JOURNAL OF ENERGY TECHNOLOGY
Vol. 18, No. 1, pp. 55–64, May 2025

THE IMPACT OF WIND POWER PLANT SIZE ON ECONOMIC VIABILITY AT THE OJSTRICA LOCATION

Professional Article

Submitted
20. 2. 2025

Accepted
1. 4. 2025

Published
30. 5. 2025

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Abstract Wind energy in Slovenia has not yet achieved a significant share in the energy resource mix, due primarily to the limited number of suitable locations and opposition from local communities. Nevertheless, interest in wind power plants is increasing, as they represent significant potential for utilising renewable energy sources. The paper analyses the economic viability of wind farm installation and electricity production at the proposed Ojstrica site in the Dravograd Municipality. Two scenarios were considered, involving wind turbines with capacities of 3.5 MW and 7 MW. Based on wind speed data, turbine power curves, and an electricity selling price of 75 EUR/MWh, the study calculated the maximum investment costs for each turbine type to ensure economic viability under the condition of a net present value (NPV) equal to zero. The results show that the maximum allowable investment is 5.99 million EUR for the 3.5 MW turbine and 15.60 million EUR for the 7 MW turbine.

Keywords
Ojstrica,
wind turbines,
economic viability,
renewable energy,
net present value

https://doi.org/10.18690/jet.18.1.55-64.2025

University of Maribor Press

1 Introducton

Wind energy, as one of the fastest-growing forms of renewable energy, is gaining increasing attention globally. Despite having limited suitable locations, Slovenia is showing a growing interest in the development of wind power plants. However, the installation of wind farms often faces challenges, such as spatial constraints, environmental impacts, and opposition from local communities. The Ojstrica location near Dravograd represents one of the potential areas with favourable wind conditions, as evidenced by the measured wind speeds.

An important factor influencing decisions to install wind power plants is the economic viability of the investment, which is determined strongly by the investment cost. Different wind turbines have varying production capacities, which are related directly to their power curves. In this context, the question arises as to which option offers greater economic viability—investing in smaller wind turbines with lower installed capacity, or larger turbines with higher production capacity.

The economic feasibility analysis of wind turbines often involves evaluating parameters such as Net Present Value (NPV), Levelised Cost of Electricity (LCOE) and benefit-cost ratios (BCR). Colla et al. highlighted the significance of using multi-disciplinary indicators for a thorough evaluation of energy projects [1]. Kamel et al. (2023), demonstrated the application of simulation tools like WAsP® to estimate annual energy production (AEP) and economic performance for wind farms in various locations [2]. These studies highlight the significance of accurate energy predictions and cost optimisation in renewable energy projects. Building on these principles, our research focuses on determining the maximum allowable investment costs for wind turbines under predefined electricity price conditions.

In this study, we will analyse the impact of the installed capacity on the economic viability of two different types of wind turbines—Enercon E-101 E2 with a capacity of 3.5 MW [3] and Siemens Gamesa SG 7.0-170 with a capacity of 7 MW [4]. Based on the available wind speed data at the Ojstrica location, the lifetime of the turbines, the expected electricity production, and the assumed electricity selling price of €75/MWh, we will calculate the maximum allowable investment cost under the condition of a net present value equal to zero.

2 Wind power plants

The working principle of wind turbine operation is the conversion of moving air into mechanical energy using aerodynamically shaped rotor blades. The mechanical energy is transferred to a wind turbine generator, converted to electrical energy and transferred to the grid.

The power of the moving air is calculated using equation 2.1:

$$P_w = \frac{1}{2}\rho A_r u^3 \tag{2.1}$$

where ρ is the density of the air, A_r is the swept area and u is the wind speed.

The maximum theoretical extracted power from the wind is defined as (Equation 2.2)

$$P_{m,\text{ideal}} = \frac{1}{2}\rho(A_{r1}u_1^3 - A_{r2}u_2^3) = \frac{1}{2}\rho\left(\frac{16}{27}Au^3\right) \tag{2.2}$$

where $\frac{16}{27} = 0{,}593$ is known as Betz's limit, and it states that no more that $\frac{16}{27}$ can be extracted from the wind and converted into mechanical energy. In other words, the maximum theoretical wind turbine efficiency is 59,3%.

