ECONOMIC ANALYSIS OF WIND ENERGY INTEGRATION IN TEC VLORE'S ENERGY SYSTEM USING HOMER PRO

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Abstract

This study presents a techno-economic assessment of integrating 800 kW of wind energy into the energy system of TEC Vlore sh.a., a currently non-operational thermal power plant in southern Albania. Using the HOMER Pro software, the analysis model hybrid configurations to determine the optimal solution in terms of cost, performance, and energy reliability. Simulation results demonstrate that the integration of wind energy significantly reduces reliance on electricity imports, lowers annual operational costs from €280,867 to €40,234, and increases energy autonomy. The optimal configuration achieves a renewable energy penetration of 74.1%, with a Net Present Value (NPV) of €2.9 million, a Return on Investment (ROI) of 116.2%, and an Internal Rate of Return (IRR) of 121%. The system's payback period is less than one year, indicating strong economic feasibility. Furthermore, over 1 million kWh of excess energy is exported to the grid annually, providing an additional revenue stream. These findings highlight the financial and strategic viability of wind energy deployment in Albania's industrial energy systems. The study contributes to ongoing discussions on renewable integration by offering a replicable model for energy transition in similar infrastructures across the Western Balkans. It underscores the importance of leveraging local wind resources to enhance energy security, reduce costs, and support national decarbonization targets.

Keywords: *Wind Energy, HOMER Pro, Economic Feasibility, TEC Vlore, Hybrid Energy System*

INTRODUCTION

The Vlora Thermal Power Plant (TEC Vlore), located in Vlora, Albania, is a 97 MW facility constructed in 2011. Although originally intended to play a vital role in the country's energy infrastructure, the plant has remained non-operational due to persistent technical and environmental challenges. A critical fault in the cooling system [1], essential for steam turbine activation, has prevented it from producing electricity. As a result, TEC Vlore currently operates only as a consumer, drawing electricity from the national grid via a 20 kV connection and incurring annual operating costs of approximately €280,868.

Albania's energy sector is predominantly reliant on hydropower, rendering it vulnerable to seasonal variations. In periods of low precipitation, hydropower output declines, requiring increased electricity imports. In 2022, Albania generated 7,002 GWh of electricity, yet consumption reached 7,924 GWh—resulting in a 922 GWh deficit that was met through imports [6]. This dependency undermines energy security, increases operational costs, and reduces system resilience.

To address these challenges, renewable energy diversification is essential. Hybrid Renewable Energy Systems (HRES)—which combine wind, solar, hydro, and biomass—have been extensively studied and proven effective in optimizing energy supply, reducing environmental impacts, and improving cost-efficiency [2,7,13]. Due to TEC Vlore's advantageous coastal location facing the Adriatic Sea, wind energy is particularly promising. The region experiences steady sea breezes, making wind power a reliable and sustainable solution.

This study investigates how integrating wind energy could transition TEC Vlore from a passive consumer to a partially self-sufficient, cost-effective energy system. Specifically, it evaluates the feasibility of integrating an 800-kW wind turbine capable of operating in both grid-tied and off-grid modes. The goal is to reduce electricity expenses and enhance energy security [16].

Using HOMER Pro software, the study incorporates hourly energy consumption data to simulate system behaviour and estimate economic viability. HOMER Pro also enables sensitivity analysis to assess the impact of varying parameters—such as wind speed and energy demand—on overall performance [4,5,8,14].

The findings aim to offer a strategic pathway for TEC Vlore, illustrating how renewable energy integration can improve energy autonomy and serve as a replicable model for other industrial-scale facilities in Albania.

2. Literature Review The integration of renewable energy sources into conventional power systems has been widely studied. Several research works highlight the economic and environmental benefits of wind energy adoption [10,12]. Research has demonstrated that wind power can substantially reduce dependence on fossil fuels, mitigate greenhouse gas emissions, and achieve long-term cost reductions [8,12,14].

HOMER Pro, a leading microgrid simulation and optimization tool, is frequently used to design and evaluate renewable energy systems. Its capability to model complex hybrid configurations and conduct detailed sensitivity analyses makes it a preferred choice for researchers [3,9]. This section synthesizes key literature that supports wind energy integration and outlines the economic rationale for hybrid systems.

3. CASE STUDY: TEC VLORE WIND ENERGY INTEGRATION

3.1 METHODOLOGY

To assess the feasibility of wind energy integration at TEC Vlore, the study employs HOMER Pro software, renowned for modeling and optimizing hybrid energy systems. HOMER Pro simulates different system configurations and evaluates them based on technical, economic, and environmental metrics.

