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Technical note

Wind energy potential estimation and micrositting on Izmir Institute of Technology Campus, Turkey

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Abstract

The aim of this study was to predict the wind energy content over the campus area of Izmir Institute of Technology. The wind data were collected at 10 and 30 m mast heights for a period of 16 months. Mean wind speeds were 7.03 and 8.14 m/s at 10 and 30 m mast heights, respectively. The 'WAsP' and 'WindPRO' softwares were used for the wind statistics and energy calculations. Suitable sites were selected according to the created wind power and energy maps. Wind turbines with nominal powers between 600 and 1500 kW were established for annual energy production calculations and best fitted ones were used for the micrositting.

Keywords: Wind energy; Micrositting; Wind site; Annual energy production; Wind farm

1. Introduction

There is a growing awareness for renewable energy resources in Turkey as a result of rapidly increasing population and industrial development. Total electricity installed capacity was 31,846 MW and total electricity production was 129,400 GWh in 2002. According to the eight Five Year Development Plan prepared by the State Planning Organization, estimated electricity installed capacity and total electricity production are 42,783 MW and 193,900 GWh for 2005, respectively. Since electricity consumption estimation is 195,100 GWh, the gap is planned to be imported [1,2].

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Turkey does not possess enough conventional fossil fuel reserves, but possesses rich renewable energy resources such as hydrolic, solar, geothermal and wind. Among all, wind energy seems to be the most suitable renewable energy resource for electricity production. The first and second wind farms in Turkey were installed in Cesme-Izmir in 1998. One with 1.7 MW nominal power capacity, generates 4,500,000 kWh electricity per year and the other with 7.2 MW nominal power capacity, generates 20,000,000 kWh electricity per year. The last wind farm, so far, with 10.2 MW nominal power capacity was installed in Bozcaada-Canakkale in 2000. It generates 30,000,000 kWh electricity per year. It must be noted that, despite her natural capacity, the usage of wind energy is very limited in Turkey.

In order to provide a broad wind resource assessment over Turkey, the wind characteristics must be studied in detail. Wind resource assessments can be divided into two main areas: regional assessment and micrositting. Regional assessment is overall estimation of the mean energy content of the wind over a large area. Micrositting is to position one or more wind turbines on a land in order to maximize the overall yearly energy output of a wind farm.

During the last decade, advanced computational methods have been developed to gain the data to use in estimation of wind energy potential and micrositting [3–7]. A precise prediction of the wind speed at a given site is essential for the determination of regional wind energy resources. Because of aerodynamic reasons, the power output of a wind turbine is proportional to the third power of the wind speed. It is a fact that, especially in complex terrain, wind energy content may vary significantly from one region to another. Therefore, wind data taken over many years are utilised to calculate wind climatology. European Wind Atlas [8] is a good example of this. Some other wind resource maps such as Wind Atlas of Russia [9] and the Irish Wind Atlas [10] also have been prepared.

According to the European Wind Atlas, the western Anatolia appears to have good wind energy potential. Izmir Institute of Technology campus which occupies 3500 ha area is located on a hilly topography right by the Aegean Sea. Several studies have been done to estimate the potential, especially, in western Anatolia [11–15]. However, further studies are necessary. This article aims to provide a wind energy potential estimation and to perform micrositting study on Izmir Institute of Technology campus in order to bridge this gap.

2. Material and method

2.1. Site selection

Wind speed and, consequently, wind energy potential are heavily influenced by the surface roughness of the surrounding area of nearby obstacles such as trees or other buildings, and by the contours of the local terrain. Therefore, in most cases, using meteorological data directly will underestimate the true wind energy potential in an area. Mast should be located in the site area where characteristic wind parameters of the location can be measured as a representative of the whole site.

