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A STUDY OF PROSPECTS OF WIND RESOURCES FOR WATER PUMPING AND ELECTRICITY GENERATION IN BANGLADESH

Sultan Ahmmed[1] and M. Quamrul Islam[2]
[1]Farm Machinery and Post-Harvest Process Engineering Division
Bangladesh Agricultural Research Institute (BARI), Gazipur-1701, Bangladesh.
[2]Mechanical Engineering Department
Bangladesh University of Engineering and Technology, Dhaka
A. K. M. Sadrul Islam
Mechanical Engineering Department
Bangladesh University of Engineering and Technology, Dhaka

Abstract Proper assessment of a wind resource is a prerequisite for its successful utilization through appropriate wind energy conversion system (WECS). In this paper, the wind data for 16 years (1981-1996) from meteorological department have been studied for 20 different locations. Wind energy estimation depend on the location of the measuring instrument and the wind data obtained from the meteorological stations do not, in any case, represent the exact values for the site of a wind turbine. One of the causes of poor condition of meteorological data is that the wind speeds have not been measured at standard height. However, for proper operation of the wind turbine, hub-height generally ranges from 20 to 40m [Rahman, 1996]. The available meteorological data have been corrected for hub-height at 20m by applying power law expression. After height correction, it has been observed that there is a great potential for harnessing wind power for water pumping and for electricity generation in some regions like Patenga, Thakurgaon, Jessore, Khepupara etc. of Bangladesh.

Keywords: Wind, Energy, Pump, Irrigation

INTRODUCTION

Bangladesh is one of the highly energy deficient countries in the world. Wind resources may be an alternative source of energy for electricity generation and water pumping. However, it needs to be examined because the oil and gas reserve in our country is very small. A relatively small coal deposit exists at a depth of 600-900 meter below the earth surface [.Hussain, et al.,1986] and the available hydro-electric energy is also limited.

Bangladesh farming needs adequate supply of irrigation water at right time and in right quantities for maximum agricultural production. About 50 % of irrigation pump operate at a head of 6 m or less, depending on the terrain of the country. For driving these pumps, either diesel engine or electric motors are used. These pumps can be driven with the help of wind turbine [Islam, et al., 1995].
For selecting the size and type of wind turbine, the information about wind speed, direction and its duration should be known beforehand.

Bangladesh is situated between $20^0 34^{'\ 0}$ to $26^0 38'$N latitudes and $88^0 01'$ to $92^0 41'$ E longitudes with nearly 130 million people living on 1,44,000 sq. km. of area. It has 724 km long coastal belt, around 200 km hilly-coast-line and about 50 islands in the Bay of Bengal. The strong south/south-westerly monsoon wind coming from the Indian Ocean, after travelling a long distance over the

water surface, enter into the coastal areas of Bangladesh. This trade wind blows over the country from March to October. This wind speed is enhanced when it enters the V-shaped coastal regions of our country [Rahman, 1995]. In this study, an attempt has been made to investigate the application of wind energy for water pumping and for electricity generation in different regions of Bangladesh. For this purpose, 16 years wind speed data of 20 meteorological stations have been studied and the wind velocity is estimated at 20 meters height by using power law expression.

At present, there are many types of wind turbines for extracting energy from the wind. Among these, the horizontal axis wind turbines are very popular due to higher power coefficient (C_P). These are used for water pumping and for electricity generation. The performance of wind turbine rotors depends on the type of design and the ratio of the rotor tip speed to the wind velocity [Islam, et al., 1995].

Bangladesh is neither rich in commercial resources of energy nor progressing satisfactorily in the area of wind

energy. It is the appropriate time to expand research and development in the area of wind energy utilization for daily life.

