

Wind energy and assessment of wind energy potential in Turkey: A case study for Mersin province

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Abstract: Today, decrease in fossil resources and the ever increasing need for energy increases the importance of renewable energy resources. Wind power; It has an important potential and usage area in clean and renewable energy sources. The measurement of wind speed and direction values is very important in terms of evaluating the data of wind power plant (WPP) project and estimating the amount of energy that can be produced. Wind energy is a good example of clean energy source due to its advantages such as cleanness fast commissioning, and reliability. There has been a significant increase in recent years especially in terms of utilizing wind energy. By the end of 2016, the installed wind power capacity in the world is 486749 MW, Turkey takes the 11th place with 6081 MW of installed capacity. In this study, the use of wind power in Turkey's Mersin province were studied. Mersin province in terms of installed wind power capacity has an important place in Turkey. As of 2016, the installed wind power capacity throughout the province is 364 MW, but the usable wind energy potential in the region is about 3414 MW.

Keywords: renewable energy; wind energy; wind power plant, Mersin

1. Introduction

The rapid growth of the population and industrialization have increased the demand for renewable energy sources all over the world due to insufficient fossil fuel energy resources. Accordingly, wind energy as a renewable energy source has attracted attention because of its sustainability, efficiency, and cleanness. As a result, worldwide wind power plant (WPP) investments have increased in recent years [1]. The fact that fossil energy resources will be depleted in the future, cause environmental pollution and depend on the countries where these resources are located, has increased the demand for renewable energy sources [2]. Energy production is one of the basic requirements for development in industrialized societies. Today, industrialized countries obtain approximately 65% of their energy from fossil fuels. Researches indicate that developed countries will realize 50% of world energy production by 2030 [3]. While the depletion times of the world's energy reserves are approximately 200 years for coal, 65 years for gas and 40 years for oil, this period is endless for wind energy [4]. The energy consumption rate in the world is 300 thousand times the formation rate of fossil fuels [5]. Regarding the history of wind turbines, it is estimated that the oldest wind power machine, the windmill, was

built near Alexandria 3000 years ago [6]. Renewable energy sources are sources that reduce external dependency, help protect the environment and do not harm humanity. In addition, these energy resources, which are not consumed in nature, have the characteristics of accessibility, availability and acceptability [7]. Renewable energy sources can contribute to development thanks to business and infrastructure opportunities in rural and underdeveloped areas such as mountainous regions. Although the businesses of renewable energy sources projects are



Figure 1. A photo of Wind power plant

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cheap, initial investment costs are higher than fossil-based technologies [8] [9]. There are some advantages of wind energy, which is renewable. There is no transportation problem and it does not require high technology to use at the same time. It is abundant and freely available in the atmosphere, a clean energy source that is easy to obtain and has no environmental pollution. The photograph, given in Fig. 1, shows operational wind turbines [10].

In the active use of this energy in the world, Germany has set a target in a short time and plans to obtain 50% of its energy from the wind in 2050. Regarding wind energy use, Japan shows similarity with Germany. The common goal of European countries in the 2020s is to meet 20% of their energy needs from wind energy [11]. In our country, wind energy investment was first made in 1998 in Çeşme (8.7 MW). In 2000, only an investment of 10.2 MW was made in Bozcaada. Rapid industrialization in Turkey, a large amount of energy is causing the deficit between supply and demand. Turkey imports approximately 72% of energy sources [12]. Turkey is a very rich country in terms of wind potential. If the wind is converted to energy, big gains can be obtained [13] [14]. Prepared jointly by the Electrical Works Survey Administration (EIE) and the State Meteorological Service (SMS) and published in June 2002; Turkey Wind Atlas is providing a hope in this regard [15]. According to the State Planning Organization Electric Energy Special Commission (2001), the potential mentioned in the work of the Electrical Works Survey Administration is about 10000 MW [16] [17]. Investments in wind energy have been increased especially in recent years; Because investments such as wind energy provide a significant advantage due to the limited resources such as natural gas and coal and being dependent on foreign sources [18]. According to Wind Map of Turkey, the regions with the greatest wind potential is given in Tab. 1.

