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Analysis of Wind Characteristics and Wind Energy Potential in Coastal Area of Bangladesh: Case Study - Cox's Bazar

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Abstract: The radioactive effect of nuclear power plants in accidental cases as well as carbon emission impact of fossil fuels have forced many countries to explore clean energy sources that are environmentally more suitable. As Bangladesh do not have good prospect in fuel cell, geothermal, tidal or wave resources, wind energy is an influential energy source in accordance with solar and biomass. In this paper, based on a2-parameter Weibull analysis method, wind characteristics and assessment of wind energy potential has been analyzed using the wind speed data of the period 2002-2011 at 10 m height of Cox's Bazar, the longest sea-beach located at the southeast of Bangladesh. From the calculation, it has been found that the monthly mean wind speed is ranged from 2.17 m/s in November to 2.90 m/s in April, the monthly values of the Weibull shape parameter (k) is ranged from 4.73 to 9.24, while the value of scale parameter (c) is ranged from 2.50 to 2.98 m/s and the monthly wind power density is ranged from 7.30 to 17.14 W/m^2. The seasonal mean wind speed has been found to be oscillated between 2.31 and 2.78 m/s, while the wind power density is ranged from 8.48 W/m^2 to 14.29 W/m^{2}for autumn and spring, respectively. The results presented in this paper will be helpful to assess the feasibility of installing wind turbine in the subjected area.

Keywords: Wind Speed, Weibull Distribution, Wind Energy, Cox's Bazar.

1. INTRODUCTION

There is almost a unanimous agreement world-wide that activities in developing countries especially in South Asian countries are going to play a major role in deciding the fate of energy and environmental issues of global concern. Cumulative energy consumption in the developing countries is not far less than the developed country which is likely to increase quickly in near future. Increasing energy consumption not only results in depletion of energy resources but also gives rise to problems like global warming and greenhouse effect through emissions generated by burning of fossil fuels. Increasing negative effects of fossil fuels combustion on the environment in addition to its limited stock have forced many countries to explore and change to environmentally friendly alternatives that are renewable to sustain the increasing energy demand. Wind energy is an alternative clean energy source compared to fossil fuel, which pollutes the lower layer of the atmosphere. The use of wind energy can significantly reduce the combustion of fossil fuel and the consequent emission of carbon dioxide, a principal cause of the enhanced greenhouse effect [1, 2]. Renewable energy has an increasing role in achieving the goals of sustainable development, energy security and environmental protection. Nowadays, it has been recognized as one of the most promising clean energy over the world because of its falling cost, while other renewable energy technologies are becoming more expensive [3]. Wind represents a significant renewable energy solution that can meet energy demand in the direct, grid connected modes, as well in standalone and remote applications [4].

Currently, wind energy is one of the fastest developing renewable energy sources across the globe due to rapid advancement of wind energy conversion technologies (WECT) efficiency. The last decade was characterized by rough development of wind power engineering all over the world [5-8]. Several countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, 14% in Ireland and 9% in Germany in 2010. Wind energy systems have made a significant contribution to daily life in some developing countries also. As of 2011, 83 countries around the world are using wind power on a commercial basis. Wind power generation has achieved a remarkably rapid growth in the past 20 years, and now it is a mature, reliable and efficient technology for electricity production [9]. Since 1996, global wind power capacity has continued to grow at an annual cumulative rate close to 40%. Over the past decade, installations have roughly doubled every two and a half years. In the year 2010, the wind capacity reached worldwide 197,637 Megawatt (Table 1), after 159,213

Table 1. Top 10 countries according to wind power generation

Country	Total Capacity		
	At the end of 2009 (MW)	At the end of 2010 (MW)	At the end of 2011 (MW)
United States	35,159	40,298	46,919
United Kingdom	4,092	5,248	6,540
Spain	19,149	20,623	21,674
Portugal	3,357	3,706	4,083
Italy	4,850	5,797	6,747
India	10,925	13,065	16,084
Germany	25,777	27,191	29,060
France	4,521	5,970	6,800
China	26,010	44,733	62,733
Canada	2,550	4,008	5,265
Rest of world	21,698	26,998	32,446
Total	**159,213**	**197,637**	**238,351**

MW in 2009, 120,903 MW in 2008, and 93,930 MW in 2007. During 2010, 9918 MW of wind power was installed across Europe, with European Union countries accounting for 9295 MW of the total [10, 11].

However, wind energy systems suffer from a major drawback since the wind resource is intermittent, hence, is not available all of the time to make turbines run continuously [12]. Therefore, wind energy systems are considered as energy-replacement rather than capacity-replacement resources. The amount of energy that can be supplied by one or more sites depends on the wind resource available, the type of wind turbines used, and the nature of the load being supplied. For these reasons, it is fundamental to study the reliability of these generation systems and to assess the effects that they will have on the entire system and on its reliability [13].

Discussing the recent scenario of the energy sector of Bangladesh in the second section, this paper represents a brief geological description of the study area Cox's Bazar in the third section. The fourth section contains the methodology, based on which the characteristic assessment of wind energy in the study area has been done. The probability density function, wind power density function and energy density functions are discussed in detail. The following section represents the analysis result as well as corresponding discussion. Wind speed data of the period 2002-2011 of Cox's Bazar has been collected at 10 m height and wind energy potential has been analyzed using this data. Finally the conclusion section focuses on the contribution of this analysis to the energy policy of Bangladesh.

