Niğde Üniversitesi Mühendislik Bilimleri Dergisi, Cilt 1 Sayı 1, (2012), 41-49

EVALUATION OF THE STUDIES CARRIED OUT ON WIND CHARACTERISTICS OF THE WESTERN PART OF TURKEY

Afsin Gungor*

Department of Mechanical Engineering, Faculty of Engineering, Nigde University, 51240, Nigde, Turkey.

ABSTRACT

Since the geography of Turkey provides appropriate meteorological conditions for the wind energy generation, it is inevitable to support the wind energy initiatives. In general, potential wind energy areas in Turkey lie in the northwestern and northern parts and at locations along the Aegean Sea coast. These regions are highly suitable for the wind energy generation, since the wind speeds exceed 3 m/s in most of these areas. So, due to the western part of Turkey are highly suitable for wind energy applications, most of researchers have focused mainly on these areas to calculate wind characteristics. This study is aimed to summarize the studies carried out on the parameters of the Weibull distribution function in western part of Turkey.

Keywords: Wind characteristics; Weibull function; Wind energy, Wind data, Turkey, West Anatolia.

BATI ANADOLU RÜZGAR KARAKTERİSTİKLERİ ÜZERİNE YAPILAN ÇALIŞMALARIN DEĞERLENDİRİLMESİ

ÖZET

Türkiye coğrafik konumu nedeniyle farklı hava akımlarının etkisi altında kaldığından, rüzgar enerjisi potansiyeli oldukça yüksek olan bir ülkedir. Türkiye'de potansiyel rüzgar enerjisi alanları genel olarak, Batı Anadolu'nun kuzey, kuzeybatı kısımları ile Ege Denizi sahili boyunca uzanmaktadır. Bu bölgelerde rüzgar hızı çoğunlukla 3 m/s değerinin üzerinde olduğundan yüksek bir rüzgar enerji potansiyeline sahip olduğu anlaşılmaktadır. Bu nedenle pek çok araştırmacı, rüzgar enerjisi karakteristikleri çalışmalarında bu bölge üzerinde yoğunlaşmıştır. Bu çalışma, Batı Anadolu'da Weibull dağılım fonsiyonu üzerinde yapılan çalışmaları özetlemektedir.

Anahtar Kelimeler: Rüzgar karakeristikleri, Weibull fonksiyonu, Rüzgar Enerjisi, Türkiye, Batı Anadolu

1. INTRODUCTION

Energy is essential to economic and social development and improved quality of life in Turkey, as in other countries. Because of the social and economic development of the country, the demand for energy, and particularly for electricity, is growing rapidly. Turkey's total primary energy production covered 35% of the total energy consumption in 2000. In 2020, indigenous primary energy production is expected to be 26%. As seen, the amount of primary energy produced in Turkey is very low at present and in the near future too. The 27,800 MW of installed electric power capacity in 2000 has to be doubled by 2010 and increased four times by 2020 to meet Turkey's growing demand. The annual rate of increase in electricity demand is around 8–10% [1].

In Turkey, thermal power plants, consuming coal, lignite, natural gas, fuel oil and geothermal energy, and hydro power plants produce electricity. A major problem Turkey faces now is to find the most suitable way of

* Corresponding author. Tel.: +90 532 397 30 88; fax: +90 388 225 01 12.
E-mail: afsingungor@hotmail.com

obtaining additional electrical power. The wind energy is one of the most significant and rapidly developing renewable energy sources in the world and it provides a clean energy resource. Turkey has a Mediterranean type of climate extending from the southern coastal plains almost to the northwestern part the country in a modified manner. Due to its geographic position, Turkey is under the influence of different air masses. These air masses give rise to potential wind energy generation possibilities in different areas [2-4].