3.2 Data inputs:

3.2.1Wind energy data

According to NASA (2020) [11], the average wind speed over a 30-year period at 50 meters elevation near Vlora is 5.04 m/s. The wind speed ranges from 4.18 m/s to 5.91 m/s, with peak values in November and consistent speeds in January, February, March, and December.

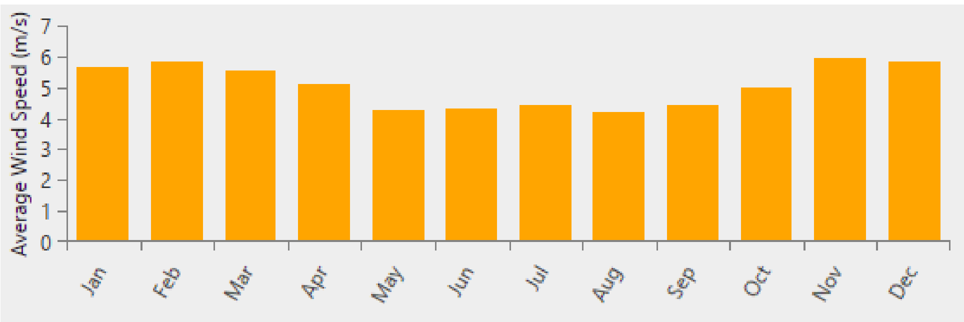

Figure 1. The average monthly wind speed

3.2.2 TEC Vlore consumption data

The hourly data for electricity consumption was obtained from the Vlora Thermal Power Plant, the annual consumption (in kWh) and the electricity price per kWh were provided by the Electricity Distribution Operator (OSHEE).

Based on their data, the annual energy sold in 2024 was 1,233,541 kWh. The annual electricity consumption cost was 18.34 ALL/kWh; 0.19 €/kWh, excluding VAT, including all transmission and distribution costs up to the metering point, while the sell-back price for excess energy is €0.1/kWh. We have the daily profile and yearly profile respectively in Figure 2. (a, b).

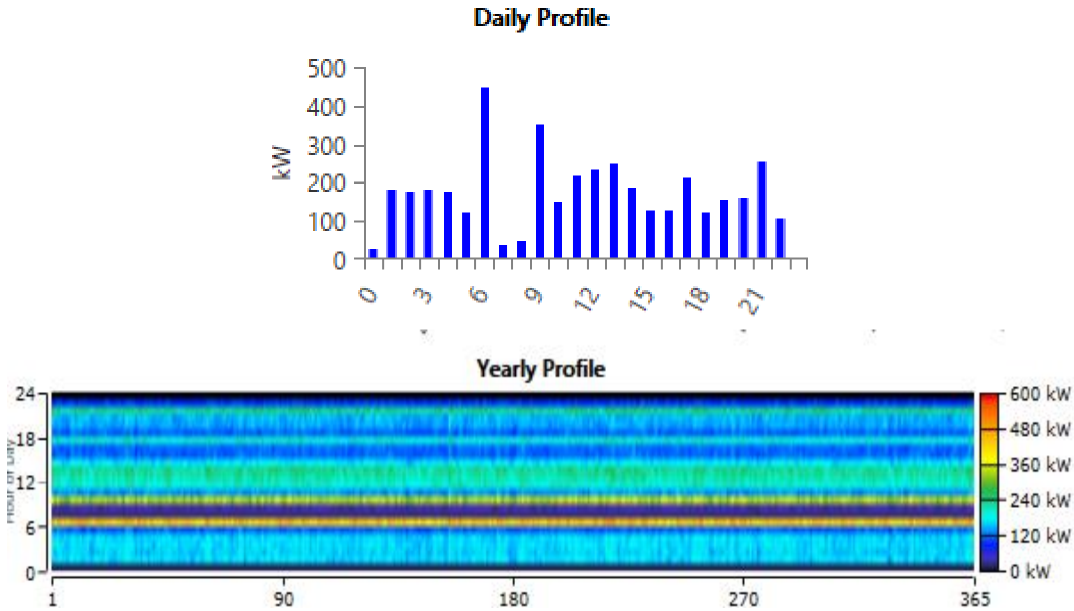

Figure 2. Energy consumption data from the TEC Vlore.

3.2.3 System configuration

As shown in Figure 2, the existing infrastructure of TEC Vlore includes fuel tanks and a central turbine building, indicating readiness for potential retrofit or hybrid energy integration**.**

Figure 3. Satellite image showing the existing infrastructure of TEC Vlore, including fuel storage tanks and turbine building layout.