2. ENERGY RESOURCES IN BANGLADESH

Bangladesh is a small as well as densely populated country in South Asia (20°34' and 26°38' north latitudes and 88°01' and 92°41' east longitudes) with a large portion of the population living under poverty line. More than 150 million people of Bangladesh live on a land area just under 147,570 square kilometers. According to per capita income, it is among the poorest countries of the world though it ranks among the top third of the countries in terms of total GDP. The GDP per capita was only USD 755 in 2011. 31.5% of the total population lives below the poverty line whereas the percentage of people under extreme poverty (under $1.25 PPP a day) is also high, about 40%. Despite of these negative scenarios, Bangladesh has been enjoying significant economic growth in the past decade with a GDP growth rate of about 6.05% in the [14-18] past five years. In 2010-2011 fiscal years, GDP growth rate was 6.66%. According with this economic growth, the energy demand to run the sectors contributing national economy is increasing day by day. Availability of sustainable and uninterruptable energy supply is one of the most important prerequisite for future development. Ignoring the little amount of oil and coal reserve as well as undeveloped renewable energy sector, natural gas is the main source of energy to meet up the demand in all sectors of Bangladesh.

The total amount of energy consumption in Bangladesh in 2008 was 0.87 Quadrillion BTU which is only 0.18% of total energy consumption of the world (Table 2). 48.5% of the total population has access in grid electricity [14-18]. The lack of generation capacity and notable amount of loss in transmission and distribution system results huge gap between demand and supply of electricity (Table 3). The outcome is frequent rationing and load shedding which becomes severe in summer months and irrigation seasons. According to Bangladesh Power Development Board (BPDB), in 2009-2010, against the maximum generation capacity of 5978 MW, the maximum power generation was 4606 MW whereas the maximum demand was 5011MW. Natural gas, petroleum and biomass are the major contributors to the total primary energy consumption in Bangladesh [19-25].

Table 2. Production and consumption of primary energy (Quadrillion BTU) in Bangladesh

	1980	1985	1990	1995	2000	2005	2009
Production	0.05	0.10	0.16	0.26	0.35	0.53	0.68
% of World	0.02	0.03	0.05	0.07	0.09	0.11	0.14
Consumption	0.13	0.17	0.25	0.38	0.50	0.71	0.87
% of World	0.05	0.06	0.07	0.10	0.13	0.15	0.18

Table 3. Power sector scenario 2010-11 (up to 15th June of 2011)

Indicator	Qty
Generation capacity, MW (Public = 3,534 ; Private = 3,197)	6,727
Maximum generation, MW	4,890
Number of consumers (million)	12
Number of villages electrified	53,281
Per Capita generation, kWh	236
Access to electricity	49%
System loss	13.11%

Natural gas is the most important indigenous source of energy that accounts for 75% of the commercial energy of the country [9, 13, 26] and it is possible because of its local availability. So far 23 gas fields have been discovered (Figure 1) with the rate of success ratio 3.1:1 of which several fields are located in offshore area. Average daily gas production capacity from 17 gas fields (79 gas wells) is about 2000 mmcfd of which International Oil Companies (IOC) produce 1040 mmcfd and State Owned Companies (SOC) produce 960 mmcfd. At present, the daily approximate projected gas demand throughout the country is 2500 mmcfd [8, 27-31]. The demand is increasing day by day. Energy and Mineral Resources Division (EMRD) has already undertaken an array of short, medium, fast track and long term plans to increase gas production to overcome prevailing gas shortage. According to this plan 995 mmcfd, 500mmcfd and 380 mmcfd gas will be added to the national gas grid by the year 2012, 2013 and 2015 respectively. After completion of these plans, production capacity is expected to increase to about 2353 mmcfd by December, 2015.

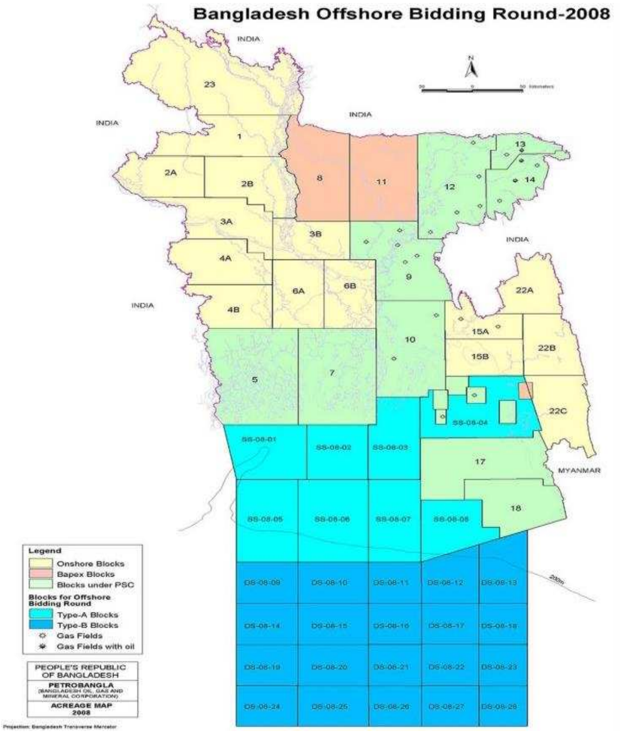

Figure 1. Gas blocks of Bangladesh

Besides natural gas, Bangladesh has a significant coal reserve. Coal reserves of about 3.3 billion tons comprising 5 deposits at depth of 118-1158 meters [32, 33] have been discovered so far in the north-western part of the country out of which 4 deposits (118-509 meters) are extractable at present. But this sector is quite undeveloped. There is only one coal based power plant which produces around 5% of the total national electricity. Most of the demand is meeting up by importing coal from neighboring countries (Figure 2 and 3) but local production has been increased in last five years (Figure 4).

