

Techno-Economic Assessment of Onshore Wind Power Plant Site Selection in Türkiye Through a Decision Support Model Based on Transmission Cost Scenarios

Elif Tarakçı^{1,2}, Ramazan Yaman³

ABSTRACT

In recent years, renewable energy (RE) has become a significant topic both globally and in Türkiye. Renewable energy systems (RESs), in particular, appear to play a significant role in decreasing many of the risks the world faces, such as global warming and increased carbon emissions. This issue is currently on the agenda of the United Nations Sustainable Development Goals (SDGs) under the heading of SDG 7: Affordable and Clean Energy, and research in this area is increasing over time. In this study, a decision-support model was developed to evaluate suitable sites for wind power plant (WPP) investments. In addition to considering the plant installation cost and operation and maintenance (O&M) cost, the model incorporates different pricing scenarios for transmission costs. Break-even times (BETs) were calculated for representative cities across the seven regions of Türkiye, taking into account the revenues obtained from the sale of energy generated by the WPPs. In addition, net present value (NPV), internal rate of return (IRR), and sensitivity analyses were conducted to further evaluate the long-term economic feasibility and robustness of the candidate investment locations. The results revealed that the developed framework and the comparative economic analysis could serve as a guide from an innovative perspective for entrepreneurs planning to invest in this sector in Türkiye.

Keywords: Renewable Energy, Techno-Economic Assessment, Energy Transmission Cost, Decision Support Model, Site Selection.

1. INTRODUCTION

Energy is a fundamental need for development. However, sustainable development can only be achieved through the implementation of sustainable energy systems. With the rise of RE technologies over the past few decades, the share of RE in electricity generation has increased in many countries. However, in some countries and sectors such as transportation, RE is still at a very early stage. This is due to the unique characteristics of each region. Therefore, for RE to advance, countries must accurately analyze the resources within their regions, identify suitable systems, and then develop these systems [1].

¹ Corresponding Author: elif.tarakci@atlas.edu.tr

² Dr., Atlas University/Istanbul/Türkiye, and ORCID Number: [0000-0002-6385-7293](https://orcid.org/0000-0002-6385-7293)

³ Prof. Dr., Balıkesir University/Balıkesir/Türkiye, and ORCID Number: [0000-0002-4115-1417](https://orcid.org/0000-0002-4115-1417)

Article Submission Date: February 26, 2026 / Acceptance Date: July 2, 2026

Doi Number: [10.18466/cbayarjbe.1897938](https://doi.org/10.18466/cbayarjbe.1897938)

Article Type: Research Article

Targets such as climate change, global warming, energy security, cost minimization, and carbon footprint reduction are particularly powerful drivers of energy development [2]. Furthermore, energy is one of the United Nations SDGs [3]. IRENA's Renewable Capacity Statistics 2025 report also demonstrates that significant progress has been made globally. According to the report, RE capacity increased by 585 GW (15.1%) in 2024. More than three-quarters of this growth came from solar energy, with an increase of 452 GW (32.2%), followed by wind energy with an increase of 113 GW (11.1%). Among countries, China is known to have accounted for more than two-thirds of the total capacity increase (+79.9 GW), while the United States achieved an increase of 5.1 GW. Brazil, India, Canada, Türkiye and some European countries are other countries that have made significant progress in capacity increase [4].

Sustainable energy is a vital area involving many different stakeholders, from generation to end-users, including the public, companies that generate and distribute energy, and intermediate suppliers [5]. While the high initial investment costs of RESs such as solar farms and wind power plants are a serious problem, they are also observed to have relatively lower O&M costs and no fuel costs [6]. The unit energy generation costs of RE sources such as wind, photovoltaic solar, and deep geothermal energy vary depending on the geographical conditions in different regions of a country. Unlike fuel-based energies such as coal, natural gas, and uranium, these sources can be transmitted through electricity transmission systems, creating new constraints and dependence on transmission infrastructure during energy transfer. The cost situation due to geographic location and the dependence on infrastructure for electricity transmission play a critical role in making realistic estimates of the expected growth in RE generation across countries. The transmission of energy between regions becomes a much more important issue, especially in reducing costs and increasing the efficiency of the energy system [7].

Different pricing methods are utilized in international electricity markets to effectively manage transmission capacity and mitigate grid congestion. While zonal pricing systems are predominantly implemented in European electricity markets, locational marginal pricing and nodal pricing approaches are widely adopted in countries such as the United States and Canada. These mechanisms directly incorporate transmission constraints and regional grid congestion into the pricing structure, thereby influencing both electricity market operations and investment decisions [8]. Transmission costs and grid constraints in international electricity markets have been extensively examined within the scope of different pricing mechanisms such as locational marginal pricing [9,12], nodal pricing [13,15], and zonal pricing [14,16]. However, the majority of existing studies mainly focus on electricity market operation, congestion management, and price formation mechanisms, whereas studies evaluating the effects of transmission-cost-based pricing structures on the economic feasibility of renewable energy investments remain relatively limited. In particular, comprehensive techno-economic studies investigating the impacts of

transmission-distance-sensitive cost structures on wind power plant investments in Türkiye are still lacking.

Developing renewable and sustainable energy systems is of paramount importance for many industrialized countries aiming to achieve global and environmental sustainability goals. However, studies have shown that meeting energy demand sustainably and efficiently, from the first industrial revolution to the present day, is one of the most complex and challenging challenges [17]. Therefore, all steps from the design to operation of these sustainable energy systems must be carefully examined to ensure their economic viability and their relationship with the environment [18]. In modern societies, a continuous supply of energy is a fundamental need for users. However, for many developing countries, uninterrupted energy supply is not achieved due to insufficient energy generation, losses incurred during transmission, and inadequate and legacy distribution infrastructures, which pose a serious problem [19].

Türkiye has made significant progress in the wind energy sector thanks to the advantages provided by its geographical location and climate, particularly the increased focus on RE sources and the government's incentive policies. There are studies showing that the wind characteristics of the Marmara, Aegean, Mediterranean, and inland regions are suitable for electricity generation [20]. Thus, many remarkable studies have been conducted in Türkiye in the field of wind energy, evaluating environmental, economic and technical criteria [21,29]. Aksu and Gencer [30] evaluated the suitability of offshore wind farms to be established in Türkiye's marine areas using two different methodological approaches. Aktekin et al. [31] conducted a techno-economic feasibility assessment in Mersin, Türkiye, to design a clean and sustainable energy system combining wind and solar energy systems with nuclear power plants. This study aimed to provide uninterrupted electricity for hourly and peak residential load demands. Insel et al. [32] conducted cost analyses for onshore wind and solar photovoltaic (PV) installations in Türkiye under various local and global investment scenarios. These scenarios sought to develop a forecast for Türkiye's annual installed power potential through 2030. Gönül et al. [33] conducted a feasibility study and a SWOT analysis of Türkiye's competitive position to discuss Türkiye's wind energy situation and the current feed-in tariff scheme. They suggested policies and incentives that could pave the way for Türkiye's progress in wind energy. Tagliapietra et al. [34] conducted an analysis of the capital costs of wind energy investments using data from 138 wind farms included in the feed-in tariff program in 2017. This analysis concluded that the capital cost in Türkiye, with an upper limit of 12%, was not higher than in EU countries. Dayi et al. [35] conducted a feasibility study to analyze the feasibility of wind power plants to be built in several districts of the Kastamonu region. The study showed that the expected payback period of the investment could vary between 2 and 25 years, depending on various factors, including the site and turbine size.

In this study, the installation, operation, maintenance, and transmission costs, together with the revenues obtained from electricity sales, were calculated for provinces selected from seven different regions of Türkiye. To evaluate the economic feasibility of wind power plant investments, three different transmission-cost-based pricing scenarios were developed and BET values were calculated for each scenario. In addition to BET analyses, NPV and IRR analyses were conducted to evaluate long-term economic performance. Furthermore, sensitivity analyses based on capacity factor, electricity selling price, and transmission unit cost parameters were performed to assess the robustness of the proposed framework under different operating conditions. In this respect, the study aims to be one of the limited number of techno-economic studies evaluating the effects of transmission-cost-sensitive pricing structures on the economic performance of wind power plant investments by jointly utilizing BET, NPV, IRR, and sensitivity analyses. Thus, the study comprehensively examines the effects of transmission-distance-sensitive pricing structures on the economic feasibility of wind power plant investments in Türkiye. The details of the proposed mathematical model are presented in Section 2.

