Economic Comparison of the Two Proposed Wind Farms in Mamaj, Albania

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Abstract: *The study addresses to an economic comparison of two proposed wind farms in the same area in Mamaj, Albania, respectively 10.8 MW and 12.6 MW. The 12.6 MW wind farm proposed is predicted to produce 34 GWh energy, with a capacity factor of 30.8%, while the 10.8 MW wind farm is predicted to produce 30.4 GWh, with a capacity factor of 32%. For the 12.6 MW wind farm since there is a higher installed power, is expected to produce more energy, but referring that they will be built in same area, the wake losses will indicate in overall efficiency of the wind farm. The wake losses calculated for the 10.8 MW wind farm are 0.98%, meantime for the 12.6 MW wind farm wake losses is calculated 2.58%, means that the overall efficiency of the 10.8 MW wind farms is higher. For the economic evaluation RETScreen Expert software is used. With a discount rate of 7%, the benefit-cost ratio is 2.9 and simple payback period 7.6 years for 10.8MW wind farm, and for the 12.6 MW the benefit-cost ratio is calculated 2.6, with a simple payback year of 8 years.*

Keywords: *WIND ENERGY, WAsP, BENEFIT-COST RATIO, DISCOUNT RATE, NET PRESENT VALUE, SIMPLE PAYBACK PERIOD, RETSCREEN EXPERT.*

1. Introduction

Power generation from renewables is the only major source of energy that has continued to grow, and this resilience sets the tone for the next decade and beyond [1]. Renewables are becoming more and more competitive in energy landscape [2]. The current crisis in Ukraine clearly showed how weak and vulnerable is the economy of countries with an energy system deeply intertwined with fossil fuels.

There is a need for strong national strategies to phase out fossil fuels and in parallel increase the production of renewable energy and use that energy much more efficiently than we do today [3].

Some 80% of the global population lives in coutries that are net energy importers. With the abundance of renewable potential yet to be harnessed, this percentage can be dramatically reduced [4]. Often, renewable energy is thought of as a novel technology, although its origins date back thousands of years [5, 6]. Today, with a rapid technological development that focuses not only on economic efficiency but also on mitigating environmental repercussions, wind energy as well as solar power as being used in increasingly cost-efficient ways, making renewables a crucial power source.

Wind and sunshine don't cost anything, and nations that embrace renewables as the backbone of their energy system will be protected from the price swings of volatile fossil fuels [7].

According to Director-General of International Renewable Energy Agency, the global shift to renewables is underway. 2021 was a strong year for the energy transition – the world added almost 257 Gigawatts (GW) of renewables contributing to an unprecedented 81% of global power additions [8]. 2020 marked a record year for new global installations of wing energy with 93 GW. 2021 was also a big year for wind installations with a total of 94 GW of wind installed around the world. This demonstrates the incredible resilience and an upward trajectory of the global wind industry. However, within this decade, wind installations need to increase almost 4 times compared to 2021 in order to meet the goal of the Paris Agreement to limit the increase of global average temperature to 1.5^0C above pre-industrial levels (see Figure 1) [7, 9, 10].

Europe installed 17.4 GW of new wind energy capacity in 2021. This was 18% more than 2020. Onshore wind made 81% of the new wind installations with 14 GW. Europe now has 236 GW of wind capacity generating 437 TWh of electricity in 2021, covering 15% of the Europe's electricity demand [11]. Although 2021 is a record year for new wind installations, the rate of growth is still not sufficient for Europe to reach its 2030 energy and climate goals [8, 11].