Due to a small amount of petroleum production within the country, major portion of the petroleum demand is met by import [27, 34]. The major usage of petroleum is in the transportation sector though the role of petroleum in this sector has been decreasing since the government launched policy to encourage compressed natural gas (CNG) as transportation fuel. About 27% of the total electricity generation capacity is based on diesel and furnace oil (Figure 5). The amount of consumption and imported petroleum product over the past two plus decades is shown in Figure 6 and Figure 7.

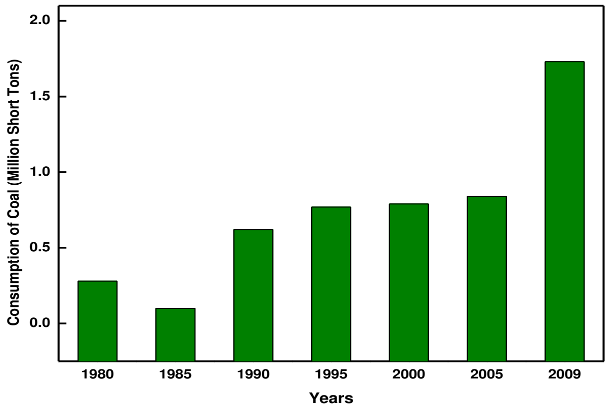

Figure 2. Year by year consumption of coal (Million Short Tons)

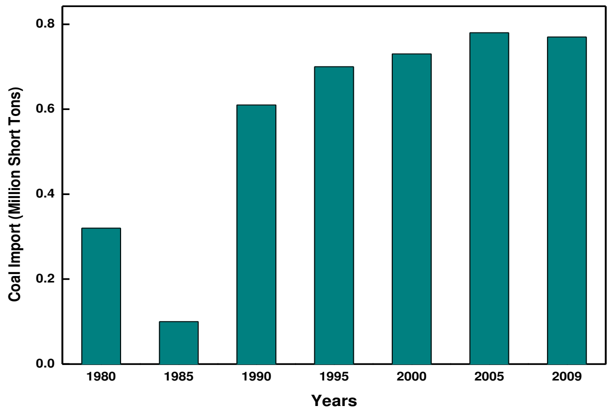

Figure 3. Year by year coal import (Million Short Tons)

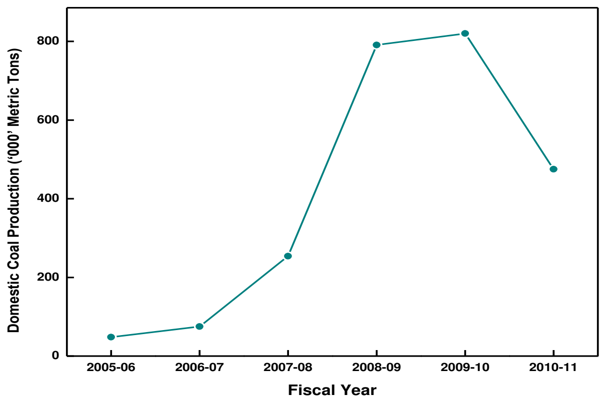

Figure 4. Recent domestic coal production (‘000’ Metric Tons)

Among the renewable energy sources, solar power has a good prospect in Bangladesh [35]. Greatest amount of solar energy in the world is available in two broad band encircling the earth between 15º and 35º latitude north and south. The next best position is the equatorial belt between 15º N and 15º S latitude [19]. Most of the developing countries, being situated in these regions, are in a favorable position in respect of solar energy. Bangladesh is situated between 20.34º and 26.38º latitude north and as such has a good solar energy potential.

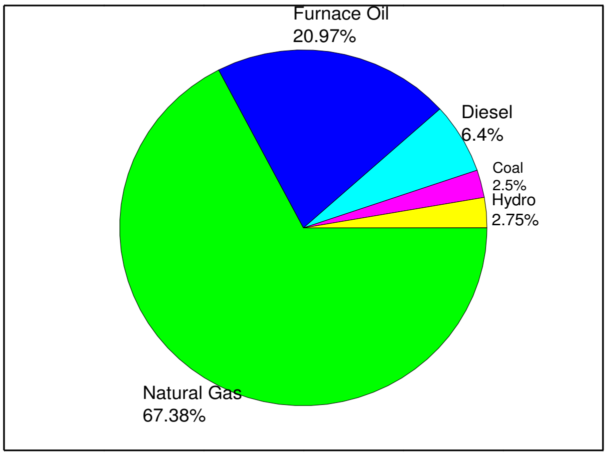

Figure 5. Percentage contribution of fuel used in power generation (March, 2012)