DATA COLLECTION AND HANDLING

The meteorological department of Bangladesh collects 3-hourly wind speed data with the help of vertical axis cup type anemometers. These wind data for the period 1981-1996 of 20 stations were taken and monthly average speeds were computed for all the 20 stations, presented in Table-1. It can be seen from Table-1 that the wind speeds at different sites are very low except Patenga, which are not feasible for electricity generation and water pumping. The causes of poor conditions of the meteorological data are [Rahman, 1995]:

- Most of the meteorological stations are situated in the places of roughness class 3 as shown in Table-2. So the wind after loosing 70% energy is measured by the meteorological stations and for this reasons meteorological stations show poor wind speeds. The wind generators are normally installed near the coastal areas where higher velocities are exists.
- Few meteorological stations are located several kilometers away from their respective sea coast and the anemometers do not face the winds coming from the sea directly. So in the areas, directly open to the sea, wind speed will be higher than those in the present locations. Experiments carried out by the International Energy Agency (IEA) and the European Community (EC) countries show that this increase in wind speed may range from 5-100 %.
- Some of the meteorological stations are surrounded by trees, buildings, hills and hillocks etc. As the wind coming from the coast faces these obstacles, it becomes weaker and this weaker wind is measured by our meteorological stations.
- Generally, meteorological stations measure winds at heights of 5 to 10m. But the normal hub-heights of modern wind turbines ranges from 20 to 40 meters. So at these heights wind speeds would be better. A thumb rule is that if the height is doubled in the areas of roughness class-3, wind speed is increased by 20% and in the areas of roughness class-0, wind speed increased by 10 %.
- The anemometers of these stations are not calibrated for long times.

The meteorological data provide little information about the fluctuation in the speed and direction of the wind, which are also necessary to predict the performance of turbine appropriately.

Wind velocity changes with height. The rate of increase of velocity with height depends upon the roughness of the terrain. The variation of average wind speed can be determined from the following power law expression [Sarkar, et al., 1991],

$$\frac{V_Z}{V_{ref}} = \left(\frac{h}{h_{ref}} \right)^{\alpha} \quad (1)$$

where, V_Z and V_{ref} are the average speeds at h meters and at the reference height of V_{ref}=10m above the ground respectively and α varies from 0.1 to 0.4 depending on the nature of the terrain. The value of α for the different terrain has been shown in Table-2 [Beurskens, 1978]. A value of 0.17 for α may be used, in general, although this is applicable for the open terrain only. The value of α may be chosen as 0.28 for the terrain with trees and houses like the suburb area. But for the city with tall buildings the value of α should be considered as 0.4.

In the present analysis, the average wind speed at 20 m height is determined (Table-3) from the power law expression as in equation (1), taking the value of power exponent, α = 0.28.

Attempt would be made to give a detailed idea about various kinds of presentation of the wind data at different sites at 20m height. This would provide information to make decision whether that site has reasonably potential for the operation of wind machine. Fig.1 shows the monthly variation of average wind speed for several places in Bangladesh. It can be seen that wind speeds are higher from March to August for all places. A wind turbine, if properly designed and located, can supply enough wind energy. The peak rainfall in Bangladesh occurs during the months of June, July and August. But peak wind speeds are available during the hottest and driest months of March, April and May. During this period wind turbine may be used for water pumping for irrigation, if the water is previously stored in a reservoir during the monsoon season. In these operating seasons, subsoil water from shallow wells can be pumped by low lift pump (LLP) run by wind turbine. From September to February the velocities are not at all promising for harnessing power. One point can be noted that there is wide variation of wind velocity in the coastal areas throughout the year. Patenga, Chittagong, Jessore, Thakurgaon, Khepupara and Satkhira are relatively prospective site for extraction of energy.

Extractable wind power of an area determines the size and shape of the rotor appropriate to that location. Wind data shown in Table 4, give an estimation of available wind power. The wind data analyzed here are the average of the data recorded during the period 1981 to 1996 at 20 meters height. In Fig. 2, the annual average wind velocity in different regions of Bangladesh is presented.