In Turkey, it is estimated that a wind power plant with a power of 5 MW .km² can be built in areas with 50 meters above ground level and at least 7.5 m . s⁻¹ of wind speed;. Accordingly, Turkey wind energy potential figure is determined to be about 48000 MW. Wind power plants

start generating electricity from 3 m . s⁻¹ and continue to generate electricity up to 25 m . s⁻¹ wind speed. When the wind map of Turkey is analysed, it can be seen that even the places receiving the least wind have more than 3 m . s⁻¹ wind potential (Fig. 2) [20].

In determining the wind energy potential of a region, statistical data obtained by processing raw data are used. Rayleigh and Weibull distributions are the most commonly used among statistical methods used for this purpose (Fig. 3) [21].

When the situation of Mersin province is analysed according to the latest data, it is seen that the wind power plants (WPP) in the enterprise come after Osmaniye and Çanakkale provinces in the installed power distribution according to the provinces (Fig. 4) [22]. In this context, it is seen that the existing potential is appropriate and started to be evaluated.

Gülersoy and Çetin have obtained the wind data from 2008 and 2009, by measuring hourly; They showed that the wind energy potential of Menemen is suitable for the production of electricity [23]. Intense population growth in Turkey, as in other developing countries, industrialization effort to increase investment and support for the development of technology; it increases the demand for energy day by day [2]. Arslan et al. analyzed the wind energy potential of a region located in the campus area of Kırıkale University and whose wind speed was determined [24]. Yıldırım et al. analyzed the wind energy potential of Niğde province statistically [25]. With today's technology, wind energy is one of the most suitable renewable energy source. It is at a level to compete with conventional fossil fuels in suitable wind areas. Its cost also decreases as wind technology improves and usage areas increase. It is thought that, with the technological developments occurring in the wind energy sector, the costs of the wind turbine and its components decrease and the incentives given to the wind energy increase, it will gain importance

Table 1. Distribution according to the months SE total potential of Turkey[19]

Region	Average annual wind speed (m . s ⁻¹)	Annual average wind density (W . m ⁻²)
Marmara Region	3.29	51.91
Aegean Region	2.65	23.47
Mediterranean region	2.45	21.36
Central Anatolia Region	2.46	20.14
Black Sea region	2.38	21.31
Eastern Anatolia Region	2.12	13.19
Southeastern Anatolia	2.69	29.33
Region Average	2.58	25.82