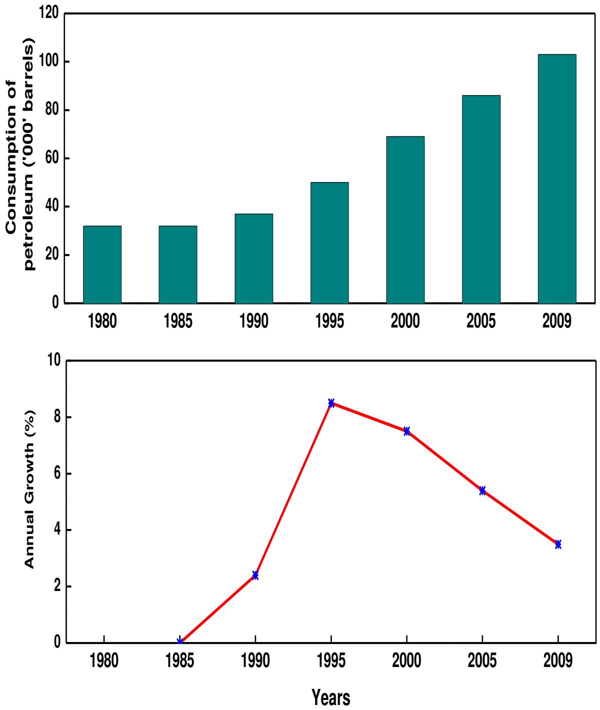

Figure 6. Year by year consumption of petroleum (‘000’ barrels)

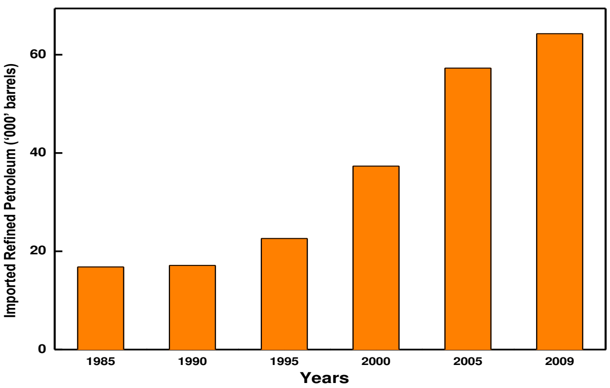

Figure 7. Amount of imported refined petroleum (‘000’ barrels) by year

Average daily solar irradiation at flat surface is around 4.0 to 6.5 kWh/m^2 in Bangladesh. Solar photovoltaic (PV) panels have gained popularity in those rural areas where grid electricity is unavailable. Rural Electrification Board (REB) is providing solar panels to rural people on monthly bill payment system whereas NGOs offering the facility on microcredit scheme. In urban areas, installation of solar panels has been made compulsory by government policy to apply for the connection from grid. Consequently, scenario of urban areas is changing abruptly. Currently about 264,000 solar panels are installed throughout the country [17, 18] with cumulative capacity of about 16 MW.

Biogas is a promising renewable energy source. Presently there are about 50,000 households and village level biogas plants throughout the country. Biomass is primarily used in rural areas for cooking and heating. Traditional biomass sources include agricultural residue (rice husks, rice and jute stalks, sugarcane waste etc.), animal waste, scrub wood and fire wood [21]. The share of biomass in total primary energy consumption is consistently decreasing in the country as it is moving up on the energy ladders. It is estimated that biomass contributed around 54% of all primary energy consumption in Bangladesh in 1994which has reduced to around 35% in just over a decade in 2005.

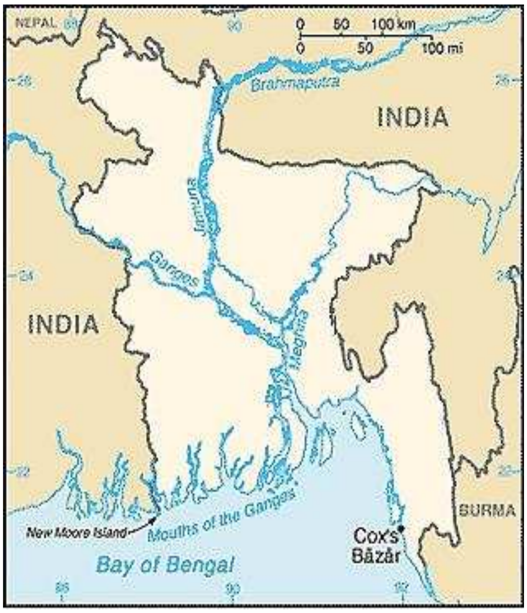

Figure 8. Cox’s Bazar in Bangladesh Map

As Bangladesh is a flat bed country so only a small contribution (3.44%) comes from the only hydro power plant of 230 MW in national grid. The opportunity of installing further hydropower plant is also negligible although some micro-hydro plants could find niche areas of application [17, 18]. But present or future support from wind power source from off-shore areas of Bangladesh is still depending on future investigation and assessment.

3. COX’S BAZAR: THE STUDY AREA

Located along the Bay of Bengal in South Eastern Bangladesh (Figure 8 and 9), Cox's Bazar is the main tourist city of Bangladesh. It is famous for its wide sandy beach which is the world's longest natural sea beach (120 kilometers (75 miles) including mud flats) with a gentle slope. It is located 150 km south of the divisional city Chittagong. Cox's Bazar District has an area of 2491.86 km². It is located at 21°35′0″N92°01′0″E and is bounded by Bay of Bengal in the south, Chittagong district on the north, the Bay of Bengal on the west and Bandarban district on the east. The area of the city of Cox's Bazar is 6.85 km².

