

PARAMETRIC ANALYSIS OF ELECTRICAL ENERGY PRODUCTION BY WIND ENERGY FOR BOZCAADA

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ABSTRACT

In this study, the economic analysis of the wind power plant to be installed in Bozcaada district has been investigated. The aim of this study is to find the most economical wind turbine for Bozcaada and to analyze the electricity production cost for different economic and technical parameters such as interest rate, wind speed, hub height, capacity factor, etc. As a result, the developed model is solved by using RETScreen and Excel program, and then the effect of the studied parameters on electricity generation cost is investigated. The electricity production cost was found minimum for the Vestas V80-67M turbine. Consequently, Vestas V80-67M was preferred as the most suitable turbine for Bozcaada.

Keywords: *Wind Power Plant, Economic Analysis, Electricity Production Cost, RETScreen*

INTRODUCTION

Today, energy is needed in all areas of our life. Increasing world population, industrialization, lighting, cause the increase of energy consumption. Renewable energy is a natural energy, and Most of renewable energy resources are formed from solar energy. Uncontrolled consumption of fossil fuels causes environmental pollution and global warming [1-3]. Therefore, the use of renewable energy resources increases. In the recent years, wind energy is one of the most preferred among the renewable energy sources [3-11]. Wind energy has many advantages such as being environmentally friendly, reducing external energy dependency, providing new job opportunities, fast installation. But besides all these advantages, there are also some disadvantages such as discontinuity, noise pollution and bird deaths.

Wind energy is one of the most important renewable energy sources for Turkey. Turkey's total wind energy potential is very high (about 48000 MW). Developments in wind turbine technology cause the installed powers to rise and the unit production cost to fall. For this reason, the share of wind energy in electricity generation has been increased day by day. In Turkey, the share of wind power plants generating electricity is approximately are many 2.67% and 7.3% within the total installed power, in 2010 and 2016, respectively [12].

In the literature, there are many papers concerning the analysis of wind power plants [3-11, 16, 17]. For instance, Taner and Demirci [3] have investigated energy and economic analysis of installing 1 MW of the wind turbine for the Aksaray city. As a result, they have calculated energy production, investment cost, operation cost, maintenance cost. Kaplan [7] has evaluated the current status of renewable energy potential for Turkey and the world. Keeley and Ikeda [8] have stated that renewable energy support policies have equivalent or greater effect compared to the widely accepted determinants such as corruption level, price stability and finance. Hdidouan and Staffell [17] have proposed a framework for assessing the impact of climate change on the cost of wind energy.

In this study, the economic analysis of the wind power plant to be installed in Bozcaada district has been examined. Consequently, sensitivity analysis is performed and, the effects of technical and economic parameters such as capacity factor, interest rate, and wind speed are examined on electricity production cost. As a result, the outcomes of this study can provide a basis used for the considered wind power plants.

MODELING OF WIND POWER PLANT AND ECONOMIC ANALYSIS PROJECT VALUES

For the project analysis of wind power plants, meteorological data such as at least one-year average wind speed, temperature and pressure are needed. At this study, the Turkish Wind Energy Potential Map (REPA) was utilized. Average wind speed varies between 7.5 and 8.5 m/s in the large majority of Bozcaada at a height of

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50 meters [13]. Therefore, average wind speed was accepted as 8 m/s in the analyses [13]. The other climate data used in the analysis were obtained from the RETScreen software database.

ENERGY MODEL

In the RETScreen software, the energy model consists of the selection of the wind turbine, the wind speed, the electricity sales price, and the wind turbine.

In this study, the average wind speed was taken as 8 m/s [13]. The electricity produced in wind energy plants in Turkey can be sold at a price of 73 Dollars/MWh. Electricity sales price can reach 110 Dollars/MWh depending on domestic equipment usage [10].

ECONOMICALLY ANALYSIS

Electricity production cost consists of investment cost and annual operating maintenance costs. The investment cost decreases as the turbine power and the total installed capacity increases. In this study, the investment cost of the wind turbines was taken from the literature. Table 1 shows the investment cost of the wind turbines. In this study, the annual operating and maintenance cost is accepted as 40\$/kW-year and this value selected equal for all turbine types [11,14-17].

Table 1. Investment cost for wind turbines

Wind Turbine Model	Specific investment cost
Vestas V80-67M	2100 (\$/kW)
Enercon 48-60M	2600 (\$/kW)
Nordex N54-70M	2300 (\$/kW)

The inflation rate and interest rate was taken as 8% and 10% in this study. The economic life of wind energy plants is about 20-25 years. In this study, the economic life was accepted as 20 years. In case of credit withdrawal to establish wind power plant, the banks would like to guarantee at least 20% of the total cost of the project from you. Therefore, the maximum debt ratio can be up to 80%. The debt ratio in this study was taken as 80%. The maturity of the loan to be used was taken as 10 years.

