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Wind Energy Potential at Different Cities of Assam Using Statistical Models

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ABSTRACT

Energy is an important role in any country's economy and infrastructure growth. Wind energy is renewable form of energy and environment friendly compared to conventional energy resources that pollute the environment. A proper analysis of wind speed data is an important parameter to estimate wind energy potential at a particular site. This article investigates the wind energy potential at three different cities of Assam viz. Dibrugarh, Guwahati and Tezpur of Assam, India by using statistical methods over a period of eight years from 2010-2017. The speed data revealed that the mean wind speed of Tezpur city was lower in-comparison to Dibrugarh and Guwahati. The average wind speed of Dibrugarh is highest i.e. 5.398 km/hr followed by Guwahati city 4.628 km/hr. The average monthly wind data shows that the mean wind speed for city Dibrugarh is highest in the month of April as 7.8625 km/hr. The mean test analysis between Dibrugarh and Guwahati shows that the mean speed different between two cities is significant as $P<0.05$. Weibull probability distribution function revealed that higher occurrence of probability at higher wind velocities for each city. The probability distribution plot shows that the 99% probability of occurance of Wind speed is 7.45093 km/hr for city Dibrugarh. The data also revealed that the average wind power density for the city Dibrugarh is 0.897451 W/m^2 followed by city Guwahati 0.578349 W/m^2. The above analysis shows that there is a possibility of wind power generation in the city of Dibrugarh followed by city Guwahati at these low wind speed region and the vertical axis wind turbines can be installed for power generation in cities Dibrugarh and Guwahati.

Keywords: *Wind Energy; Mean Speed; Weibull Probability Density Function; Shape Factor; Wind Power Density.*

1.0 Introduction

Energy is a basic input needed to support economy and an important part in any contry's economic infrastructure growth [1]. Energy is also important rule for the for human development index as it is directly related to level of economic development and per capita energy consumption by human [2]. The effective use of energy can guide to higher economic growth by reducing the energy required per unit of output. India's per capita consumption of energy is only one eighth of global average. This shows that India has low rate of energy consumption as compared to developed nations.

With rapid industrialization in our country, the demand for energy is increasing rapidly [3]. Therefore, there is a need for balance between the requirements of the people need in our country and the availability of the conventional energy resources like petroleum, coal, natural gas and nuclear energy. It is essential to add extra elements called non-conventional energy resources to the needs of people for future generations effeciently. Luckily, our country has large amount of sustainable non-conventional energy resources viz geothermal energy, wind tidal energy and biomass along with small hydro power and industrial and domestic wastes. The renewable energy resources are natural, free of cost,

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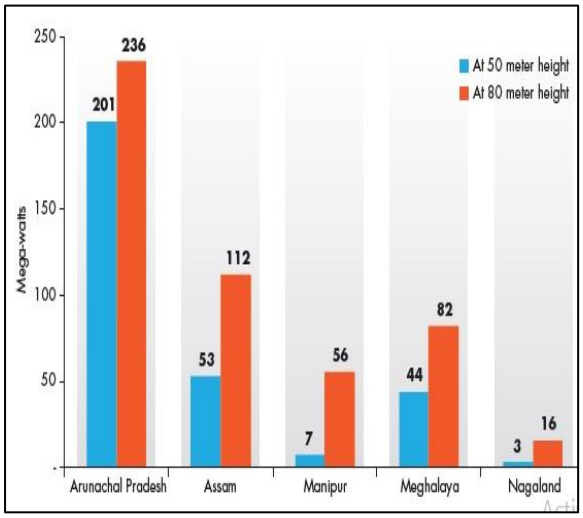
easily abailable, pollution free and easy to use for the creation of energy. So there is a need for the development of non- conventional energy resources in the country. Due to deplation of conventional energy resources, the environmental friendly and pollution free energy resources has become a feasible substitute against conventional energy resources. The non- conventional energy resources will help the economy to a great extent by improving the power generation [4].