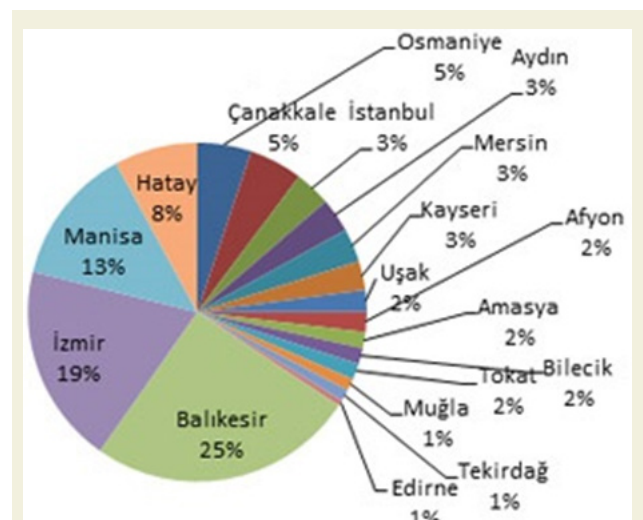


Figure 4. Distribution of wind power plants in the enterprise by provinces

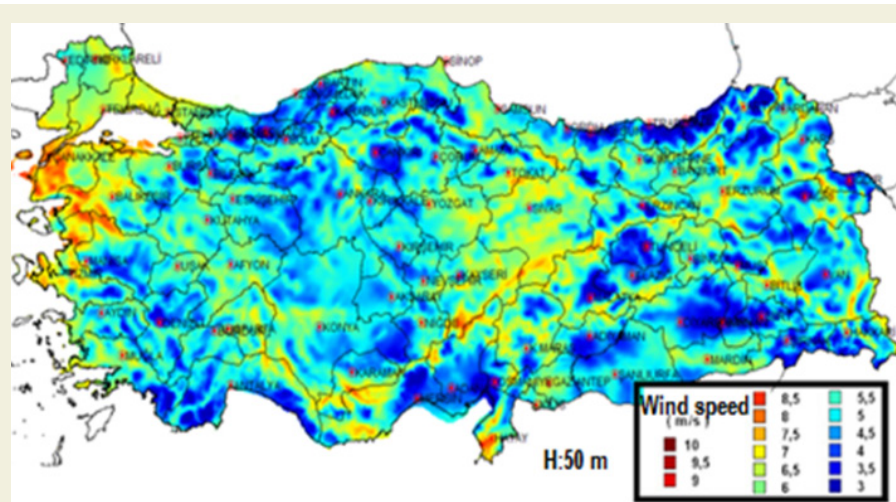


Figure 2. Turkey wind energy potential

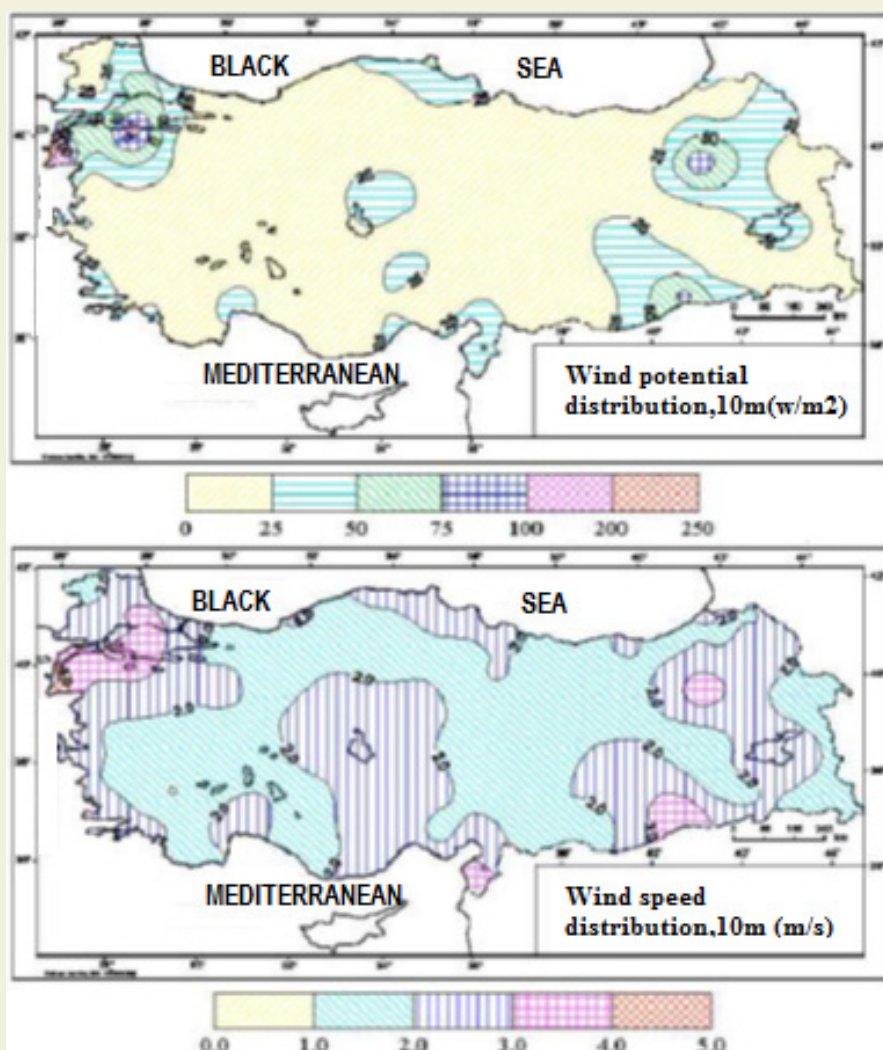


Figure 3. Wind potential distribution map (10 m)

in the investments to be made. Turkey has provided for 72% of the available energy supply from outside. This raises the issue of utilizing the potential of renewable energy sources to reduce this dependency. To analyse the wind energy potential of any region, hourly wind speed and direction information in that region should be measured for at least one year. Wind energy, Turkey's natu-

ral conditions and terms of energy production costs, is a potential that needs assessment. Turkey has an important place in terms of wind energy potential in Europe. As it is close to the regions where consumption is intensive and it has wind investments and potential, Çukurova region is one of the most important regions of the country, and with the development of the energy sector, it is an in-