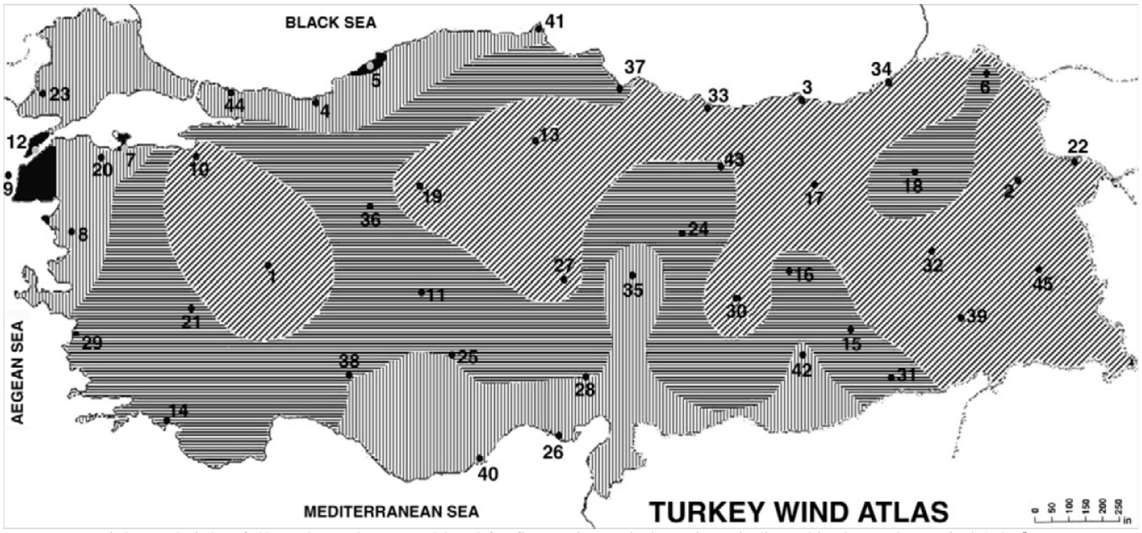
According to the European Wind Atlas, the western Anatolia appears to have good wind energy potential. In the western part of Turkey geomorphological features have long valleys that run perpendicular to the Aegean coast. These are parallel to the cyclonic movements that originate from the Genoa bay and move towards the east and therefore show strong wind effects at the Aegean coast as well as the moving air which penetrates deep in these valleys. Accordingly, many islands in the Aegean Sea such as Bozcaada in the northern Aegean region have high wind power generation possibilities in addition to some suitable locations along the coastal line especially in Cesme on the Anatolian main land. So, due to the western part of Turkey are highly suitable for wind energy applications, most of researchers have focused mainly on these areas to calculate wind characteristics. This study is aimed to summarize the studies carried out on the parameters of the Weibull distribution function in western part of Turkey.

2. WIND ENERGY POTENTIAL AND ITS ASSESSMENT

Electricity generation through wind energy for general use was first realized at the Cesme Altinyunus Resort Hotel (The Golden Dolphin Hotel) in Izmir, Turkey, in 1986 with a 55 kW nominal wind power capacity. Between 1986 and 1996, there were some attempts to generate electricity from wind, but they were never completed. In 1994, the first build-own-transfer (BOT) feasibility study for a wind energy project in Turkey was presented to the Ministry of Energy and Natural Resources (MENR) [5,6]. Apart from the high initial investment costs in harnessing wind energy, lack of adequate knowledge on the wind speed characteristics in the country is the main reason for the failure to harvest energy from the wind. In terms of generating electricity from wind, the development of wind energy in Turkey started in 1998 when some wind plants were installed at several locations in the country. By January 1998, the MENR has received 25 BOT and two auto producer (the production of electricity by industrial facilities for their own use in Turkey, based on the Turkish Trade Law, is called “auto production”) type wind energy project proposals due to a change in government policy concerning wind energy. Currently, wind energy projects are concentrated in the Aegean region (21 projects), the Marmara region (15 projects), the Southeast region (3 projects) and the Black Sea region (1 project). The total capacity of these projects is between 1056 and 1184 MW [7].

As mentioned above, a change in government policy concerning wind energy, leads both to promotion of numerous companies to submit applications for the construction of new wind power plants and to investigation of potential wind energy sites. The commercial companies show the greatest interest in western part of Turkey. Before making plans or programs related to the use of the wind energy, it is necessary to discover the potential of this resource.

