Contribution of Bergama Wind Power Plants to Turkey's General Energy Consumption

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Abstract. Wind energy has a 10.4% share of the 326.3 TWh electrical energy consumed in Turkey in 2023, and this study focuses on this percentage. More specifically, it considered the power of seven wind energy power plants in Izmir's Bergama district in this consumption. The power plants in Bergama generated a total of 1.259 million kWh in 2023. In Izmir, they contributed 0.26% to 2% of energy consumption nationally, and between 0.01% and 0.13% throughout Turkey. Still, the Bergama Wind Power Plant produced the most, while the 2% consumption rate in Izmir and the 0.13% consumption rate across Turkey stand out. Overall, this analysis assesses the power plants' energy production based on their efficiency and the contribution to the overall consumption of energy nationally, using a comparison based on production and consumption rates. Therefore, the results should demonstrate the immense potential of investing in this field to increase Turkey's energy diversity and security, stressing the need for renewable energy to dominate energy consumption.

1. Introduction

Wind power qualifies as the most crucial renewable resource that is necessary for bolstering sustainable development and a cleaner environment. Beyond being a replacement to depleting fossil basis, wind energy is economical, given its high availability, in that it can address the surging demand [1]. While the fossil reserves are rapidly depleting, governments seek energy security, prompting the search for the domestic, eco-friendly, and cost-efficient sources [2-3]. Wind power is also instrumental in the "green energy" trend, experienced due to its zero pollution and renewable characteristics. Wind energy becomes less dependent on subsidies and develops its technological capacities, maintaining its crucial role among renewables. The future indicates a pathway to a less carbon-intensive future [4].

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Turkey is on a transformative journey from fossil fuel dependency to embracing renewable energy. Although renewables currently meet less than 10% of the nation's energy needs, the goal is to elevate this to 30% by 2023. The country's geographical advantage is significant for the exploitation of renewables like wind, solar, hydroelectricity, and geothermal power [5]. Turkey aims to curtail its energy imports, which represent 70% of its consumption, by harnessing its own clean energy resources [6]. Renewable energy cooperatives are emerging as key players in sustainable development and in reducing the environmental impact of energy consumption [7]. Adopting renewable energy is not only an environmental and economic priority but also a strategic move to diminish the current account deficit linked to expensive energy imports [8].

The Bergama district of Izmir features a high wind energy potential due to wind favorability. The information provided by the local meteorological stations ensures that the wind frequency and distribution are elaborated in the detailed abstract [9]. While the information on wind classification in regards to Bergama is not explicitly stated in the researched abstracts, the possibility of the implementation of small turbines in analogous cases under a wind speed is confirmed. Thus, the aforementioned views on Bergama's wind characteristics correspond to Turkey's goals in renewable energy.

Thus, this study will allow obtaining a more detailed grasp of the interactions in the Turkish wind energy sector, namely, generation trends for electricity in Bergama, Izmir, and its place in national consumption, to discuss. Research involves analyzing and assessing the annual production's data from seven wind power-plant companies producing energy of Bergama and the interaction of the production input of this source with consumption of the energy in the city of Izmir and Turkey as a whole. The purpose of this research is to demonstrate the role of the wind power-generation potential of Bergama in the Energy Strategy of the country and the adoption of the objectives to utilize the renewable sources.

2. Literature review

The rise of wind energy marks a significant milestone towards cleaner energy sources across the globe. Wind turbines generate electricity from the wind in more than 100 countries. China, the United States, and Germany lead in terms of installed wind energy capacity. Turkey also boasts a remarkable journey ranking 7th in Europe and 12th globally in terms of installed wind power plant capacity. Nations across the world aim for net zero emissions, and hence, renewable energy is the next big move and wind energy, in particular, must be expanded [10]. Wind energy potential is researched, examining the prevailing conditions that enable a state to meet its energy needs sustainably. Turkey demonstrates its dedication to renewable energy. Wind farms play a significant role in satisfying the grid, making substantial electricity production. The majority of electricity derived from this source is still hydro, but wind power contribution is growing remarkably. Research explores the challenges and opportunities in wind energy as the country and other states focus on a greener future and consider wind as paramount in attainting their energy aspirations [11].

This wind energy review of Turkey, especially the Bergama district of Izmir, reflects a positive trend in the wind energy field that needs to be expanded due to the growing energy needs of Turkey and the necessity for renewable power sources. In particular, the study Investigation of Wind Characteristics in terms of Wind Energy for Bergama conducted by Yavuz et al. in 2016 investigates the wind energy potential of the Bergama district of Izmir according to long-term wind speed and direction data at an 80-meter altitude. The results show that during 1981-2014, the area selected for the analysis was suitable for wind farm project development, as the average wind speed was 8.37 m/s, and the extreme wind speeds were minimal. The study also employed several statistical analyses of the data and wind energy forecasting methods to confirm the promise of wind energy production in Bergama

[12]. In another study conducted in 2020, Pınar et al. provide a general geographical perspective on Turkey's latent wind energy potential. According to the results of this research, geographical analysis of wind turbines and power capacity in Turkey shows that there is a dense cluster on the Aegean and Marmara coasts, which mostly have suitable wind conditions. Researchers have also found that Turkey's wind potential is significantly under-explored [13].