The actual wind turbine power is calculated using Equation 2.3:

$$P_m = C_p \cdot P_w \tag{2.3}$$

where C_p is the coefficient of power, and it changes with every wind turbine type, which usually ranges from 0,4 to 0,45. [5, 6]

The coefficient of power is a value of a wind turbine's maximal efficiency. The actual power output is determined using the wind turbine's power curve. Power curves are usually obtained from the manufacturer, since every wind turbine model has a different power curve.

The power curves for Enercon E-101 E2 3.5 MW (left) [3] and for Siemens Gamesa SG 7.0-170 7MW (right) [4] wind turbine can be seen in Figure 1.

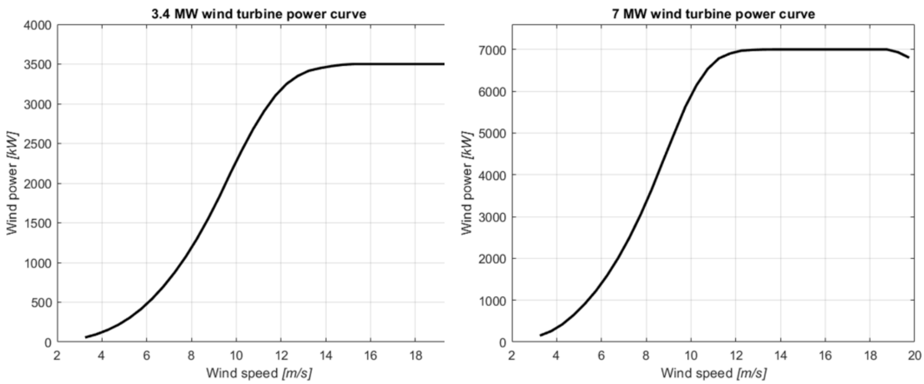

Figure 1: Power curve for Enercon E-101 E2 3.5 MW (left) and Siemens Gamesa SG 7.0-170 7MW (right)

In this study we compare two different installed capacities, namely, 3.5 MW and 7 MW. Larger power capacity usually implies higher energy production, but larger turbines are often associated with higher investment and maintenance costs.

The lifetime of a wind power plant refers to the expected operational period during which the turbine will produce electricity. This period typically ranges between 20 and 25 years, depending on the type of turbine, weather conditions and maintenance quality.

The electricity production of a wind power plant is related directly to the wind speeds at a specific location. The turbine's efficiency is described by its power curve, which indicates how much energy it can generate at varying wind speeds. The expected energy production for each turbine has been calculated based on the measured wind speeds at the Ojstrica location.

Investment costs include the procurement of wind turbines, installation, construction works, grid connection and other associated costs. Larger wind turbines with higher installed capacity typically have higher initial costs, but may also deliver greater returns due to increased energy production.

In addition to the initial investment costs, we also consider operational costs, which include maintenance, repairs, and potential component replacements throughout the turbine's lifetime. Larger turbines generally incur higher operational costs because of their greater complexity and the need for more expensive components.

2.1 Comparison of Two Scenarios

The economically viable maximum investment costs were calculated for two scenarios:

- **Scenario 1**: Investment in wind turbines with a capacity of 3.5 MW
- **Scenario 2**: Investment in wind turbines with a capacity of 7 MW

3 Results and Analysis

3.1 Calculation of the Annual Energy Production

Based on the available wind speed data at the Ojstrica location, we calculated the predicted annual energy production for both wind turbines. The wind speed at Ojstrica was measured at multiple heights. Figure 2 shows the average wind speed, depending on the height above ground level. The average wind speed at a height of 100 metres is 6.3 m/s, represented by the orange colour in the Figure.

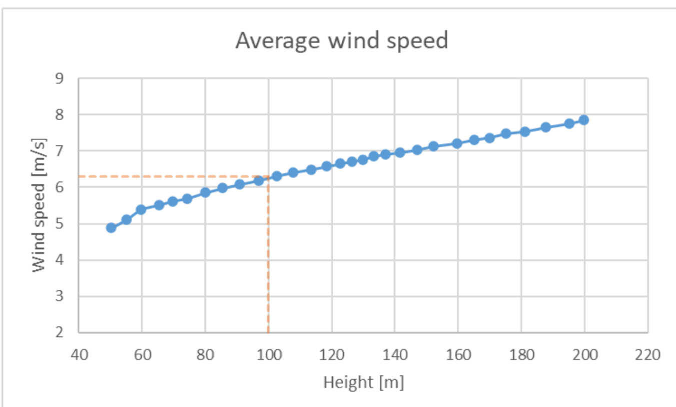

Figure 2: Average wind speed by height
Source: [7]

The energy production was calculated based on the power curve for each wind turbine and the data on wind speed frequency at a height of 100 metres, as shown in Figure 3.