Wind atlas, prepared to display areas potentially suitable for energy production from wind energy, describes statistical data on regional mean wind speeds and power densities. There are several wind atlas developed for Turkey since 1984. Oztopal et al. [3] prepared various maps based on 42 wind velocity measurement stations in Turkey and showed the regional variations of wind resource from the available data. According to the maps, the Aegean Sea coast is singled out, having the richest wind energy potential. Sahin [8] studied 68 wind speed measurement stations in Turkey and produces wind velocity exceedence maps over 10, 12, 15, and 20 m/s, and the necessary interpretations were given. These maps showed that especially the western part of Turkey and, particularly, coastal areas are risky locations for structural stability and wind erosion. Dundar et al. [9] have made onsite surveys at 96 meteorological stations distributed homogeneously over Turkey. They evaluated the data gained from 45 stations for the preparation of the Turkey Wind Atlas and drawn the atlas using well-known WASP (Wind Atlas Analysis and Application Program) model used for the European Wind Atlas [10]. Figure 1 illustrates a map of Turkey's various wind regimes drawn by Dundar et al. [9] (observation station in 10 m high). As it is seen from the figure, although there are many regions with significant wind power potential, it has been observed that the most wind potential area is along the Aegean Sea region in the western part of Turkey where most of the current projects are concentrated.



Power potentials at a height of 50 m above the ground level for five various windy regimes indicated in the Turkey Wind Atlas[a].

	Unopen area[b]		Open area[c]		Sea shore[d]		Sea surface[e]		Hills and slopes[f]	
	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400

[a]Wind potential represents the wind power. Wind turbines may utilize between 20–30% of the available potential. The mean air density at sea level is taken to be 1.23 kg/m3 at a temperature of 15◦C.
[b]Agricultural fields concentrated with settlements, forests and wind barriers (roughness class 3).
[c]Open areas having a little amount of wind barriers (roughness class 1).
[d]Smooth sea shores and shores including wind barriers in a very little amount.
[e]Sea surfaces with a distance of minimal 10 km from shores (roughness class 0).
[f] It has been obtained from the calculations based on a symmetrical hill with a height of 400 m and a diameter of 4 km. The increase in wind velocity depends on the height, length and structure of the hill.

Figure 1. Wind map of Turkey [9].

3. CALCULATED WEIBULL PARAMETERS

The effective utilization of wind energy entails a detailed knowledge of the wind characteristics at the particular location. The distribution of wind speeds is important for the design of wind farms, power generators and agricultural applications like irrigation. It is not an easy task to choose a site for a wind turbine because many factors have to be taken into account. The most important factors are wind speed at propeller height, wind energy potential, the generator type and the feasibility study.

The wind speed probability density distributions and the functions representing them mathematically are the main tools used in the wind related literature. Their use includes a wide range of applications, from the techniques used to identify the parameters of the distribution functions to the use of such functions for analyzing the wind speed data and wind energy economics [11]. The general form of the Weibull distribution function, which is a two-parameter function, for wind speed is given in Table 1.

Table 1. Weibull probability density function

Weibull distribution function $$f(v)=\left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1}\exp\left(\left(-\frac{v}{c}\right)^{k}\right)$$	Shape factor $$k=\left(\frac{\sum_{i=1}^{n} v_i^{\,k}\ln(V_i)}{\sum_{i=1}^{n} v_i^{\,k}}-\frac{\sum_{i=1}^{n}\ln(v_i)}{n}\right)^{-1}$$
Weibull cumulative distribution function $$F(v)=1-\exp\left(\left(-\frac{v}{c}\right)^{k}\right)$$	Scale factor (m/s) $$c=\left(\frac{1}{n}\sum_{i=1}^{n} v_i^{\,k}\right)^{1/k}$$
Mean velocity (m/s) $$v_{ort}=c\Gamma\left(1+\frac{1}{k}\right)$$	Gamma function $$\Gamma(x)=\int_0^\infty e^{-t}t^{x-1}dt$$
Wind power density (W/m^2) $$\frac{P}{A}=\int_0^\infty P(v)f(v)dv=\frac{1}{2}\rho c^3\Gamma\left(k+\frac{3}{k}\right)$$	

