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Developing Wind Energy in Turkey

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1. Introduction

An important portion of the world's electrical energy requirement in today has been supplied by thermal power plants that use fossil fuels. The increasing negative effects of fuels based on carbon that are non-renewable in recent years have forced the scientists to draw attention to clean energy sources that are both environmentally more suitable and renewable such as wind, solar, biomass, and geothermal energy. Actually, the wind power has played a long and important role in the history of civilization. Wind energy has been utilized by mankind for thousands of years. Since earliest recorded history, wind power has been used to drive ships, pump water and grind grain. However, the use of wind turbines to generate electricity can be traced back to the late nineteenth century with windmill generator constructed in the US. In spite of technical advances and the enthusiasm, among others, there was little sustained interest in wind generation until the price of oil rose dramatically in 1970s. The sudden increase in the price of oil stimulated a number of substantial research, development and demonstration. The wind technology was gradually improved since the early 1970s. By the end of the 1990s, wind energy has re-emerged as one of the most important renewable energy resources (Burton et al, 2001). The cost of wind electricity production cost has been gradually decreasing with improving technology.

At present, wind energy has been widely used to produce electricity in many countries in America, Asia and especially Europe Continent. According to 2009. data, total installed wind power capacity in the world is reached 160,084 MW by increase 31% compared to 2008 year. US, 22% of the global wind capacity, is worldwide the leading wind energy country. US have 35159 MW installed capacity. Electricity generation from wind power is projected to reach 4.5% of total electricity generation in 2030. worldwide, compared with less than 1% in 2007. Wind power is projected to soon become the most significant source of renewables-based electricity after hydropower, ahead of biomass (World Energy Outlook, 2009.).

Turkey as a bridge between Europe and Asia Continent has been developing both economically and technologically day-by-day. Electrical energy in Turkey is mainly produced by thermal and hydroelectric power plants. Because of limited energy sources, Turkey is heavily dependent on imported oil and gas. The primary energy consumption of Turkey is about 90.1 million tons of equivalent oil (Mtep) according to 2009. records (BP Statistical Review of World Energy, 2010.). Utilization of renewable energy as indigenous source in the electricity generation is an important fact for Turkey in terms of both security of energy supply and environmental concerns. When it comes to Turkey' s situation pertaining to wind energy exploitation, it can be seen that Turkey is rather unsuccessful in using its potential (Gökçek et al., 2007.). Technical potential in Turkey in terms of wind

power is about 83,000 MW. In spite of this potential, Turkey' s wind energy installed capacity was about 802 MW at the end of 2009. (TWEU, 2010). Considerable wind source in Turkey must be used by taking into account both environmental and economic concerns.
In this study, the wind-electricity status in Turkey is investigated and according to the recent developments on wind utilization in the world, the wind Turkey' s wind energy potential is considered. In addition, a case study was carried out for both wind characteristics and wind energy production.

2. Energy situation of world

The total primary energy demand of the world in 2007. was realized as 12,013 Mtep in 2007. This energy demand in the Reference Scenario is projected to increase by 1.5% per year between 2007. and 2030., reaching 16,790 Mteo—an overall increase of 40% (World Energy Outlook, 2009). This increase is smaller than previous prediction due to the impact of financial and economic crisis on demand growth in early of the projection period. The demand declines by 0.2% per year in 2007.-2010., because of a significant drop in 2009. The fossil fuels remain the dominant sources of primary energy worldwide, accounting for almost 77% of the overall increase in energy demand between 2007. and 2030. Oil that is a pollution fuel was the largest fuel in primary energy sources in 2007. Coal was also second largest fuel this energy sources in 2007. Renewables' share in the energy mixing was realized as 1514 Mteo in 2007. The contribution of renewable sources will be increased in future, especially wind energy.

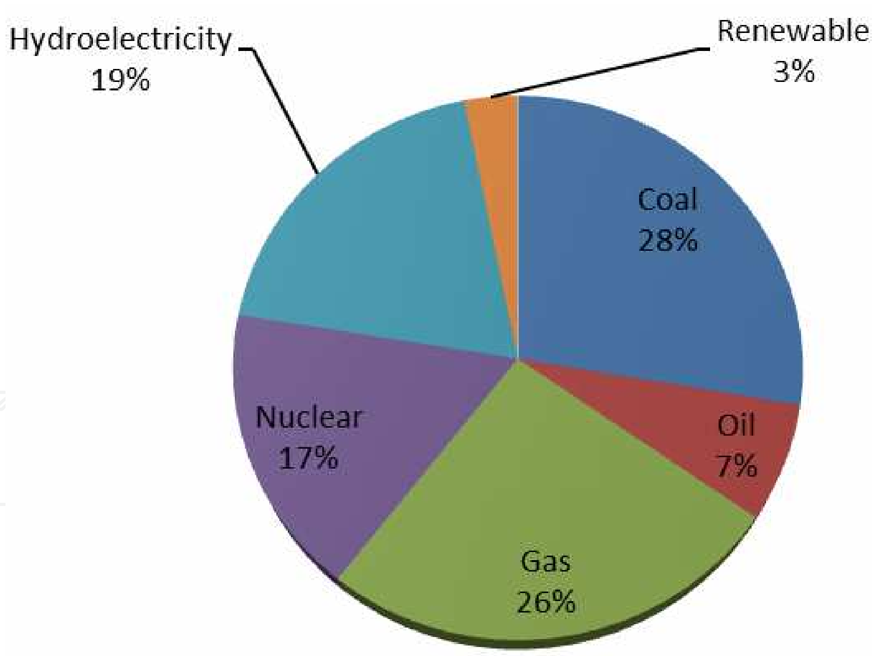

Fig. 1. Global electricity production according to the source distribution in 2007.

The electrical energy production of the world in 2007. was 19,756 TWh and it is estimated that the world will consume 34,292 TWh in 2030. The wind share of the total energy production was also 173 TWh in 2007. It is expected that wind electricity production will have 1535 TWh in 2020. (World Energy Outlook, 2009.). Figure 1 shows the electricity production from different sources in 2007.