The campus area which is located in Urla, Izmir, occupies 3500 ha area. It includes several hills covered with typically Mediterranean bush. Topography of the region is hilly,

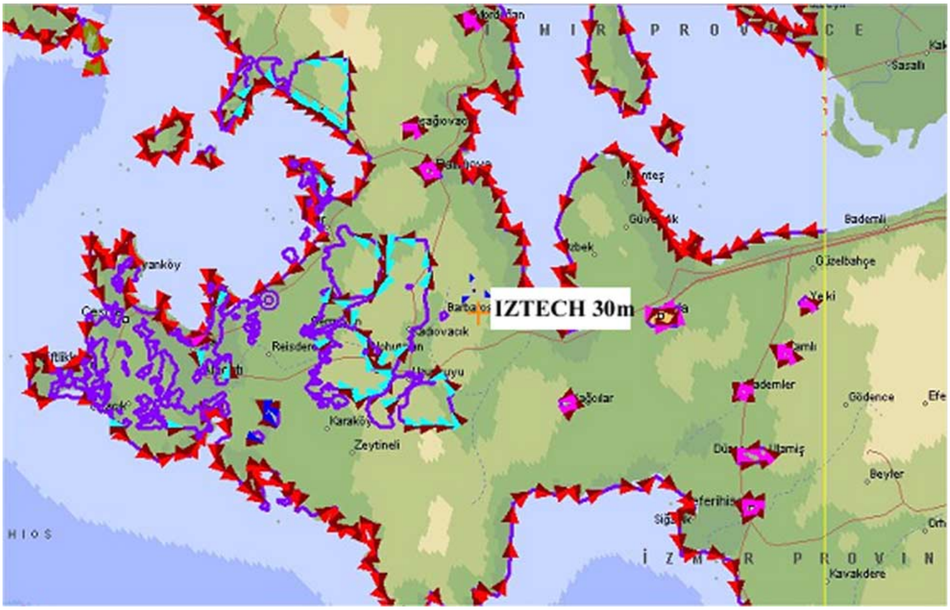

Fig. 1. Location of the mast on Izmir province.

rocky and steep with 15–25% incline. Soil depth is very low and not suitable for vegetation. No agricultural activity is being practiced in the area.

Site with coordinates 465684 E, 4243843 N (in UTM coordinate system) at 460 m height was found to be the most suitable location in the area. There were no obstacles detected around the measurement area. Surface roughness was low due to low plant heights, which is important in wind shear. Site was directly open to the sea at north direction. The south and north west directions were covered with higher mountains. Fig. 1 shows the location on Izmir province map.

2.2. Monitoring station instrumentation

Measured main parameters were wind speed, wind direction, and air temperature. Table 1 lists the nominal specifications for the sensors used during the measurements. The anemometer consists of a three-cup assembly centrally connected to a vertical shaft for rotation. A wind vane was used to measure wind direction. The temperature measurement was made by a Pt100-resistor composed of three parts: the transducer, an interface device, and a radiation shield.

The data logger mounted on the mast was capable to measure mean, maximum, and minimum wind speeds, prevailing wind direction, and mean temperature. The mast was also equipped with a GSM-system, which makes it possible to make a remote contact with the station by computer or mobile phone. A backup power supply should be included to minimize chances of data loss caused by power failure. This was accomplished by a solar panel and a battery.

Table 1
Nominal specifications of the monitoring station instrument sensors

Specification	Anemometer	Wind vane	Thermometer
Measurement range	0–50 m/s	0–360° (≤8° deadband)	−40 to 60 °C
Starting threshold	≤1.0 m/s	≤1.0 m/s	N/A
Distance constant	≤4.0 m	N/A	N/A
Operating temperature range (°C)	−40 to 60	−40 to 60	40–60
Operating humidity range (%)	0–100	0–100	0–100
System error	≤3%	≤5°	≤1 °C
Recording resolution	≤0.1 m/s	≤1°	≤0.1 °C

Grounding equipment is especially important when using electronic data logger and sensors. Therefore, complete grounding kit provided by the manufacturer was used to protect the system. The tubular type tower, also, was strengthened by guyed wires in order to be kept in vertically aligned position.

2.3. Methodology

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. In this study, the missing data were 3.7%. The ‘CALLaLOG’ software was used for remote data transferring. The ‘WindPRO’ and ‘WAsP’ softwares were played a key role to evaluate all collected data in order to make wind energy analysis and micrositting considering orography and topography at the site.