2. MATERIALS AND METHODS

The establishment of a WPP involves an initial investment cost, including not only the turbine cost but also other installation costs. Once a WPP becomes operational, revenue begins to be generated through electricity sales. However, electricity transmission and O&M costs arise. For a power plant to turn a profit, revenue must exceed the total of the initial investment, transmission, and O&M costs. This study aims to achieve the BET where revenues and costs are equal, as quickly as possible. To this end, an innovative mathematical model is proposed that contributes to the literature by considering a different transmission cost calculation. The proposed framework performs comparative economic evaluations of candidate locations under different transmission pricing scenarios.

The model designed two different scenarios for transmission costs. In the first scenario, transmission costs are calculated based solely on the amount of energy transmitted per unit of time; in the second scenario, a model was developed that considers the amount of energy transmitted as well as the transmission distance. In addition to the initial investment and O&M costs involved in site selection for a onshore WPP, the impact of transmission costs calculated using different pricing methods was analyzed. During the implementation phase, BET values, which represent the payback period of the investment and the total revenue generated by transmitting electricity generated by wind turbines installed in selected cities across seven regions of Türkiye to Istanbul, a city with a high industrial density and very high electricity consumption, were calculated. The results indicate that when calculating transmission costs, the distance between the investment location and the destination can be an important factor in determining location selection, in addition to the amount of energy transmitted per unit of time. In this study, all calculations were performed in MS Excel. The model's notations, assumptions, objective function, and constraints are presented below.

Notations, Parameters and Decision Variables

r = Index for installation region ($r = 1, 2, \dots, p$)

n_r = Number of turbines in region r

c_r = Cost of a turbine in region r (\$)

p = Number of installation regions

BET_r = BET in region r (year)

IC_r = Installation cost in region r (\$)

TC_r = Turbine cost in region r (\$)

OC_r = Other installation costs in region r (\$)

TMC_r = Transmission cost in region r (\$/year)

OMC_r = O&M cost in region r (\$/year)

R_r = Total revenue in region r (\$/year)

α_r = Ratio of other installation costs to turbine costs

E_w = Amount of energy generated per unit time by a turbine (MWh)

E_p = Amount of energy transmitted per unit time (MWh)

C_u = Fixed annual transmission line system usage fee by installation region (\$/MWh)

C_p = Unit transmission fee per unit of energy (\$/MWh)

C_v = Unit sales price per unit of energy (\$/MWh)

L = Straight-line distance from the installation region to the transmission point (km)

$q = \begin{cases} 1, & \text{If the transmission cost depends only on the amount of energy transmitted} \\ 0, & \text{If the transmission cost depends on both the transmitted energy and the transmission distance} \end{cases}$

$y_r = \begin{cases} 1, & \text{if installation is carried out in the region} \\ 0, & \text{otherwise} \end{cases}$

γ = Ratio of annual O&M cost to installation cost

t = Operation period (years)

CF_r = Capacity factor of installation site r

$z = 24 \times 365$ (hours)

Assumptions

1. Installed capacity is equal in all regions.
2. Installation will be carried out in each region by purchasing or leasing approximately equal-sized non-zoned land.
3. The distance from the installation region to the main grid is assumed to be covered by overhead transmission lines.
4. The transformer to be installed in each region will have the same capacity.
5. It is assumed that all the generated energy is transmitted and sold.

Objective Function

$$Z = \min(BET_r) \quad (1)$$

Constraints

$$BET_r = IC_r / (R_r - TMC_r - OMC_r) \quad (2)$$

$$TC_r = n_r c_r \sum_{r=1}^P y_r \quad (3)$$

$$OC_r = TC_r \alpha_r \quad (4)$$

$$IC_r = TC_r + OC_r \quad (5)$$

$$TMC_r = C_u + E_p z C_p q + E_p z (L/100) C_p (1 - q) \quad (6)$$

$$OMC_r = IC_r \gamma \quad (7)$$

$$R_r = E_p z C_v \quad (8)$$

$$\sum_{r=1}^P y_r = 1 \quad (9)$$

$$\max\{E_p\} \leq \max\{n_r E_w\} \quad (10)$$

$$E_w, E_p, C_p, C_v, c_r \geq 0 \quad (11)$$

- (1) The model ensures the minimization of the BET.
- (2) It defines the time at which the revenue in a region equals the sum of total installation cost, transmission cost, and O&M cost.
- (3) It represents the turbine cost in a given region.
- (4) It accounts for the costs other than turbines cost in a wind farm to be installed in a region.
- (5) The installation cost consists of the sum of turbine cost and other installation costs.
- (6) It defines the cost incurred during the transmission of the generated energy.
- (7) It includes the costs of wind turbines, other installed equipment, and O&M.
- (8) It represents the revenue obtained from the sale of the energy generated.
- (9) The model ensures that a region is selected.

- (10) The maximum amount of energy transmitted per unit time cannot exceed the maximum energy that the WPP can generate per unit time [36].
- (11) The model ensures the non-negativity condition.

3. RESULTS AND DISCUSSION

When planning the installation sites of WPPs, many parameters such as wind speed, power density, and capacity factors are considered. Beyond turbine and other installation costs during system establishment, transmission costs of the generated energy and O&M costs can significantly affect the payback period of the investment. This study aims to provide investors and decision-makers with a perspective on how long it would take for WPPs installed with equal capacity in selected cities across Türkiye's regions that stand out for wind energy potential to reach their BETs, considering investment costs together with transmission and O&M costs against revenues from electricity sales.

For medium-scale WPPs to be installed in these cities, an equal number (30 turbines) and equal capacity (5 MW) of turbines were selected [37]. Therefore, turbine costs (nacelle, rotor, tower, etc.) [38] and other installation costs (foundation construction, electrical infrastructure and grid connection, transportation and installation expenses, road and site preparation, permit-license and consultancy costs, etc.) are assumed to be the same across all cities. The ratio of other installation costs to turbine costs was taken as approximately 0.45 [38]. Thus, the initial investment cost, i.e., the installation cost, is considered equal for all cities. While calculating the annual O&M costs, their ratio to the installation cost was considered and determined as 0.015 [39].

Although the installed capacity is equal in all cities, the average capacity factors [40] differ; therefore, the amount of energy that a single turbine can generate per unit time also varies. This indicates that the amount of energy transmitted per unit time changes from city to city.

In this study, two different cases were considered in the calculation of transmission costs. In the first case, the transmission cost was based solely on the amount of energy transmitted, independent of distance. In the second case, the transmission cost was calculated by taking into account not only the amount of energy transmitted but also the transmission distance. Furthermore, for Case 2, where the transmission distance is considered, an additional Case 3 with a different pricing policy is presented below. In addition to BET-based evaluations, NPV, IRR, and sensitivity analyses were also conducted to further assess the long-term economic feasibility and robustness of the proposed investment scenarios. Furthermore, model limitations and future research directions are discussed in order to provide a more comprehensive evaluation of the proposed framework.

3.1. BET Results Under Different Transmission Pricing Scenarios

3.1.1. Case 1: Transmission cost based on the amount of transmitted energy

First, in Türkiye, the transmission cost of a WPP was priced solely based on the amount of energy transmitted per unit time, according to the tariffs determined by the Energy Market Regulatory Authority (EPDK) for the year 2025. Each city is located within a tariff zone and depending on the city where the WPP is installed, both a fixed annual fee and system usage and operation fees per 1 MWh are charged. In this pricing scheme, the transmission distance is not considered [41]. Figure 1 shows the annual transmission costs of the total energy produced by the cities when pricing is carried out based solely on the transmitted energy.