3. Energy situation of Turkey

The main purpose of energy policy in Turkey is to supply the sufficient energy to the utilization taking to account environmental and economic aspects by supporting the economical growing and social development (EÜAŞ Sector Report, 2008). Mainly components of Turkey's energy policy are given as follows;

- Raising of security of energy and kinds of energy
- Maintaining of the reform studies that is need for sector
- Supplying of increase for the investments in the all areas of the energy sector by taking into account the environmental aspects
- Playing an active role for trading and carrying of hydrocarbons by complying with concept of energy terminal and passage

Turkey purposes the realization of the development targets, rising of national advancement, international achievement of industrial sector. To do this, energy demand in Turkey is gradually growing. In future, to be continuing the trend of growing has been calculating.

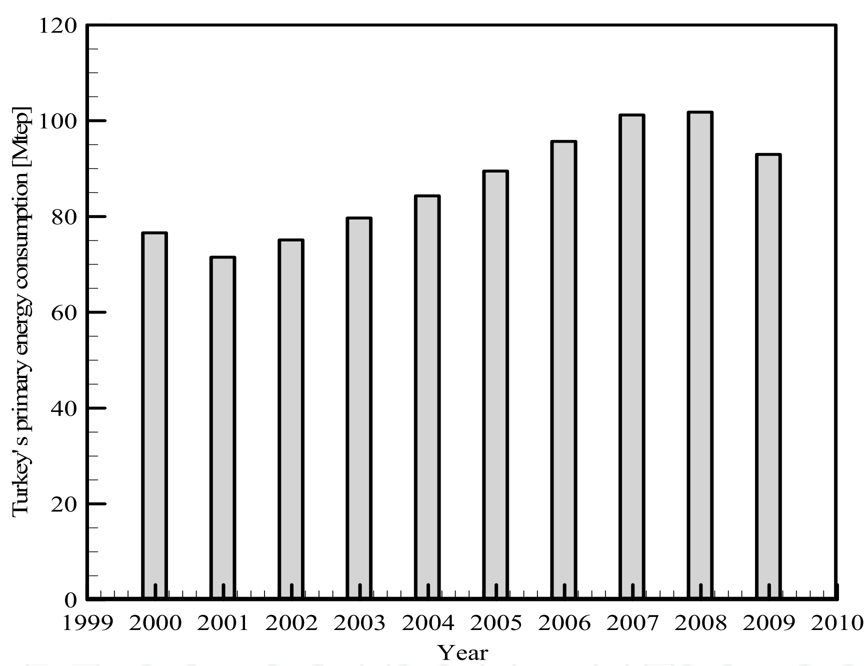

Fig. 2. The annual variation of primary energy consumption in Turkey

Turkey's gross electricity consumption in 2008. was realized as 191.8 billion kWh. It was realized as 193.3 billion kWh with a decrease about 2.42% in 2009. when compared to 2008. Electricity production was also realized as 194.1 billion kWh with a decrease about 2.02% in 2009. when compared to the values of 2008. that is 198.4 billion kWh. It is expected that consumption of electricity in 2020. will be 488 TWh according to higher demand scenario and 406 TWh according to the lower demand scenario. The installed power of electricity capacity in Turkey has reached 44600 MW in the end of 2009. (MENR, 2010).

Turkey's primary energy sources include natural gas, coal, oil, hydraulic, geothermal, wood, waste, solar and wind. The primary energy consumption of Turkey was realized as about 93 Mtep (Oil 31%, Natural gas 31%, Coal 29%, Hydroelectric 9%) in 2009 (BP Statistical Review of World Energy, 2010). The annual variation of primary energy consumption in Turkey is shown in Fig.2.

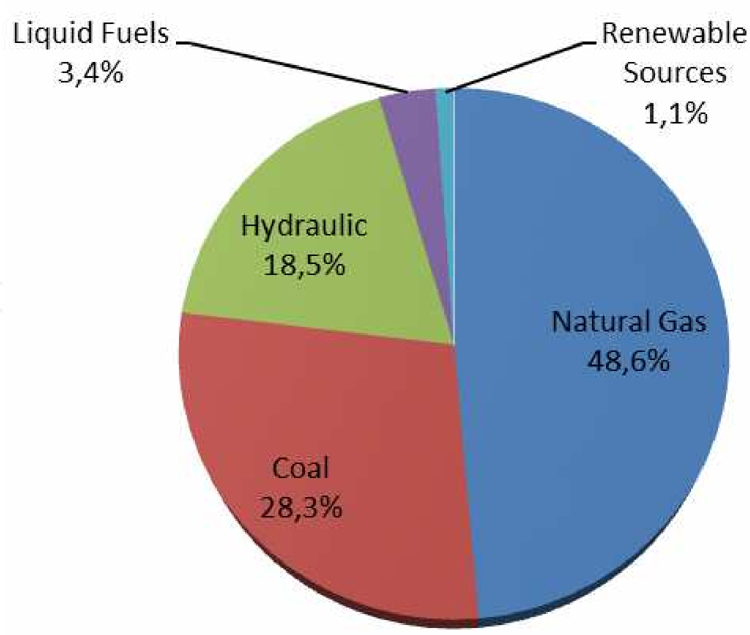

Fig. 3. Share of energy sources for electricity production in Turkey in 2009.

Turkey' s primary energy consumption is shown in Fig. 3 (MENR, 2010.). As shown in the figure, mainly primary energy source to generate electrical energy in 2009. is natural gas that is imported.

4. Global status of wind energy usage

Total installed wind power capacity reached up to 157,899 MW at the end of 2009. in the world (GWEC, 2010.).

Countries	Capacity (MW)	%
US	35,159	22.3
Germany	25,777	16.3
China	25,104	15.9
Spain	19,149	12.1
India	10,926	6.9
Italy	4,850	3.1
France	4,492	2.8
United Kingdom	4,051	2.6
Portugal	3,535	2.2
Denmark	3,465	2.2
Total top 10	136,508	86.5
Rest of the world	21,391	13.5
World total	157,899	100

Table 1. Top 10 cumulative capacity in the world in 2009.