Figure 9. Cox's Bazar District

The annual average temperature in Cox's Bazar is 34.8 °C and a minimum of 16.1 °C. The climate remains hot and humid with some seasons of temperate weather. The average amount of rainfall is 4285 nm. The major livelihood of Cox's Bazar district is tourism. Millions of foreign and Bangladeshi natives visit this coastal city every year. Apart from tourism linked people (23.83%) major occupations include agriculture 15.86%, agricultural laborer 13.1%, wage laborer 7.86%, commerce 19.34%, service 7.93%, transport 2.79%, fishing 6.55%, industries 1.32% and others 1.42%. The urban population is 60234; male 57.09% and female 42.91% with literacy rate of 52.2%.

Power Grid Company of Bangladesh (PGCB) Ltd., a government owned company is responsible for power transmission through 132kV high voltage transmission line from Chittagong to Cox's Bazar. Only one 132/33kV PGCB substation meets up the total demand (max. demand of 56 MW) of the district. Apart from some stand-alone solar and biomass generation, there is no government or private generation unit at Cox's Bazar. Rural Electrification Board (REB) purchase electricity from PGCB and distributes at the customer and through 33/11/.415 kV system.

4. METHOD OF CHARACTERISTIC ASSESSMENT

In this study the wind speed data has been collected for ten years (2002-2011) of different locations of Cox's Bazar from Bangladesh Export Processing Zones Authority (*BEPZA*) which is the official organ of the government to promote, attract and facilitate foreign investment in the Export Processing Zones. Continuous 6 hours daily readings over the period considered were used and subjected to various statistical analyses. The data were recorded at a height of 10 m and presented graphically in Figure 10. The figure gives the monthly mean wind speed of the location for the ten years.

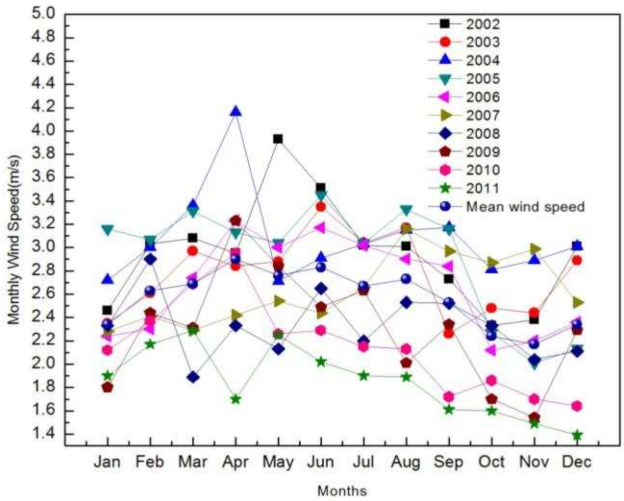

Figure 10. Monthly mean wind speed of Cox's Bazar from 2002to 2011

4.1 Probability Density Function

The computation of the wind speed probability distribution functions (PDFs) constitutes the first fundamental step to assess the wind energy potential, since it can effectively determine the performance of wind energy systems for a given location and time [36]. Several PDF have been proposed in the literature to represent the frequencies of the wind speed. However, the Weibull Probability Density Function with its two characteristic parameters (*c* scale parameter and *k* shape parameter) has been found to be the accurate and adequate in analyzing and interpreting the wind speed distribution and estimate wind energy potential. The general form of the Weibull PDF [37] is given by:

$$f(v, k, c) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1}\exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

where $f(v, k, c)$ is the probability of observing wind speed v, k is the dimensionless Weibull shape parameter, and c is the Weibull scale parameter (in units of speed) [38]. Higher values of k indicate sharper peaked curves while lower k means more flat or more evenly distributed speeds.

The corresponding cumulative probability function of the Weibull distribution [38] is given by the equation:

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^k\right] \quad (2)$$

where $F(v)$ is the cumulative distribution function of observing wind speed v. The two parameters of Weibull PDF, k and c can be related to the mean wind speed v_m and standard deviation σ by [39,40]:

$$k = \left(\frac{\sigma}{v_m}\right)^{-1.086} \quad (3)$$

$$c = \frac{v_m}{\Gamma\left(1+\frac{1}{k}\right)} \quad (4)$$

The mean value of the wind speed v_m and standard deviation σ for the Weibull distribution as defined in terms of the Weibull parameters k and c are given as [40]:

$$v_m = c\,\Gamma\left(1+\frac{1}{k}\right) \quad (5)$$

$$\sigma = c\left[\Gamma\left(1+\frac{2}{k}\right) - \Gamma^2\left(1+\frac{1}{k}\right)\right]^{.5} \quad (6)$$

where Γ is the gamma function (standard formula) and using the Stirling approximation the gamma function of (x) can be given as follows:

$$\Gamma(x) = \int_0^\infty u^{x-1}e^{-u}du \quad (7)$$

4.2 Wind Power Density Function

It is well known that the power of the wind that flows at speed (v) through a blade sweep area A, increases as the cube of its velocity is given by [40].

$$P(v) = \frac{1}{2}\rho A v^3 \quad (8)$$

where ρ is the mean air density (1.225 kg/m^3 at average atmospheric pressure at sea level and at 15°C), which depends on altitude, air pressure, and temperature. Wind power density, expressed in Watt per square meter (W/m^2), takes into account the frequency distribution of the wind speed and dependence of wind power on air density and the cube of the wind speed. Therefore, wind power density is generally considered as a better indicator of the wind energy resource than wind speed.