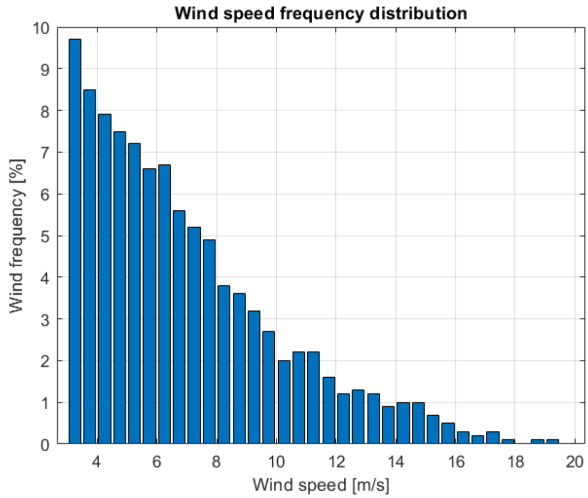

Figure 3: Wind speed frequency distribution
Source: [7]

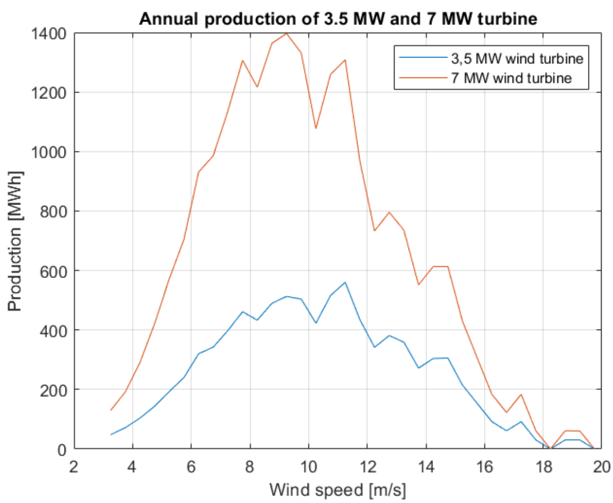

Figure 4: Annual energy production for 3.5 MW and 7 MW wind turbines

Figure 4 illustrates the calculated annual energy production for the 3.5 MW and 7 MW turbines. The annual production is determined as the product of the wind speed frequency, the number of hours in a year, and the power output of the wind turbine corresponding to each wind speed. The calculated production for the 3.5 MW turbine is 8,867 MWh, while for the 7 MW turbine, it is 22,039 MWh.

In addition to the initial investment costs, it is important to account for maintenance costs, which include regular repairs, component replacements and operational monitoring. Larger wind turbines typically incur higher operational costs, due to their increased complexity and the requirement for more expensive spare parts.

3.2 Investment Cost

One of the criteria for the economic viability of an investment is that the net present value (NPV) is greater than zero. We performed calculations to determine the maximum allowable investment cost that would result in an NPV of zero. The calculation assumes an electricity selling price of €75/MWh and a discount rate of 7%. The lifetime of both wind turbines was assumed to be 20 years. If the estimated investment is below the calculated maximum investment, the project is considered economically viable. The reference for the electricity price is the projected price for JEK 2 [8].

The results of the calculated maximum investment costs are shown in Table 1. For the 3.5 MW wind turbine the maximum investment is €5.99 million, while, for the 7 MW turbine, it is €15.60 million.

Table 1: Maximum economically justified investment costs

Parameter	Turbine 3,5 MW	Turbine 7 MW
Investment Cost [€ million]	5,99	15,60
Annual Energy Production [MWh]	8867	22039
Selling Price [€/MWh]	75	75

4 Conclusion

The calculations in this paper are based on wind speed and frequency measurements obtained using the LiDAR method. Using the power curve data for the selected wind turbines, we calculated the expected electricity production for each turbine.

The results show that, based on an assumed electricity selling price of €75/MWh, a discount rate of 7%, and a net present value of zero, the maximum allowable investment per turbine is €5.99 million for the 3.5 MW turbine and €15.60 million for the 7 MW turbine.