Fig. 4. shows installed wind power capacity in the world between 2000. and 2009. There is a tremendous increasing trend in installed wind energy over this period. It is estimated that installed wind power will be reached in 600 GW in 2030. (GWEC, 2010.). US has the highest

installed wind capacity with 35,159 MW which is equal the 22% of world installed capacity as shown in Table 1 (GWEC, 2010.). The new additions to the global wind capacity are being continuously made in the aware of clean energy production. 34.7% of these new additions were made in China. The US with 26.5% addition ratio is in the second order. Germany being the member of Europe Union among the countries in world Top 10 has the biggest installed capacity whose is 25,777 MW. The biggest share of global wind energy capacity is held by Europe at 48%. The bulk of Europe's wind energy capacity has been concentrated in three countries, Germany, Spain and Italy, which are now home to 39 per cent of all capacity in Europe. Turkey had a share of 0.01% in Europe' s installed capacity at the end of 2009. By the end of 2009 global wind energy installation as continental is shown in Fig. 5.

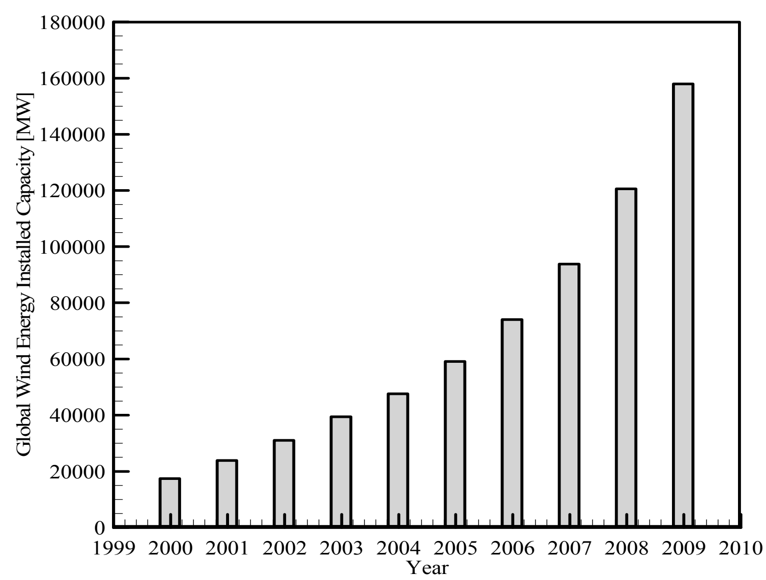

Fig. 4. The annual variation of global cumulative installed wind capacity

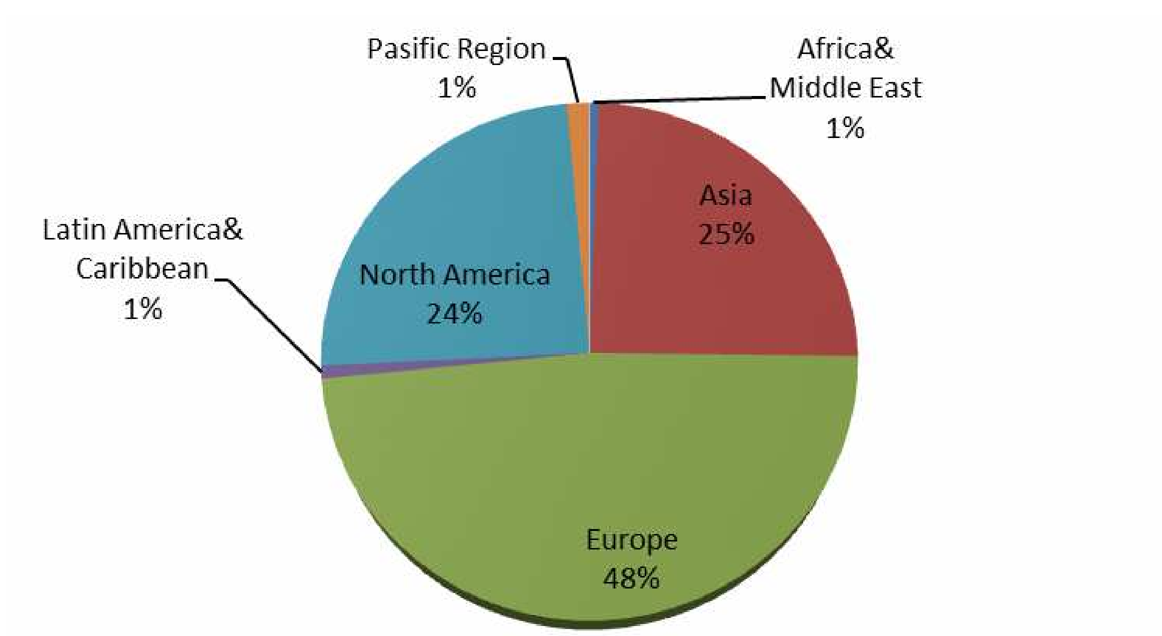

Fig. 5. Usage of wind power as continental.

Wind energy is now an important player in the world's energy markets. The growth of the Europe wind energy sector has also recently been reflected in other continents, most particularly in China, India and the US. In 2008., over 11 GW of new wind capacity was installed outside Europe, bringing the global total up to about 158 GW. In terms of economic value, the global wind market was worth about €25 billion in 2007. in terms of new generating equipment (EWEA, 2009.). China was the world's largest market in 2009., nearly doubling its wind generation capacity from 12.104 GW in 2008 to 25.104 GW at the end of 2009. with new capacity additions of 13 GW (GWEC, 2010.).

5. Wind energy potential and its usage in Turkey

Turkey is a country that is located between Europe and Asia like a bridge and surrounded by seas around three sides. The large part of the land of Turkey is in Asia and the small part called as Thrace is in Europe (Gökçek et al., 2007.). Turkey possesses neither large fossil fuel nor natural gas reserves. Therefore, Turkey to meet the energy necessity is the sources importing country and almost all of the petroleum and natural gas needed is imported. Energy consumption in Turkey is increasing parallel to the technological development as became a developing country. Electricity is produced by hydro power plants and thermal power plants used fossil fuels in Turkey.

Region	Annual mean wind speed (m/s)	Annual mean power density (W/m^2)
Marmara	3.29	51.91
Aegean	2.65	23.47
Mediterranean	2.45	21.36
Middle Anatolia	2.46	20.14
Black Sea	2.38	21.31
Eastern Anatolia	2.12	13.19
South-Eastern Anatolia	2.69	29.33

Table 2. Average wind power densities and speeds on a regional basis

Hydro electricity production is varied whether became dry of weather. Wind energy that is a renewable energy source is also among the other sources that must be investigated very seriously. Turkey has an important wind energy potential especially in the Aegean region, the Marmara region coasts of western and southern Anatolia. The study of geographical distribution of wind speeds, characteristic parameters of the wind, topography and local wind flow and measurement of the wind speed are very essential in wind resource assessment for successful application of the wind energy systems (Herbert et al., 2007.). According to the data of the General Directorate of State Meteorological Studies, Turkey's annual mean wind speed is 2.58 m/s and wind power density is 25.82 W/m^2 (Kaygusuz, 2010.). Mean wind speed and annual power density for Turkey are listed in Table 2.