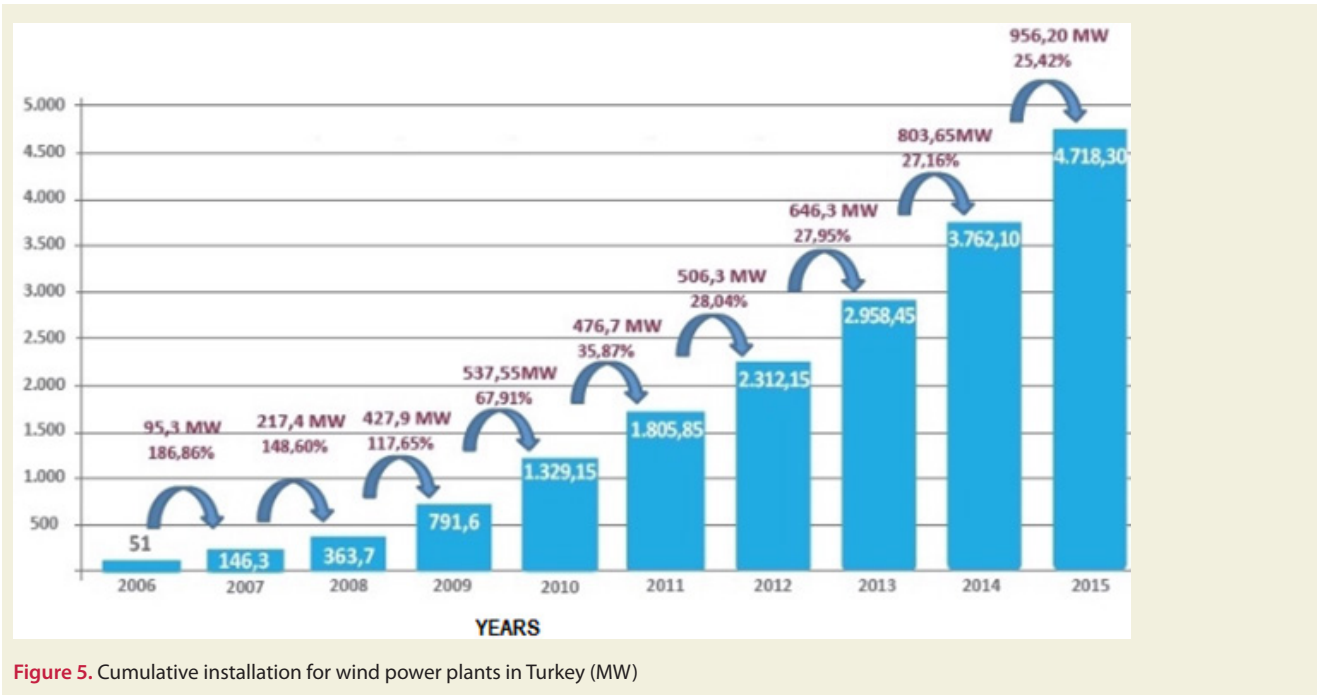


Figure 5. Cumulative installation for wind power plants in Turkey (MW)

creasingly important region. Mediterranean region with wind energy projects with 156 of them in the assessment stage is ranked third in Turkey. 7 of these projects are in Çukurova region. In addition to the land and wind structure, in the region; Considering that the industry is also developed, the Çukurova region means a new market for the wind energy sector. It is possible to express these developments in wind energy field with numerical data. In 2015, the global installed renewable energy power reached 913.48 GW and the installed power in the wind reached 428 GW. In 2015, the installed wind energy capacity of the European Union countries increased by 5.4 percent to 13805.3 MW. Turkey in terms of installed capacity, which ranks 10th in Europe, and was ranked 15th in the world. In addition, wind power plants, which were put

into operation in 2015, have taken their place as the 10th largest market in the world with its installed power (Fig. 5) [26].

Looking at the wind energy view; Turkey in terms of wind power installed capacity in the year 2015, 956 megawatt power plant was put into operation. While reaching 4718 megawatts in total; While 74 percent of the wind power plants in the circuit are located in the Aegean and Marmara regions, the Mediterranean Region is in the third place with a share of 9.85 percent. On the other hand, the total installed power of 88 licensed wind power plants, whose construction has not started, reaches 3144 megawatts. With its 174 megawatts of power capacity, the Mediterranean Region is in the fifth place. The total installed power of 61 Wind Power Plants, which is currently under construction, reaches 869 megawatts. The Mediterranean Region ranks third with 184 megawatts (Tab. 2) [26].