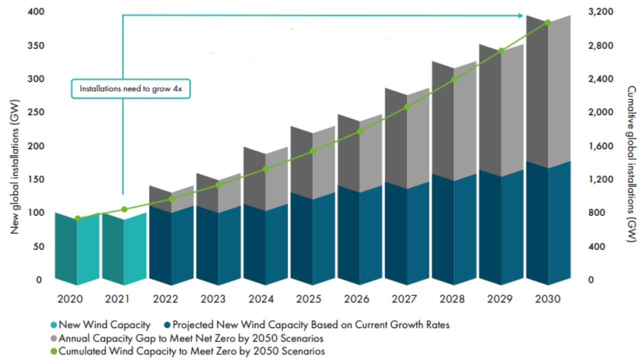

Fig. 1 *The annual wind energy installation needs to scale up by four times in this decade to stay-on track for a net zero/1.5^0C pathway. Source: GWEC [7]*

The Albanian government has set national energy targets in order to further integrate the country into the European energy infrastructure. Renewable energies are projected to be 42% of the total energy consumption by 2030. Consistent with the Paris Agreement, in 2015 the Albanian government commits to reducing GHG emissions by 11.5% by 2030, compared with the baseline scenario of the year 2016. [12]. Although Albania's energy mix already features one of the highest shares of renewables in the region due to the extensive installed hydropower capacity, diversifying the electricity mix including solar and wind power, can contribute to a secure, stable, affordable national energy supply. Furthermore, this would contribute to the reduction of imports in the energy sector. The hydric sources are mostly concentrated in the northern region of the country, while the highest number of consumers are based in the western part and around 35% of theirs are in the eastern part of the country. Therefore, a shift towards non-hydro-based renewable generation close to demand centers would be advantageous in continued power sector development and in decreasing of electricity losses [12, 13]. Since the introduction of the solar and wind FiT support, Albania has made progress towards the diversification of electricity production but only for solar power.

According to the energy balance of 2021, no kWh of electricity has been produced through wind power yet [14]. The applications for the construction of the wind plants up to 3 MW according NANR are still being evaluated for their wind potential. Each successful bidder of projects with a minimum capacity of 30 MW and a maximum capacity of 75 MW, through a tender process according to the law, will sign a 15-year Power Purchase

Agreement for the sale of 100% of the electricity generated through the Contract for Difference support mechanism [15]. On June 12th 2018, the Council of Ministers of Albania passed a decision on wind farm projects over 3MW, specifying that support will be given through an open, non-discriminatory, transparent and competitive process for the projects that offer optimal conditions in terms of energy cost, level of technology and building plan. The competitive process will result in a feed-in tariff which will remain unchanged for a period of time of up to 15 years. This tariff will not be higher than 76 €/MWh which is the amount that ERE has approved for this technology.

The success of wind power projects relies on finding the specific area with wind potential, the choice of the most effective turbine, and the site-planning of the turbines as to have the least wake losses. The aim is to generate the most electrical energy with the least wake losses to ensure a higher capacity factor for the proposed wind farm.

Wind farm projects require from the beginning a large investment of capital. The capital cost of wind energy project is dominated by the cost of the wind turbines including there the cost of the tower and installation. Often it is known as CAPEX (Capital Expenditures) and this can be between 64% and as much as 84% of the total installed cost for onshore wind projects [16]. Thus, a wind farm is capital-intensive compared to conventional fossil fuel fired technologies such as a natural gas power plant, where as much as 40-70% of costs are related to fuel and O&M [17]. Investors' decision to build a wind farm relies on a detailed economic analysis. This study is considering two wind farm projects, 10.8 MW and 12.6 MW respectively, proposed in the same area in Mamaj, Albania. WAsP software is used to do the technical evaluation. This study shows the importance of the economic analysis in selecting the best project. RETScreen Expert is used to do the economic evaluation.

2. Materials

The two proposed wind farms in our study are respectively 10.8 MW and 12.6 MW in the same area in Mamaj, north of Tepelenë, Albania. Both the map of potential areas for wind energy in Albania, from Balcan Wind Atlas (50m above ground level) and the map of Albania's annual average wind speeds at 100m hub-height from Global Wind Atlas 1.0, identify the area proposed as one of the estimated sites for wind potential (see in Figure 2, 3).