In order to evaluate available wind resource at the location, it is required to calculate the wind power density. It shows how much energy is available at the location for conversion to electricity by a wind turbine. The expected monthly or annual wind power density per unit area of the location based on a Weibull probability density function can be expressed as following [40]:

$$\frac{P_W}{A} = \frac{1}{2}\rho c^3\Gamma\left(1+\frac{3}{k}\right) \quad (9)$$

4.3 Wing Energy Density

The wind energy density for a desired duration, T, can be calculated as:

$$\frac{E}{A} = \left(\frac{P_W}{A}\right)T = \frac{1}{2}\rho c^3\Gamma\left(1+\frac{3}{k}\right)T \quad (10)$$

This equation can be used to calculate the available wind energy for any defined period of time when the wind speed frequency distributions are for a different period of time.

5. RESULTS & DISCUSSION

In this study, wind speed data over the period of ten years (2002 to 2011) has been collected and analyzed of Cox's Bazar. The calculations were made to obtain the Weibull distribution parameters in terms of k and c, mean wind speed and measured and predicted mean wind power. The salient features of the analysis obtained from the statistical calculation can be summarized as follows:

5.1 Average Wind Speed

To calculate the monthly variation of average wind speed, measurements have been carried out at 10 m height above the ground level. The value of Monthly mean wind speed, Weibull parameters k and c, standard deviation and monthly wind power density are listed in Table 4. The monthly mean wind speeds for the investigated location are shown in Figure 10. The figure reflects that the average wind speed varies between 2.17 and 2.90 m/s. The maximum value of the mean wind speed is found in the month of April while the minimum value is found in the month of November.

Table 4. Monthly calculated mean wind speed (m/s), standard deviation, Weibull parameters and wind power density and energy at Cox's Bazar (at 10 m height from ground level) from 2002 to 2011

Months	v_m (m/s)	σ	c (m/s)	k	P (W/m^2)
Jan	2.34	0.39	2.50	6.99	8.46
Feb	2.63	0.34	2.78	9.24	11.70
Mar	2.69	0.49	2.89	6.33	13.15
Apr	2.90	0.66	3.15	5.02	17.14
May	2.76	0.53	2.97	6.04	14.23
Jun	2.83	0.53	3.04	6.21	15.29
Jul	2.67	0.44	2.85	7.09	12.59
Aug	2.73	0.54	2.95	5.78	13.91
Sep	2.53	0.55	2.75	5.24	11.36
Oct	2.24	0.43	2.41	6.01	7.60
Nov	2.17	0.52	2.37	4.73	7.30
Dec	2.34	0.55	2.55	4.81	9.09

The seasonal mean wind speeds for the study area, calculated from 2002 to 2011 has been represented in Table 5. It is observed that the maximum value of the mean wind speed is about 2.78 m/s, available in the spring season; while the minimum value is about 2.31 m/s which were in the summer season. The graphical representation of seasonal mean wind speed of Cox's Bazar is elaborated in Figure 11.

Table 5. Seasonal Weibull parameters and characteristic speeds (m/s) for the years 2002-2011 of Cox's Bazar at 10 m height

Seasons	v_m (m/s)	σ	c (m/s)	k	P (W/m^2)	E/A (kWh per m^2 per season)
Spring	2.78	0.47	2.98	6.92	14.29	31.56
Summer	2.74	0.47	2.94	6.76	13.74	30.34
Autumn	2.31	0.46	2.50	5.72	8.48	18.52
Winter	2.43	0.36	2.58	8.00	9.40	20.31

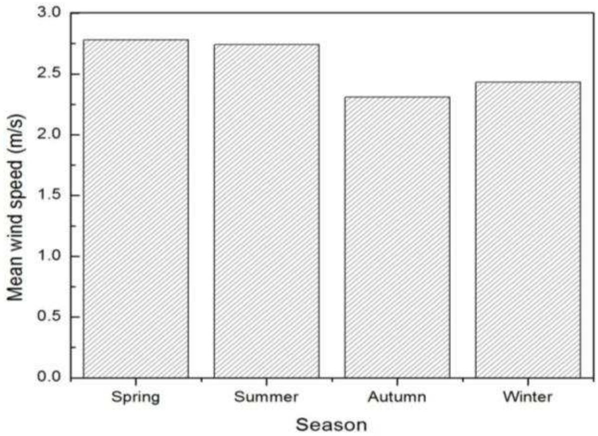

Figure 11. Seasonal mean wind speed of Cox's Bazar (2002- 2012)

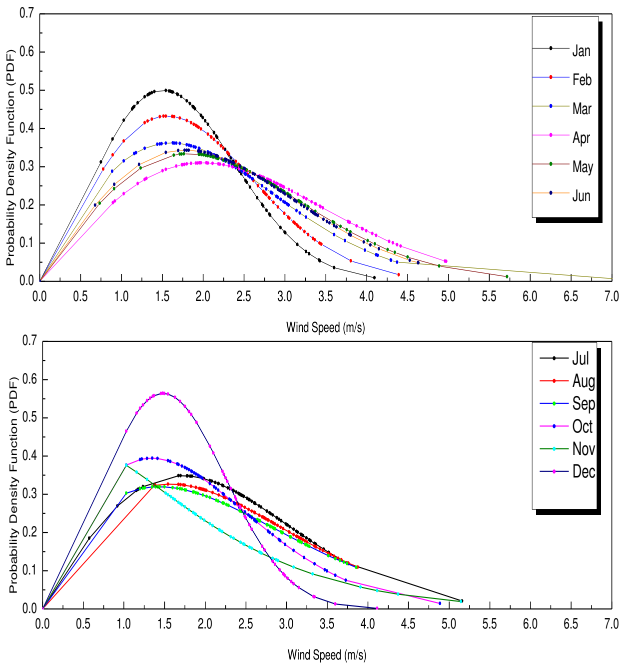

Figure 12. Monthly wind speed probability density distributions Cox's Bazar from 2002 to 2011