The wind power per unit area of approach is proportional to the cube of wind speed [Beurskens, 1978] and can be expressed as $P/A = 0.6V^3$(watts), where P/A is in W/m^2 and V is in m/s. The available wind power represents the strength of the wind and

Table-1: Average Wind Speed (m/s) at 10 Meters Height at Different Locations in Bangladesh

Locations	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barisal	2.38	2.11	2.11	2.92	2.65	2.38	2.22	2.16	2.11	1.73	1.70	1.68
Bogra	1.60	1.80	2.50	3.30	3.40	3.00	2.80	2.50	2.10	1.80	1.50	1.40
Chittagong	2.98	2.36	4.06	4.11	4.52	5.65	5.81	5.60	3.80	2.31	2.78	1.80
Comilla	1.85	2.21	2.11	4.47	3.14	2.62	2.36	2.42	1.49	1.95	1.34	1.39
Cox'sBazar	3.08	3.14	3.70	4.57	3.14	3.39	3.14	3.24	2.62	2.67	2.11	2.67
Dhaka	2.78	2.67	3.60	4.73	5.19	4.68	4.93	4.83	3.60	2.83	2.16	2.42
Dinajpur	2.20	2.00	4.00	2.00	2.40	2.20	2.10	2.00	2.00	2.90	2.00	2.00
Hatiya	2.49	2.16	3.41	3.25	3.95	5.30	4.71	2.16	2.43	2.27	2.51	2.11
Jessore	2.36	2.42	4.06	6.84	6.84	5.14	5.04	4.06	3.55	2.83	2.72	2.62
Khepupara	3.44	3.60	3.14	5.81	4.78	3.86	3.39	3.24	2.93	3.03	2.42	2.11
Khulna	2.43	1.35	2.49	2.50	3.41	3.19	2.71	2.00	2.06	1.62	2.71	1.95
Kutubdia	1.45	1.49	1.90	2.21	2.27	3.00	2.96	2.57	1.73	1.19	0.97	1.06
Mongla	0.88	1.03	1.41	2.06	2.40	2.16	2.03	1.93	1.50	1.04	0.84	0.83
Rangamati	1.19	1.35	3.62	2.54	1.73	2.65	1.41	1.84	1.19	1.19	1.14	1.30
Sandip	1.90	2.47	2.62	3.96	2.00	3.14	2.78	2.21	1.90	1.34	1.39	1.39
Sylhet	1.80	2.40	2.70	2.60	2.00	2.20	2.00	1.70	1.40	1.60	1.55	1.50
Teknaf	3.03	3.29	3.60	3.29	2.72	3.19	3.14	2.36	2.00	1.80	1.29	1.44
Patenga	5.10	5.20	6.04	6.49	6.94	7.12	7.54	7.00	6.13	5.68	5.50	4.84
Sathkhira	3.45	3.61	3.15	5.82	5.01	3.90	3.50	3.30	2.97	3.10	2.90	2.30
Thakurgaon	3.40	4.15	6.50	6.91	7.10	6.60	6.50	5.40	5.20	4.90	4.30	3.90

Table-2: Types of Terrain, Roughness Classes and Their Energy Contains

Roughness Class	Terrain Type	Value of α	% Energy
0	Water areas, airports, plain lands, etc.	0.17	100
1	Country areas with few bushes, trees and buildings	0.28	70
2	Farmlands with scattered buildings	0.35	60
3	Build-up areas.	0.40	30

strength of theoretically 59% of this power is extractable but practically only 30-40% can be extracted.

Practically, extractable power by any type of windmill can be written approximately as [Beurskens, 1978], $P_e = 0.1\ AV^3$ (watt), where A is the total swept area of the rotor blades and V is wind speed (m/s).

Extracted power per square meter of swept area for different months for 20 locations in Bangladesh are shown in Fig. 3. From this figure it can be seen that wind energy can be used in the hottest months i.e., March, April and May for irrigation purposes.