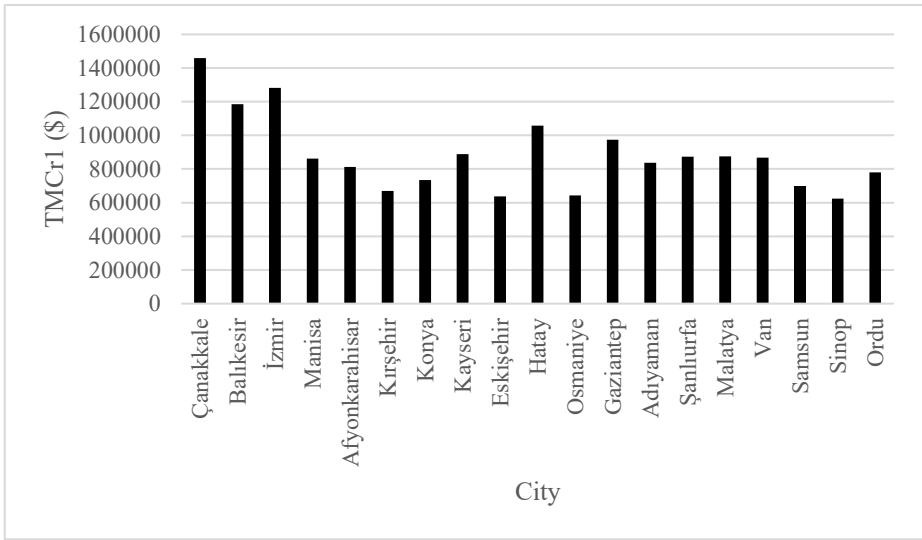


Figure 1. The annual transmission cost of the cities is calculated based on the amount of transmitted energy (for Case 1).

3.1.2. Case 2: Transmission cost based on both the amount of transmitted energy and the transmission distance

In the second evaluation, a pricing approach that considers transmission distance currently not applied in Türkiye but with examples worldwide was adopted [8]. The energy generated by the WPP is transmitted from the city of installation to Istanbul, where industrial activity and energy consumption are concentrated. Distances were approximated as straight-line distances. At this stage, the unit price was calculated based on the base fee determined by EPDK for usage and operation, multiplied by a coefficient obtained by dividing the distance between the installation city and Istanbul by 100. In this way, a unit price dependent on transmission distance was derived. Figure 2 presents the annual transmission costs of the

total energy produced by the cities when both the amount of transmitted energy and the transmission distance are considered.

3.1.3. Case 3: Transmission cost based on the amount of transmitted energy and transmission distance, with a tiered pricing scheme

While a fixed unit price based on distance was considered in Case 2, in this evaluation, it is assumed that the unit price increases for every 100 km. Although distance-based transmission pricing is not currently implemented in Türkiye, it varies in international electricity markets depending on cost structures and grid conditions, thereby influencing investment decisions and economic incentives [8].

With this approach, decision-making authorities would be encouraged to promote energy generation closer to consumption centers, transmission to the grid, increased reliability, and the reduction of technical problems. For the first 100 km, the initial price was calculated based on the base fee determined by EPDK for usage and operation. From this point, a certain rate of price increase was applied for each additional 100 km. The impact of this price variation on transmission cost was analyzed. The price increase per 100 km was taken as 0.05. Figure 3 shows the annual transmission costs of the total energy produced by the cities when transmission cost is calculated based on the transmitted energy, transmission distance, and a tiered price adjustment for every 100 km.

An examination of the three cases clearly shows that distance significantly affects transmission costs. As illustrated in Figure 3, even a small price increase of 0.05 per 100 km considerably raises transmission costs. As this rate grows, the transmission costs rise even further. Compared to the transmission cost calculated solely based on transmitted energy, when distance is also considered in Case 2 and Case 3, the costs for cities closer to Istanbul, such as Çanakkale and Balıkesir, increase by approximately 137% and 145% for Çanakkale, and by 77% and 81% for Balıkesir, respectively. However, in more distant cities, such as Van, transmission costs rise dramatically, reaching 1157% and 1597%.

Türkiye consists of seven different regions, and for this study, the cities with the highest capacity factors where WPPs can operate most efficiently were selected from each region. For all three cases, the installation cost, annual O&M cost, and transmission cost of the cities were calculated. In addition, the unit sales price of the electricity generated by the WPPs was based on the tariff determined by the RE Resources Support Mechanism (YEKDEM) [42] for August 2025. In Figure 4, after the costs and sales prices were determined, BET was calculated for each city in each case to indicate how long it would take for the WPPs to become profitable.

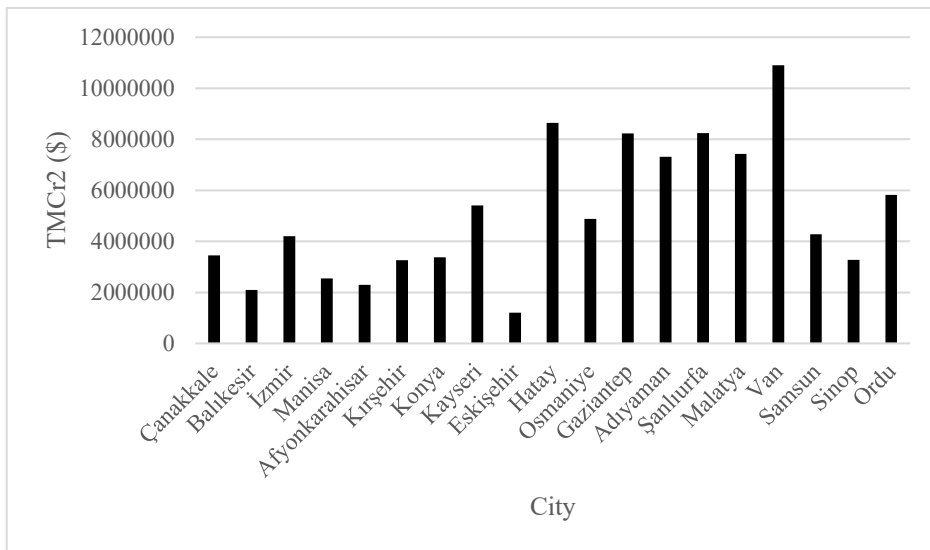


Figure 2. Annual transmission cost of the cities is calculated based on both the amount of transmitted energy and the transmission distance (for Case 2).

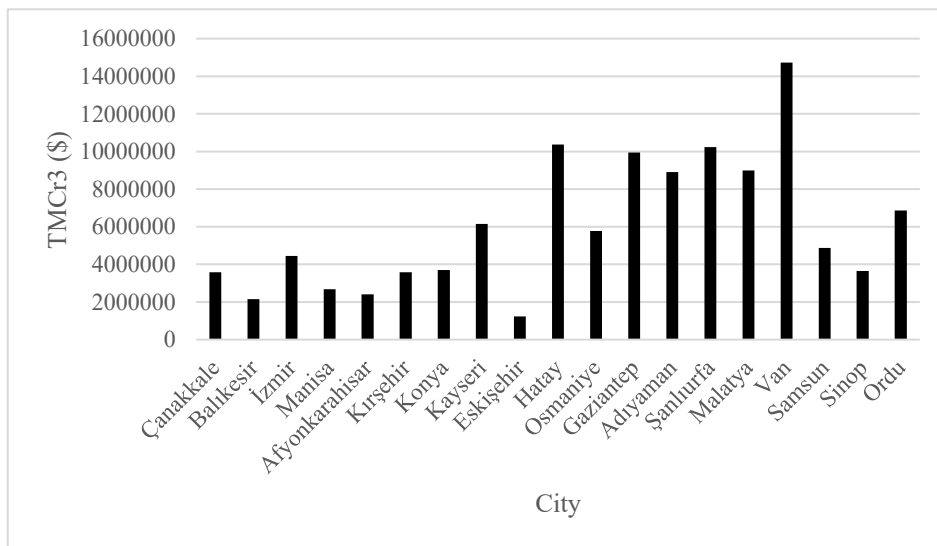


Figure 3. Annual transmission cost of the cities is calculated based on both the amount of transmitted energy and the transmission distance (for Case 3).