In recent year, the generation of wind energy in India has increased and at the end of December 2017 the total installed wind power capacity was 32848.46 MW and spread across the South, West and North regions of India [5]. The Northeast state region of india has a total installed capacity of 3,550.02 MW for electricity generation. Fossil fuels contributes to 57.6 per cent of total installed capacity.

According to the Central Electricity Authority, there is currently a gap of 4.7 per cent between the requirement and availability of electricity in north east states. In terms of per capita consumption of North East states, the average per capita consumption lower then the national average and that affect the development of this region.

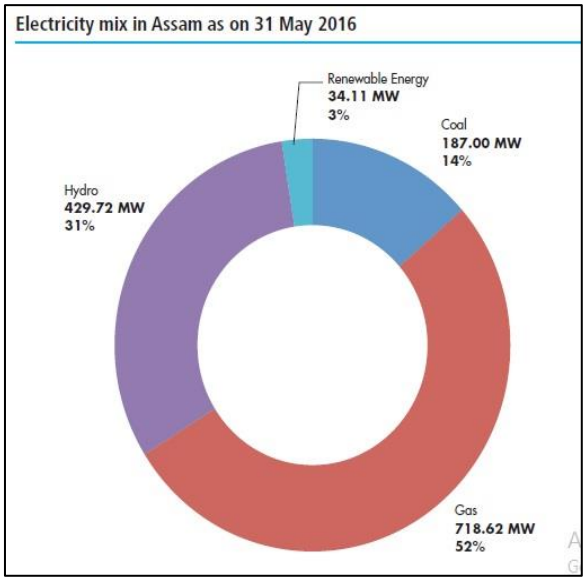
Wind power has not been fully exploited in the Northeast states, though the region has ability to produce 300 MW-500 MW energy from non conventional energy resources at even the low turbine installation heights of 50m and 80 m [6]. Figure 1 shows that the installation potential of wind energy in North East states.

Fig 1: Indicative Installed Potential of Wind Power [6]



The energy sector in Assam is also dominated by fuels like natural gas and coal and contribute two-third of the installed capacity . Assam is one of the highest deficits in availability of energy and also one of the poorest state in terms of electrification compare to other states of India. According to Census 2011, only 37 per cent of the state is electrified [6]. The non conventional energy resources contributes only 3% of total energy production as shown in figure 2. Therefore production of energy in Assam is essential for stability in economy, improving infrastructure and life style of people of Assam through renewable energy resources.

Fig 2: Pie Chart of Energy Mix in Assam [6]



The Assam Energy Development Agency (AEDA) was established for implementation of some of the major programmes in the sector of science and technology, remote sensing, renewable energy sources [7].

Sengupta et al. investigated the wind energy potential at Silchar of Assam, India by using Weibull and Rayleigh's, autoregressive integrated moving average distribution over a period from 2008-2011. They found that the peak mean wind speed for Silchar was found to be 1.48 m/s at 10 m height and 1.69 m/s at 25 m height. They concluded that the vertical axis wind turbines would be suitable for power generation at low wind speed region. [8]**.** Veysel YILMAZ and H. Eray ÇELİK determined Weibull distribution was the best distribution representing wind data. [9]. Bedri Yüksel and Ergun

Ates investigated the effects of wind speed, insolation levels, and the meteorological parameters of temperature and humidity on the energy potential in Balıkesir, in the Marmara region of Turkey and found that the regression equations yielded best results [10]. Faton Merovc and Ibrahim Elbatal studied a three parameter lifetime model, called the Weibull Rayleigh distribution and obtained some of its mathematical properties [11]. T. R. Ayodele et al. investigated the wind power potential in the coastal regions of South Africa. The optimum wind speed and shear exponential which were important factors in the selection of wind turbines [12]. Ayodele et al. also analysed wind power potential of Port Elizabeth using statistical Weibull parameters. The results showed that the shape parameter ranges from 1.319 in April 2006 to 2.107 in November 2009 and the scale parameter varies from 3.983 in May 2008 to 7.390 in November 2009.The [13]. Rajat Gupta and Agnimitra Biswas studied the wind energy potential at Silchar, Assam, India from 2003 – 2007 by using Weibull and also Rayleigh's distribution functions. They observed that the average wind velocity in Silchar was about 3.11 km/hr and wind power density analysis indicated that the average power density was found to be highest during the month of March to April [14]