RESULTS AND DISCUSSION

In this study, 1 unit 2000 kW VESTAS V80-67M wind turbine was used. In addition, 3 units of 800 kW capacity ENERCON 48-60M and 2 units of 1000 kW capacity NORDEX N54-70M wind turbines are compared with VESTAS wind turbine. Figure 1 shows the power and energy curve data for the selected VESTAS turbine. This data has been automatically retrieved from the RETScreen database. This data may vary according to region. Using the available data, the capacity factor was calculated as 37.6% for Vestas V80-67M, 37.8% for Enercon 48-60M and 35.4% for Nordex N54-70M. The capacity factor can be defined as the ratio of annual wind energy production to the maximum amount of energy produced by turbine. The capacity factor can range from 0% to 60%, theoretically. The value of capacity factors is between 25% and 40%, generally.

The annual electricity generated by the turbines using the available data is calculated as 6595 MWh for Vestas, 7950 MWh for Enercon and 6199 MWh for Nordex. The number of households in this study is taken as 2500. The daily electricity consumption of households is taken approximately as 7 kWh.

The interest rate, inflation rate, economic life and debt term have been taken as 10%, 8%, 20 years and 10 years, respectively. Depending on these values, unit electricity production cost was calculated 50 \$/MWh for Vestas V80-67M, 66 \$/MWh for Enercon 48-60M and 67 \$/MWh for Nordex N54-70M (Figure 2). As a result, Vestas V80-67M was determined as the most economic wind turbine for Bozcaada. So, parametric studies have been carried out for Vestas V80-67M. The hub height, rotor diameter, swept area and number of blades for Vestas V80-67M is 67 m, 80 m, 5027 m² and 3, respectively.

Figure 1 illustrates change in power and energy of Vestas V80-67M with respect to wind speed. From 0 to 12 m/s wind speed, both power and energy increase and after that point power and energy converge to 2000 kW and 13000 MWh, respectively.

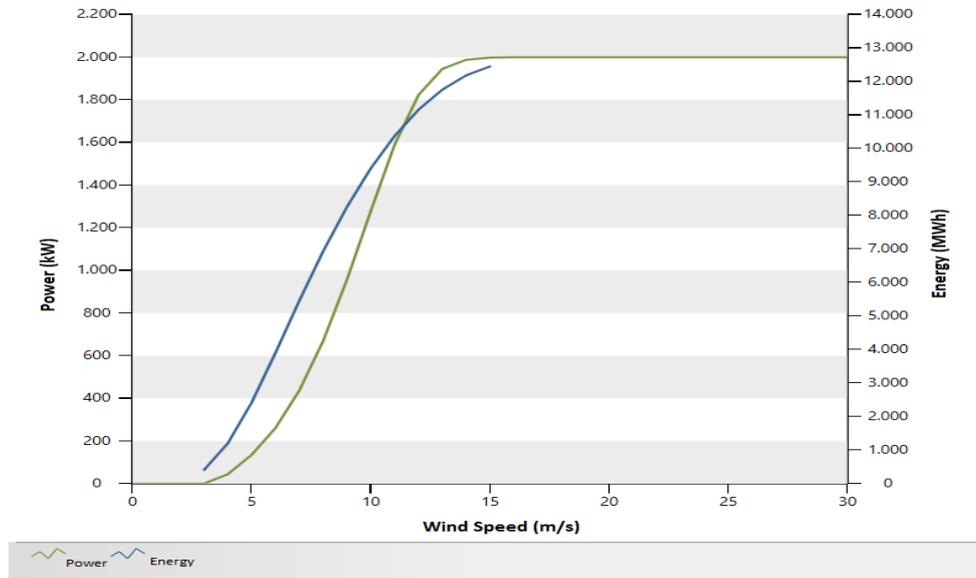


Figure 1. Power and energy curve data for VESTAS V80-67M

Figure 2 shows the change of electricity production cost according to interest rate for Vestas V80-67M, Enercon 48-60M and Nordex N54-70M wind turbines. As the interest rate increases, the electricity production cost also increases for the all wind turbines. Compared to Enercon 48-60M and Nordex N54-70M wind turbines, the electricity production cost of Vestas V80-67M wind turbine is lower for the same interest rate, while Enercon 48-60M and Nordex N54-70M have almost the same electricity production cost for the same interest rate.