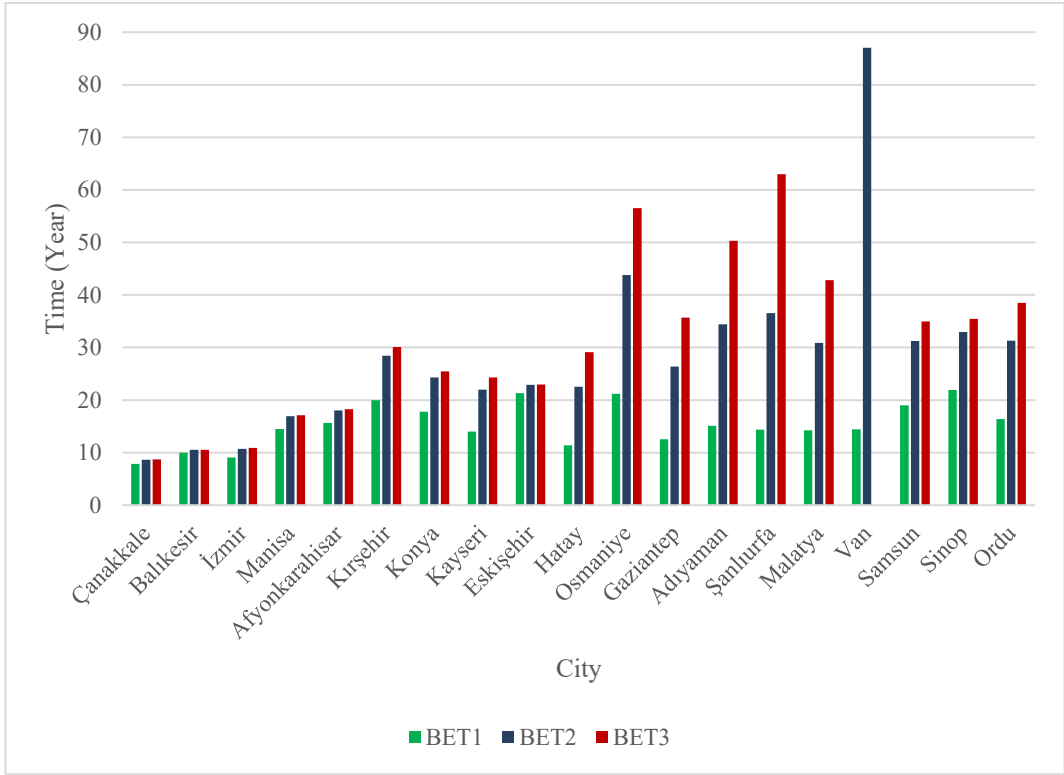


Figure 4. BET values calculated for each case of the cities

When the results are examined in the context of Balıkesir and Çanakkale, the findings show that although Balıkesir is geographically closer to Istanbul than Çanakkale, the BET1, BET2 and BET3 values of Balıkesir are higher than Çanakkale because the capacity factor of Balıkesir is lower than Çanakkale. If transmission costs are calculated based on the amount of energy transmitted per unit of time, Balıkesir has a BET1 value approximately 27% higher than Çanakkale; however, when transmission distance is also taken into account, the differences in BET2 and BET3 decrease to approximately 22% and 21%, respectively. This suggests that, under different transmission cost scenarios, a WPP installed in a city with a low capacity factor but close to the consumption area could create a cost advantage. Çanakkale has a high capacity factor and is the second closest city to Istanbul among the selected cities. However, when the transmission cost for a WPP installed in Çanakkale is calculated based solely on the energy transmitted per unit of time, its high energy generation capacity becomes a disadvantage, resulting in higher transmission costs compared to other cities. In Cases 2 and 3, where transmission distance is also taken into account, the volume of energy transmitted and its proximity to the demand region make it more advantageous than other provinces.

Among the selected cities, İzmir has the second-highest capacity factor, and although BET1 is approximately 9 years, its distance to Istanbul is almost twice that of Balıkesir, resulting in BET2 and BET3 values that are about 2% and 3.6% higher, respectively, compared to Balıkesir. For Manisa, since its distance to Istanbul is greater than that of the selected cities in the Marmara region and its capacity factor is lower, all BET values exceed 14 years.

Among the Central Anatolian cities, Kayseri has the lowest BET1 since its capacity factor is higher than those of Afyonkarahisar, Kırşehir, Konya, and Eskişehir. Afyonkarahisar appears to be in a more advantageous position in terms of both capacity factor and distance. On the other hand, Kırşehir and Konya have higher BET2 and BET3 values due to their greater distance from Istanbul.

For the Mediterranean, Southeastern Anatolia, and Eastern Anatolia regions, since the distances of the selected cities to Istanbul exceed 700 km, Hatay, which has a high-capacity factor, achieves BET1 in about 11 years in Case 1, where transmission distance is not considered. However, when distance-based transmission costs are included, BET2 and BET3 nearly double or increase even further. While a BET3 value is calculated for a wind turbine installed in Van, the sum of annual O&M costs and transmission costs exceeds revenue, making the BET3 value uncalculated. This demonstrates that when distance-based pricing policies are implemented, closeness of the wind turbine to the consumption location becomes a critical objective.

Although the Black Sea cities are geographically closer to Istanbul compared to those in the Mediterranean, Southeastern Anatolia, and Eastern Anatolia, their low-capacity factors especially in Samsun and Sinop result in high BET1 values. Compared to BET1, BET2 is about 64% higher for Samsun, 50% higher for Sinop, and 91% higher for Ordu. Among these three cities, Ordu has a better capacity factor; however, due to its greater distance from Istanbul compared to the others, BET3 shows a 135% increase relative to BET1.

Considering all these findings and evaluations, it is evident that BET values increase when transmission distance is considered in the calculation of transmission costs. In this regard, if distance-based pricing of long transmission lines is introduced in the future, both the capacity factor of the region and the distance of the installation site to the demand center will emerge as significant constraints. Therefore, while some regions may appear advantageous under energy-only pricing schemes, their investment payback times become much longer when distance-based fixed or tiered pricing is applied. This study thus demonstrates that, to lessen this risk in the future, distance-based pricing must be taken into account when selecting regions for investment.

3.2. NPV and IRR Analysis

NPV analysis was employed to evaluate the total economic value of the discounted net revenues generated throughout the project lifetime. IRR analysis was additionally

incorporated into the study to determine the internal rate of return of the investment and to comparatively evaluate the obtained results with the assumed discount rate. In this context, the project lifetime was assumed to be 25 years [43], considering the commonly accepted technical operational lifetime of wind power plants reported in the literature. Furthermore, a discount rate of 10% was adopted based on the discount rate ranges suggested in the literature for low-carbon and renewable energy investments [44].

The NPV approach was utilized to evaluate the long-term economic feasibility of candidate investment locations by considering discounted cash flows. The NPV formulation used in this study is presented in Equation 12. Similarly, the IRR approach was employed to determine the internal rate of return of the investments, and the corresponding calculation is given in Equation 13. IRR values higher than the assumed discount rate indicate that the investment is economically feasible, whereas IRR values below the discount rate indicate lower economic attractiveness of the investment.

$$NPV_r = -IC_r + \sum_{k=1}^t \frac{(R_r - OMC_r - TMC_r)}{(1+i)^k} \quad (12)$$

$$0 = -IC_r + \sum_{k=1}^t \frac{(R_r - OMC_r - TMC_r)}{(1+IRR)^k} \quad (13)$$

where:

k is the year index,

i is the discount rate.

NPV1, NPV2, and NPV3 represent the transmission cost scenarios of Case 1, Case 2, and Case 3, respectively. As shown in Figure 5, only Çanakkale exhibited positive NPV values under all transmission cost scenarios. In some cities such as Balıkesir and İzmir, near-zero or slightly negative NPV values were obtained particularly under the Case 1 scenario, where the transmission pricing mechanism was based solely on the amount of transmitted energy. However, when transmission distance was also incorporated into the cost structure in Case 2, and especially under the tiered pricing mechanism applied in Case 3, NPV values decreased significantly. Positive NPV values indicate that the discounted revenues generated throughout the project lifetime are sufficient to recover the total investment costs, whereas negative NPV values indicate lower economic feasibility of the corresponding investment. In addition, NPV values generally became more negative as the transmission cost scenarios became more restrictive. This result demonstrates that transmission costs have a significant impact on the economic sustainability of wind power plant investments.