One of the foundations to fulfill the studies related to determination of wind energy potential in Turkey is EIEI (Electrical Power Resources Survey and Development

Administration). Studies on determining wind energy potentials of windy areas are gaining importance. Table 3 is listed the wind speeds at 10 m height above the ground level taken from wind observation station of EIEI for various locations (EIEI, 2010.). According to the "Turkey Wind Map", prepared by EIEI, wind speed at 50 m height and outside the residential areas, at Marmara, West Black sea, and East Mediterranean coasts and inner parts of these regions are 6.0−7.0, 4.5−5.0 m/s, respectively. Fig. 6. shows the wind speed scattering in 30 m high in Turkey (İlkılıç & Turkbay, 2010.). Yearly mean power density for 50 m is shown in Fig.7. (Akdağ & Güler, 2010.). Compared to seven regions of the country, wind power densities are seemed to be higher at Marmara, Aegean and South-East Anatolia. Wind speeds are therefore higher at these three regions. In addition, meteorological data by the US space studies have been shown that Turkey has high wind capacity.

Location	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Bababurnu	6.1	6.2	5.9	5.1	4.3	5.5	5.7	6.2	4.9	5.0	5.3	6.1	5.5
Belen	5.6	5.6	5.6	5.8	6.6	8.5	10.4	10.5	7.8	5.0	4.8	5.1	6.8
Datca	5.1	5.8	5.8	5.3	5.1	6.3	7.1	7.0	6.3	5.4	4.2	5.1	5.7
Kocadag	8.8	9.1	9.1	7.2	7.0	7.8	8.9	8.6	7.4	7.9	7.9	10.0	8.3
Karabiga	7.5	6.7	7.0	5.1	5.4	5.2	6.8	7.1	6.4	7.4	7.3	6.9	6.7
Nurdagı	4.0	4.7	5.5	6.3	6.7	9.7	13.4	12.0	8.9	4.7	3.6	3.5	7.3
Senkoy	7.1	7.5	8.9	8.0	6.7	8.1	9.8	7.9	6.9	6.3	7.6	6.5	7.7
Gokceada	7.5	7.5	7.6	6.2	6.0	5.5	6.7	7.1	5.6	6.9	6.7	8.4	7.0
Akhisar	5.4	6.0	6.4	4.9	5.5	7.1	8.5	8.4	5.7	5.6	5.3	6.1	6.2
Foca	5.2	5.6	5.4	4.5	4.7	5.5	5.5	6.0	4.9	5.1	4.7	6.2	5.3
Gelibolu	7.1	7.0	6.9	5.2	5.6	5.8	6.0	7.3	6.2	6.4	6.5	7.8	6.5
Bodrum	5.7	6.9	7.0	6.4	5.7	6.2	6.1	6.2	5.9	5.8	5.1	6.6	6.1

Table 3. Monthly and annual mean wind speeds (m/s) from the observation station of EIE.

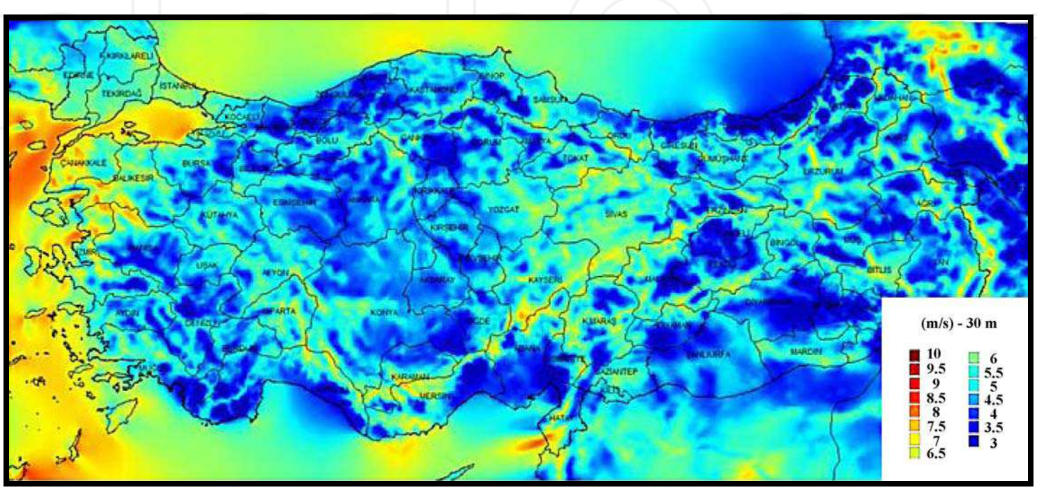

Fig. 6. Distribution of wind velocity in 30 m high.

It is estimated that Turkey’ s technical wind energy potential is 88,000 MW, economical potential is approximately 10,000 MW depending on the technical condition. The EIE’ s wind atlas reported that, Turkey’ s technical wind energy potential was 83,000 MW, production potential was 166 TWh/year.

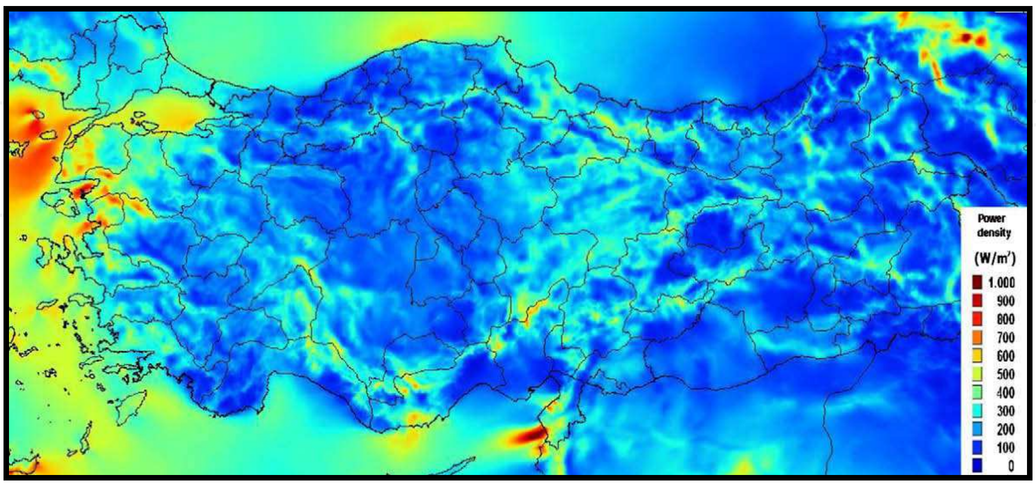

Fig. 7. Yearly mean power density for 50 m.