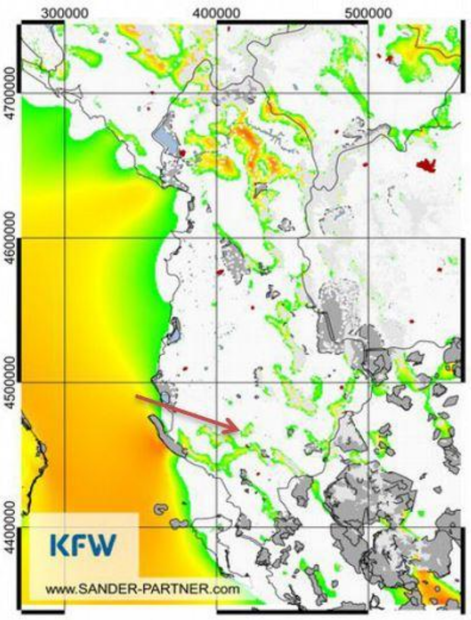

Fig. 2 *The map of potential areas for wind energy with good wind conditions, that respect natural reserves. The area of the proposed wind projects is an estimated site. Source: Balkan Wind Atlas, KFW sander@sander-partner.com*

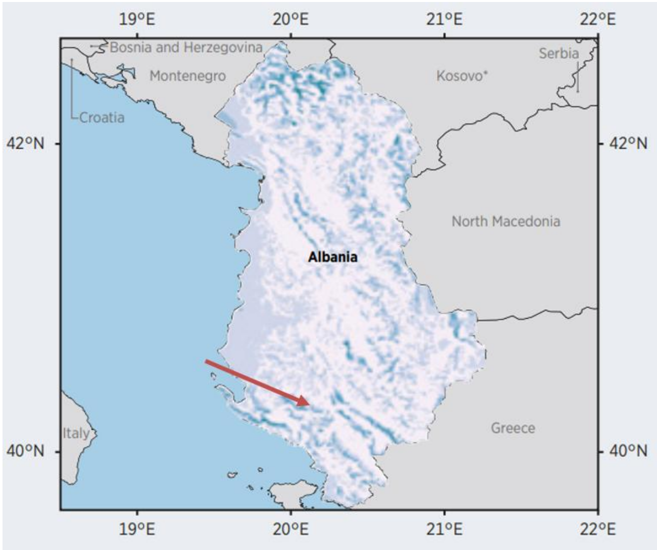

Fig. 3 *The map of potential areas for wind energy according of Global Wind Atlas 1.0. Mamaj, the proposed wind farm project's site as one of the estimated. Source:[13]*

The meteorological data such as air temperature, atmospheric pressure, wind direction and wind speed were acquired through anemometers installed in two separate towers with a height of 60m each and in a distance about 800m from each other at the exact location for 456 days. In a previous study, wind resource assessment of the site based on the map of wind potential distribution (resource grid) generated by WAsP program, showed that the mean wind speed was found to be 5.64 m/s on the hill and the annual mean wind power density of 304 W/m^2, in 50m height above ground level defining this site to correspond to the wind power class 3 [18, 19]. This wind power class is appreciated for building a wind farm.

Wind farm prediction with WAsP software demonstrated that maximum Annual Energy Production with minimum wake losses was achieved in case of Vestas V100/1800 wind turbines with arrangement of 6 and 7 wind turbines respectively as in Figure 4 and Figure 5.