There are many studies in the literature about western part of Turkey's wind characteristics [2,5,12-20]. It is possible to classify the studies about wind characteristics as follows:

a. Yearly wind characteristics
b. Monthly wind characteristics

3.1. Yearly Wind Characteristics

It is important for the investors to have detailed information about availability of local wind power in order to make use of wind power for generating electricity and to determine the amount of energy to be produced. The first step of this purpose is to provide yearly averaged wind characteristics of appropriate locations accurately. Yearly averaged wind characteristics studies are given in Table 2. As it seen from the Table 2, detailed study has been made on Gokceada in the Northern Aegean Sea which is located in one of the Turkey's richest wind energy potential area, by Tolun et al. [12]. In this study, wind data collected over a period of 3 years at four different locations (Cinaralti, Doruktepe, Ugurlu, National Weather Service (NWS)) were used to estimate the regional mean wind speed distribution of Gokceada. Another study using the Turkish Meteorological Service hourly wind data on Gokceada has been carried out by Incecik and Erdogmus [13] and Sen and Sahin [14], which also covered the whole Western Anatolia coast, including locations such as Ayvalık, Bodrum, Bozcaada, Canakkale, Dikili, Edremit, and Izmir. In addition to the studies of Sen and Sahin [14] on wind characteristics of Izmir, using the Solar/Wind-Meteorological Station of the Solar Energy Institute at Ege University in their study, Ulgen and Hepbasli [5] investigated wind characteristics at Bornova, Izmir. The average seasonal Weibull distributions for Izmir are also given in that study.

Bozcaada Island's wind power potential has been evaluated by Turksoy [15] and the conclusions came out that the average wind speed is 6.4 m/s and the mean energy density is 324W/m^2 at the Bozcaada meteorological station. Inan and Dundar [16] also investigated the wind energy application possibilities for Bozcaada in Turkey. In their study, wind data which were measured hourly at the Bozcaada Meteorological Station at 10 m above the ground level between the years 1975 and 1984 were used. Approximately 68% of total wind speed data were found to be greater than 4.5 m/s as calculated from the observed meteorological wind data. The average of calculated wind speeds at 10 m above the ground level was calculated to be 6.4 m/s.

Ozerdem and Turkeli [17] studied to predicting the wind energy content over the campus area of Izmir Institute of Technology (46.5684 E, 42.43843 N). The wind data were collected at 10 and 30 m mast heights for a period of 16 months. The data were collected on 1 h time intervals for first 6 months. Then, time interval rate was changed to 144 data per day by using 10 min time intervals for the rest of the monitoring period. The missing data were 3.7%. Wind energy maps were created by using collected data, orography and roughness maps. The wind power map was determined in W/m^2 by considering only mean wind speed values. The wind energy map was determined in kWh/m^2 per year. This map considers whole values of Weibull histogram. The wind power map shows eight zones in which wind power value is more than 700 W/m^2. There are also several zones in which annual energy production value is more than 6000 kWh/m^2 per year in the wind energy map. Mean speeds were 7.03 m/s and 8.14 m/s at 10 m and 30 m. respectively. In this study, north was found as prevailing wind direction.

Table 2. Yearly averaged wind characteristics of Turkey

Location	Data	Latitude	Longitude	Height of Anemometer (m)	Weibull Parameters		Mean Wind Speed (m/s)	Wind Energy Potential (W/m^2)
					Scale c (m/s)	Shape k (-)		
Gökçeada [13, 14]	1979-1983	25°54'	40°11'	10	4.67	1.70	4.14	112.88
NWS station-Gokceada [12]	12 months	25°92'	40°74'	10	4.2	1.3	3.8	118
Doruktepe-Gokceada [12]	12 months	25°82'	40°17'	10	9.2	1.7	8.2	767
Ugurlu-Gokceada [12]	12 months	25°73'	40°11'	10	3.8	0.96	3.9	238
Cinaralti-Gokceada [12]	12 months	25°83'	40°20'	10	6.5	1.5	5.9	342
Çanakkale [13, 14]	1979-1983	26°24'	40°08'	10	4.63	1.78	4.13	93.50
Bozcaada [13, 14]	1979-1983	34°02'	41°58'	10	7.15	2.02	6.36	319.50
Edremit [13, 14]	1979-1983	27°01'	39°35'	10	2.73	1.73	2.44	19.80
Ayvalık [13, 14]	1979-1983	26°41'	39°19'	10	3.74	1.57	3.29	59.30
Dikili [13, 14]	1979-1983	26°52'	39°03'	10	2.76	1.73	2.50	20.50
Izmir [13, 14] Bornova-Izmir [5]	1979-1983 1995-1999	27°10'	38°24'	10 15	4.11 1.552	2.13 3.222	3.65 2.805	53.40
Bodrum [13, 14]	1979-1983	27°26'	38°02'	10	4.52	1.49	4.10	114.70
Kutahya [18]	2001-2003 20 months	39°52'	29°80'	30	5.48	1.67	4.62	36.62
Akhisar-Manisa [2]	1997-1998	38°55'	27°51'	10	6.8	1.73	5.8	308.00