2.0 Methodology

2.1 Location of cities

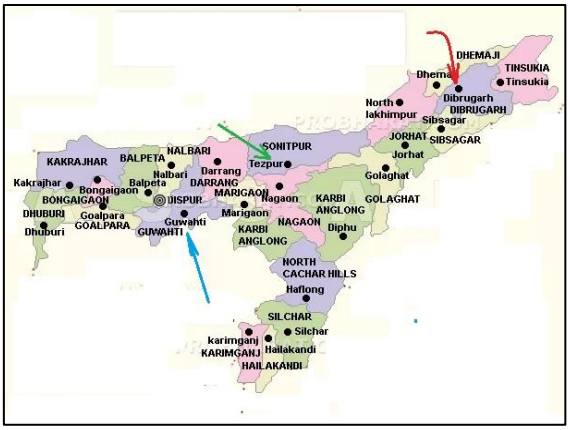
This paper investigates the possibility of the wind renewable energy resource in three different cities of Assam, India. The cities for consideration are Dibrugarh, Guwahati and Tezpur. Dibrugarh is is located 27.48 latitude and 94.91 longitude and it is situated at elevation of 110 meters above sea level. Guwahati is located at 26.18 latitude and 91.75 longitude and at elevation 59 meters above sea level. Tezpur is located at 26.63 latitude and 92.80 longitude and it is situated at elevation of 74 meters above sea level. The location of this city in India has been shown in fig.[3]

2.2. Wind Rose Data

The wind rose for Dibrugarh as shown in figure 4(a) shows how many hours per year the wind blowing from the indicated direction. The Wind is mostly blowing from South to North. Similar observation has been noticed for the city Tezpur.

The wind is blowing from west south west to east north east for the city Guwahati. [16]

Fig 3: State Map of Assam [15]



The wind speed data for cities Dibrugarh, Guwahati and Tezpur is shown in table. The wind energy data have been collected from weather online [17]

2.3 Wind speed data

Fig 4(a): Rose Diagram (Dibrugarh)

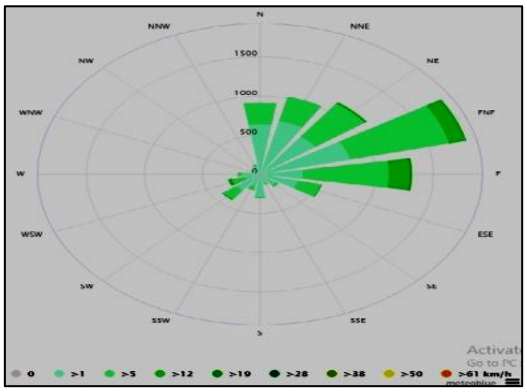


Fig.4(b) Rose Diagram (Guwahati)

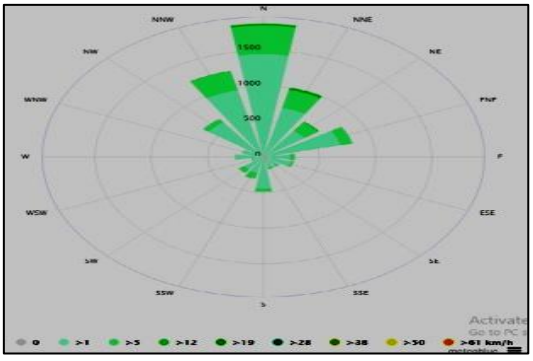
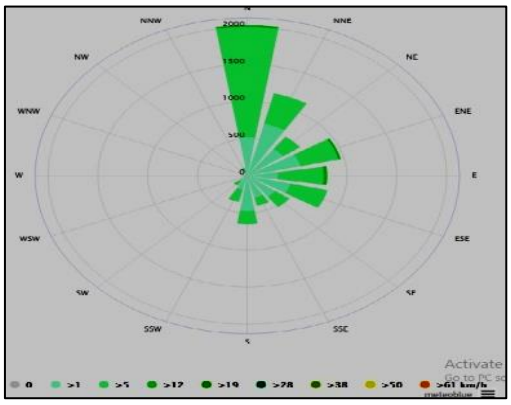