In the case of installing multiple wind turbines to form a wind farm, the costs of access roads, logistics, and energy distribution infrastructure do not increase – or do not increase linearly – with the number of turbines. Therefore, constructing a wind farm is economically more feasible.

For a precise selection of the wind farm size, it is necessary to obtain exact prices and data from wind turbine manufacturers and contractors. This information will ultimately determine the most economically viable wind farm size.

References

[1] Colla, Martin, Ioannou Anastasia, Falcone Gioia. Critical review of competitiveness indicators for energy projects. *Renewable and Sustainable Energy Reviews*. 2020, vol.(125), 109794
[2] Kamel, Rashad M., El Badawi Mohamed, Alanzi Sultan Sh. An optimum design and economic feasibility analysis of wind farms in Kuwait using different wind generation technologies. *Journal of Engineering Research*. 2024, vol.(12) (4), 840-858
[3] Enercon: *Enercon E-101 E2 3.5*. 2015 [cited 2024 15.10.2024]; Available from: https://en.wind-turbine-models.com/turbines/1289-enercon-e-101-e2-3.500
[4] Siemens Gamesa: *SG 7.0-170 Onshore wind turbine*. 2024 [cited 2024 15.10.2024]; Available from: https://www.siemensgamesa.com/global/en/home/products-and-services/onshore/wind-turbine-sg-7-0-170.html
[5] James F. Manwell, Jon G. McGowan, Anthony L. Rogers, Wind Energy Explained: Theory, Design and Application. 2009: Wiley
[6] Masters, G.M., Renewable and Efficient Electric Power Systems. Second edition ed. 2013, New Jersey: John Wiley & Sons, Inc.
[7] A-projekt d.o.o.: Strokovne podlage glede hrupa vetrnih elektrarn na lokaciji Ojstrica nad Dravogradom. 2020
[8] GEN Energija d.o.o.: Okvirna predinvesticijska ekonomska analiza projekta JEK2. 2024

Povzetek v slovenskem jeziku

Vpliv velikosti vetrnih elektrarn na ekonomsko upravičenost na lokaciji Ojstrica. Vetrna energija v Sloveniji še ni dosegla velikega deleža v tortnem diagramu virov energije, predvsem zaradi omejenega števila primernih lokacij in nasprotovanja lokalnih skupnosti. Kljub temu pa se zanimanje za vetrne elektrarne povečuje, saj so pomemben potencial za izkoriščanje obnovljivih virov energije. Prispevek analizira ekonomsko upravičenost postavitve vetrnih elektrarn in proizvodnjo električne energije, proizvedene z vetrnimi turbinami na predvideni lokaciji postavitve na Ojstrici v občini Dravograd. Poudarek prispevka je na izračunu predvidene proizvodnje električne energije z vetrnimi turbinami. Za izračun so uporabljeni razpoložljivi podatki o hitrosti vetra in porazdelitvi frekvence hitrosti vetra na izbrani lokaciji vetrne elektrarne, krivulja moči posamezne izbrane turbine in podatki o višini cene električne energije. Študija vključuje dva primera, kjer ocenjujemo ekonomsko upravičenost postavitve vetrne elektrarne iz vetrnih turbin različnih zmogljivosti, 3,5 MW in 7 MW. Z analizo smo glede na vhodne podatke za oba tipa vetrnih turbin izračunali maksimalno višino investicije po turbini, da je investicija še ekonomsko smiselna oziroma da je neto sedanja vrednost večja od 0. Prispevek analizira ekonomsko upravičenost postavitve vetrne elektrarne in proizvodnje električne energije na predvideni lokaciji postavitve Ojstrica v občini Dravograd. Obravnavana sta bila dva scenarija, ki vključujeta vetrni turbini z inštalirano močjo 3,5 MW in 7 MW. Študija je na podlagi podatkov o hitrosti vetra, krivuljah moči turbin in prodajni ceni električne energije v višini 75 EUR/MWh izračunala največje dopustne investicijske stroške za posamezno vrsto turbine, s čimer je zagotovljena ekonomska upravičenost ob pogoju, da je neto sedanja vrednost (NPV) enaka nič. Rezultati kažejo, da je največja dovoljena investicija 5,99 milijona EUR za turbino z inštalirano močjo 3,5 MW in 15,60 milijona EUR za turbino z inštalirano močjo 7 MW.