The expression of kinetic energy of air in wind is

$$E_k = \frac{1}{2} m V^2 \tag{1}$$

where m is total mass of the air, V is wind speed. Since, $m = \rho A V \Delta t$ then,

$$E_k = \frac{1}{2} \rho A V^3 \Delta t \tag{2}$$

where ρ is air density, A is area which air moves, Δt is period of time. The power of wind may be expressed as,

$$P = \frac{1}{2} \rho A V^3 \tag{3}$$

and the wind power density may be expressed as,

$$P_d = \frac{1}{2} \rho V^3 \tag{4}$$

The Weibull probability density distribution function used for wind speed is,

$$p(V)_w = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^k\right] \tag{5}$$

Table 2
Sectoral mean wind speeds and their frequencies at 10 m

Sector	Mean wind speed (m/s)	Frequency (%)
North (N)	7.17	78.6
North northeast (NNE)	7.56	4.7
East northeast (ENE)	3.66	0.7
East (E)	3.88	0.7
East southeast (ESE)	7.71	1.5
South southeast (SSE)	7.21	3.2
South (S)	6.10	2.6
South southwest (SSW)	5.66	2.3
West southwest (WSW)	6.47	0.9
West (W)	5.54	0.9
West northwest (WNW)	5.28	1.6
North northwest (NNW)	6.99	2.4
Mean	7.03	100

where k is a dimensionless shape factor and c is the scale factor. The linear approximation of the data is obtained by using the least square method.

Commercially available ‘Encarta Digital Atlas’ compact disc was used for area map. Digital height counter map which covers area with 5 km radius and surface roughness map which covers 20 km radius around measurement point were created and loaded into ‘WindPRO’ software.

3. Results

3.1. Measurement parameters analysis

Mean wind speed and Weibull distribution are the most effective parameters in wind energy analysis. Mean speeds were 7.03 and 8.14 m/s, respectively, at 10 and 30 m

Table 3
Sectoral mean wind speeds and their frequencies at 30 m

Sector	Mean wind speed (m/s)	Frequency (%)
North (N)	8.35	74.9
North northeast (NNE)	8.74	5.3
East northeast (ENE)	3.99	0.8
East (E)	4.20	0.8
East southeast (ESE)	8.94	1.7
South southeast (SSE)	8.31	3.9
South (S)	7.03	3.5
South southwest (SSW)	7.16	2.9
West southwest (WSW)	7.23	1.0
West (W)	5.88	0.9
West northwest (WNW)	5.68	1.7
North northwest (NNW)	8.04	2.8
Mean	8.14	100

heights. Calculated mean wind shear values were 0.14 and 0.13, respectively, at 10 and 30 m heights.

Prevailing wind direction was north and north northeast on the site. Analysis of Weibull distribution showed that, 78.6% of the wind at 10 m and 74.9% of the wind at 30 m blew