Similarly, IRR1, IRR2, and IRR3 represent the internal rate of return values calculated for the corresponding scenarios. The IRR results presented in Figure 6 were generally found to be consistent with the NPV analysis. Çanakkale stood out as one of the most economically favorable investment locations, with IRR values above the assumed 10% discount rate under all scenarios. In some cities such as Balıkesir and İzmir, positive IRR values were obtained under all scenarios; however, these values generally remained below the assumed 10% discount rate, indicating limited economic attractiveness. Under the Case 1 scenario, where transmission pricing was based only on the amount of transmitted energy, cities such as Kırşehir and Osmaniye exhibited positive or near-zero IRR values. However, when transmission distance was incorporated into the pricing structure in Case 2 and Case 3, IRR values became negative. This finding indicates that distance-based transmission pricing mechanisms impose a significant economic burden, especially for regions located far from transmission infrastructure. Furthermore, IRR values in many cities remained below the assumed 10% discount rate. IRR values above the discount rate indicate economically feasible investments, whereas IRR values below the discount rate indicate lower economic attractiveness. Overall, the findings reveal that transmission-cost-based pricing mechanisms play a decisive role in the economic performance of wind power plant investments.

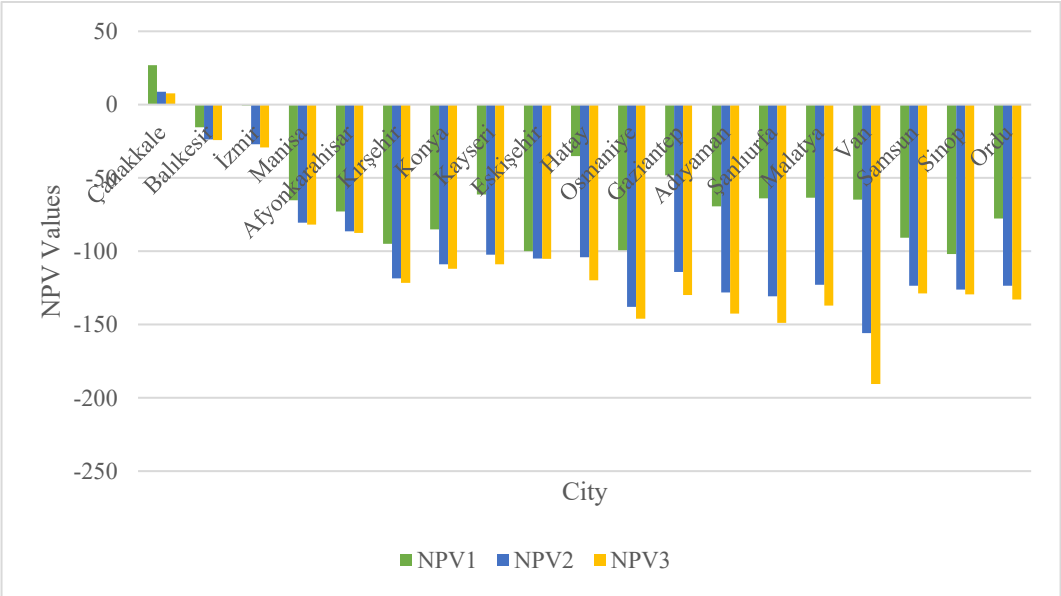


Figure 5. NPV values calculated for each case of the cities

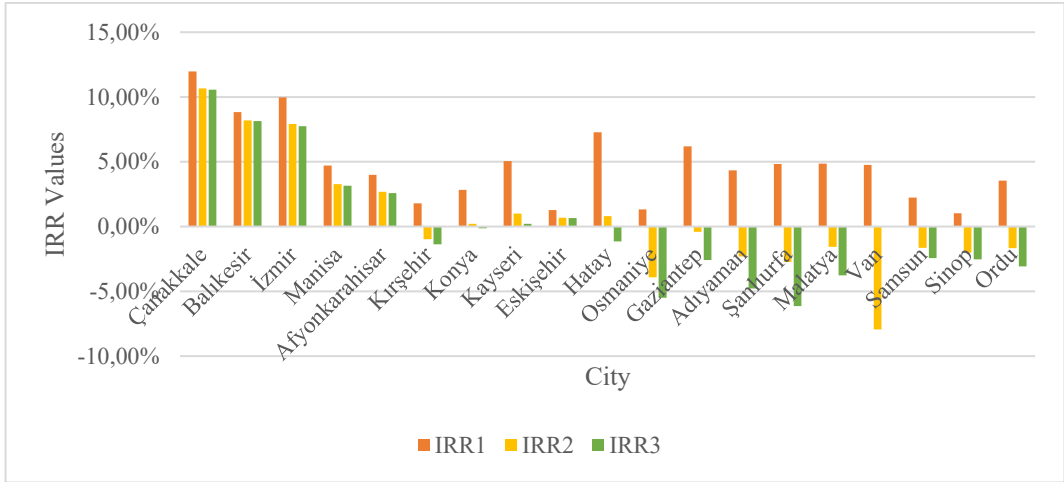


Figure 6. IRR values calculated for each case of the cities

3.3. Sensitivity Analysis

Sensitivity analysis was conducted in order to evaluate the robustness of the results under different operating conditions and alternative parameter assumptions. In this context, similar to the techno-economic sensitivity analysis approaches widely used in the literature [45, 46], the baseline parameter values were varied within specific ranges and their effects on BET results were examined. In the sensitivity analysis, capacity factor, electricity selling price, and transmission unit cost parameters were considered, and these parameters were analyzed by varying them within a $\pm 20\%$ range relative to their baseline scenario values. Base BET values remain identical across all sensitivity analyses since the same baseline scenario was used as the reference condition.

3.3.1. Capacity factor sensitivity analysis

The capacity factor sensitivity analysis results presented in Table 1 indicate that increasing capacity factor values generally reduce BET values for all cities and scenarios. In contrast, lower capacity factor values lead to noticeable increases in BET values. This effect becomes more pronounced particularly in BET2 and BET3 scenarios, where transmission distance and tiered pricing structures are incorporated into the transmission cost calculations. These findings demonstrate that variations in capacity factor significantly affect the economic feasibility of investments, especially in regions associated with higher transmission-related costs. Relatively lower BET values were obtained for cities such as Çanakkale, Balıkesir, and İzmir under all capacity factor levels, whereas considerably higher BET values were observed in cities such as Van, Osmaniye, and Şanlıurfa, particularly under the BET3 scenario. Overall, the results indicate that capacity factor is one of the most critical parameters directly influencing the economic performance of wind power plant investments (Table 1).

Table 1. Sensitivity analysis results of BET values under different capacity factor variations.

City	Capacity Factor (-20%)			Capacity Factor (Base)			Capacity Factor (+20%)		
	BET1	BET2	BET3	BET1	BET2	BET3	BET1	BET2	BET3
Çanakkale	10,13	11,16	11,23	7,86	8,64	8,69	6,42	7,05	7,09
Balıkesir	12,94	13,68	13,72	9,96	10,51	10,54	8,10	8,54	8,56
İzmir	11,78	14,00	14,23	9,11	10,75	10,92	7,42	8,72	8,85
Manisa	19,20	22,57	22,87	14,53	16,91	17,12	11,68	13,52	13,68
Afyonkarahisar	20,76	24,19	24,49	15,64	18,04	18,25	12,54	14,38	14,54
Kırşehir	27,01	39,79	42,37	19,99	28,43	30,07	15,86	22,12	23,30
Konya	23,78	33,41	35,15	17,76	24,29	25,43	14,17	19,08	19,93
Kayseri	18,48	30,00	33,42	14,01	22,02	24,30	11,28	17,39	19,09
Eskişehir	28,96	31,32	31,45	21,32	22,90	22,99	16,86	18,05	18,12
Hatay	14,86	30,82	40,84	11,38	22,57	29,10	9,22	17,80	22,60
Osmaniye	28,75	65,48	89,75	21,17	43,77	56,55	16,76	32,87	41,28
Gaziantep	16,48	36,60	51,57	12,56	26,38	35,72	10,15	20,62	27,32
Adıyaman	19,99	49,38	77,52	15,09	34,40	50,30	12,11	26,39	37,23
Şanlıurfa	18,96	53,00	103,16	14,35	36,58	63,00	11,54	27,92	45,34
Malatya	18,86	43,69	63,75	14,28	30,89	42,80	11,49	23,90	32,21
Van	19,11	161,68	N/A	14,46	87,04	N/A	11,63	59,55	N/A
Samsun	25,58	44,24	50,35	19,00	31,24	34,99	15,12	24,14	26,81
Sinop	29,88	47,02	51,15	21,93	32,96	35,47	17,33	25,37	27,15
Ordu	21,86	44,34	56,30	16,41	31,31	38,53	13,14	24,19	29,28