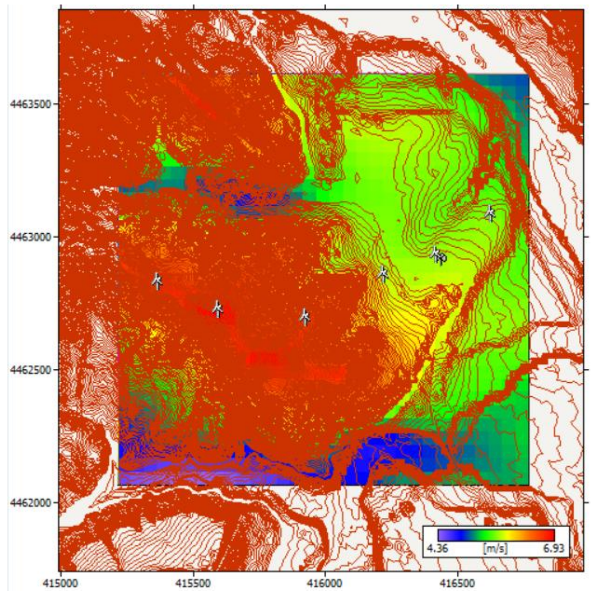

Fig. 4 *Mamaj Wind Farm Layout Design of 10.8 MW.*

Total net AEP [GWh]	*30.4*
Proportional wake losses [%]	*0.98*
Capacity factor	*32%*
Efficiency	*99.02%*

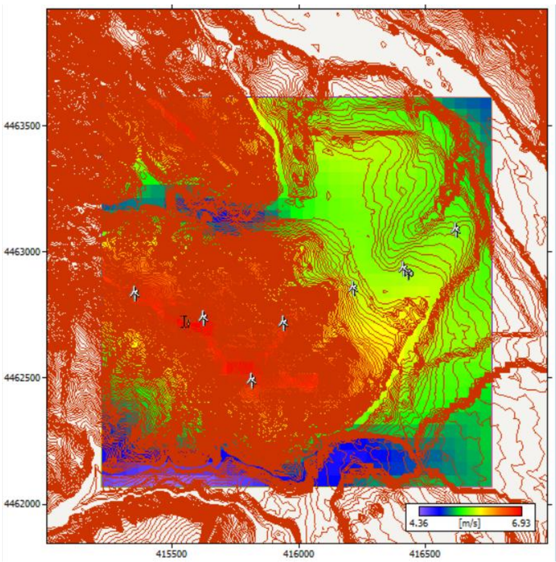

Fig. 5 *Mamaj Wind Farm Layout Design of 12.6 MW.*

Total net AEP [GWh]	34
Proportional wake losses [%]	2.58
Capacity factor	*30.8%*
Efficiency	*97.42%*

RETScreen Expert is used to do the economic evaluation. In both cases the debt ratio is considered 70%, debt term 15 years, with a 3-year debt interest rate. Discount rate is considered 7% and the inflation rate 2.5%. The electricity generated by the wind farms is assumed to be delivered with a sell price of 76 €/MWh.

In two previous research studies [20, 21] is provided a sensitivity economic analysis for helping the decision-makers to understand the importance of the impact of financial feasibility indicators in relation to key technical parameters in wind farm projects. In this study an "Relative analysis" to define the best of the proposed wind farms in terms of costs and benefits is used.

The benefit-cost ratio, (B-C), is an expression of the relative profitability of the project (equation 1). It is calculated as a ratio of the present value of annual revenues (income and/or savings) fewer annual costs to the project equity:

$$B - C = \frac{NPV + (1 - f_d)C}{(1 - f_d)C} \qquad (1)$$

where: C is the total initial cost of the project, *NPV* is Net Present Value (the value of all future cash flows, discounted at the discount rate, in today's currency), and f_d is the debt ratio. The higher the ratio, means the more the euro savings realized per euro of investment.

The net annual returns include the revenue from selling the electricity produced from the wind farm during its active operation period. They are dependent on the wind farm capacity factor, as well as the price of electricity is being sold at, which in turn are dependent on the climate of the proposed area of the project, the type of wind turbines and layout design of wind farm, as well as on O&M's annual costs.

We estimated the predicted revenue during a project lifetime of 25 years. However, due to multiple factors, one euro earned or spent tomorrow in not worth the same as one euro today. This concept leads to a technique of economic appraisal known as discounted cash flow (DCF) analysis.

Therefore, to bring back to the present the future net incomes stream that flow every year from the project, we have to know, the discount rate r. The level of the discount rate depends on the risk of the investment [22].