Wind speed data for Mersin province was obtained from the General Directorate of State Meteorology Affairs.

In this study, suitable areas were researched for the wind energy potential and for the establishment of a Wind Power plant (WPP) in Mersin region based on the hourly wind speed data measured. To focus on the elements necessary to increase the efficient use of this resource is to determine how we can utilize wind energy more efficiently with the national renewable energy policy to be regulated [27].

2. Materials and Methods

Mersin province is located in the southern part of Mediterranean coast (36° 48' It is in North Latitude and 34° 38' East longitudes). The settlement map of Mersin province

Table 2. Wind power plants (WPP) in operation

Project	Installed Power(M)	Province	Turbine Manufacture
Altık Belen WPP	18.0	Hatay	Gamesa
Belen WPP	48.0	Hatay	Vestas
Çerçikaya WPP	57.0	Hatay	ACCIONA
Dağpazarı WPP	39.0	Mersin	Siemens
Gökçedağ WPP	135.0	Osmaniye	GE
Hasanbeyli WPP	50.0	Osmaniye	Nordex
Hilal-2 WPP	9.9	Mersin	Vestas
Mersin MutWPP	42.0	Mersin	Vestas
Mut WPP	52.8	Mersin	Vestas
Sebenoba WPP	63.7	Hatay	Vestas
Senkoy WPP	36.0	Hatay	Alstom
Şenbük WPP	27.7	Hatay	Vestas
Şenbük WPP	38.1	Hatay	Vestas
Ziyaret WPP	76.0	Hatay	GE



Figure 6. Location of Mersin on Turkey map

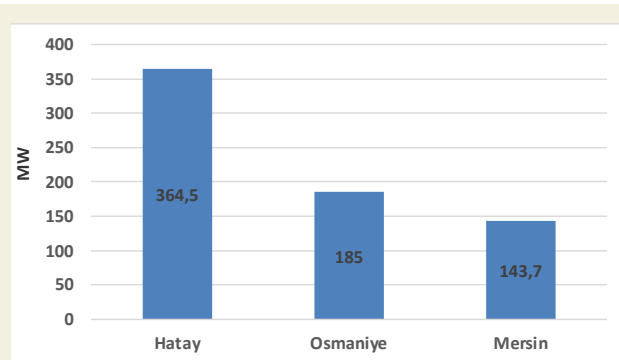


Figure 7. Distribution of WPPs in business in Çukurova region by province

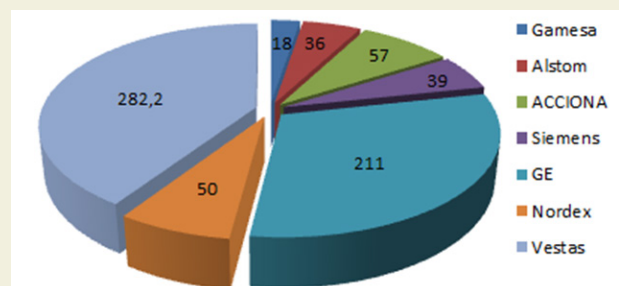


Figure 8. Distribution of WPPs in the enterprise by turbine brands (MW)

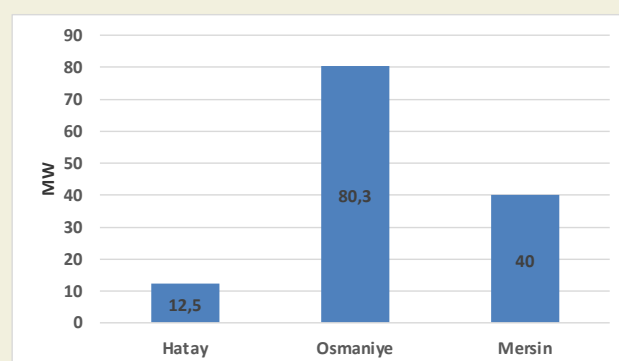


Fig. 9 The installed power (MW) distribution of WPPs in different provinces of Çukurova region

is shown in Fig. 6 [28].

Çukurova region, one of the most important area of the Mediterranean Region with a great potential in terms of wind energy. The developments in the electricity market have important repercussions on the Çukurova region. Distribution of WPPs in the service in the Çukurova Region by Provinces is shown in Fig. 7.