Table 1: Monthly Average Wind Speed Data (km/hr) for the Selected Cities of Assam from 2011 to 2017 [17]

Place	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average speed (km/hr)
Dibrugarh	2017	4.6	6.3	8	8.3	9.5	10.5	8.8	7.1	7.6	6.5	4	4.7	7.158333
	2016	2.8	3.9	5.9	10	7.2	7.8	8.5	7.7	7.7	6	4.3	5.6	6.466667
	2015	4.1	4	5.5	7.5	6.2	8.1	6.9	5.9	5.3	3.2	3	2.5	5.183333
	2014	2.1	4.1	4.1	6.5	7.7	6.3	6.4	7.6	4.6	3.6	3.2	3.3	4.958333
	2013	2.1	2.5	5.8	6.8	7.5	6.3	7.4	5.6	5.3	4.4	2.3	2.3	4.858333
	2012	2.7	3.2	5.2	7.5	6.1	6.6	7.1	5.2	6.7	4.3	3.5	2.1	5.016667
	2011	3	3.3	6.7	6.3	4.2	6.5	4.6	4.3	3.3	3.1	2.6	2	4.158333
	2010	1.9	4.1	7.1	10	8.9	7.3	6.4	4.4	5.2	3.7	2.7	2.5	5.383333
Guwahati	2017	3.2	4.3	7.3	7.7	7.1	6.8	7	5.7	4.2	5.4	4.8	4.1	5.633333
	2016	3.1	4.6	7.2	8.8	6.3	5	5	5.9	4.5	4.7	4.1	3.3	5.208333
	2015	3	3.8	5.3	6.3	3.9	5.1	4.3	2.3	2.6	2.9	2.7	3.1	3.775
	2014	1.8	1.4	3.3	6.3	6.5	4.3	4.4	4.3	3	2.1	2.4	2.7	3.541667
	2013	1.8	2.4	5.7	5.8	5.2	4.2	4.1	3.3	2.8	3.2	2.8	1.7	3.583333
	2012	3.2	4.6	5.2	7.5	5.6	4.6	3.6	4.4	3.8	3	2.4	1.9	4.15
	2011	4.3	4.9	7.7	8.5	7	5.4	5.8	6.7	5.3	4.4	3.4	2.2	5.466667
	2010	3.1	4.7	6.6	7	6.9	7.7	5.7	5.9	5.2	6.5	3.9	4.8	5.666667
Tezpur	2017	0.2	2	3.1	2.1	2.5	0.5	0.6	0.6	0.8	0.8	1	0.7	1.241667
	2016	0.6	1.8	3	3.3	0.9	0.5	0.7	0.5	0.4	0.5	0.4	0.9	1.125
	2015	0.3	0.5	0.7	1.7	0.7	1.2	2.4	0.7	0.6	0.7	0.9	0.7	0.925
	2014	1	1.1	2	2.6	2	1	0.8	0.7	0.3	0.2	0.4	0.2	1.025
	2013	0.8	0.7	3	3.1	2.1	1.1	1.3	0.8	0.3	0.7	1	0.6	1.291667
	2012	1	0.9	2.1	2.1	0.7	1.1	1.3	1.1	1.7	1.3	0.9	0.6	1.233333
	2011	0.4	1	2.3	2.1	0.8	0.6	0.8	0.4	0.7	1	1.2	1.4	1.058333
	2010	0.3	0.7	2.3	1.1	0.4	0.1	0.3	0	0.2	0.5	0.4	0.4	0.558333

Fig 4(c): Rose Diagram (Tezpur)



3.0 Result and Discussion

3.1 Variation of wind speed data from year 2010-2017

The variation of wind speed of different cities viz. Dibrugarh, Guwahati and Tezpur is shown in figure 5. The variation of wind speed in three different cities revealed that wind speed increases from year 2015 to 2017. The average wind speed of Dibrugarh is highest 5.398 km/hr followed by Guwahati city 4.628 km/hr from year 2010-2017. The mean speed of Tezpur city is 1.057 km/hr, which is lower than the city Guwahati. The frequency distribution of average wind speed data from year 2010-2017 as shown in figure 6(a)-6(c) revealed that frequency at higher wind speed i.e. 7km/hr was achieved in the year 2017 and maximum frequency lies in 5km/hr for the city Dibrugarh during the year from 2010-2017.