Using the measurement mast at Dumlupinar University Main Campus, Kose [18] has concluded the wind energy potential of Kutahya is enough for water pumping applications. Although it is away from the coastal areas, the geomorphological setup of the region provides a preferential situation. The wind energy generation potential is exemplified for Turkey in Akhisar, which lies within the most wind power potential area of Turkey, the Aegean Sea region (the annual wind energy output which varies between 31416 MWh and 41560 MWh according to the calculations and expert views) [2].

3.2. Monthly Wind Characteristics

Determination of monthly averaged wind characteristics for a certain location is an important parameter that forecasts the effectiveness of wind farms in terms of indicating monthly energy production in the course of a year.

Table 3. Monthly wind characteristics in Bornova, Izmir [5]

Izmir, 1995-1999, (15 m)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
k	1.616	1.437	1.645	1.598	1.475	1.563	1.720	1.705	1.551	1.544	1.518	1.544
c	3.514	3.007	3.445	2.432	2.670	3.232	3.893	3.652	3.015	3.272	3.062	3.497
v_m	3.20	2.75	3.10	2.20	2.45	2.90	3.50	3.35	2.70	2.95	2.81	3.20

The maximum likelihood technique as an estimation technique to forecast Weibull parameters was used for Aksehir region in Turkey of year 2002 by Genc et al. [19]. In that study, the average wind speed reaches its maximum value of 2.31 m/s in April, while its maximum value of 1.41 m/s occurs in February. Table 3 gives the monthly average wind characteristics of Bornova, Izmir, of whose yearly wind characteristics were given above.

Table 4. Wind characteristics at three different locations of Gokceada (National Weather Service, Cinaralti, Ugurlu) [12].