The region has an important potential in terms of wind, hydroelectricity and solar resources. Especially in Mersin, Gülnar, Mut and Silifke districts and Belen district of Hatay attract attention with their wind power plant investments. The installed power of the wind power plants, in operation, in the Çukurova region was 534.8 MW in 2014. In line with the 2015 data, it increased by 27% (149.4 megawatts). The cumulative installed power reached 693.2 MW. There are 14 wind power plants and 252 wind turbines in this region. The wind power plants of the region produce electricity that can meet the electrical energy needs of approximately 475601 houses. In 2015, Hatay took the first place with 87.5 MW and Mersin took the second place with an installed capacity increase of 62.7 MW. On the basis of provinces, Hatay is the fourth with 7.73%, Osmaniye is the seventh with 3.92% and Mersin is the 10th with 3.05%. It has been remarkable that Osmaniye and Mersin have risen one line lately. Distribution of WPPs in the enterprise by Turbine brands (MW) is shown in Fig. 8.

Vestas, which is among the turbine brands used in operating wind power plants in Çukurova, ranks first with 282.2 megawatts. While General Electric is in second rank with 211 MW, Acciona is in third rank with 57 MW. Apart from these turbine brands, turbine brands such as Alstom, Gamesa, Nordex and Siemens are also used in power plants. 75% Vestas at the plants commissioned in 2015, 25% Acciona brand turbines were used.

Mersin, Hatay and Osmaniye have more favourable areas for the establishment of wind power plants compared to Adana. This situation also explains the reason for the current location of WPP investments in these cities. Wind power plants, which were under construction in the Mediterranean Region in 2014, which were 177.3 megawatts, became 184 megawatts in 2015. At the same time, while the wind energy capacity in the Çukurova region, which was 98.18 megawatts in 2014, increased by 20% (24.62 megawatts) compared to the previous year, the capacity of 4 wind energy projects under construction in 2015 was 122.8 egawatts (Tab. 3).

The distribution of installed power (MW) of WPPs in different provinces of Çukurova region is shown in Fig. 9.

The total installed power of the three licensed WPP projects with approximately 47 MW, whose construction has not been started. With 33 MW of these projects, two are located in Hatay and one in Mersin. There are also two unlicensed WPP in the region. Two power plants with a total capacity of 1000 kW belongs to Baykal Energy Ltd. In addition, there are 1750 kilowatts of unlicensed WPP projects in the same city, with three project approvals. There are 156 wind energy projects in the evaluation stage in Turkey and 72 of these projects are in the region of Çukurova. It ranks third as the total power is considered. Wind Power Plants that are under evaluation are given in Fig. 10.

There are 10 projects with a total power of 275 MW in Hatay, 2 projects with 34 MW in Osmaniye and 41 projects with 1909 MW in Mersin. It is striking that the projects are concentrated in the districts of Mut, Gülnar and Silifke in Mersin, while in Hatay, they are concentrated in Yayladağı and the Center. Turkey Electrical Works Study Administration prepared wind map in cooperation with the State Meteorology Affairs General Directorate of Turkey for the evaluation of the wind energy potential. When the map and data are analysed, it is seen that Çukurova Region has a very rich potential in terms of wind energy. The annual average wind speed at the height of 10 m in the Mediterranean Region was $2.5 \text{ m} \cdot \text{s}^{-1}$ and the power density was $21.36 \text{ W} \cdot \text{m}^{-2}$. Çukurova region, Turkey's wind energy power density of $20 \text{ W} \cdot \text{m}^{-2}$ not exceeding, has greater potential than 64.5%. In line with all

Table 3. Wind Power Plants Under Construction

Trade Name	Project	Installed Power (MW)	Province
Aksa Energy Products Inc.	Atik Belen WPP	12.5	Hatay
Zorlu Wind Products Inc.	Demirciler WPP	23.3	Osmaniye
Hanay Energy Products Inc.	Elmalı WPP	30.0	Mersin
Zorlu Wind Products Inc.	Saritepe WPP	57.0	Osmaniye