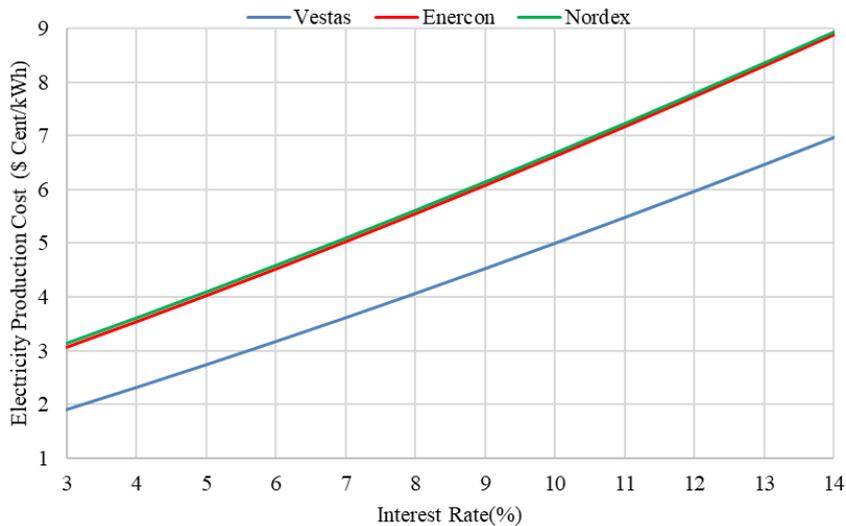


Figure 2. The change of electricity production cost according to interest rate

Figure 3 shows the change of electricity production cost with hub height for Vestas V80-67M turbine. As the hub height increases, the amount of electricity production rises. Thus, the electricity production cost also drops.

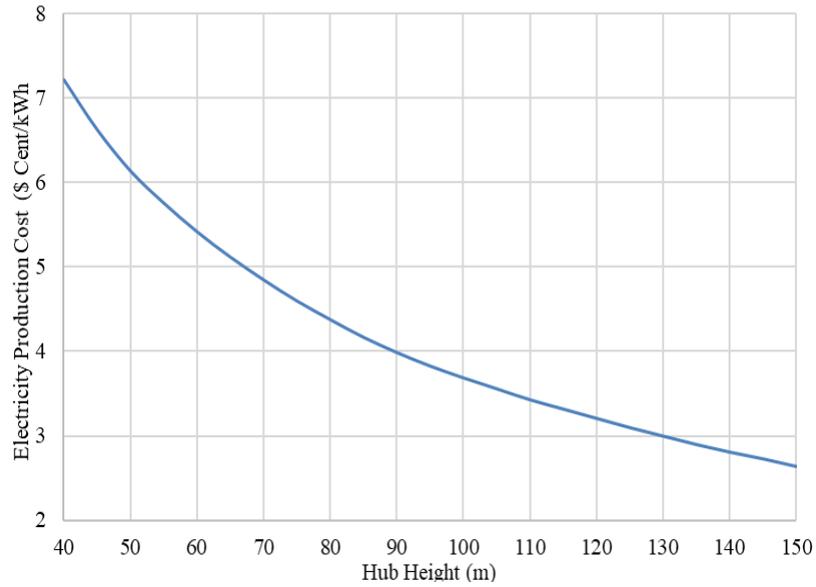


Figure 3. The change of electricity production cost with hub height

Figure 4 shows the change of electricity production cost with average air temperature for the Vestas V80-67M turbine. When the air temperature increases, the electricity production cost increases.