The wind data at other locations also show similar strength of wind energy. The installation of wind power machines at the coastal and island areas will be useful for lifting water and for generation of electricity.

DISCUSSION

The wind data presented here for Bangladesh at 20m hub-height may be helpful for lifting water, which may solve energy problem in the country to some extent. In most of the areas in Bangladesh, the pumping head is less than 6 m, which is appropriate for using diaphragm pumps and the man-powered pumps. For these pumps, the available wind power in the country can produce good results with a suitable rotor. The use of locally available materials and technology can produce satisfactory wind pumping unit for lifting water.

In coastal areas, island and isolated villages, the wind speed is expected to be reasonably sufficient for installing wind plant for electricity. In many areas, the transmission of electricity is either expensive or impossible. The installation of wind plant for generating electricity will be very useful for such areas. Lack of proper analysis of the wind regime often led to disappointments on the water yields. In Bangladesh,

about 30% of total irrigated area is irrigated by hand pumps. So the wind turbine-pumping set may be useful by replacing hand pumping system for irrigation purposes in rural areas.

Table-3: Average Wind Speed (m/s) at 20 Meters Height at Different Locations in Bangladesh

Locations	Months												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Barisal	2.90	2.57	2.57	3.56	3.23	2.90	2.71	2.64	2.57	2.11	2.07	2.05	2.66
Bogra	1.95	2.20	3.05	4.03	4.15	3.66	3.42	3.05	2.56	2.20	1.83	1.71	2.82
Chittagong	3.64	2.88	4.95	5.01	5.51	6.89	7.09	6.83	4.64	2.82	3.39	2.20	4.65
Comilla	2.26	2.70	2.57	5.45	3.83	3.20	2.88	2.95	1.82	2.38	1.63	1.70	2.78
Cox'sBazar	3.76	3.83	4.51	5.58	3.83	4.14	3.83	3.95	3.20	3.26	2.57	3.26	3.81
Dhaka	3.39	3.26	4.39	5.77	6.33	5.71	6.01	5.89	4.39	3.45	2.64	2.95	4.52
Dinajpur	2.68	2.44	4.88	2.44	2.93	2.68	2.56	2.44	2.44	3.54	2.44	2.44	2.83
Hatiya	3.04	2.64	4.16	3.97	4.82	6.47	5.75	2.64	2.96	2.77	3.06	2.57	3.74
Jessore	2.88	2.95	4.95	8.34	8.34	6.27	6.15	4.95	4.33	3.45	3.32	3.20	4.93
Khepupara	4.20	4.39	3.83	7.09	5.83	4.71	4.14	3.95	3.57	3.70	2.95	2.57	4.24
Khulna	2.96	1.65	3.04	3.05	4.16	3.89	3.31	2.44	2.51	1.98	3.31	2.38	2.89
Kutubdia	1.77	1.82	2.32	2.70	2.77	3.65	3.61	3.14	2.11	1.45	1.19	1.29	2.32
Mongla	1.07	1.25	1.72	2.51	2.92	2.63	2.48	2.35	1.83	1.27	1.02	1.01	2.20
Rangamati	1.45	1.65	4.42	3.10	2.11	3.23	1.72	2.24	1.45	1.45	1.39	1.59	2.15
Sandip	2.32	3.01	3.20	4.83	2.44	3.83	3.39	2.70	2.32	1.63	1.70	1.70	2.76
Sylhet	2.20	2.93	3.29	3.17	2.44	2.68	2.44	2.07	1.71	1.95	1.89	1.83	2.38
Teknaf	3.70	4.01	4.39	4.01	3.32	3.89	3.83	2.88	2.44	2.20	1.57	1.76	3.17
Patenga	6.22	6.34	7.37	7.92	8.47	8.69	9.20	8.54	7.48	6.93	6.71	5.91	7.48
Sathkhira	4.21	4.40	3.84	7.10	6.11	4.76	4.27	4.03	3.62	3.78	3.54	2.81	4.37
Thakurgaon	4.15	5.06	7.93	8.43	8.66	8.05	7.93	6.59	6.34	5.98	5.25	4.76	6.59