Fig.5 Variation of Wind Speed with Years from 2010-2017

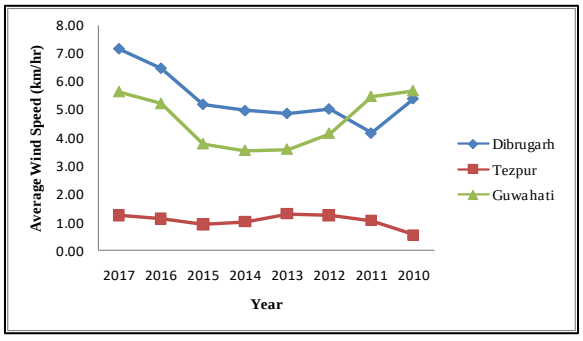


Fig 6(a): Histogram of Avg. Wind Speed for city Dibrugarh

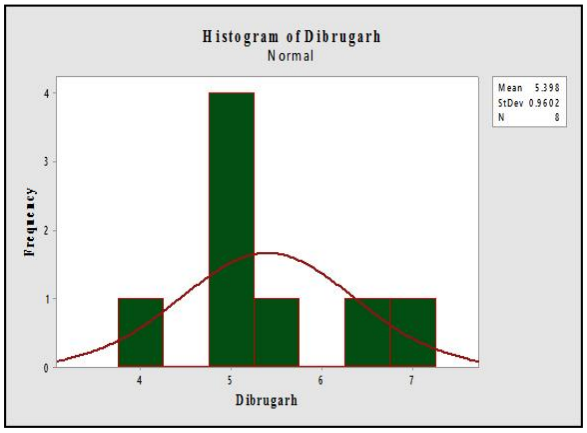


Fig 6(b): Histogram of Avg. Wind Speed for City Guwahati

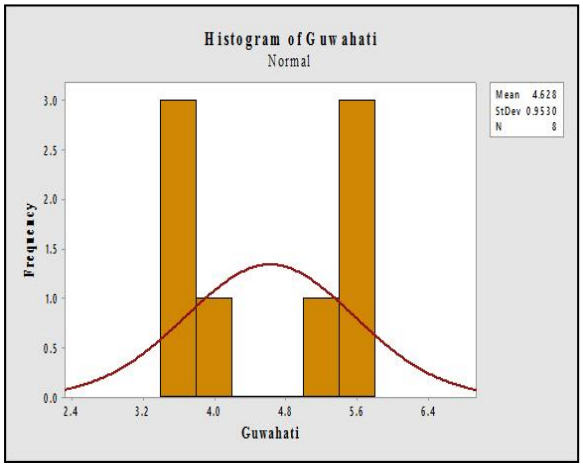
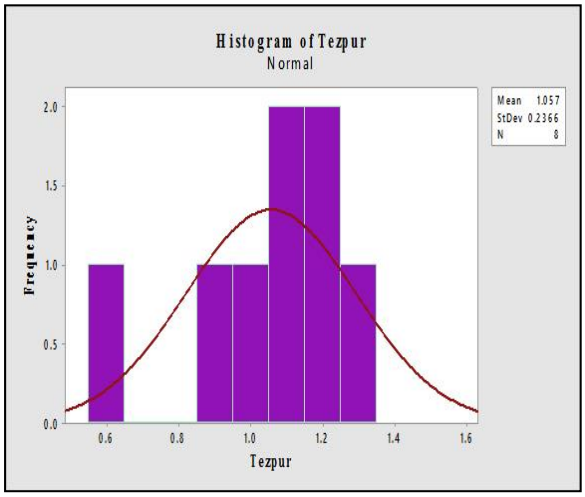