The first law on the use of Renewable Energy Resources for the Generation of Electrical Energy was enacted in May 2005. Electricity produced by renewable sources is supported by this law. Tariff of the law was increased slightly to €5 – 5.5 ct/kWh by a revision of the law in May 2007. (Saidur et al., 2010.). Although the level of support is low in comparison with other European countries, the production licence to the private sector companies is given by EPDK the ARES wind farm was built in Cesme-Alacatı and it includes 12x600 kW wind turbines.

Fig. 8. A wind power plant in Çeşme-Alaçatı

First small-scale application to generate electrical energy in Turkey was started with a plant that has 55 kW installed power at Altinyunus Hotel in Izmir – Cesme in the Aegean region in 1986. The first power plant in large-scale was also installed in 1998. Cesme- Germiyan with 1.74 MW capacity. In 1998, the ARES wind farm was built in Cesme-Alacat and includes 12x600 kW wind turbines. Fig. 8. shows the wind power plant in Cesme-Alacat . The biggest wind energy power plant that is constructed in Osmaniye-Bahçe in Turkey in 2009. has 95 MW capacitiy. Current wind energy project in Turkey is listed in Table 4.

Wind power projects under operation in Turkey					
Location	Company	Installed Capacity(MW)	Commissio-ning Date	Turbine Manufacturer	Turbine Capacity and Number
İzmir-Çeşme	Alize Corp.	1.50	1998	Enercon	0.5x3
İzmir-Çeşme	Ares Corp.	7.20	1998	Vestas	0.6x12
İstanbul-Hadımköy	Sunjüt Corp.	1.20	2003	Enercon	0.6x2
Balıkesir-Bandırma	Yapısan Corp.	30.00	2006	GE	1.5x20
İzmir-Çeşme	Mare Corp.	39.20	2006	Enercon	49
İstanbul-Silivri	Teperes Corp.	0.85	2007	Vestas	0.85x1
Çanakkale-İntepe	Anemon Corp.	39.40	2007	Enercon	0.8x38
Manisa-Akhisar	Deniz Corp.	10.8	2007	Vestas	1.8x6
Çanakkale-Gelibolu	Doğal Corp.	14.90	2007	Enercon	0.8x13 and 5x0.9
Manisa-Sayalar	Doğal Corp.	34.20	2008	Enercon	0.9x38
İstanbul-Çatalca	Ertürk Corp.	60.00	2008	Vestas	3x20
İzmir-Aliağa	İnnores Corp.	57.50	2008	Nordex	2.5x23
İstanbul-GOP	Lodos Corp.	24.00	2008	Enercon	2x12
Muğla-Datça	Dares Corp.	29.60	2008	Enercon	0.9x37
Hatay-Samandağ	Deniz Corp.	30.00	2008	Vestas	2x15
Aydın-Didim	Ayen Corp.	31.50	2009	Suzlon	2.1x15
Balıkesir-Şamlı	Baki Corp.	90.00	2009	Vestas	3x30
Hatay-Belen	Belen Corp.	30.00	2009	Vestas	3x10
Tekirdağ-Şarköy	Alize Corp.	28.80	2009	Enercon	2x14 and 1x0.8
İzmir-Urla	Kores Corp.	15.00	2009	Nordex	2.5x6
Çanakkale-Ezine	Alize Corp.	20.80	2009	Enercon	2x10 and 0.8x1
Balıkesir-Susurluk	Alize Corp.	20.70	2009	Enercom	0.9x23
İzmir-Çeşme	Mazı-3 Corp.	30.00	2009	Nordex	2.5x12
Balıkesir -Bandırma	Akenerji Corp.	15.00	2009	Vestas	3x5
Balıkesir -Bandırma	Borasco Corp.	45.00	2009	Vestas	3x15
Osmaniye-Bahçe	Rotor Corp.	95.00	2009	GE	2.5x55
Manisa-Soma	Soma Corp.	49.50	2010	Enercom	0.9x55
Balıkesir -Bandırma	As MaksanCorp.	24.00	2010	Nordex	3x8
Mersin-Mut	Akdeniz Corp.	33.00	2010	Vestas	3x11
Çanakkale-Bozcada	Bores Corp.	10.20	2000	Enercon	0.6x17
İzmir-Aliağa	Bergama Corp.	90.00	2010	Nordex	2.5x36
Edirne-Enez	Boreas Corp.	15.00	2010	Nordex	2.6x6
Total Operating Capacity		1029.85			
Projects Under Construction and to be Commmissioned in 2010					
Balıkesir-Havran	Alize Corp.	16.00	2010	Enercon	2.0x8
Manisa-Kırkağaç	Alize Corp.	25.60	2010	Enercon	0.8x32
Osmaniye-Bahçe	Rotor Corp.	45.50	2010	GE	2.5x18
Osmaniye-Bahçe	Rotor Corp.	60.00	2010	GE	2.5x24
Osmaniye-Bahçe	Rotor Corp.	50.00	2010	GE	2.5x20
Manisa-Soma	Soma Corp.	90.90	2010	Enercon	0.9x33,2x29,0.8x4
İzmir-Aliağa	Doruk Corp.	30.00	2010	Enercon	2.0x15
Manisa-Soma	Bilgin Corp.	90.00	2010	Nordex	2.5x36
Hatay-Samandağ	Ziyaret Corp.	35.00	2010	GE	2.5x14
İzmir-Bergama	Ütopya Corp.	15.00	2010	GE	2.5x6
Balıkesir- Bandırma	Kapıdağ Corp.	34.85	2010		
Total Operating Capacity		492.85			

Table 4. Wind Power Plant Projects in Turkey in 2010.