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NWS station (10 m)	**k**	1.40	1.80	1.84	2.23	1.62	1.65	2.09	2.33	1.46	1.30	2.51	1.79
	c (m/s)	5.7	6.3	5.4	4.9	3.2	3.6	4.5	5.5	3.9	3.8	6.8	4.5
	v_m (m/s)	2.5	5.6	4.8	4.3	2.9	3.2	4.0	4.8	3.6	3.5	6.0	4.0
	P/A (W/m^2)	260	226	140	86	37	47	70	116	78	93	207	87
NWS station (30 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	1.41	1.81	1.87	2.33	1.73	1.76	2.12	2.35	1.47	1.31	2.58	1.83
	c (m/s)	7.7	8.6	7.3	6.5	4.3	4.6	6.0	7.3	5.3	5.1	9.1	6.2
	v_m (m/s)	7.0	7.6	6.5	5.8	3.8	4.1	5.3	6.5	4.8	4.7	8.1	5.5
	P/A (W/m^2)	620	572	337	195	78	92	169	279	187	217	496	212
NWS station (50 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	1.42	1.82	1.90	2.4	1.81	1.84	2.16	2.39	1.50	1.33	2.62	1.86
	c (m/s)	8.7	9.8	8.3	7.4	5.0	5.2	6.9	8.4	6.1	5.8	10.3	7.0
	v_m (m/s)	7.9	8.7	7.4	6.6	4.4	4.6	6.1	7.4	5.5	5.4	9.2	6.3
	P/A (W/m^2)	895	843	494	287	112	123	250	409	272	313	723	309
Ugurlu (10 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	1.30	1.45	1.34	1.22	1.41	1.53	2.23	3.67	1.42	1.32	1.99	1.44
	c (m/s)	5.8	6.4	5.4	6.1	7.1	9.6	14.6	9.6	4.4	4.3	7.3	6.5
	v_m (m/s)	5.4	5.8	5.0	5.8	6.5	8.6	12.9	8.6	4.0	4.0	6.5	5.9
	P/A (W/m^2)	323	344	248	450	506	1039	2280	500	120	127	323	366
Ugurlu (30 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	1.35	1.50	1.41	1.25	1.45	1.56	2.29	3.85	1.46	1.40	2.06	1.48
	c (m/s)	6.9	7.7	6.6	7.5	8.7	11.6	17.6	12.0	5.6	5.5	9.3	8.2
	v_m (m/s)	6.4	6.9	6.0	7.0	7.9	10.4	15.6	10.8	5.1	5.1	8.2	7.4
	P/A (W/m^2)	508	556	397	775	856	1778	3894	977	232	241	636	692
Ugurlu (50 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	1.36	1.55	1.45	1.27	1.46	1.56	2.28	3.93	1.49	1.44	2.10	1.51
	c (m/s)	7.8	8.6	7.4	8.4	9.7	12.9	19.6	13.3	6.3	6.2	10.4	9.1
	v_m (m/s)	7.2	7.8	6.7	7.8	8.8	11.6	17.3	12.0	5.7	5.7	9.2	8.2
	P/A (W/m^2)	713	742	529	1042	1168	2458	5404	1330	314	325	864	913
Cinaralti (10 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	2.96	N/A	N/A	N/A	1.51	1.65	1.74	3.36	1.32	1.19	2.12	1.49
	c (m/s)	12.9	N/A	N/A	N/A	9.0	8.0	9.8	7.1	4.0	4.4	8.2	5.9
	vm (m/s)	11.5	N/A	N/A	N/A	8.1	7.1	8.7	6.4	3.7	4.2	7.3	5.3
	P/A (W/m^2)	1318	N/A	N/A	N/A	876	529	906	211	102	183	428	251
Cinaralti (30 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	3.17	N/A	N/A	N/A	1.38	1.63	1.68	3.26	1.33	1.20	2.12	1.78
	c (m/s)	17.9	N/A	N/A	N/A	13.4	11.6	13.8	9.9	5.3	6.0	11.0	7.2
	v_m (m/s)	16.1	N/A	N/A	N/A	12.3	10.4	12.3	8.8	4.9	5.7	9.7	6.4
	P/A (W/m^2)	3460	N/A	N/A	N/A	3524	1653	2647	570	235	449	1015	352
Cinaralti (50 m)		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	k	N/A	N/A	N/A	N/A	1.33	1.60	1.67	3.28	1.38	1.23	2.16	1.86
	c (m/s)	N/A	N/A	N/A	N/A	14.9	12.8	15.1	10.9	5.9	6.7	12.0	7.8
	v_m (m/s)	N/A	N/A	N/A	N/A	13.7	11.5	13.5	9.8	5.4	6.3	10.6	7.0
	P/A (W/m^2)	N/A	N/A	N/A	N/A	5150	2300	3518	773	303	572	1360	428

Monthly average Weibull characteristics, average wind speed and wind energy potential based on long-term data at different heights in Gokceada are tabulated in Table 4. The highest monthly average of the scale parameter and wind speed was observed in November, but the highest wind energy was presented in January in National Weather Service Station. The seasonal wind speed analysis indicated that higher values were observed in winter at the NWS which is interior part of the island. In contrast, at the coastal stations Ugurlu and Cinaralti, greater wind speeds were recorded in summer periods because of the etesian winds and air-sea-land interactions [12]. The northern Aegean coast of Turkey and surrounding islands' wind characteristics also were evaluated by Borhan [20].

The hourly wind speed data of 1995-1996 selected winter and summer months were analyzed for predicting the energy output in the region of Gokceada, Bozcaada islands and Canakkale site as higher wind power potential regions (Table 5). These values are valid for 30 m above the ground level. The monthly distribution of wind speed and wind density of Kutahya measured between July 1, 2001 and February 28, 2003 is illustrated in Table 6 [18]. According to these results, it is found that the wind speed was high in winter months, reduced in the autumn and reached its minimum level (3.58 m/s) in October 2002. The wind speed started rising again after this month and reached the value of 6.1 m/s in February 2003. The wind energy density was 79.1 W/m^2 in February 2002 and its minimum level (15.99 W/m^2) was in October 2002.