3.3.2. Electricity price sensitivity analysis

The electricity selling price sensitivity analysis results presented in Table 2 indicate that increasing electricity selling prices generally reduce BET values for all cities and scenarios, whereas lower electricity selling prices significantly increase BET values. This effect becomes particularly pronounced in BET2 and BET3 scenarios, where transmission distance and tiered pricing mechanisms are included in the transmission cost structure. Cities such as Çanakkale, Balıkesir, and İzmir maintained comparatively lower BET values under all electricity price levels, indicating relatively stronger economic resilience. In contrast, eastern and inland cities such as Osmaniye, Adıyaman, Şanlıurfa, Malatya, and Van exhibited substantial increases in BET values under lower electricity price assumptions, especially in the BET3 scenario. In some cases, extremely high or unstable BET values were observed, indicating that the economic feasibility of these investments becomes highly sensitive to electricity selling price fluctuations. Overall, the results demonstrate that electricity selling price is one of the most influential parameters affecting the economic performance and investment feasibility of wind power plant projects (Table 2).

Table 2. Sensitivity analysis results of BET values under different electricity selling price variations.

City	Electricity Selling Price (\$/MWh) (-20%)			Electricity Selling Price (\$/MWh) (Base)			Electricity Selling Price (\$/MWh) (+20%)		
	BET1	BET2	BET3	BET1	BET2	BET3	BET1	BET2	BET3
Çanakkale	10,30	11,68	11,78	7,86	8,64	8,69	6,36	6,86	6,89
Balıkesir	13,17	14,15	14,20	9,96	10,51	10,54	8,01	8,36	8,38
İzmir	11,99	15,01	15,34	9,11	10,75	10,92	7,34	8,37	8,47
Manisa	19,58	24,16	24,60	14,53	16,91	17,12	11,55	13,00	13,13
Afyonkarahisar	21,17	25,84	26,26	15,64	18,04	18,25	12,39	13,86	13,98
Kırşehir	27,58	46,74	51,33	19,99	28,43	30,07	15,67	20,43	21,26
Konya	24,27	38,37	41,30	17,76	24,29	25,43	14,00	17,77	18,37
Kayseri	18,84	36,87	43,75	14,01	22,02	24,30	11,15	15,69	16,82
Eskişehir	29,59	32,74	32,91	21,32	22,90	22,99	16,66	17,61	17,66
Hatay	15,13	44,41	79,57	11,38	22,57	29,10	9,12	15,13	17,81

Osmaniye	29,37	103,49	222,20	21,17	43,77	56,55	16,55	27,75	32,39
Gaziantep	16,79	55,94	125,65	12,56	26,38	35,72	10,04	17,26	20,82
Adıyaman	20,38	84,38	375,75	15,09	34,40	50,30	11,98	21,60	26,95
Şanlıurfa	19,32	106,40	N/A	14,35	36,58	63,00	11,41	22,08	29,57
Malatya	19,23	69,65	186,83	14,28	30,89	42,80	11,36	19,85	24,17
Van	19,48	N/A	N/A	14,46	87,04	N/A	11,50	34,11	135,40
Samsun	26,11	56,53	70,14	19,00	31,24	34,99	14,94	21,58	23,31
Sinop	30,53	57,13	65,12	21,93	32,96	35,47	17,11	23,16	24,37
Ordu	22,30	63,04	101,26	16,41	31,31	38,53	12,99	20,82	23,79

3.3.3. Transmission cost sensitivity analysis

The transmission unit cost sensitivity analysis results presented in Table 3 indicate that increasing transmission unit costs generally increase BET values for all cities and scenarios. In contrast, lower transmission unit costs lead to reduced BET values. This effect becomes more pronounced particularly in BET2 and BET3 scenarios, where transmission distance and tiered pricing mechanisms are incorporated into the transmission cost structure. Relatively lower BET values were obtained for cities such as Çanakkale, Balıkesir, and İzmir under all transmission cost levels, whereas cities such as Osmaniye, Gaziantep, Adıyaman, Şanlıurfa, Malatya, and Van exhibited substantial increases in BET values under higher transmission cost assumptions. Particularly in the BET3 scenario, extremely high and economically unstable BET results were observed for some cities. These findings indicate that transmission-cost-based pricing mechanisms have a critical impact on the economic feasibility of investments, especially in regions located far from transmission infrastructure. Overall, the results demonstrate that transmission unit cost is one of the major economic parameters directly affecting the payback period of wind power plant investments (Table 3).

Table 3. Sensitivity analysis results of BET values under different transmission unit cost variations.

City	Transmission Unit Cost (\$/MWh) (-20%)			Transmission Unit Cost (\$/MWh) (Base)			Transmission Unit Cost (\$/MWh) (+20%)		
	BET1	BET2	BET3	BET1	BET2	BET3	BET1	BET2	BET3

Çanakkale	7,76	8,35	8,39	7,86	8,64	8,69	7,97	8,95	9,02
Balıkesir	9,83	10,25	10,27	9,96	10,51	10,54	10,10	10,79	10,82
İzmir	8,98	10,22	10,34	9,11	10,75	10,92	9,23	11,33	11,56
Manisa	14,32	16,11	16,27	14,53	16,91	17,12	14,74	17,79	18,07
Afyonkarahisar	15,41	17,22	17,37	15,64	18,04	18,25	15,87	18,94	19,22
Kırşehir	19,69	25,70	26,75	19,99	28,43	30,07	20,30	31,81	34,32
Konya	17,50	22,20	22,96	17,76	24,29	25,43	18,03	26,81	28,51
Kayseri	13,81	19,37	20,74	14,01	22,02	24,30	14,21	25,50	29,33
Eskişehir	20,99	22,20	22,27	21,32	22,90	22,99	21,65	23,65	23,76
Hatay	11,22	18,44	21,61	11,38	22,57	29,10	11,54	29,08	44,55
Osmaniye	20,85	35,14	41,11	21,17	43,77	56,55	21,51	58,01	90,55
Gaziantep	12,39	21,11	25,36	12,56	26,38	35,72	12,74	35,13	60,37
Adıyaman	14,87	26,69	33,20	15,09	34,40	50,30	15,31	48,38	103,70
Şanlıurfa	14,15	27,17	36,19	14,35	36,58	63,00	14,56	55,95	243,15
Malatya	14,08	24,45	29,68	14,28	30,89	42,80	14,49	41,95	76,74
Van	14,26	41,64	154,61	14,46	87,04	N/A	14,67	N/A	N/A
Samsun	18,72	27,08	29,25	19,00	31,24	34,99	19,30	36,91	43,52
Sinop	21,59	29,32	30,88	21,93	32,96	35,47	22,28	37,63	41,67
Ordu	16,18	25,88	29,55	16,41	31,31	38,53	16,66	39,60	55,34

- N/A indicates economically non-interpretable BET results under the corresponding scenario.

3.4. Model limitations and future research directions

The obtained results demonstrate that not only wind energy potential, but also transmission cost structure and grid accessibility, play a decisive role in the feasibility of wind power plant investments. The proposed transmission-cost-based pricing approach indicates that

investment feasibility can increase in regions located close to transmission infrastructure, while economic performance may significantly decrease in distant regions. These findings highlight the importance of regional transmission incentives, infrastructure investments, and alternative pricing mechanisms for policymakers. From an investor perspective, considering transmission costs during the investment site selection process is critical for long-term economic sustainability.