There are also some wind power projects established by private sector to supply their electrical energy needs. Table 1. is listed the wind power plant projects in Turkey in 2010. Installed wind power capacity for electrical energy production is shown in Fig. 9. It is expected that total wind energy installed capacity will have reached 1522.7 MW by the end of 2010.

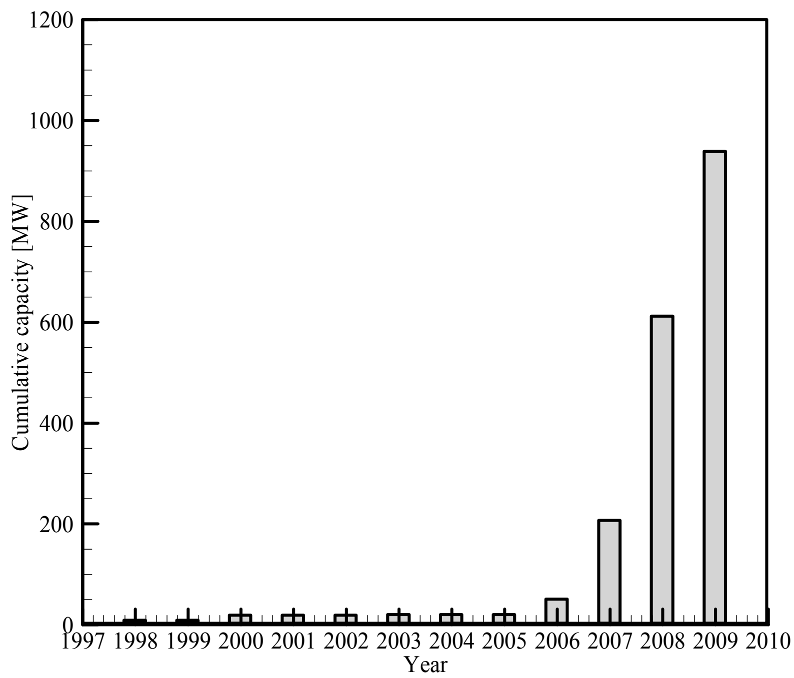

Fig. 9. Installed wind power capacity for electrical energy production in Turkey

6. Prediction of the wind characteristics

Determining of wind energy potential for the selected site is made by investigating detailed knowledge of the wind characteristics, such as speed, direction, continuity, and availability. Thus, proper wind turbine selection and micrositting process for the wind power plants are obtained. Knowledge of the wind speed distribution is a very important factor to evaluate the wind potential in the windy areas. In addition to speed distribution, meteorological data and topographical information for considered site have same importance. If ever the wind speed distribution in any windy site is known, the power potential and the economic feasibility belonging to the site can be easily obtained. Wind data obtained with various observation methods has the wide ranges. Therefore, in the wind energy analysis, it is necessary to have only a few key parameters that can explain the behavior of a wide range of wind speed data. The simplest and most practical method for the procedure is to use a distribution function. There are several density functions, which can be used to describe the wind speed frequency curve. The most common two are the Weibull and Rayleigh functions (Gökçek et al., 2007.a).

6.1 Weibull and Rayleigh distribution function

The Weibull distribution function that is a special case of generalized gamma distribution for wind speed is expressed with Eq. (1)

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

where v is the wind speed, c is a Weibull scale parameter in m/s and k is a dimensionless Weibull shape parameter. Besides, the cumulative probability function of the Weibull distribution is calculated as below

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

There are several methods of determining Weibull k and c parameters, such as least-square fit to observed distribution method, mean wind speed-standard deviation method etc. In this study, the two parameters, k and c, are obtained using Eq. (3) and (4), namely using mean wind speed-standard deviation method (Justus et al., 1977.).

$$k = \left(\frac{\sigma}{\overline{v}}\right)^{-1.086} \quad (1 \le k \le 10) \tag{3}$$

$$c = \frac{\overline{v}}{\Gamma\left(1 + \frac{1}{k}\right)} \tag{4}$$

where $\overline{v}$ is the mean wind speed and is calculated using Eq. (5), σ is the standard deviation and is calculated using Eq. (6)

$$\overline{v} = \frac{1}{n}\left(\sum_{i=1}^{n} v_i\right) \tag{5}$$

$$\sigma = \left[\frac{1}{n-1}\sum_{i=1}^{n}\left(v_i - \overline{v}\right)^2\right]^{0.5} \tag{6}$$

where n is the number of hours in the period of the considered time such as month, season or year. Another distribution function used in determination of the wind speed potential is Rayleigh distribution. This distribution is a special case of Weibull distribution and validate situation where the dimensionless shape parameter k of the Weibull distribution is assumed to be equal to 2. Probability density and cumulative function of the Rayleigh distribution are given by Eq. (7) and Eq. (8), respectively,

$$f_R(v) = \frac{\pi v}{2\overline{v}^2} \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v}{\overline{v}}\right)^2\right] \tag{7}$$

$$F_R(v) = 1 - \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v}{\overline{v}}\right)^2\right] \tag{8}$$

6.2 Calculation of wind power

The wind power per unit area in any windy site is of importance in assessing of the wind power projection for the power plants. The wind power density of the considered site per unit area based on any probability density function can be expressed as (Gökçek et al., 2007.)

$$P_m = \frac{1}{2}\rho\int_0^{\infty} v^3 f(v)dv \tag{9}$$

where ρ is the standard air density, 1.225 kg/m3, v is the wind speed, m/s. In the current study, the power of the wind was calculated using Weibull function and observed data. When the Weibull function is chosen as distribution function f(v), the average wind power density is calculated as below

$$P_{mw} = \frac{1}{2}\rho \bar{v}^{3} \frac{\Gamma(1+3/k)}{\left[\Gamma(1+1/k)\right]^3} \tag{10}$$

7. Calculation of electrical power output from a wind turbine

Annual energy production (AEP, Ep) for the potential site can be calculated using the wind speed data belongs to that site and the power curves regarding the wind turbines that selected [1,20]. The method of calculation requires combining the power curve of turbine considered with the wind speed data prepared in the form of time-series. An algebraic equation of degree n according to the power curve of the wind turbine between cut-in and rated speed or cut-in speed and cut-out speed can be formed as shown Eq. (11), to predict the wind energy output from the wind turbine (Gökçek et al. 2007.b).

$$P_i(v) = \begin{cases} 0, & v < v_{ci} \\ \left(a_n v^n + a_{n-1} v^{n-1} + \ldots + a_1 v + a_0\right), & v_{ci} \le v < v_R \\ P_R, & v_R \le v < v_{co} \text{ or} \\ \left(a_n v^n + a_{n-1} v^{n-1} + \ldots + a_1 v + a_0\right), & v_{ci} \le v < v_{co} \\ 0, & v \ge v_{co} \end{cases} \tag{11}$$

where a_n, a_{n-1}, a_1 and a_0 are regression constants, v_{ci} is the cut-in speed, v_R is the rated speed, v_{co} is the cut-out speed and P_R is the rated power and also $P_i(v)$ is the power generating in the related wind speed.