Table 5. Wind characteristics of Bozcaada, Gokceada, Canakkale regions [20]

		Jul-95	Aug-95	Dec-95	Jan-96	Jul-96	Aug-96	P/A (W/m^2)	
Bozcaada	k	2.83	2.26	1.58	2.31	2.40	2.22	Winter	1109.1
	c (m/s)	6.91	5.72	6.63	7.26	6.04	5.61		
	v_m (m/s)	8.3	7.3	9.7	9.2	7.6	7.2	Summer	425.7
	P/A (W/m^2)	505.6	394.1	1410.9	803.3	421.3	381.7		
		Jul-95	Aug-95	Dec-95	Jan-96	Jul-96	Aug-96	P/A (W/m^2)	
Gokceada	k	1.90	1.83	1.79	1.85	1.63	N/A	Winter	657.7
	c (m/s)	3.83	3.34	5.48	6.14	3.68	N/A		
	v_m (m/s)	5.2	4.6	7.6	8.4	5.3	N/A	Summer	166.9
	P/A (W/m^2)	168.6	120.2	549.6	751.9	211.7	N/A		
		Jul-95	Aug-95	Dec-95	Jan-96	Jul-96	Aug-96	P/A (W/m^2)	
Canakkale	k	2.35	2.19	1.43	2.21	2.39	2.11	Winter	449.2
	c (m/s)	4.26	3.87	4.66	4.52	4.61	3.69		
	v_m (m/s)	5.4	5.0	7.2	5.8	5.8	4.8	Summer	149.5
	P/A (W/m^2)	158.7	131.8	689.6	208.7	186.9	120.5		

Table 6. Monthly distribution of wind speed and wind density of Kutahya [18].

Months	Average Wind Speed (m/s) 10 m	30 m	Energy Density (W/m^2)
Jul-01	4.2	4.58	33.48
Aug-01	4.2	4.55	32.82
Sep-01	3.9	4.23	26.37
Oct-01	3.9	4.31	27.90
Nov-01	4.7	5.12	46.77
Dec-01	4.8	5.71	64.88
Jan-02	4.0	4.50	31.75
Feb-02	4.0	4.34	28.48
Mar-02	4.7	4.96	42.52
Apr-02	4.2	4.50	31.75
May-02	4.1	4.36	28.88
Jun-02	4.8	5.13	47.05
Jul-02	4.1	4.41	29.89
Aug-02	3.9	4.12	24.37
Sep-02	3.5	3.67	17.22
Oct-02	3.4	3.58	15.99
Nov-02	3.7	4.10	24.01
Dec-02	3.9	4.30	27.70
Jan-02	5.5	5.90	71.57
Feb-02	5.8	6.10	79.10

4. RESULTS

The western Anatolia appears to have good wind energy potential. In the western part of Turkey geomorphological features have long valleys that run perpendicular to the Aegean coast. These are parallel to the cyclonic movements that originate from the Genoa bay and move towards the east and therefore show strong wind effects at the Aegean coast as well as the moving air which penetrates deep in these valleys. Accordingly, many islands in the Aegean Sea such as Bozcaada in the northern Aegean region have high wind power generation possibilities in addition to some suitable locations along the coastal line especially in Cesme on the Anatolian main land. On the other hand, although Akhisar is away from the coastal areas, the geomorphological setup of the region provides a preferential situation. So, due to the western part of Turkey are highly suitable for wind energy applications, most of the current projects have concentrated and researchers have focused mainly on these areas to calculate wind characteristics.

The effective utilization of wind energy entails a detailed knowledge of the wind characteristics at the particular location. The wind characteristics for a typical site are usually described using the so-called Weibull distribution. In this regard, over the last decade, there are many studies in the literature about western parts of Turkey's wind characteristics.