The integration of wind energy into the TEC Vlore energy system is explored, focusing on the findings that the Karaburun Peninsula experiences stronger winds during the winter months, providing a reliable source of renewable energy that could significantly contribute to Albania's energy detailed assessment [15]. Their study analyzed wind profile characteristics, including wind speed, direction, and seasonal variability, and evaluated the potential for electricity generation using various turbine configurations.

Figure 4. Satellite image showing the location of TEC Vlore facing the Karaburun Peninsula along the Adriatic Sea.

The most suitable wind turbine was the E48, which has a hub height of 50m and a rotor diameter of 48m, achieving the highest capacity factor, ranging from 21.71% to 33.44%. The average wind power output ranged between 218.33 kW and 668.95 kW. We modeled a grid-tied system with 800 kW of wind turbine capacity, including a turbine cost of €200,000 (capital and replacement), and an O&M cost of €20,000 annually with a lifetime of 20 years.

Building on this foundational work, HOMER Pro [9] models and assesses the impact of integrating 800 kW of wind capacity into the TEC Vlore system. The configuration of the system is given in Figure nr. 5

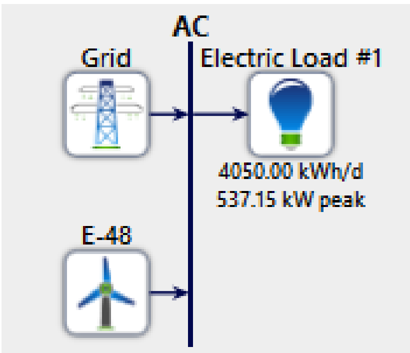

Figure 5. The design of the hybrid system

3.2.4 HOMER Pro simulations:

The system configuration was modeled to assess the integration of 800 kW of wind energy into TEC Vlore's energy system. Sensitivity analysis was conducted to evaluate how variations in key parameters (e.g., wind speed, energy consumption) affect the system's performance [8].

Figure 5 presents the grid design. We have chosen a random variability of 5% on HOMER Pro to predict the wind speed fluctuation [10] around the average 4046 kW/day and peak load 536.62 kW during the day and between days, improving the accuracy of system performance estimates.

4. RESULTS AND DISCUSSION

The HOMER Pro simulations indicated that incorporating 800 kW of wind energy into the TEC Vlore system could significantly reduce the plant's dependency on electricity imports. The optimized system configuration, which included the 800-kW wind turbine, demonstrated the following outcomes in Table 1.

Table 1. Economic and operational metrics for wind + grid vs. grid-only system

Metrics	Scenario 1 (Wind Turbine-Grid configuration)	Scenario 2 (Grid Configuration)
Net Present Cost, NPC (€)	€720,131	€3.63M
Levelized Cost of Energy, LCOE (€/kW)	€0,0291	€0.19
Renewable energy penetration (%)	74,1	0
Operation cost (€/yr)	€40,653	€280,867
Capital Expenditure, CAPEX (€)	€200,000	0
Energy Purchased (kWh)	653,034	1,478,250
Energy Sold (kWh)	1,059,947	0

NPC represents the total lifecycle cost (capital, replacement, O&M, and salvage) discounted to present value.
Scenario 1 is about 80% cheaper over the project lifetime, showing that integrating wind significantly reduces long-term costs.

The levelized cost of Energy (**LCOE**) represents the cost per unit of electricity generated over the system's lifetime. Scenario 1: €0.0291/kWh; Scenario 2: €0.19/kWh. Wind integration reduces energy costs by over 84%, making it a highly cost-effective solution. Scenario 1 uses wind energy for **74.1%** of its total consumption, drastically reducing dependence on grid electricity. The penetration of the wind energy is displayed in Figure 6.
Scenario 2 relies entirely on grid power, leading to higher costs and no renewable contribution.