Energy corresponding to a specific wind speed is calculated by the product of the power delivered by the turbine at the wind speed v and the time for which the wind speed v prevails at the investigated site. The total energy generated by the turbine over a period can be computed by adding up the energy corresponding to all possible wind speeds in the related conditions, at which the system is operational. In this study, the hourly mean wind speed is used in order to obtain the energy output from a turbine. Thus, energy output from the turbine can be calculated by Eq. (12)

$$E_p = \sum_{i=1}^{n} P_i(v) \cdot t \tag{12}$$

where n is the number of hours in the period of the considered time such as year, season or month, t is one hour time duration. Capacity factor is one of the important indicators for assessing the field performance of a wind turbine. The capacity factor of a turbine at a given location is defined as the ratio of the energy actually produced by the system to the energy that could have been produced by it, if the machine would have operated at its rated power throughout the time period. The capacity factor for the wind turbine can be investigated based on monthly, seasonal and annual values. Annual value of the capacity factor can be calculated as given below;

$$Cf = \frac{E_{\mathrm{p}}}{E_{rated}} \tag{13}$$

8. A case study for western anatolia

Turkey has an important wind energy potential especially in the Marmara region, coasts of western and southern Anatolia. The main purpose in the case study is to investigate the wind energy potential of Kırklareli province in the northwestern Marmara region, Turkey (Gökçek et al, 2007. a, Gökçek et al. 2007. b). In addition to this, electrical energy production was calculated by considering a wind turbine with 2300 kW rated power in the related site Wind data at 10 m height above the ground level related to the selected site were taken from EIEI for the year 2004.

8.1 Probability density functions

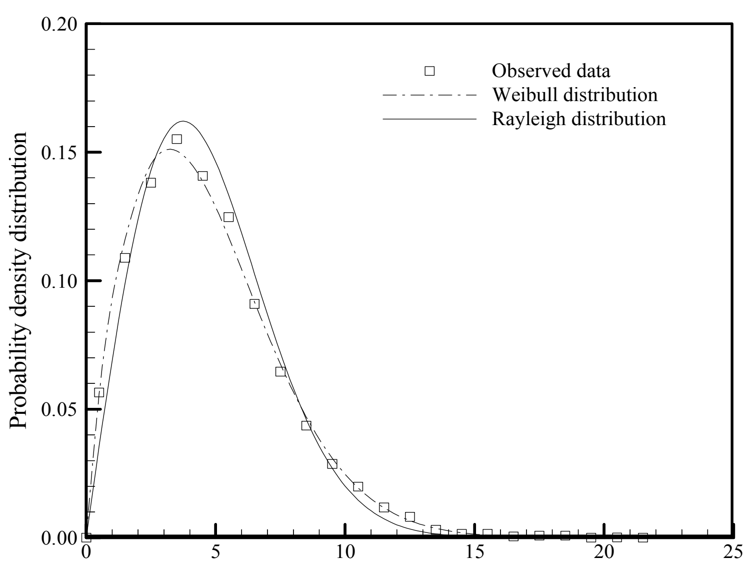

Fig. 10. Wind speed frequency distributions in the site for the year 2004.

Probability density functions such as Weibull or Rayleigh function are usually used to determine the wind speed distribution of a windy site in a period of time. In the current study, determination of wind speed distributions for the investigated site was made using Weibull and Rayleigh probability density functions. Fig. 10. reveals Weibull with the two parameters and Rayleigh distributions derived from observed data for the year 2004. As seen in this figure, the top point of the curve is the most frequent wind speed. The peak probability values vary between 0.15 and 0.165 depending on the wind speeds for the considered distribution functions (Weibull, Rayleigh and Actual probability distribution). Shape (k) and scale (c) parameters of the Weibull function were calculated using the method mentioned in the earlier section. The results of the calculation show that dimensionless shape parameter k is 1.75 while scale parameter c is 5.25 m/s for the site analyzed in the year 2004.

8.2 Wind power density

Fig. 11. shows monthly variations for the mean power density that is calculated using both observed data and Weibull function for the year 2004.

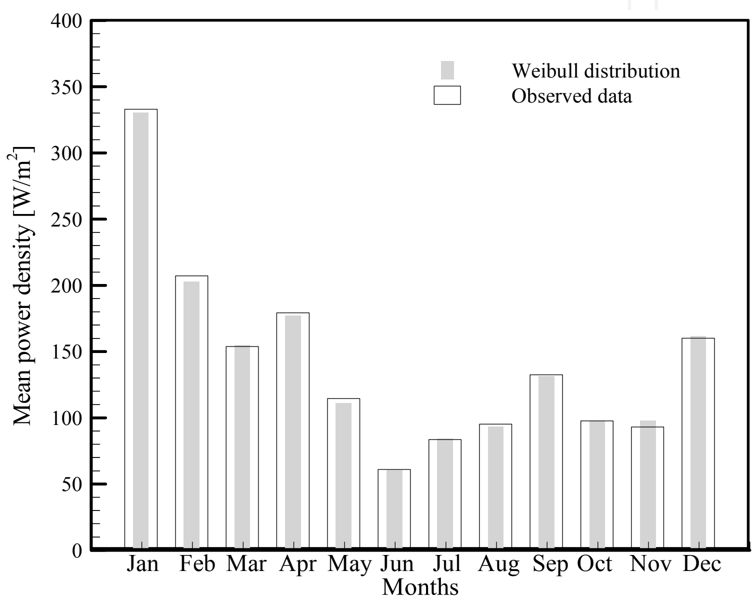

Fig. 11. Monthly variation of the mean power densities depending on Weibull function and observed data

As seen from Fig.11, the mean wind power densities decrease from January to June. In the second half of the year 2004., the changes of the mean power density show almost similar characteristics. The highest mean power density of 332.88 W/m^2 regarding actual data is calculated in the month of January while the lowest is in the month of June with the value of 60.83 W/m^2.