Wind data time periods vary to among the researchers, there is not a common time period. For example, some researchers used only collected wind data of one-year. The measurements should be evaluated in the long term in accordance with technological developments (The requirement for the data collected from an observation station to determine the wind energy potential is that the data have to be measured for a period of at least 1-year, but 2 or more years will produce more reliable results. So, it is preferable to have the wind speed data for 5 years, if the case is applicable).

Wind energy will play an important role in future energy needs. However, the potential sites of wind energy generation of the western part of Turkey have not been completely investigated in detail yet. In order to provide a broad wind resource assessment over the western part of Turkey, the wind characteristics must be studied in detail at each site separately.

REFERENCES

[1] GUNGOR, A., ESKIN, N., "The Characteristics that Define Wind as an Energy Source", Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 30 (9), 842-855. 2008.
[2] DURAK, M., SEN, Z., "Wind power potential in Turkey and Akhisar case study", Renewable Energy, 25, 463–472. 2002.
[3] OZTOPAL, A., SAHIN, A.D., AKGUN, N., SEN, Z., "On the regional wind energy potential of Turkey", Energy, 25, 189–200. 2000.
[4] UYAR, S.T., MOLLY, J.P., "Wind energy in Turkey", DEWI Magazine, 13. 2002.
[5] ULGEN, K., HEPBASLI, A., "Determination of weibull parameters for wind energy analysis of Izmir, Turkey", Int. J. Energy Research, 26, 494-596. 2002.
[6] OZGENER, O., HEPBASLI, A., "Current status and future directions of wind energy applications in Turkey", Energy Sources, 24, 1117–1146. 2002.
[7] KENISARIN, M., KARSLI, V.M., CAGLAR, M., "Wind power engineering in the world and perspectives of its development in Turkey", Renewable and Sustainable Energy Reviews, 1-29. 2004.
[8] SAHIN, A.D., "Hourly wind velocity exceedence maps of Turkey", Energy Conversion and Management, 44, 549–557. 2003.
[9] HEPBASLI, A., OZGENER, O., "A review on the development of wind energy in Turkey", Renewable and Sustainable Energy Reviews, 8, 257–276. 2004.
[10] TROEN, I., PETERSEN, E.L., "European wind atlas", Roskilde: Riso National Laboratory. 1989.
[11] CHANG, T.J., WU, Y.T., HSU, H.Y., CHU, C.R., LIAO, C.M., "Assessment of wind characteristics and wind turbine characteristics in Taiwan", Renewable Energy, 28, 851–871. 2003.
[12] TOLUN, S., MENTES, S., ASLAN, Z., YUKSELEN, M.A., "The wind energy potentials of Gökçeada in the Northern Aegean Sea", Renewable Energy, 6/7, 879-685. 1995.
[13] INCECIK, S., ERDOGMUS, F., "An investigation of the wind power potential on the Western Coast of Anatolia", Renewable Energy, 6/7, 863–868. 1995.

[14] SEN, Z., SAHIN, A., "Regional assessment of wind power in western Turkey by the cumulative semivariogram method", Renewable Energy, 12/2, 169-177. 1997.
[15] TURKSOY, F., "Investigation of Wind Power Potential at Bozcaada, Turkey", Renewable Energy, 6/8, 917–923. 1995.
[16] INAN, D., DUNDAR, C., "Investigation of wind energy application possibilities for a specific island (Bozcaada) in Turkey", Renewable Energy, 9, 822–6. 1996.
[17] OZERDEM, B., TURKELI, H.M., "Wind energy potential estimation and micrositting on Izmir Institute of Technology Campus, Turkey", Renewable Energy, 30, 1623-1633. 2005.
[18] KOSE, R., "An evaluation of wind energy potential as a power generation source in Kutahya, Turkey", Energy Conversion and Management, 45, 1631-1641. 2004.
[19] GENC, A., ERISOGLU, M., PEKGOR, A., OTURANC, G., HEPBASLI, A., ULGEN, K., "Estimation of wind power potential using Weibull distribution", Energy Sources, 27, 809-813. 2005.
[20] BORHAN, Y., "Mesoscale interactions on wind energy potential in the Northern Aegean region: a case study", Renewable and Sustainable Energy Reviews 2, 353-360. 1998.