CONCLUSION

There is a prospective source of wind energy in many places of Bangladesh. For the purpose of extracting wind energy, proper type of wind turbines may be designed and fabricated. In some regions of Bangladesh, the wind speed is satisfactory for operating pumps and for generation of electricity. The wind turbine may also be useful to drive hand pumps used for irrigating agricultural land.

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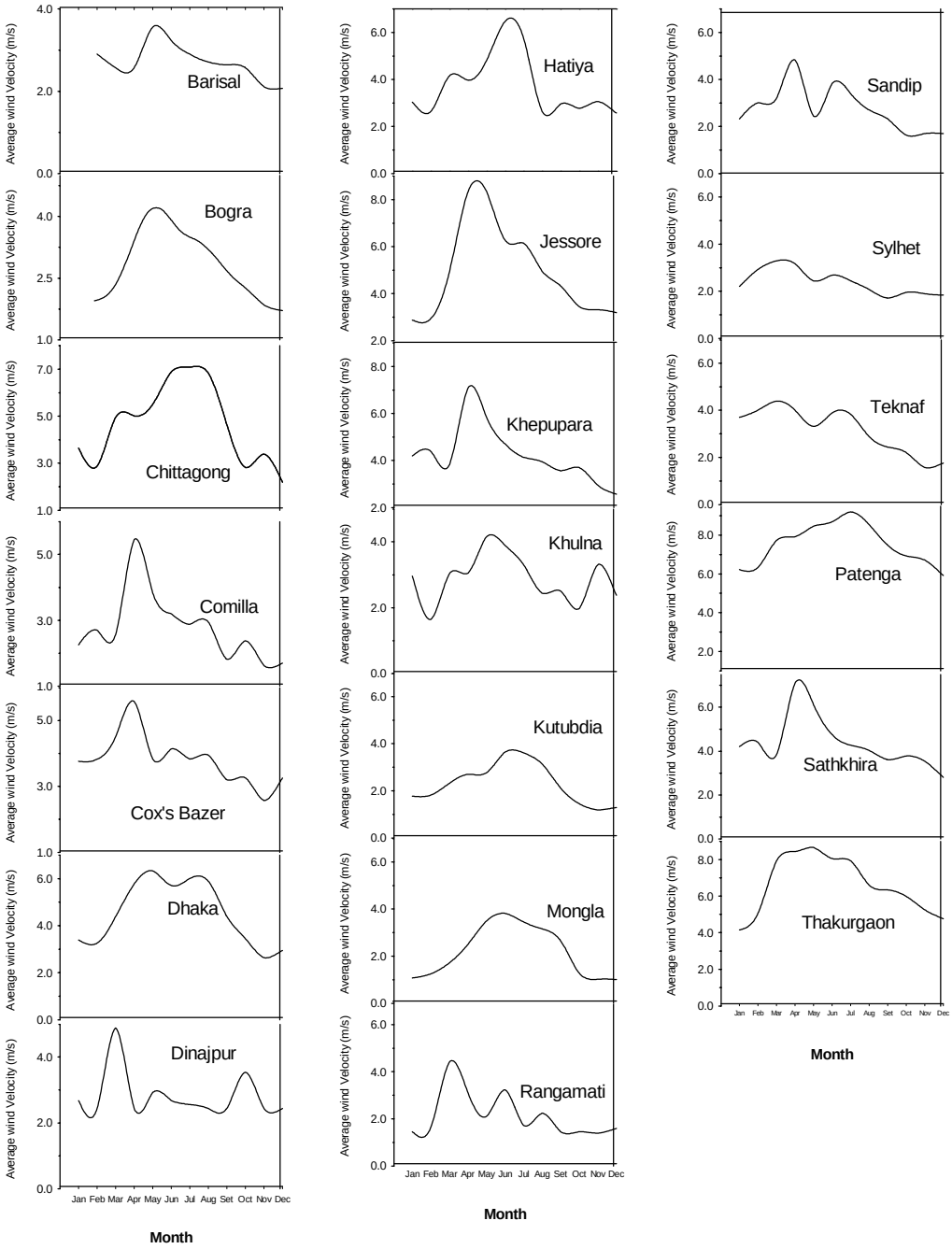