Fig 6(c): Histogram of Avg. Wind Speed for City Tezpur



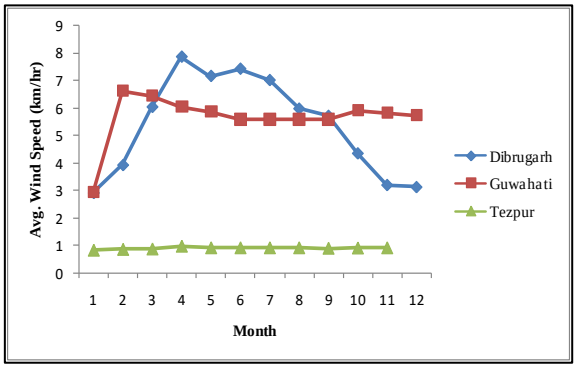
3.2 Variation of wind speed data monthly from year 2010 to 2017

The average monthly wind data shown in table 2 revealed that the mean wind speed for city Dibrugarh is maximum in the month of April as 7.8625 km/hr and the valu ranges from 5.975 km/hr to 7.8625 km/hr from month March to August. But for the city Guwahati, it is maximum for the month of February as 6.462 km/hr. The variation Wind speed with month revealed that Wind speed curve is steady for the city Guwahati. The average monthly wind speed data of Tezpur city revealed the averagemonthly speed is maximun in the month of January and mean speed is 1.0525 km/hr. The variation of average speed data as shown in figure 7 also shows that the average wind speed of city is very less in comparision to other citities and highest for city Dibrugarh 7.8625 km/hr on April month followed by city Guwahati 6.635 km/hr on February month.

Table 2. Month Wise Average Wind Speed Data

Month	Dibrugarh	Guwahati	Tezpur
January	2.9125	2.9375	1.0525
February	3.925	6.635	0.843
March	6.0375	6.462	0.8716
April	7.8625	6.0544	0.88592
May	7.1625	5.86528	0.983104
June	7.425	5.590836	0.9272248
July	7.0125	5.590836	0.9272248
August	5.975	5.590836	0.9272248
September	5.7125	5.590836	0.9272248
October	4.35	5.922503	0.9115654
November	3.2	5.833441	0.9201361
December	3.125	5.754871	0.9262031

Fig 7: Variation of Avg. Wind Speed with Each Month from Year 2010-2017



3.3 Comparison of mean wind speed

Comparison of mean wind speed between the cities has done by MINITAB software version 18. Test hypothesis are given below

Null hypothesis: Mean (Dibrugarh) - Mean (Guwahati) ≤ 0

Alternative hypothesis: Mean (Dibrugarh)- Mean (Guwahati) > 0, α level: 0.05 Mean test revealed that there is a significance difference between wind speed from year 2010-2017 for cities Dibrugarh and Guwahati as

P value$= 0.035 < 0.05$ for degree of freedom 7. Therefore, reject null hypothesis. The comparison of mean revealed that there is a possibility of wind energy generation at the low speed region of city Dibrugarh compare to city Guwahati.

3.4 Wind speed probability distribution function

Table 3 shows that Weibull probability distribution function with shape and scale factrors for different cities. The data revealed that higher occurrence of probability for higher wind velocities for each city.

It has been also observed that Weibull distribution is showing the probability distribution function is high as 0.973011 for mean wind speed 7.15833 km/hr for the city Dibrugarh..

3.5 Probability plot

The Weibull probability distribution plot as shown in figure 8(a) revealed that the shape factor increases from the city Dibrugarh to Tezpur i.e. from 6.064 to 6.547 and scale factor decreases from 5.792 to 1.140. The probability distribution plot shows that the 99% probability of occurance of Wind speed is 7.45093 km/hr and at a range of 6.45503km/hr-8.60048km/hr for city Dibrugarh, 6.41090 km/hr at a range of 5.49751 km/hr-7.47604 km/hr for city Guwahati and at 1.43903 km/hr at a range of 1.23552km/hr-1.67607km/hr for city Tezpur. Probability plot as shown in figure 8(b) for the three cities from 2010-2017 shows that scale factor increases with increasing wind speed and the shape factor also increases with increase in wind speed but changes abruptly as wind speed changes.