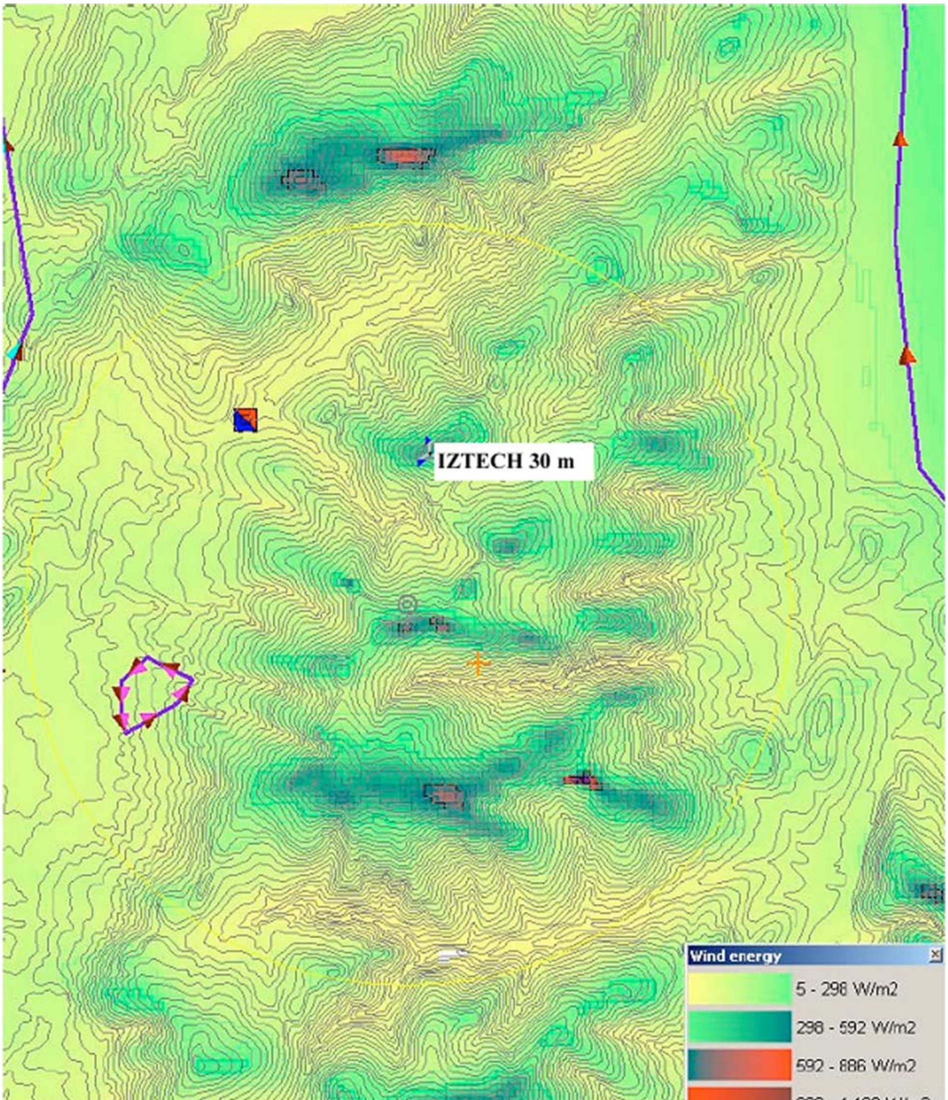

Fig. 2. Wind power map of campus area in W/m^2.

from north. The frequencies for north northeast sector were 4.7% at 10 m and 5.3% at 30 m. There were strong wind blowing from southern sectors, but their frequencies were quite low. Other sectors' frequencies were not higher than 3.9%. Therefore, north seems the only wind direction to consider in wind farm project, which will be developed on