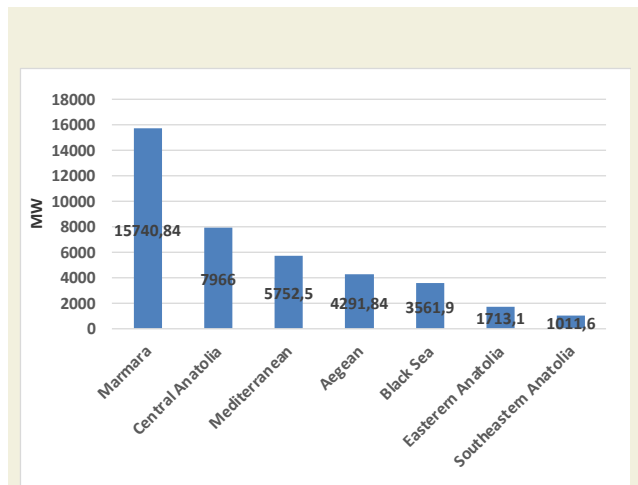


Fig. 10 Wind power plants under evaluation



Fig. 11 Wind power plant of Mersin province

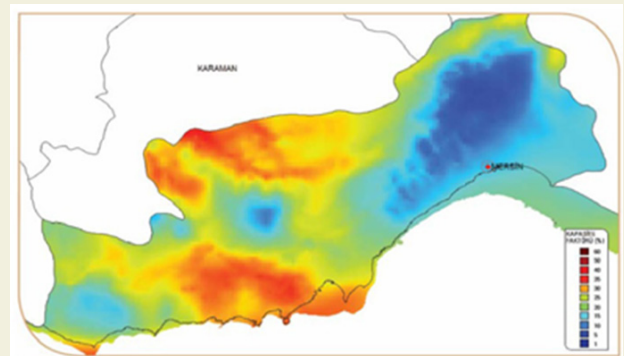


Figure 12. Capacity factor distribution of Mersin province

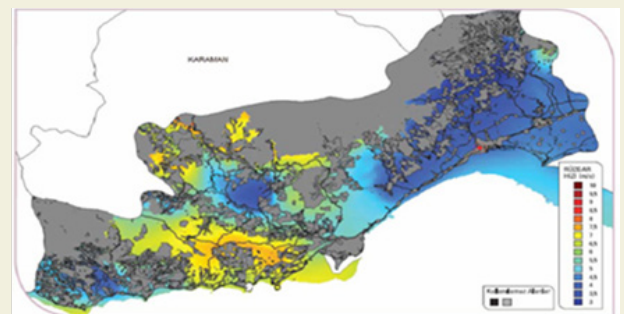


Figure 13. WPP installable areas of Mersin province

these data, in the Mediterranean and Çukurova region, number of wind power plants in operation, under construction, unlicensed and under evaluation show that the region has a very rich wind potential (Fig.11) [29].

Balıkesir province has the highest installed wind power capacity in Turkey. Balıkesir is followed by Manisa and İzmir provinces, respectively. There is a WPP named “Mersin WPP”, owned by Ağaoglu Energy Group company Akdeniz Elektrik Üretim A.Ş., operating in the Özlü Village of Mut district of Mersin. Mersin WPP project was licensed in 2003 and the operation was started in 2009.

There is also a 39 MW capacity project named “Dagpazarı WPP” of EnerjiSA, which continues in the Mut district of Mersin. Capacity factor maps were examined to determine the wind energy potential of Çukurova Region. The red areas indicate the areas where the capacity is higher and the blue areas are low (Fig. 12). According to the maps in Fig. 12 and Fig. 13 showing the capacity factor distribution and WPP installable areas of Mersin province, Silifke-Gülнар coast of Mersin province and the mountainous areas of Mut-Gülнар emerge as areas with high wind energy potential and where WPP can be established considering other criteria.

The dominant wind direction in Mersin is northwest in winter, and southwest in summer. Considering the arrival directions, generally cold / cool winds in the winter season; It is seen that the winds in the summer is high due to humidity and temperature when the arrival directions, generally cold / cool winds in the winter season are considered (Fig. 14).