3.6 Analysis of Wind Power Density

In this study wind power density has been calculated using the formula The formula for calculating the power from a wind turbine is:

Table 3: Weibull Probability Density Function for Different Cities

Weibull with shape = 6.064 and scale = 5.792 (Dibrugarh City)		Weibull with shape = 6.114 and scale = 5 (Guwahati City)	
x	P(X ≤ x)	x	P(X ≤ x)
7.15833	0.973011	5.63333	0.87517
6.46667	0.857815	5.20833	0.723368
5.18333	0.399524	3.775	0.16295
4.95833	0.322736	3.54167	0.113246
4.85833	0.291357	3.58333	0.121151
5.01667	0.341859	4.15	0.272604
4.15833	0.125472	5.46667	0.822751
5.38333	0.47358	5.66667	0.884399
Weibull with shape = 6.547 and scale = 1.14 (Tezpur City)			
x	P(X ≤ x)		
1.24167	0.826126		
1.125	0.600258		
0.925	0.224735		

Fig 8(a): Probability Distribution Plot for Three Different Cities

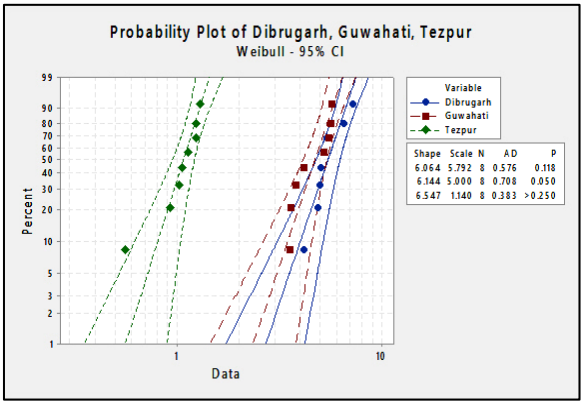
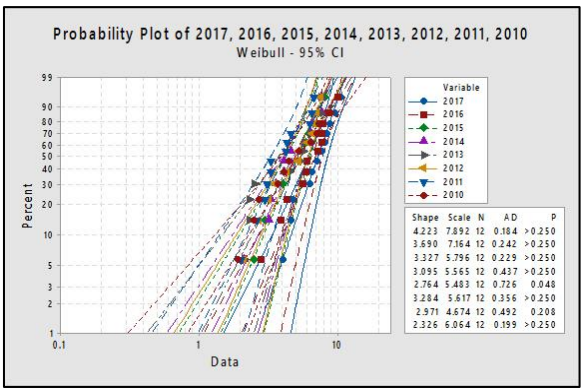


Fig 8 (b): Probability Distribution Plot for Dibrugarh City



Wind power density $(\frac{P}{A}) = C_P \times \frac{1}{2} \times \rho \times V^3$ in W/m^2

Where:

P = Power output, Cp = Maximum power coefficient=0.40

ρ = Air density=1.225 kg/m^3 [8], A = Rotor swept area (m)

V = Wind speed, m/s

Table 4 shows the Power density data (W/m^2) for three cities viz. Dibrugarh, Guwahati and Tezpur of Assam.

The data shows that power density is maximum i.e. 1.926169 W/m^2 for the year 2017 for the city Dibrugarh and minimum i.e. 0.000914 W/m^2 for the year 2010 for city Tezpur . Data also revealed that the average of wind power density for the city Dibrugarh is 0.897451 W/m^2 followed by city Guwahati 0.578349 W/m^2 and minimum for city Tezpur 0.006956 W/m^2.