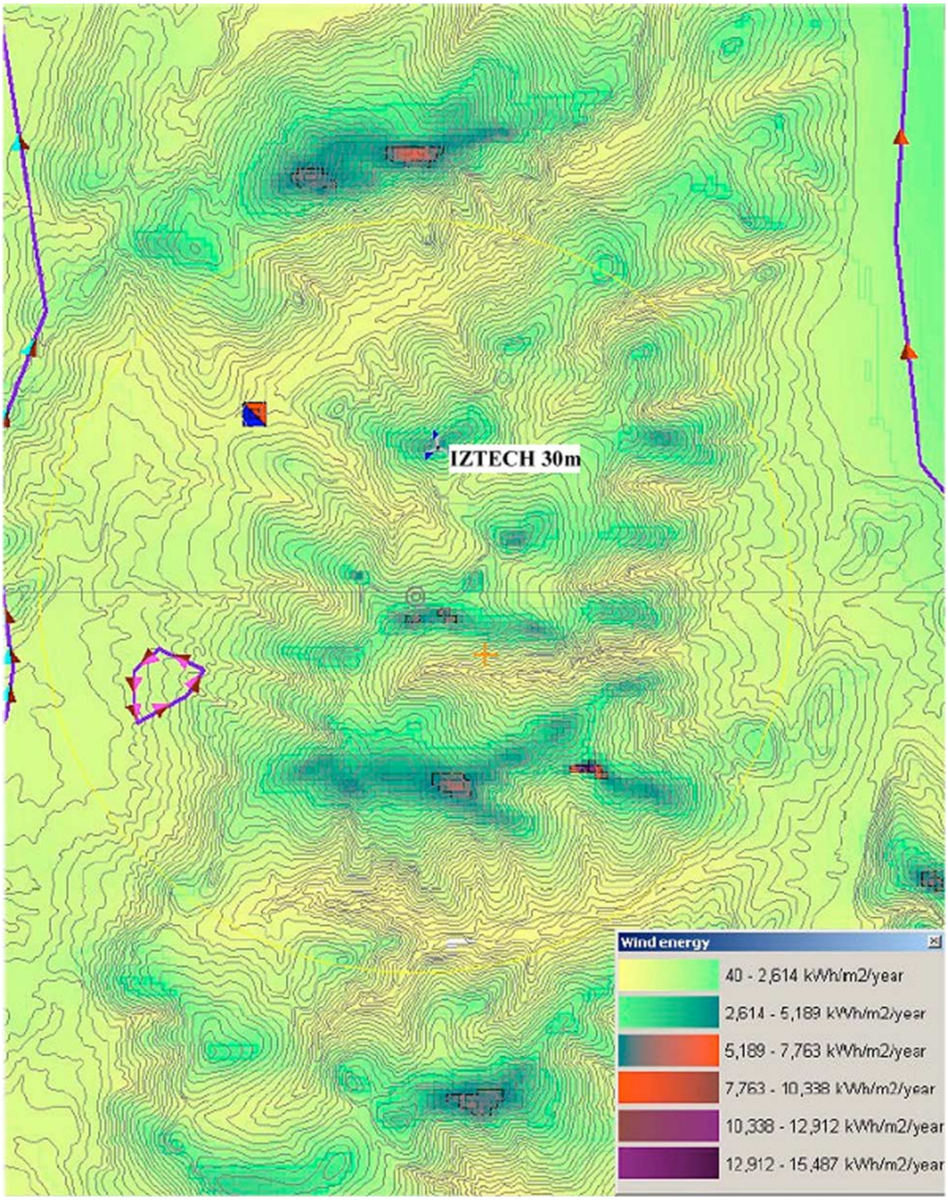

Fig. 3. Wind energy map of campus area in kWh/m^2/year.

the campus area. Average temperature was 16.3 °C. The sectoral mean wind speed values along with their frequencies are shown in Tables 2 and 3, respectively, at 10 and 30 m heights.

3.2. Wind energy analysis

Wind energy maps were created by using collected data, orography and roughness maps. Fig. 2 shows the wind power map in W/m^2 by considering only mean wind speed values. The wind energy map, Fig. 3, was determined in kWh/m^2 per year. This map considers whole values of Weibull histogram. Fig. 2 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 Fig. 3.

3.3. Selecting best fit turbines and micrositting

Annual energy productions of five turbines with different energy capacities were calculated by 'WindPRO' software using measured data. Nominal powers of these turbines were 600, 660, 850, 1,000, and 1,500 kW. Table 4 shows their nominal and estimated annual energy productions and capacity factors. Capacity factor is the ratio of estimated and nominal annual energy productions. Turbine with 1500 kW nominal power has the highest capacity factor. The second highest capacity factor is achieved for a 600 kW nominal power turbine which is used commercially very commonly. Thus, both turbines were chosen as the most suitable wind turbines for the campus area.

Wind speed and wind energy maps were used to select suitable sites to locate wind turbines. Four sites were selected to install 600 kW turbines. Their hub heights and rotor diameters were 46 and 44 m, respectively. These sites have mean speed more than 8 m/s and enough area to locate these turbines. Turbines were located 150 m distance apart each other to prevent energy production loses of park effect. Fig. 4 shows those 47 turbines which were located as aligned position in four sites according to the prevailing wind direction. Calculated energy production of located 47 turbines with total capacity of 28.2 MW was 100.3 GWh. Two sites were selected to install 1500 kW turbines. Their hub heights and rotor diameters were, 60 and 64 m. Fig. 5 shows those 26 turbines which were located 250 m distance apart and aligned according to the prevailing wind direction.

Table 4
Comparison of turbines

Turbine power (kW)	Nominal annual energy production (MWh)	Estimated annual energy production (MWh)	Capacity factor (%)
600	5256	2196	41.8
660	5781.6	2405	41.6
850	7446	3076	41.3
1000	8760	3478	39.7
1500	13,140	5927	45.1