Fig.1 Monthly Average of Wind Speed at Different Locations

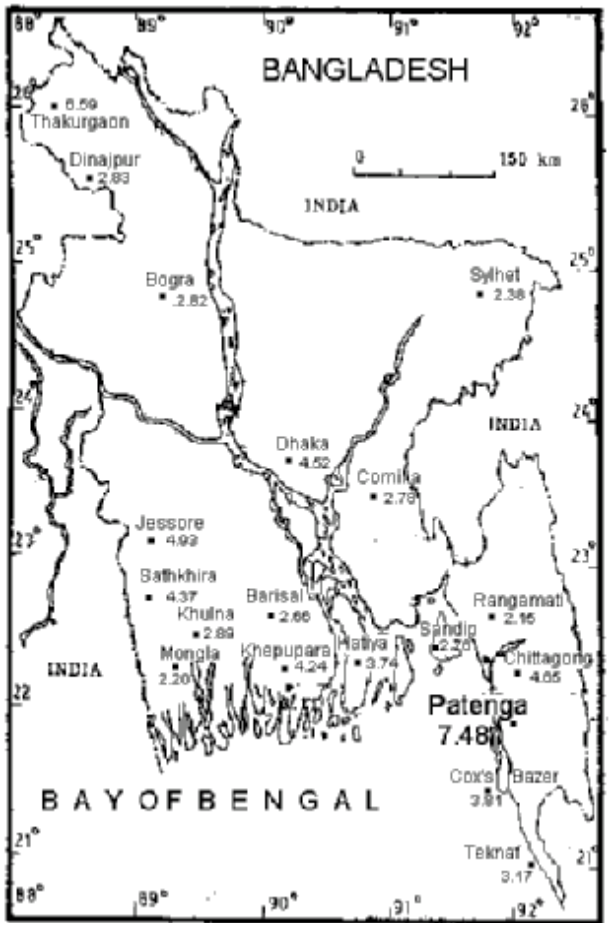

Fig. 2 Map of Bangladesh Showing Annual Average Wind Speed in m/s.

Table-4: Theoretical Available Power of Different Locations at 20 Meters Height in Bangladesh

Locations	Potential Months For Extracting Wind Power	Average Wind Velocity (m/s)	Theoretical Available Power ($W/m^{2)}$
Barisal	April to May	2.66	11.27
Bogra	April to June	2.82	13.40
Chittagong	March to September	4.65	60.49
Comilla	March to September	2.78	12.90
Cox'sBazar	May to August	3.81	33.17
Dhaka	March to October	4.52	55.26
Dinajpur	March to August	2.83	13.55
Hatiya	March to July	3.74	31.29
Jessore	April to September	4.93	71.84
Khepupara	February to September	4.24	45.88
Khulna	April to July	2.89	14.47
Kutubdia	April to August	2.32	7.49
Mongla	May to August	2.20	6.39
Rangamati	April to May	2.15	5.97
Sandip	April to July	2.76	12.55
Sylhet	April to July	2.38	8.13
Teknaf	February to September	3.17	19.06
Patenga	February to November	7.48	251.11
Sathkhira	March to September	4.37	50.16
Thakurgon	March to August	6.59	172.04