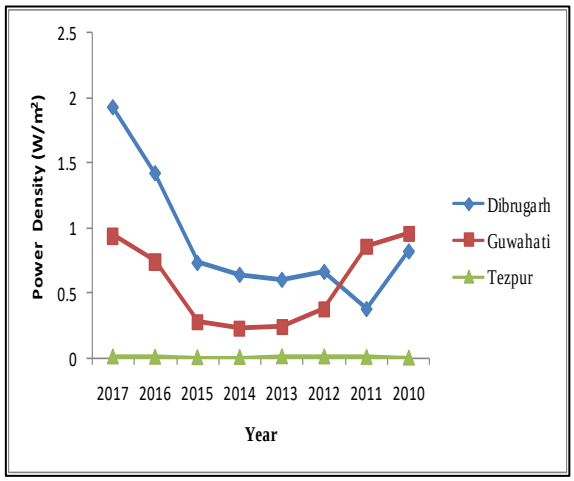
The variation of Wind Power with respect to year from 2010-2017 shown in figure 9 indicates that the Wind Power density increases from 2015 to 2017 for cities Dibrugarh and Guwahati and remains nearly same for the city Tezpur.

The above analysis shows that there is a possibility of wind power generation in the city of Dibrugarh followed by city Guwahati at low wind speed region and low cut-in wind speed vertical axis wind turbines could be installed for power production in low wind speed cities Dibrugarh and Guwahati [8, 14].

Table 4: Power Density Data (W/m^2) for Three Cities of Assam

Dibrugarh	2017	1.926169	Tezpur	0.010052
	2016	1.420038		0.007477
	2015	0.731284		0.004156
	2014	0.640126		0.005655
	2013	0.602172		0.011316
	2012	0.662986		0.009851
	2011	0.377587		0.006225
	2010	0.819242		0.000914
Guwahati	2017	0.938761		
	2016	0.741916		
	2015	0.282494		
	2014	0.233282		
	2013	0.241613		
	2012	0.375321		
	2011	0.85788		
	2010	0.955524		

Fig 9: Variation of Energy Density from Year 2010-2017



4.0 Conclusions

This article investigates the wind energy potential at three different cities of Assam viz. Dibrugarh, Guwahati and Tezpur of Assam, India by using statistical analysis over a period of eight years from 2010-2017.

The variation of mean wind speed shows that the wind speed increases from year 2015 to 2017. The average wind speed of Dibrugarh city is highest 5.398 km/hr followed by Guwahati city 4.628 km/hr and Tezpur city is 1.057 km/hr from year 2010-2017. The frequency distribution of average wind speed data from year 2010-2017 revealed that frequency at higher wind speed i.e. 7km/hr was achieved in the year 2017 and maximum frequency lies in 5km/hr for the city Dibrugarh during the year from 2010-2017. The average monthly wind data revealed that the mean wind speed for city Dibrugarh is highest in the month of April as 7.8625 km/hr. On the other hand, for the city Guwahati, it is highest for the month of February as 6.462 km/hr. The variation Wind speed with month revealed that Wind speed curve is steady for the city Guwahati. The variation of average speed also shows that the average wind speed of city Tezpur is very less in comparision to other citities. Mean test revealed that there is a significance difference between wind speed from year 2010-2017 for cities Dibrugarh and Guwahati.. Weibull probability distribution function with shape and scale factrors data revealed that higher occurrence of probability at higher wind velocities for each city. It has been also observed that Weibull distribution is

showing the probability distribution function is high as 0.973011 for mean wind speed 7.15833 km/hr for the city Dibrugarh wind. Probability plot for the three cities from 2010-2017 shows that scale factor increases with increasing wind speed and the shape factor also increases with increase in wind speed but changes abruptly as wind speed changes. The Power density data shows that power density is maximum i.e. 1.926169 W/m^2 for the year 2017 for the city Dibrugarh and minimum i.e. 0.000914 W/m^2 for the year 2010 for city Tezpur. The statistical data analysis shows that there is a possibility of wind power generation in the city of Dibrugarh followed by city Guwahati at low wind speed region. The vertical axis wind turbines could be installed for power generation in low wind speed cities Dibrugarh and Guwahati.

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