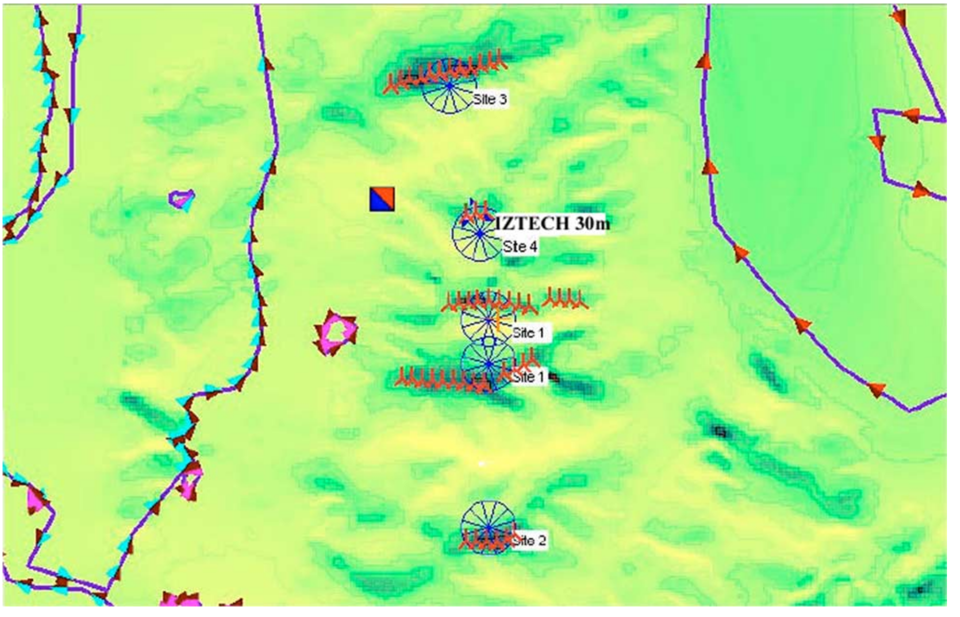

Fig. 4. Micrositting of 600 kW turbines on the campus area.

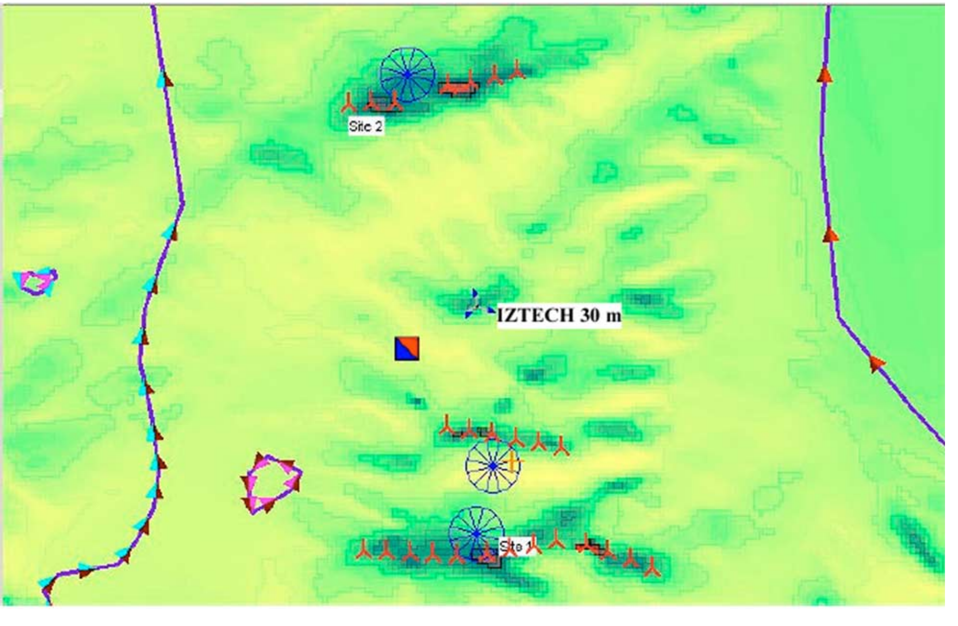

Fig. 5. Micrositting of 1500 kW turbines on the campus area.

Calculated energy production of 26 turbines with total capacity of 39 MW was 122.4 GWh.

4. Conclusion

The aim of this study was to estimate wind energy potential and to perform the most suitable micrositting study. The presence of high wind speed and, therefore, high wind power on Izmir Institute of Technology campus area were explicitly demonstrated. The wind power parameters were evaluated by using a great deal of measured data. Mean speeds were 7.03 m/s at 10 m height and 8.14 m/s at 30 m height. North was found as prevailing wind direction. In addition to wind characteristics, wind energy map was created. The most suitable turbines were located at the most convenient sites in order to utilize wind power. The annual energy productions of the micrositted turbines with 600 and 1500 kW nominal powers were, respectively, 100.3 and 122.4 GWh/year. The result derived from this study encourages the utilization of wind power especially in the western Anatolia region of Turkey which has a long coast to Aegean Sea.

Acknowledgements

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