The simple payback *SP* is the number of years it takes for the cash flow (excluding debt payments) to equal the total investment (which is equal to the sum of the debt and equity) (equation 2):

$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})} \qquad (2)$$

where: *IG* is the value of incentives and grants; C_{ener} is the annual energy savings or income; C_{capa} is the annual capacity savings or income; C_{RE} is the annual renewable energy (RE) production credit income; C_{GHG} is the GHG reduction income; $C_{O\&M}$ is the yearly operation and maintenance costs incurred by the clean energy project and C_{fuel} is the annual cost of fuel or electricity.

The year-to-positive cash flow (also known as Equity payback) N_{PCF} is the first year that the cumulative cash flows for the project are positive. It is calculated by solving the equation (3) for N_{PCF}:

$$0 = \sum_{n=0}^{N_{PCF}} \widetilde{C_n} \qquad (3)$$

where $\widetilde{C_n}$ is the after-tax cash flow in year n.

The equity payback represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback is a better time indicator of the project merits than the simple payback.

3. Results

For the Mamaj area two wind farms are proposed, respectively 10.8 MW and 12.6 MW. To do technical evaluation WAsP software is used. The 10.8MW wind farms consists in the installation of 6 Vestas V100-1.8MW wind turbines, with a power capacity of 1.8 MW for each wind turbine. The projected wind farm is calculated to export 30.4GWh electricity yearly, with a capacity factor equal to 32% and with an overall efficiency of the farm that is predicted to be approximately 99%, because of wake losses which are equal to 0.98% of the overall efficiency of the wind farm. While, the 12.6 MW wind farm consists in 7 Vestas wind turbine, with the same power capacity installed for each wind turbine, 1.8MW. Wind farm is calculated to export 34 GWh electricity yearly, with a wind farm capacity factor of 30.8% because of the wake losses calculated approximately 2.58% hence, the overall efficiency of the windfarm will be approximately 97.42%.

To do the economic evaluation RETScreen Expert will be used. The initial infilled parameters values for both 10,8MW and 12,6MW wind farms are in Table 1. In both cases the debt ratio is considered 70%, debt term 15 years, with a 3-year debt interest rate, since is a high initial project cost. Discount rate is considered 7%, as the normal interval varies from 5% to 11%.

Table 1. Infill parameters values for the both 10.8MW and 12.6MW wind farms.

Components	Value	Unit
Inflation rate	2.5	%
Discount rate	7	%
Project life	25	yr
Debt ratio	70	%
Debt interest rate	3	%
Debt term	15	yr

For the wind farm 10.8 MW, the equity payback is calculated 4.2 years and simple payback 7.6 years, with a cumulative cash flow of 22.44 M€, and a net yearly cash flow-first year equal to 0.972 M€ (see in Figure 6).

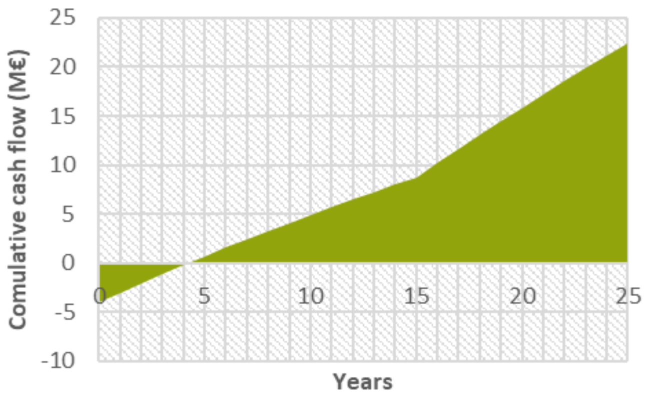

Fig. 6. *Payback period and cumulative cash flow for the 10.8MW wind farm in years*

From the RETScreen simulation is seen that for the 10.8MW the NVP (Net Present Value – the difference between the inflows and outflows cash of project) is equal to 7.461 M€, with a benefit cost ratio of 2.9. The LCOE for this project is calculated 0.055 €/kWh, Table 2.