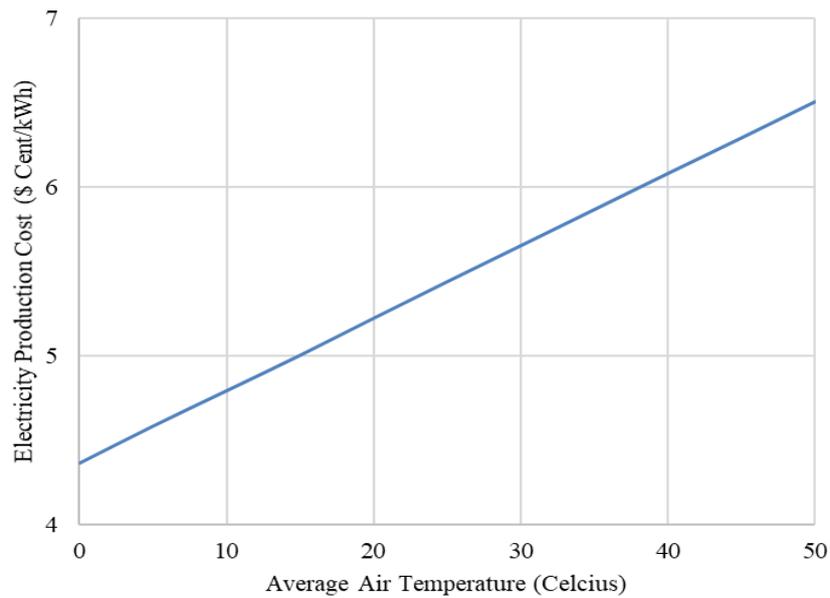


Figure 4. The change of electricity production cost with average air temperature

Figure 5 shows the change of electricity production cost with capacity factor for the Vestas V80-67M turbine. Electricity production cost decreases as the capacity factor increases. Figure 6 shows the change of electricity production cost with wind speed for the Vestas V80-67M turbine. When the wind speed increases, the electricity production cost decreases.

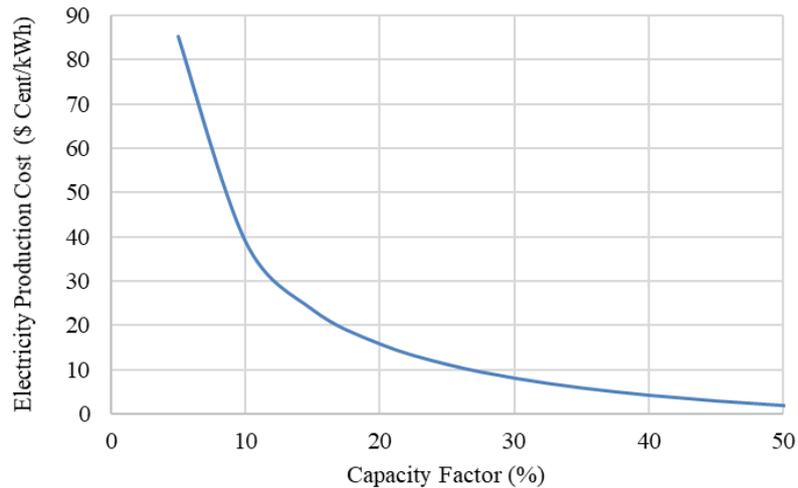


Figure 5. The change of electricity production cost with capacity factor

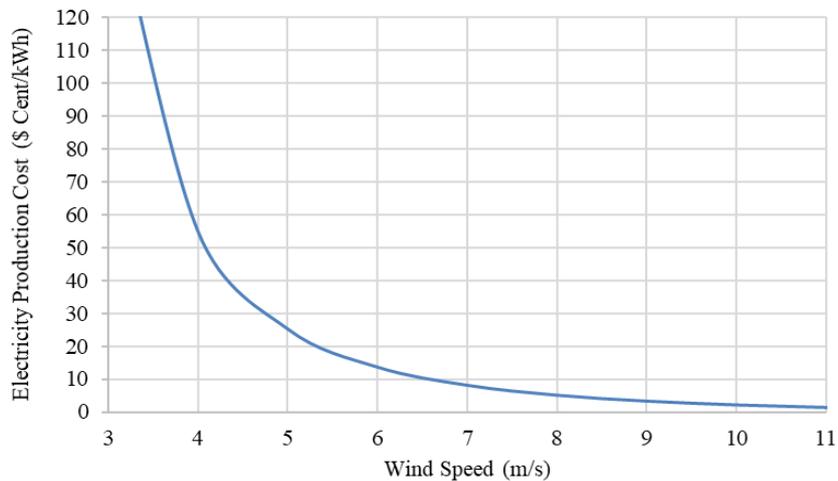


Figure 6. The change of electricity production cost with wind speed

CONCLUSION

Nowadays, energy is needed in all areas of our life. The possibility of running out of fossil fuels in the near future and the hazardous effects on the environment, lead human to look for alternative and renewable energy sources. Thus, interest in the renewable energy sources (especially in wind energy) has been increased.

In this study, economic analysis of the wind power plant for Bozcaada has been investigated. The main findings obtained from economic analysis are summarized as follows:

- Vestas V80-67M turbine for Bozcaada was found as the most economical wind turbine. The electricity production cost was calculated about 50 \$/MWh for the Vestas V80-67M turbine model. Therefore, parametric analysis has been applied for Vestas V80-67M.
- For investigated parameters, it is shown that the hub height, average air temperature, capacity factor, wind speed and interest rate have significant influences on electricity production cost. When the hub height, capacity factor and wind speed increase, the electricity production cost decreases. On the contrary, when the average air temperature and interest rate increase, the electricity production cost increases.
- The outcomes of this study can provide a basis used for the considered wind power plants.

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