Bergama is a Turkish district in which the cultural heritage of the country is organically intertwined with the current and future aspects of its development. Bergama's ancient ruins, including the well-known Pergamum, structures of the Acropolis, the Asklepion, and the Red Basilica, provide a picture of the past that forms the district's cultural landscape. Still, Bergama is not a city living in the past. It actively invests in renewable energy, mainly wind power. The excellent wind conditions in the area have made it a center for wind power plants, which power the future by contributing to Turkey's shared energy consumption. By combining the natural and historic significance of the district, Bergama realizes a model of ecological and historical sustainability. This perspective is reflected in the wider context of Turkey's approach towards its renewable energy goals, showing the country's commitment to a sustainable local and global future while guaranteeing the creation of a significant energy independence tool. Therefore, Bergama is a successful and crucial example of how wind plants and local contributions affect the national energy system and the country's success in achieving sustainable development goals [14].

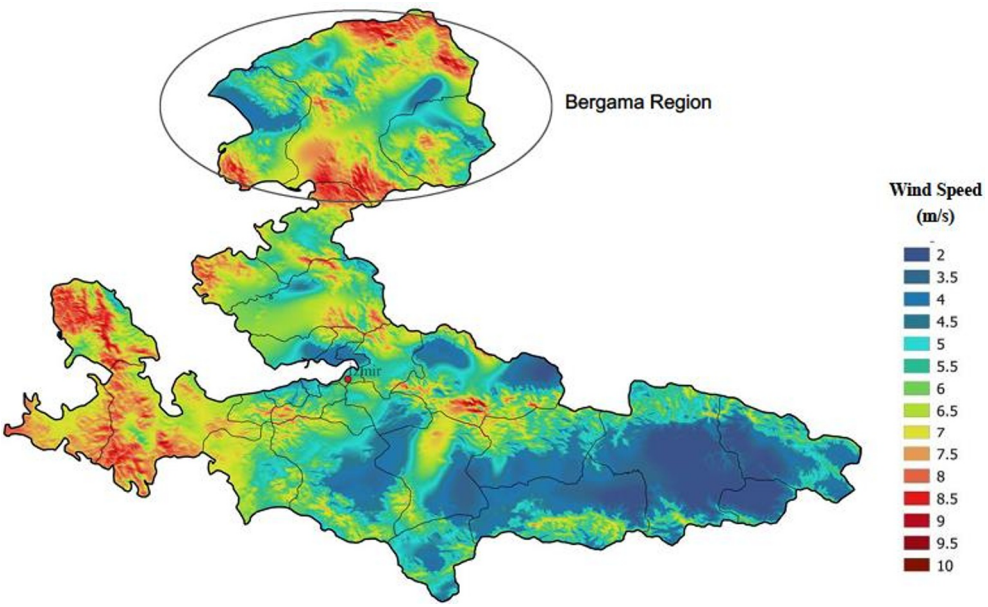


Fig. 1. Average Wind Speed Distribution in Izmir - 100 meters (*Source: Republic of Turkey Ministry of Energy and Natural Resources, Energy and Electricity Info Bank, https://repa.enerji.gov.tr/REPA/, accessed April 15, 2024)*

In Fig. 1, the colored map of Izmir depicts average wind speed distribution at 100 meters' altitude in the mentioned city. The wind speed is indicated by color codes in meters per second (m/s), changing from 2 m/s to almost 10 m/s. Thus, if we look at the color coding of the map, the Bergama region is obviously characterized by high wind speeds. Therefore, it can be assumed that the wind energy generation potential of the region allows to build energy units based on wind energy. Therefore, considering the interpretation of this part of the map in terms of the presence of wind power plants, it is seen that Bergama has the potential to meet a significant part of the energy needs of Izmir and Turkey [15].

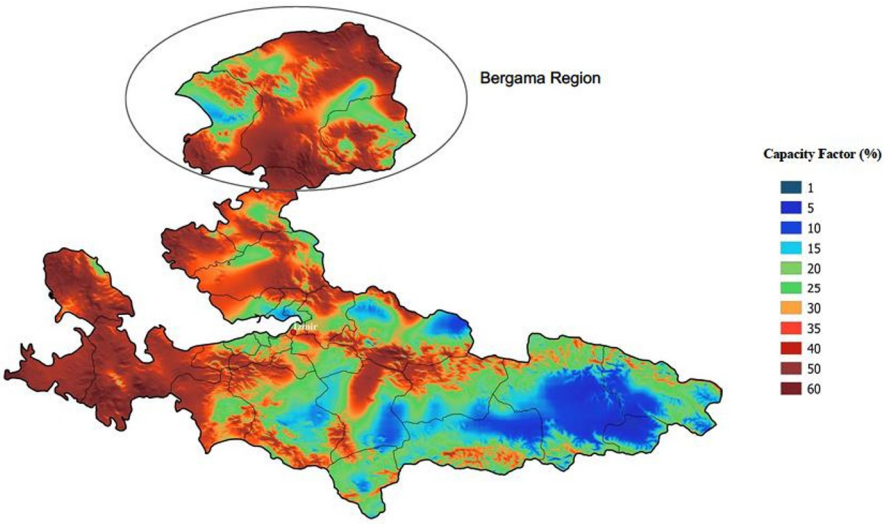


Fig. 2. Wind Capacity Factor Distribution in Izmir – 100 Meters (*Source: Republic of Turkey Ministry of Energy and Natural Resources, Energy and Electricity Info Bank, https://repa.enerji.gov.tr/REPA/, accessed April 15, 2024)*

