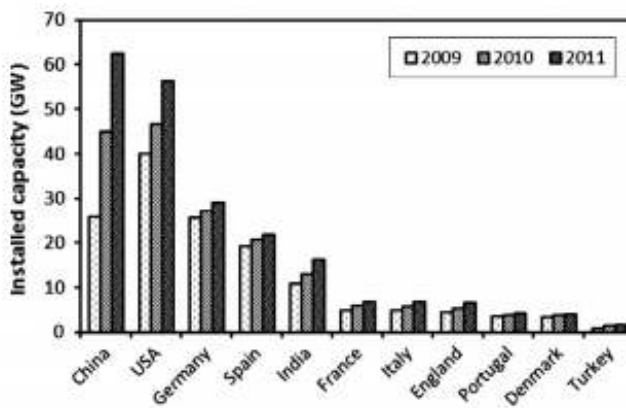


Figure 4: Country wise installed capacity of wind energy [12]

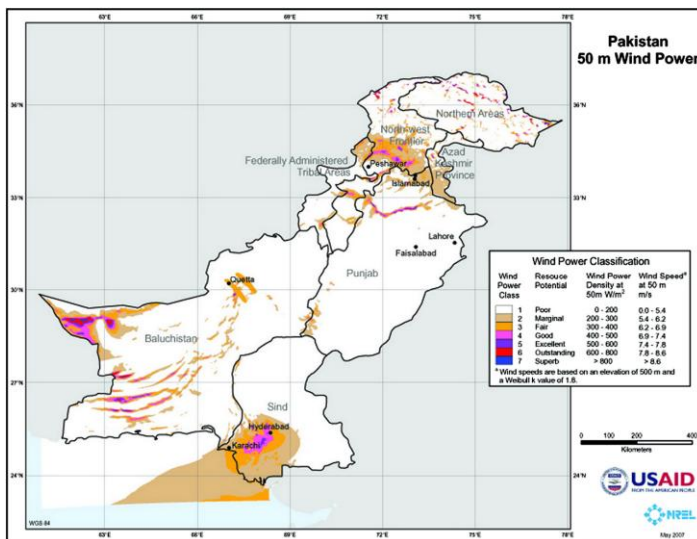


Figure 5: Wind Map of Pakistan [19]

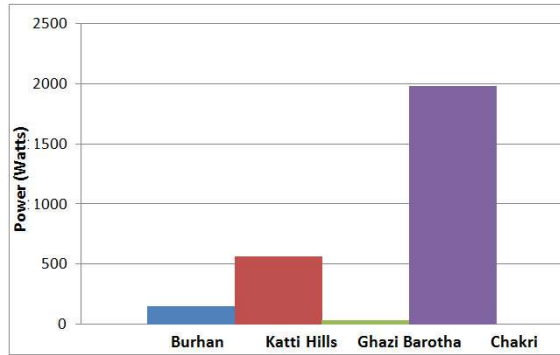


Figure 6: Power Potential of various sites along Motorway

Table 1: Available and expected renewable installed potential till 2015 (MW) [5]

Energy Source	Technology	Total potential (2010)	Capacity addition	Total installed capacity	Remaining potential
Wind	CNT	12,764	900	900	11,864
Solar PV	DECNT	9,893	0	0	9,893
	CNT	116,197	1	1	116,196
Solar thermal	CNT	22,587	0	0	22,587
Biomass	CNT	5,420	24	24	5,396
Small hydro	CNT	2,658	166	312	2346
Total		169,519	1091	1237	168282

Table 2: Recorded Wind speeds along Motorways

Location	No of Observations	Maximum Speed (m/s)	Minimum Speed (m/s)	Average Speed (m/s)	Standard Deviation (m/s)
Burhan Interchange	30	4	2.5	3.24	0.36
Katti Hills Corridor	27	6	4	5	0.52
Ghazi Brotha Canal	30	2.9	1.2	2.02	0.47
Chakri (Ref 335-339)	34	8.7	6	7.5	0.46

Table 3: Calculated Wind potential along Motorways

Site	Wind Speed Range (m/s)	Average Speed (m/s)	Average Power Potential / turbine (Watts)	No of possible Turbine at selected sites	Power Potential (kW)
Burhan Interchange	2.5 - 4	3.24	155.3	100	15.530
Katti Hills Corridor	4-6	5	564.3	100	56.430
Ghazi Brotha Canal	1.2-2.9	2.02	37.36	100	3.736
Chakri Wind Corridor	6.3-8.7	7.5	1982	400	792.800

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