Nevertheless, the study has several limitations. Capacity factor values were assumed to be constant, and annual wind variability was not considered in the analysis. In addition, transmission distances were calculated using a linear distance approach instead of actual grid topologies. Furthermore, only a single demand center, Istanbul, was considered in the analyses. Although these assumptions simplified the computational process of the model, they may have influenced the obtained results to a certain extent.

Future studies may incorporate multiple demand centers, actual transmission network routes, dynamic electricity pricing structures, and time-dependent wind variability into the proposed framework. In addition, considering different economic uncertainties may contribute to more comprehensive techno-economic evaluations.

4. CONCLUSION

Transforming a naturally existing form of energy into a usable state and transmitting it to specific locations where it is needed for intended purposes requires significant engineering effort and economic decision analysis. Since the generation of wind energy depends on geographical conditions, supplying it to industrial regions with high demand requires an efficient transmission infrastructure to deliver the produced electricity through existing transmission lines. The use of existing transmission infrastructure and/or the establishment of a new one involves considerable costs that cannot be overlooked and also introduces numerous critical technical constraints in the decision-making process. Furthermore, the utilization of the existing infrastructure is subject to the rules and pricing imposed by certain national and international authorities.

This study provides a perspective under Türkiye's conditions to demonstrate how BET of an investment is affected when electricity generated from potential wind resources in different geographical regions is transmitted to high-demand regions under comparable investment conditions. Similar to practices in some countries where transmission and distance-based costing are considered, this study presents distance-dependent costing examples for Türkiye, rather than a fixed-cost approach, based on data obtained from real cases.

In addition to BET evaluations, NPV and IRR analyses confirmed the long-term economic feasibility of several candidate regions, particularly for western cities with lower transmission-related costs. Furthermore, sensitivity analyses demonstrated that capacity

factor, electricity selling price, and transmission unit cost significantly influence BET results and investment feasibility.

In conclusion, as anticipated, since the fundamental approach of producing energy exactly at the point of demand cannot be realized under real conditions, decision-makers must consider this critical constraint. The findings of this study highlight that transmission limitations and costs constitute a significant technical and economic decision parameter by directly influencing both investment and energy costs.

Processes related to energy production and consumption, as well as the factors influencing these processes, are at the center of current research. RESs, with their openness to development, carry the potential for many managerial or design innovations developed by different disciplines on a global or local scale, from generation to transmission, from demand forecasting to secure supply. Through developed models and comparative evaluations based on various criteria, the most suitable solutions can be identified for different energy types.

Research and Publication Ethics Statement

The entire process of the manuscript was carried out in compliance with the research and publication ethics guidelines of the Celal Bayar University Journal of Science.

Author's Contributions

Elif Tarakçı: Contributed to the conceptualization and development of the methodology, conducted the research and data collection, performed the calculations and analyses, discussed and interpreted the results, and drafted and wrote the manuscript.

Ramazan Yaman: Contributed to the conceptualization and development of the methodology, discussed and interpreted the results, and reviewed and edited the manuscript.

REFERENCES

- [1]. Østergaard, PA, Duic, N, Noorollahi, Y, Mikulecic, H, Kalogirou, S. 2020. Sustainable development using renewable energy technology. *Renewable Energy*; 146: 2430-2437. <https://doi.org/10.1016/j.renene.2019.08.094>.
- [2]. Al-Shetwi, AQ. 2022. Sustainable development of renewable energy integrated power sector: Trends, environmental impacts, and recent challenges. *Science of the Total Environment*; 822: 153645. <https://doi.org/10.1016/j.scitotenv.2022.153645>.
- [3]. United Nations Environment Programme (UNEP). 2026. SDG Goal 7: Affordable and Clean Energy. Available online: <https://www.unep.org/topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-7> (accessed at 15.02.2026).

- [4]. International Renewable Energy Agency (IRENA). 2025. Renewable Capacity Highlights; IRENA: Abu Dhabi, United Arab Emirates. Available online: <https://static.poder360.com.br/2025/04/capacidade-energia-renovavel-mar2025-irena.pdf> (accessed at 15.02.2026).
- [5]. Subramanian, ASR, Gundersen, T, Adams, TA. 2018. Modeling and simulation of energy systems: A review. *Processes*; 6: 238. <https://doi.org/10.3390/pr6120238>.
- [6]. Schlachtberger, DP, Brown, T, Schäfer, M, Schramm, S, Greiner, M. 2018. Cost optimal scenarios of a future highly renewable European electricity system: Exploring the influence of weather data, cost parameters and policy constraints. *Energy*; 163: 100-114. <https://doi.org/10.1016/j.energy.2018.08.070>.
- [7]. McCalley, JD, Krishnan, V. 2014. A survey of transmission technologies for planning long-distance bulk transmission overlay in US. *International Journal of Electrical Power & Energy Systems*; 54: 559-568. <https://doi.org/10.1016/j.ijepes.2013.08.008>.
- [8]. Ruderer, D., Zöttl, G. 2019. Transmission pricing and investment incentives. *Utilities Policy*; 55: 14-30. <https://doi.org/10.1016/j.jup.2018.08.005>.
- [9]. Lewis, G.M. 2010. Estimating the value of wind energy using electricity locational marginal pricing. *Energy Policy*; 38(7): 3221–3231. <https://doi.org/10.1016/j.enpol.2009.07.045>.
- [10]. Pollitt, M.G. 2023. Locational Marginal Prices (LMPs) for Electricity in Europe? The Untold Story. *Energy Policy Research Group Working Paper, University of Cambridge*. <https://www.repository.cam.ac.uk/items/748513c4-ca09-4537-90a9-8e4bf7e428a3>.
- [11]. Zabihi, A., Badesa, L., Hernández, A. 2026. On the impact of voltage unbalance on distribution locational marginal prices. *International Journal of Electrical Power & Energy Systems*; 177: 111808. <https://doi.org/10.1016/j.ijepes.2026.111808>.
- [12]. Hadadi, A., Aliabadi, M.H., Rabbani, P. 2025. A stochastic power-based distribution locational marginal pricing framework for frequency regulation in isolated micro-grids using battery energy storage systems. *International Journal of Electrical Power & Energy Systems*; 172: 111180. <https://doi.org/10.1016/j.ijepes.2025.111180>.
- [13]. Eicke, A., Schittekatte, T. 2022. Fighting the wrong battle? A critical assessment of arguments against nodal electricity prices in the European debate. *Energy Policy*; 170: 113220. <https://doi.org/10.1016/j.enpol.2022.113220>.
- [14]. Knörr, J., Bichler, M., Dobos, T. 2024. Zonal vs. Nodal Pricing: An Analysis of Different Pricing Rules in the German Day-Ahead Market. *arXiv preprint*; arXiv:2403.09265. <https://doi.org/10.48550/arXiv.2403.09265>.
- [15]. Holmberg, P., Lazarczyk, E. 2015. Comparison of Congestion Management Techniques: Nodal, Zonal and Discriminatory Pricing. *The Energy Journal*; 36(2): 145–166. <https://doi.org/10.5547/01956574.36.2.7>.
- [16]. Kang, C.Q., Chen, Q.X., Lin, W.M., Hong, Y.R., Xia, Q., Chen, Z.X., Wu, Y., Xin, J.B. 2013. Zonal marginal pricing approach based on sequential network partition and congestion contribution identification. *International Journal of Electrical Power & Energy Systems*; 51: 321–328. <http://dx.doi.org/10.1016/j.ijepes.2013.02.033>.
- [17]. Yoro, KO, Daramola, MO, Sekoai, PT, Armah, EK, Wilson, UN. 2021. Advances and emerging techniques for energy recovery during absorptive CO₂ capture: A review of process and non-process integration-based strategies. *Renewable and Sustainable Energy Reviews*; 147: 111241. <https://doi.org/10.1016/j.rser.2021.111241>.