5.2 Probability Density and Cumulative Distributions

The monthly probability density and cumulative distributions derived from the wind speed data of Cox's Bazar, the results are presented in Figures 12 and 13, respectively. It is seen from these two figures that all the curves have a similar tendency of wind speeds for the cumulative density and probability density. The Weibull parameters for the available data are calculated using Equations (3) and (4), the results are presented in Table 4. The results showed that the parameters are distinctive for different months of the period (2002-2011). This means that the monthly wind speed distribution differs over a whole period. The monthly values of c range from 2.37 to 3.15 m/s. The minimum value of c is found in November, but the maximum value is found in April, while the values of k range from 4.73 to 9.24. The minimum value of k is found in November, but the maximum value is found in February. Hence, with regards to the Weibull shape parameter k for the location, wind speed is most uniform in February while it is least uniform in November. The peak of the density function frequencies of the location slightly skewed towards the higher values of the mean wind speed, which also indicate the most frequent velocity.

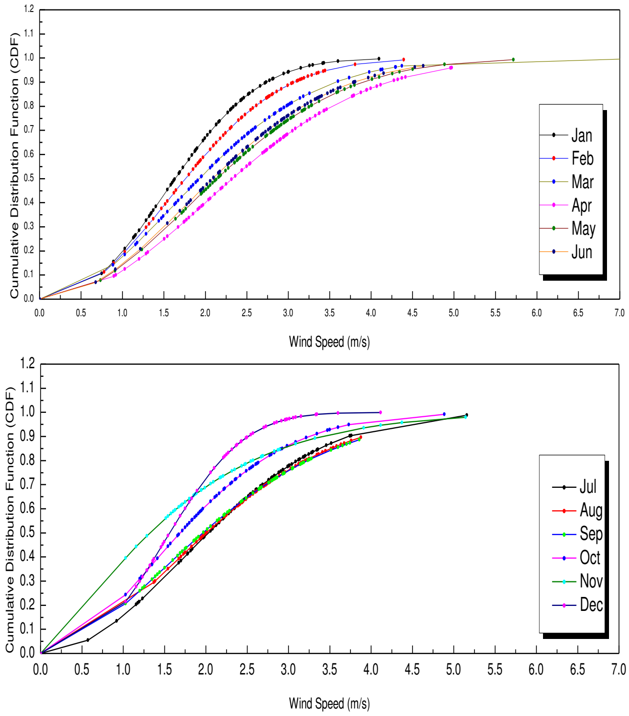

Figure 13. Monthly wind speed cumulative density functions of Cox's Bazar from 2002 to 2011

The seasonal probability density and cumulative distributions obtained from Weibull probability density functions for the investigated location are shown in Figures 14 and 15, respectively. The seasonal wind characteristics in Cox's Bazar are given in Table 5. As seen from this Table, the highest mean wind speed value with 2.78 m/s is determined in the spring season, while the lowest value is noticed in the autumn season with 2.31 m/s. The Weibull shape parameter k varies between 5.72 and 8.00. While the scale parameter c varies between 2.50 to 2.98 m/s. The maximum c value is found in the spring season and the minimum value is seen in the autumn season.

5.3 Wing Power Density

The monthly power densities calculated from the measured probability density distributions and those obtained from the Weibull distributions are shown in

Figure 16. The monthly variation of the mean power density for the location shows the some monthly changes in the wind power density. It is clear that the maximum value is 17.14W/m^2 in April, while the minimum value 7.30 W/m^{2}occurred in November. The obtained results are reported in details in Table 4.

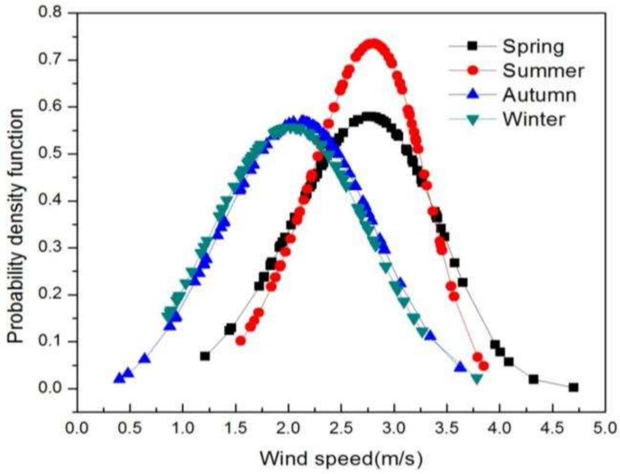

Figure 14. Seasonal Weibull probability distributions of Cox's Bazar from 2002 to 2011