8.3 Electrical energy production

The factors influencing the energy produced by the turbine at the considered site during the related time period are the power response of the turbine to different wind velocities, wind regime and wind speed distribution. In this study, annual energy production is calculated by the time-series approach for all turbines considered at the site using the wind data of the year 2004. Fig. 12. shows power curve of the wind turbine considered in this study.

In the result of the case study, annual capacity factor for wind turbine considered is calculated as 27.08%. In January, electrical energy produced by turbine is about 728 MWh. This production is highest energy production when considering monthly production. In addition to this, capacity factor for the related month is calculated as 42.52%. In June, electrical energy produced by turbine is calculated about 254 MWh. Energy production in the June contrast to January is poor. Capacity factor for the June is also calculated as 15.33%.

In power generating, the load duration curves are used to illustrate the relationship between generating capacity requirements and capacity utilization. In Fig. 13., the load duration curve for the wind energy production related to turbine considered is shown. As it can be seen in this figure, turbine is operated 6153 hours at the related year.

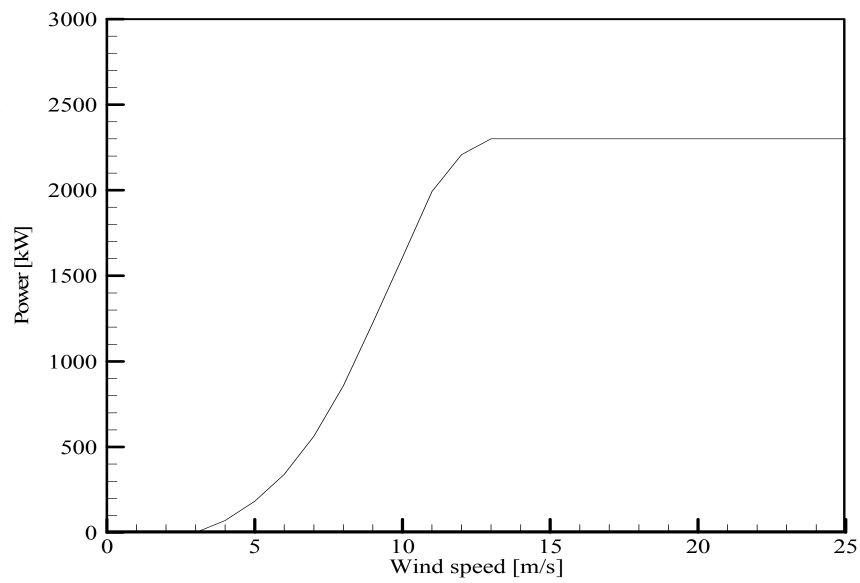

Fig. 12. Power curve for a turbine of 2300 kW rated power

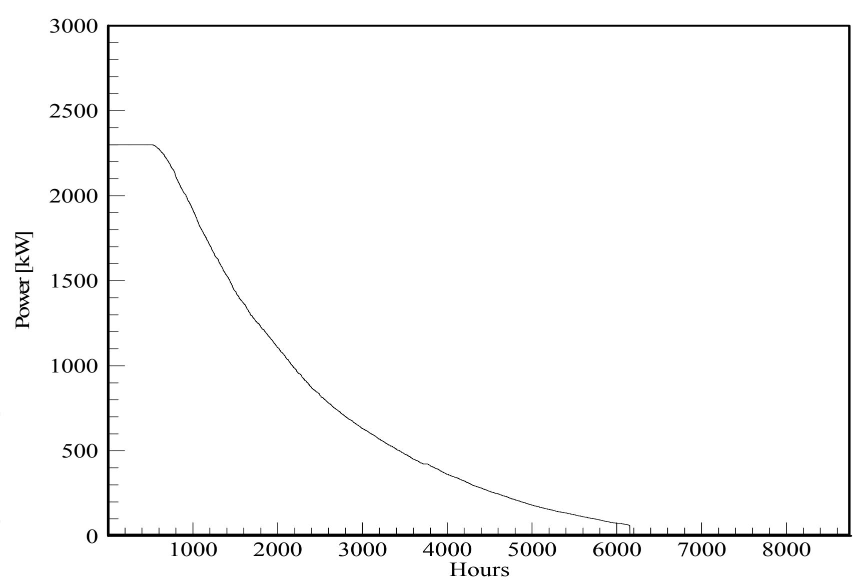

Fig. 13. Load duration curve for the wind turbine

9. Conclusion

In this study, wind-electricity status of Turkey was considered according to the recent developments on wind utilization in the world and wind Turkey' s wind energy potential is reviewed. In addition, a case study was carried out for both wind characteristics and wind energy production. Turkey has a significantly high poetantial of wind energy. This potential can be utilized to satisfy a part of the total energy demand in the country. Turkey has about

83,000 MW wind energy potential. By the end of 2009., the wind power plants of 802 MW capacity was constructed in Turkey. Wind energy maps of Turkey have been presented and the potential areas are identified with the emphasis on their significance. The potential windy areas in Turkey lie in northern parts and the Northwestern parts, at locations along the Aegean Sea and Marmara Sea coast. The case study shows that there is an important potential to use wind energy in Western Marmara, Turkey.

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The world's reliance on existing sources of energy and their associated detrimental impacts on the environment- whether related to poor air or water quality or scarcity, impacts on sensitive ecosystems and forests and land use - have been well documented and articulated over the last three decades. What is needed by the world is a set of credible energy solutions that would lead us to a balance between economic growth and a sustainable environment. This book provides an open platform to establish and share knowledge developed by scholars, scientists and engineers from all over the world about various viable paths to a future of sustainable energy. It has collected a number of intellectually stimulating articles that address issues ranging from public policy formulation to technological innovations for enhancing the development of sustainable energy systems. It will appeal to stakeholders seeking guidance to pursue the paths to sustainable energy.

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