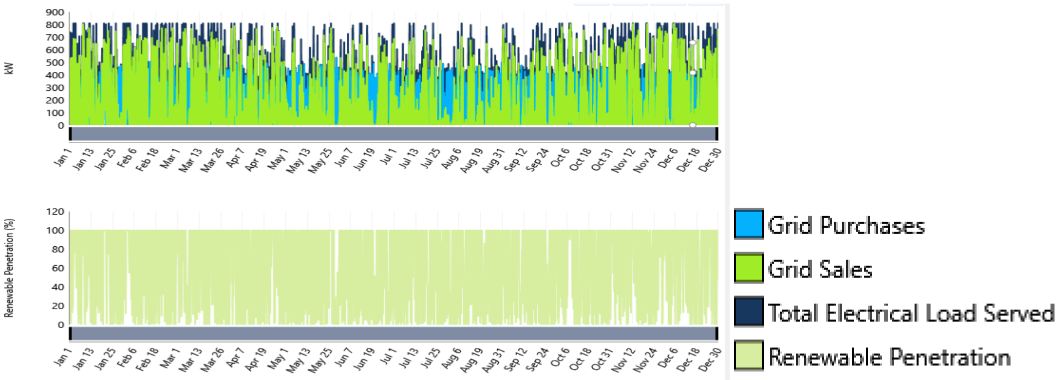

Figure 6. The Wind Penetration in the configuration proposed

The grid-only has 7x higher operational costs, largely due to the cost of purchasing electricity. Scenario 1 significantly reduces operational expenses, leading to long-term savings. **Capital Expenditure (CAPEX),** scenario 1 requires an initial investment for the wind turbine but saves substantial costs in the long run meanwhile, scenario 2 avoids CAPEX but incurs much higher operating costs over time. Wind Turbine-Grid configuration produces surplus wind energy and sells over 1 million kWh to the grid, potentially generating revenue. Grid-only does not generate or sell electricity if it will go on to stay under no-operation conditions. The graph below explains in detail for every month energy purchased (kWh) and Energy sold (kWh) during the year.

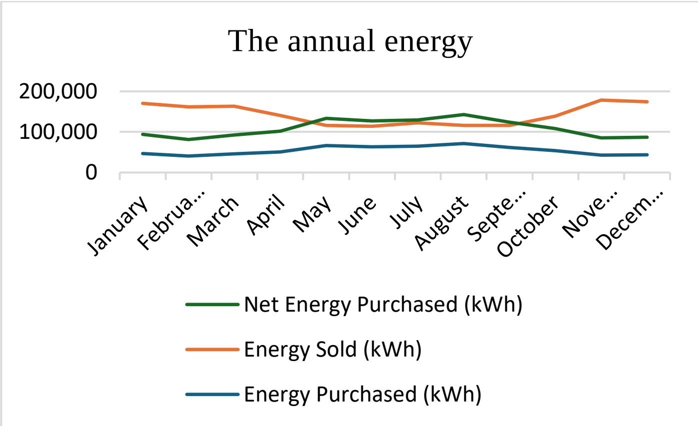

Figure 7. The Annual energy in the grid.

Key performance metrics such as Net Present Value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR), and payback periods are displayed in Table 2.

Table 2. Financial performance metrics for wind + grid configuration

NPV, (Present Value) (€)	€2,905,374
ROI, (Return on Investment) (%)	116.2
Payback of period (yr)	0.83
Discount payback (yr)	0.87
Operating cost	€40,234

The project shows a very high NPV of €2.9 million; a substantial ROI of 116.2%; and An IRR of 121% indicating that is expected to generate exceptionally strong profits compared to typical investment opportunities. Operating costs are relatively low, enhancing profitability.

Payback period -0.83 approximately 10 months; Discount Payback -0.87 (approximately 10.5 months) highlights that the system will recover its initial investment in under one year, with the payback achieved through cost savings and revenue generation. In less than a year, the system essentially "pays for itself," demonstrating its high efficiency and strong appeal as an investment

5. CONCLUSION

This study demonstrates the economic, operational, and environmental benefits of integrating wind energy into TEC Vlore's energy system. By incorporating an 800-kW wind turbine, TEC Vlore can significantly reduce its reliance on electricity imports, lower operational costs, and contribute to Albania's broader energy transition. The analysis confirms that wind energy is a cost-effective and sustainable alternative to conventional grid dependence, offering enhanced energy security and economic resilience.

From a financial perspective, the wind + grid system proves to be highly advantageous, with a Net Present Value (NPV) of €2.9 million, a Return on Investment (ROI) of 116.2%, and an Internal Rate of Return (IRR) of 121%. Additionally, the system achieves a payback period of just 0.83 years, reinforcing its financial viability. With low annual operating costs (€40,234) and a renewable energy penetration rate of 74.1%, this configuration significantly outperforms the grid-only alternative.

Given these promising results, further research is recommended to refine the system design, explore integration with other renewable sources, and assess long-term feasibility under varying market conditions. The adoption of wind energy at TEC Vlore could serve as a scalable model for similar facilities across Albania, advancing the country's shift toward a sustainable and resilient energy future

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