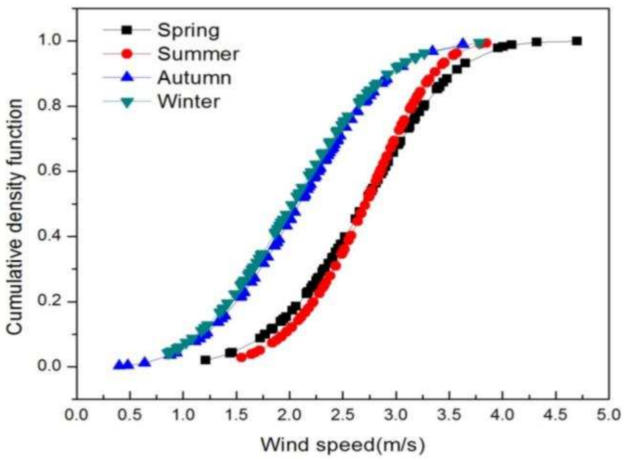

Figure 15. Seasonal cumulative of Cox's Bazar from 2002 to 2011

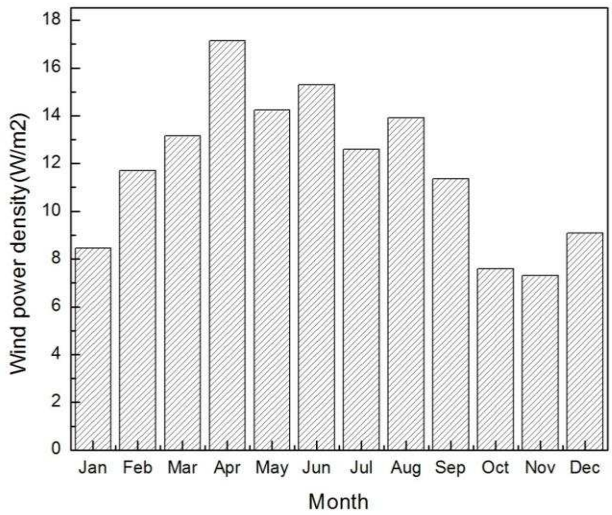

Figure 16. Monthly wind power density of Cox's Bazar from 2002 to 2011

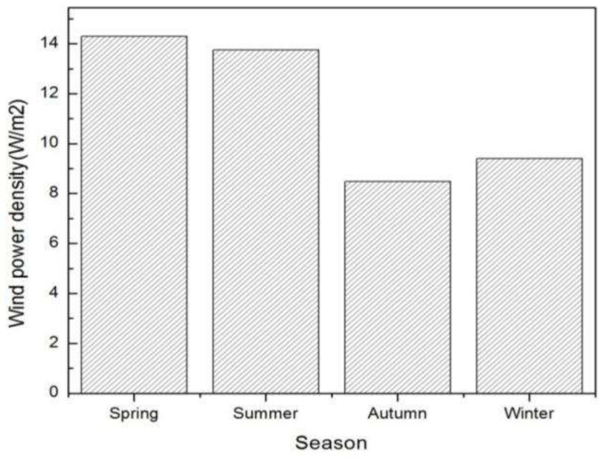

Figure 17. Seasonal wind power density of Cox's Bazar from 2002 to 2011

In addition, the seasonal variation of the mean wind power density for the investigation location is presented in Figure 17, and is also summarized in Table 5. It is observed that the highest value of the mean wind power Density is 14.29 W/m^2 is observed in spring season while the lowest value 8.48 W/m^2 is found in the autumn season. The seasonal wind power energy density was evaluated, by Equation (10) and shown in Table 5. It is clear that the highest value of wind power energy 31.56 kWh/m^2/Season is observed in spring while, the lowest value 18.52 kWh/m^2/Season is found in autumn.

The study and analysis of the paper has been carried out on wind speed data of year 2002 to 2011 at different places of the concern district at 10 meter height. This speed may be not sufficient for wind turbine to generate power. The larger commercial wind farm turbines have a tower height in the range of about 300 to 325 feet with blades about 120 ft to 150 ft long. Medium size commercial wind towers may be about 200 to 250 feet in height. Using Equation 11, wind speed at convenient height can be calculated from 10m height.

$$\frac{V_z}{V_{ref}} = \left(\frac{h}{h_{ref}}\right)^{\alpha} \qquad (11)$$

where V_z = average wind velocity at height h meter (m/s), V_{ref} = average wind velocity at reference height meter (m/s), h = the height where the velocity of wind is to be calculated (m), h_{ref} = reference height (m), α = dimensional constant that varies from 0.1 to 0.4 depending on the nature of the terrain.

6. CONCLUSION

Based on Weibull Probability Density Function with its two characteristic parameters (*c* scale parameter and *k* shape parameter), this paper attempts to characterize the wind speed nature and make an assessment of wind energy density in Cox's Bazar, the most attractive tourist point of Bangladesh. This study will provide vital information for developing wind energy in Cox's Bazar, broadly in coastal areas of Chittagong division and for planning economical wind turbines capacity for the electricity production in the region. Based on the method which is elaborated in this paper, similar wind energy assessment can be carried out in isolated islands of Bangladesh (such as Kutubdia, Saint Martin, Swandip) where national grid is not possible to expand in near future. The tabulated numerical outcome and probability density distribution curves will be very much useful for Rural Electrification Board (REB), Bangladesh to enhance their solar powered irrigation pump project into wind-solar hybrid powered irrigation project.

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