Table 2. Results for 10.8MW wind farm.

Components	Value	Unit
Simple payback	7.6	yr
NVP	7,461,796	€
Benefit-cost ratio	2.9	-
Energy production cost	0.055	€/kWh

Regarding the 12.6 MW wind farm, with an initial cost of 15.38 M€, the cumulative cash flow will be 23.52 M€, with a simple payback period of 8 years and equity payback equal to 4.7 years, as it is shown in Figure 7.

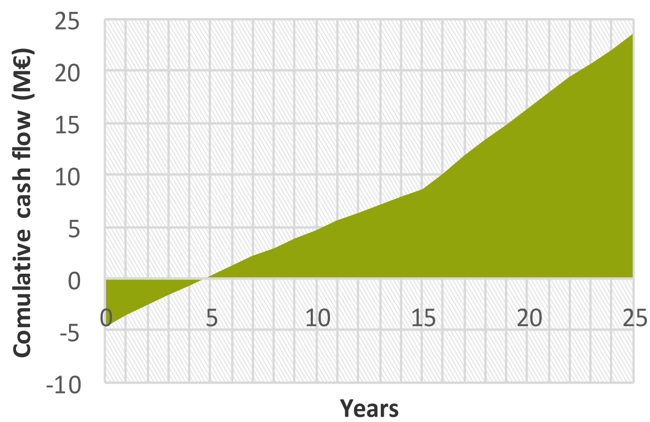

Fig. 7. *Payback period and cumulative cash flow for the 12.6MW wind farm*

Results shows that the NVP for 12.6 MW is equal to 7.46 M€, with a benefit cost ratio of 2.6. Energy production cost or LCOE in this case is 0.057 €/kWh, higher than the 10.8 MW wind farm (Table 3).

Table 3. Results for 12.6MW wind farm.

Components	Value	Unit
Simple payback	8	yr
NVP	7,461,160	€
Benefit-cost ratio	2.6	-
Energy production cost	0.057	€/kWh

3. Conclusions

This study consists in the economic evaluation of two wind farms respectively 10.8MW and 12.6MW, which will be placed in the same area. The difference between two wind farms is the number of wind turbines. For the 10.8MW wind farm will be used 6 Vestas wind turbines, with a power capacity of 1.8 MW of each turbine, while for the 12.6 MW wind farm will be used 7 same wind turbines. Since the turbines will be placed in the same are the wake losses from the array of the wind turbines, for the 12.6MW wind farm the losses will be higher than the 10.8 MW wind farm, respectively 2.58% and 0.98% of the overall efficiency of the wind farms, which indirectly indicates in the yearly electricity generation from the wind farm. Net electricity exported to grid including wake losses will be 34 GWh for the 12.6 MW wind farm and 30.4GWh for the 10.8 MW.

For the economic evaluation RETScreen software is used. As it seen from the comparison of the results from the two wind farms, with a discount rate 7%, the benefit-cost ratio is 2.9 for the 10.8 MW wind farm and 2.6 for the 12.6 MW (Table 4).

Table 4. Results for 10.8MW and 12.6MW wind farm.

Cases	Simple Payback [yr]	Benefit-cost ratio	Energy production Cost [€/kWh]
Wind farm 10.8MW	7.6	2.9	0.055
Wind farm 12.6MW	8	2.6	0.057

Also, the simple payback period is lower for the 10.8MW farm, equal to 7.6 years, with 0.4 years less than the other wind farm. Hence, the energy cost is lower respectively 0.055 €/kWh and 0.057 €/kWh, (Table 2, 3). As seen from the comparison of the results, the wind farm 10.8 MW is more cost effective, than the 12.6 MW wind farm, due to higher wake losses, which decreases the overall efficiency of the wind farm to 97.42%.

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