3. Conclusions

Today, deterioration of the ecological balance increases

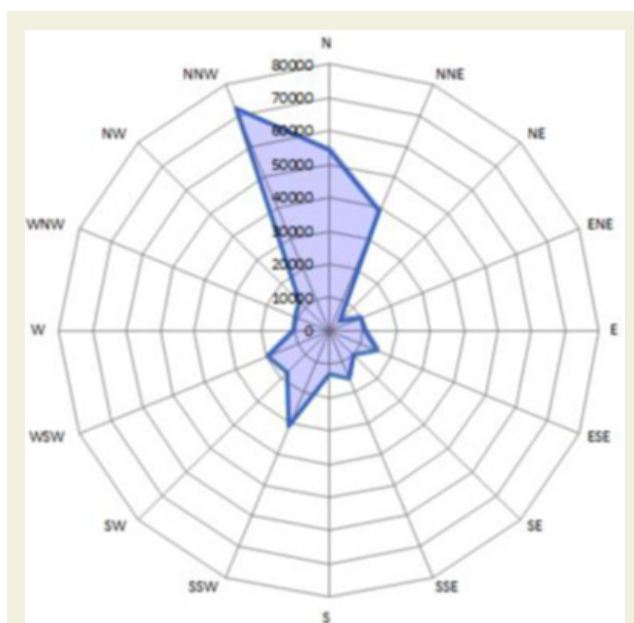


Fig. 14 Dominant wind direction in Mersin province

the importance of wind energy. In this respect, the share of wind turbines in electricity generation should be increased more. The rapid advancement of technology in the world has increased the need of countries for energy consumption. Orientation to alternative energy sources and investments have increased rapidly in recent years in order to use scarce resources such as water, oil and underground resources more efficiently and to reduce the environmental pollution that increases due to fossil fuel use. Wind Energy is an energy source that, due to its nature, causes little harm to the environment and therefore has low external costs. Technology that converts wind energy into electrical energy does not require large capital. This is an important advantage which causes a lower operating cost. Wind power is one of the renewable energy sources that stands out with its advantages such as low cost, less area of turbines compared to solar panels, low maintenance and repair costs and reduced dependency on foreign countries. Similar projects need to be supported in order to use wind energy systems more widely and put the existing potential into use. Supporting wind energy by local administrations is also important for the future of wind energy. In the study, the annual power generation values obtained with wind power plant capacity factors were compared. It is noteworthy that wind power plant capacity factors are almost the same. Wind speeds were investigated for potential wind turbines to be installed in the region by using wind speeds measured in the year of 2018 in Mersin Region. The following results can be derived from this work.

It has been observed that wind speeds in the range of 2 - 3 $m \cdot s^{-1}$ gives better results when the real values are considered.

As a result of the measurements and analyses made in this study, wind energy analysis was estimated for the Mersin region. When the wind data of Mersin is analysed, it is seen that the potential exists and that there are suitable investment areas especially in Mut district. Therefore, wind farm applications started intensely in this region. These systems can be used as a priority in energy production due to their advantages such as positive contributions to the environment and not harming the agricultural areas and changing according to the purpose of use.

The study shows that Mersin province is very suitable for wind power investment. Since the Mersin region is also an area where agricultural activities are intensive, integrating the electricity produced from turbines into agricultural activities will also provide an advantage. Turkey's current energy sources are not sufficient and the energy needs of the growing population and developing industry increasing rapidly. Therefore, the gap between energy production and consumption is growing rapidly. Considering the rapid depletion of energy resources, the use of renewable energy resources should be encouraged and the private sector should be supported in this area.

The wind power plants are far from the consumption centres and the regional energy supply security is not provided. This is one of the main problems faced by investors in wind energy in Turkey; This problem should be overcome with incentives and appropriate planning.

Considering the increasing and changing needs of the wind energy sector at the national and international level, support should be provided to companies in the region to become suppliers to both the domestic and export-oriented wind energy sector. It should also be aimed to increase the new investments to be made in this sector.

20% of the land use of Çukurova Region consists of agricultural areas and much more forest areas, it can be said that most of the region is rural. In this context, the use of small-scale wind turbines should be expanded in the countryside.

The evaluation of the wind energy potential with the intensive studies and supports made to the investors help to increase the use of wind energy in Mersin province.

It is also possible to say that Hatay, Mersin and Osmaniye will be pioneers in the increase of installed power due to available potential if the required attention is given.

4. Acknowledgements

The authors would like to thank the General Directorate of State Meteorology Affairs for providing meteorological data for Mersin province, the anonymous reviewers, managing editor, and editor in chief for their valuable help in improving the manuscript.

Conflict of interest M Dağtekin and B Yelmen declare that they have no competing interests.

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