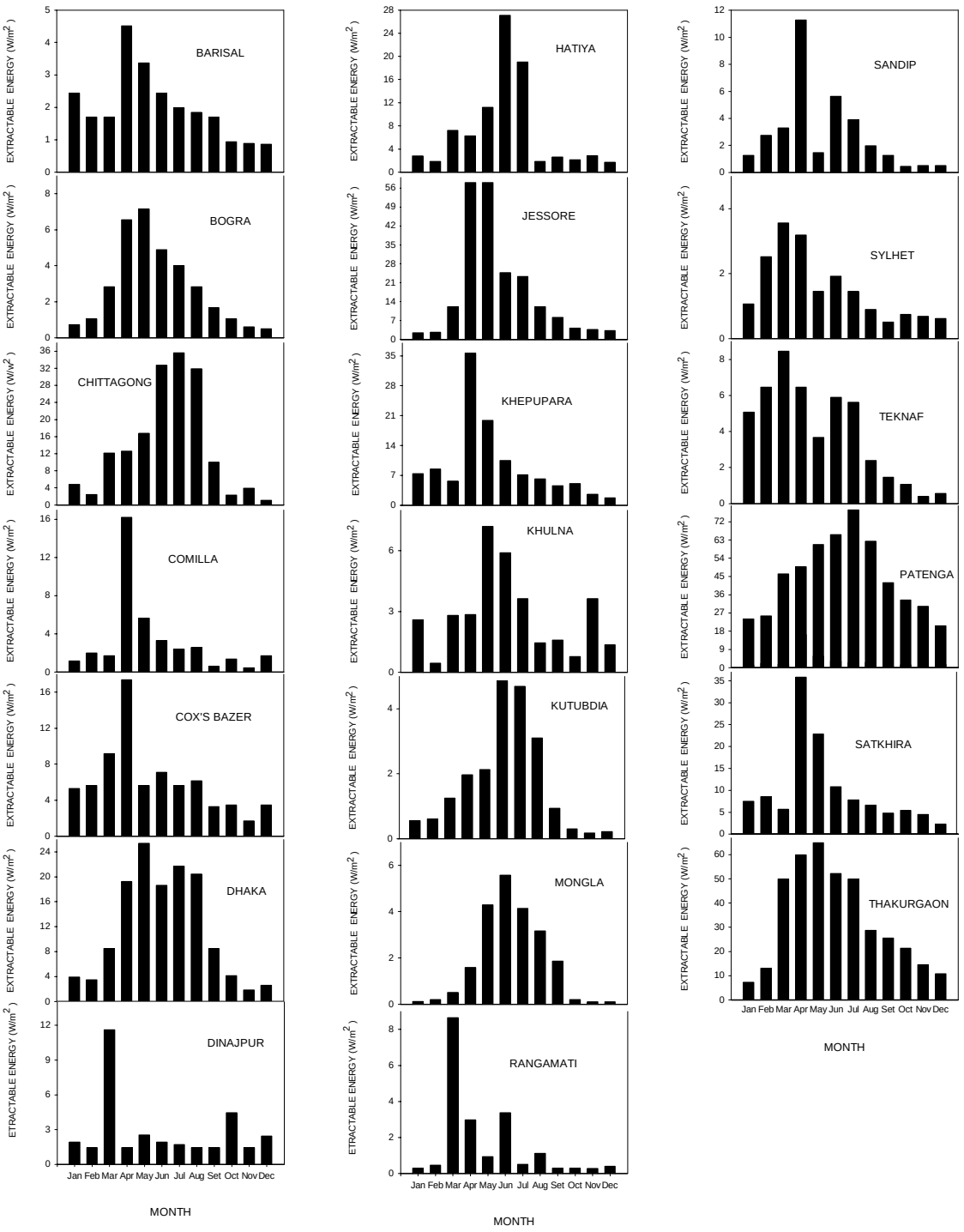

Fig. 3 Monthly Average Extractable Wind Energy at Different Locations