- [18]. Ahuja, D, Tatsutani, M. 2009. Sustainable energy for developing countries. S.A.P.I.EN.S; 2: 1. Available online: <https://journals.openedition.org/sapiens/823> (accessed at 15.02.2026).
- [19]. Hossain, SM, Hasan, MM. 2018. Energy management through biogas based electricity generation system during load shedding in rural areas. *TELKOMNIKA*; 16: 525-532. <https://doi.org/10.12928/TELKOMNIKA.v16i2.5190>.
- [20]. Sogukpinar, H, Bozkurt, I, Oyucu, S, Aksoz, A. 2025. Unveiling the wind energy future of Türkiye with policies, technologies and potential. *Heliyon*; 11: e42592. <https://doi.org/10.1016/j.heliyon.2025.e42592>.
- [21]. Bulut, A, Bingöl, O. 2023. Analysis and comparison of Weibull parameters for wind energy potential using different estimation methods: A case study of Isparta province in Turkey. *Electric Power Components and Systems*; 51: 1829-1845. <https://doi.org/10.1080/15325008.2023.2210574>.
- [22]. Kaplan, YA. 2021. Comparison of the performance of the methods used to find Weibull parameters at different heights. *Arabian Journal for Science and Engineering*; 46: 12145-12153. <https://doi.org/10.1007/s13369-021-05866-3>.
- [23]. Onay, AE, Dokur, E, Kurban, M. 2021. Performance comparison of new generation parameter estimation methods for Weibull distribution to compute wind energy density. *Elektronika ir Elektrotechnika*; 27(5): 41-48. <https://doi.org/10.5755/j02.eic.28919>.
- [24]. Bilir, L, Imir, M, Devrim, Y, Albostan, A. 2015. Seasonal and yearly wind speed distribution and wind power density analysis based on Weibull distribution function. *International Journal of Hydrogen Energy*; 40: 15301-15310. <https://doi.org/10.1016/j.ijhydene.2015.04.140>.
- [25]. İlkiliç, C. 2012. Wind energy and assessment of wind energy potential in Turkey. *Renewable and Sustainable Energy Reviews*; 16: 1165-1173. <https://doi.org/10.1016/j.rser.2011.11.021>.
- [26]. Kılıç, B. 2019. Determination of wind dissipation maps and wind energy potential in Burdur province of Turkey using geographic information system (GIS). *Sustainable Energy Technologies and Assessments*; 36: 100555. <https://doi.org/10.1016/j.seta.2019.100555>.
- [27]. Yaniktepe, B, Koroglu, T, Savrun, MM. 2013. Investigation of wind characteristics and wind energy potential in Osmaniye, Turkey. *Renewable and Sustainable Energy Reviews*; 21: 703-711. <https://doi.org/10.1016/j.rser.2013.01.005>.
- [28]. Ağbulut, Ü. 2022. A novel stochastic model for very short-term wind speed forecasting in the determination of wind energy potential of a region: A case study from Turkey. *Sustainable Energy Technologies and Assessments*; 51: 101853. <https://doi.org/10.1016/j.seta.2021.101853>.
- [29]. Rüstemli, S, Güntaş, O, Şahin, G, Koç, A, van Sark, W, Doğan, SŞ. 2024. Wind power plant site selection problem solution using GIS and resource assessment and analysis of wind energy potential by estimating Weibull distribution function for sustainable energy production: The case of Bitlis/Turkey. *Energy Strategy Reviews*; 56: 101552. <https://doi.org/10.1016/j.esr.2024.101552>.
- [30]. Özkan Aksu, E, Temel Gencer, C. 2025. GIS-based optimum location selection for offshore wind energy: A case study for Turkey. *Ocean Engineering*; 320: 120292. <https://doi.org/10.1016/j.oceaneng.2025.120292>.
- [31]. Aktekin, M, Genç, MS, Azgın, ST, Genç, G. 2024. Assessment of techno-economic analyzes of grid-connected nuclear and PV/wind/battery/hydrogen renewable hybrid system for sustainable and clean energy production in Mersin-Türkiye. *Process Safety and Environmental Protection*; 190: 340-353. <https://doi.org/10.1016/j.psep.2024.07.032>.

- [32]. Insel, MA, Sadıkoğlu, H, Melikoglu, M. 2022. Assessment and determination of 2030 onshore wind and solar PV energy targets of Türkiye considering several investment and cost scenarios. *Results in Engineering*; 16: 100733. <https://doi.org/10.1016/j.rineng.2022.100733>.
- [33]. Gönül, Ö, Duman, AC, Deveci, K, Güler, Ö. 2021. An assessment of wind energy status, incentive mechanisms and market in Turkey. *Engineering Science and Technology, an International Journal*; 24: 1383-1395. <https://doi.org/10.1016/j.jestch.2021.03.016>.
- [34]. Tagliapietra, S, Zachmann, G, Fredriksson, G. 2019. Estimating the cost of capital for wind energy investments in Turkey. *Energy Policy*; 131: 295-301. <https://doi.org/10.1016/j.enpol.2019.05.011>.
- [35]. Dayi, F, Yucel, M, Demirkol, Z, Cilesiz, A. 2024. Management of sustainable investments: A comprehensive financial evaluation of wind energy facilities in Kastamonu. *Energy for Sustainable Development*; 81: 101501. <https://doi.org/10.1016/j.esd.2024.101501>.
- [36]. Deng, X, Lv, T. 2020. Power system planning with increasing variable renewable energy: A review of optimization models. *Journal of Cleaner Production*; 246: 118962. <https://doi.org/10.1016/j.jclepro.2019.118962>.
- [37]. T.C. Enerji ve Tabii Kaynaklar Bakanlığı (ETKB), Enerji İşleri Genel Müdürlüğü (EİGM). 2026. Available online: <https://enerji.gov.tr/eigm-yenilenebilir-enerji-kaynaklar-ruzgar> (accessed at 15.02.2026).
- [38]. Stehly, T, Duffy, P. 2021. 2020 Cost of Wind Energy Review; National Renewable Energy Laboratory (NREL): Golden, CO, USA; NREL/TP-5000-81209. Available online: <https://www.nrel.gov/docs/fy22osti/81209.pdf> (accessed at 15.02.2026).
- [39]. Artigao, E, Martín-Martínez, S, Honrubia-Escribano, A, Gómez-Lázaro, E. 2018. Wind turbine reliability: A comprehensive review towards effective condition monitoring development. *Applied Energy*; 228: 1569-1583. <https://doi.org/10.1016/j.apenergy.2018.07.037>.
- [40]. T.C. Enerji ve Tabii Kaynaklar Bakanlığı (ETKB). 2026. Yenilenebilir Enerji Potansiyeli Atlası (REPA). Available online: <https://repa.enerji.gov.tr/REPA/> (accessed at 15.02.2026).
- [41]. Türkiye Elektrik İletim A.Ş. (TEİAŞ). 2026. Tarifeler. Available online: <https://www.teias.gov.tr/tarifeler> (accessed at 15.02.2026).
- [42]. Enerji Piyasası Düzenleme Kurumu (EPDK). 2026. Yenilenebilir Enerji Kaynakları Destekleme Mekanizması (YEKDEM). Available online: <https://www.epdk.gov.tr/Detay/Icerik/3-0-0-122/yenilenebilir-enerji-kaynaklari-destekleme-mekanizmasi-yekdem> (accessed at 15.02.2026).
- [43]. Mishnaevsky Jr., L., Branner, K., Petersen, H.N., Beauson, J., McGugan, M., Sørensen, B.F. 2017. Materials for wind turbine blades: An overview. *Materials*; 10(11): 1285. <https://doi.org/10.3390/ma10111285>.
- [44]. Oxera. 2011. Discount rates for low-carbon and renewable generation technologies. Prepared for the Committee on Climate Change. April 2011. <https://www.oxera.com/wp-content/uploads/2018/03/Oxera-report-on-low-carbon-discount-rates.pdf>.
- [45]. Yanbuawi, S.M., Imam, A.A., Alhussainy, A.A., Alghamdi, S., Rawa, M. 2024. Optimization and sensitivity analysis of using renewable energy resources for Yanbu City. *Sustainability*; 16(23): 10487. <https://doi.org/10.3390/su162310487>.
- [46]. Nallolla, C.A., Perumal, V. 2022. Optimal design of a hybrid off-grid renewable energy system using techno-economic and sensitivity analysis for a rural remote location. *Sustainability*; 14(22): 15393. <https://doi.org/10.3390/su142215393>.