Capacity factor distribution at 100 meters altitude for the Izmir region is presented in Fig. 2. Capacity factor is the ratio of the working energy production of a turbine to its maximum theoretical energy production and shows how efficiently the wind is used. Different colors generally range from 1% to 60% capacity factor values are represented. Especially in the Bergama region, the capacity factor exceeds high-limit values. Generally, the orange and red colors indicate a capacity factor varying between 30% and 60%. The related visual was drawn by considering the technical values of 3 MW capacity. Thus, it can be said that Bergama's wind energy potential is valuable not only because of its high-wind speed but also due to its high overall turbine efficiency [15].

As a result of the findings obtained as a result of the literature research, it is thought that the wind energy potential is not used sufficiently in various regions of Turkey, especially in the Aegean Region.

3. Material and method

The production performance of seven wind power plants in the Bergama region of the Izmir area between the years 2018 and 2023 was evaluated and the contribution of this production to Turkey's electricity consumption was analyzed. The total electricity consumption of Turkey in 2023 is 326.3 TWh and the share of wind energy in electricity production is 10.4% as given.

Secondary data sources have been examined in a reliable and honest context in the manner of ethical rules to official website of the Ministry of Energy and Natural Resources of the Republic of Turkey and the interviews with the wind power plants in Bergama region [16]. The interviews gave a highly beneficial context, especially in terms of offers how much annual energy they produce and what proportion of the electricity consumed in the country.

This study only contains current and verified data for 2023. Data on the annual energy production of power plants and the ratio of this production to the total energy consumption of Izmir and Turkey were at the center of the research.

3.1 Data analysis

The collected data were put through the quantitative analysis process. This procedure includes the calculation of the total energy production of the power plants and the ratio of this production to the total energy consumption of Izmir and Turkey.

Statistical software tools such as Microsoft Excel and SPSS were used to effectively organize, process and analyze the obtained data. This study covers only annual energy data for seven wind energy power plants in the Bergama region of Izmir. This is due to the fact that the Bergama region has a high potential of generating energy from wind. Furthermore, this analysis is entirely quantitative; thus, non-quantitative effects, such as the direct effect of these power plants on the socio-economic and environmental costs, are not evaluated.

4. Results and discussion

In this paper, the production performance of seven wind energy production facilities in the Bergama region of Izmir was analyzed, and their impact on the Turkey's national energy consumption for 2023 was estimated. Specifically, it was calculated that almost 10.4 TWh of Turkey's total electricity consumption of 326.3 TWh in 2023 was obtained from the wind energy source. The following Table 1 represents the measurements of the annual energy production of each wind power plant and the amount of the contribution to Izmir's and national energy consumption.

The Table 1 indicates that seven wind power plants in Bergama produce almost 1.26 billion kWh of the energy. It has been revealed that seven power plants contribute 6.11% to Izmir's total energy consumption and 0.38% to Turkey national energy consumption. These results identify the significance of wind energy for the development of regional and national matrices of the energy sector. Moreover, they demonstrate Turkey's substantial contribution to diversifying the energy production process using the means of natural sources.

Table 1. Izmir- Bergama Region Wind Power Plants

Plant Name	**Annual Energy Production (MWh)**	**Contribution to İzmir's Consumption (%)**	**Contribution to National Consumption (%)**
Bergama Wind Plant	414	2.00	0.13
Bergres Wind Plant	250	1.20	0.08
Yuntdağ Wind Plant	225	1.10	0.07
Düzova Wind Plant	157	0.76	0.05
Akça Wind Plant	76	0.36	0.02
Akbaş Bergama Wind Plant	83	0.39	0.02
Ovacık Wind Plant	55	0.26	0.01
Total	**1259**	**6.11**	**0.38**

5. Conclusion

Considering the desirable characteristics of the Bergama Wind Farm only, this production plant's contribution is extremely high. At the same time, it emphasizes the strategic importance of investments in the sector of wind energy for the strengthening of regional energy security and sustainable development. The peculiar impact of this power plant on the total energy consumption for Izmir and Turkey also indicates the critical role of the wind energy source in the country's energy consumption and production strategies.

This study's findings revealed that the exploitation of Turkey's wind energy potential could be easily integrated with the primary strategic goals of the country in the field of energy diversification and decrease in fossil fuels consumption. Moreover, operational indicators of wind power plants in the Bergama region make a meaningful contribution to the national objective to raise the proportion of renewable energy use in the final consumption of energy in Turkey. The information obtained within the course of the study is valuable for further wind energy development planning and policymaking, highlighting the potential contribution of wind energy to achieving the renewable energy objectives in Turkey.

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