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# Technical, Economic and Environmental Analysis of Electricity Production from Wind—Case Study in Synej Area, Kavaja Municipality (Albania)

Konalsi Gjoka and Alfred Lako

*Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana 1023, Albania*

**Abstract:** The contribution of the use of RE (Renewable Energy) sources in general and wind source in particular in the Albanian electricity sector is very important to strengthen national energy security, diversify energy sources and reduce dependence on imports. It also directly affects economic growth, employment and reduces the release of pollutants into the atmosphere, which are contributing to global warming and the greenhouse effect. The purpose of this paper is to assess the theoretical, technical and economic potential of the wind source in the Synej Area, Kavaja Municipality for electricity production in the absence of field measurements. Calculations of all technical, economic and environmental parameters are performed through the RETScreen Expert program. This analysis is sufficient for pre-implementation studies that do not require very detailed calculations and at the same time facilitates decision-making on project implementation. The study area has considerable technical potential for the use of wind energy. In this area, the analyzed project envisages the installation of 7 turbines of the Vesta 110 type, each with a power of 2 MW. The height of the turbines is 85 m. The total amount of electricity produced by this plant is estimated at 24 GWh/year, at a cost of 0.06 €/kWh. The total emission reduction for all proposed projects is 477,500 $tCO_2$ per year. The project has a positive net present value and a benefit-cost ratio greater than 1. The payback time is 8 years.

**Key words:** Renewable resources, wind energy, technical-economic-environmental analysis.

## 1. Introduction

The continuous increase in energy demand and consumption of fossil fuels is accompanied by the emission of large and increasing amounts of $CO_2$ into the atmosphere, which is the main contributor to global warming. So as a result of these emissions, it is estimated that the temperature on earth will increase by 1.5 °C between 2030 and 2050 [1].

Freeing the energy sector from carbon dependence and reducing carbon emissions to reduce the effects of climate change are at the heart of world policies for the gradual shift from the fossil fuel-based energy system to a sustainable RE-based (Renewable Energy-based) system.

After the Rio conference, climate change and the use of Renewable Energy Sources (RES) were at the center of debate and policy-making worldwide. In Europe in 1997, RE made a modest contribution, with only 6% of the total energy consumption, while the dependence of EU (European Union) countries on energy import was 50% [2].

Following these efforts, in 1997 Europe adopted the first RES strategy, Energy for the Future, which determined for the EU countries the doubling of the existing contribution of RE to the total energy consumption in the EU from 6% to 12% by 2010 [3]. The strategy estimated that in order to achieve this doubling of the role of RE, an increase in the general investment of the energy sector by nearly 30% was required, which would be accompanied by the opening of 500,000-900,000 new jobs and the reduction of $CO_2$

**Corresponding author:** Konalsi Gjoka, PhD, research fields: integrated waste management, renewable energy and energy efficiency.

emissions by 402 million tons/year.

In 2001, the target for the contribution of RE to electricity production was 21% by 2010 with the adoption of the Directive on the promotion of electricity from RES (2001/77/EC) [4]. Although the share of electricity produced by RES has grown significantly over that time, reaching 13.6% of total EU energy consumption in 2005 and 19.5% in 2010 [5], the EU still failed to meet the target established by 21%. However, of the 641 TWh of electricity produced by Renewable Sources (RS) in 2010, wind is the main contributor with 155 TWh after hydropower.

Many steps forward have been made since then and in 2009 the Council of Europe adopted for the first time a binding target for all member countries, where the energy produced by RES should occupy 20% of the total energy consumption by 2020 [6]. The member countries already have a legal obligation to define the national objectives for RES as well as to prepare every two years the National Action Plan for RES accompanied by the measures taken to achieve the objectives and the development of the energy infrastructure.

For the year 2030, the EU has adopted new objectives that are a 40% reduction in GHG (Greenhouse Gas) emissions compared to 1990, the mandatory coverage of 32% of total energy consumption from RES [7] and the achievement of an improvement with a minimum of 32.5% in energy efficiency [8].

In the longer term, the EU has set the ambitious goal of building a competitive low-carbon economy, which will be able to reduce GHG emissions by 80%-95% by 2050 [9]. Thus the energy produced by RES can increase significantly in the European Union and can occupy from 55% to 75% of the total energy consumption in 2050 [10].

From the years 2000-2010, electricity produced by wind has had the fastest growth among all RES (with 127 TWh) [11]. While the contribution of electricity produced by the wind in relation to the electricity produced by all RES, there has been a positive increasing trend from the years 2004-2016 as shown in Fig. 2 [12].

The contribution of the use of renewable energy sources in general and of the wind source in particular, in the Albanian electro-energy sector is very important to strengthen national energy security, diversify energy

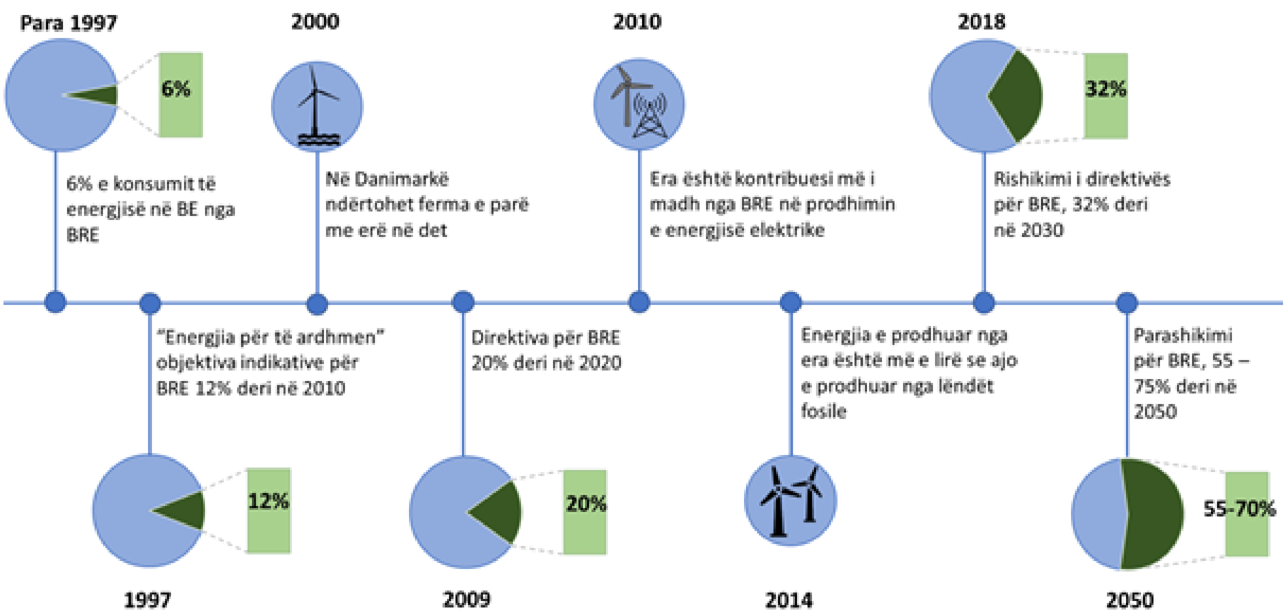



**Fig. 1 Development of EU RES targets and the role of wind energy.**
Source: EC 2020, adapted by author.

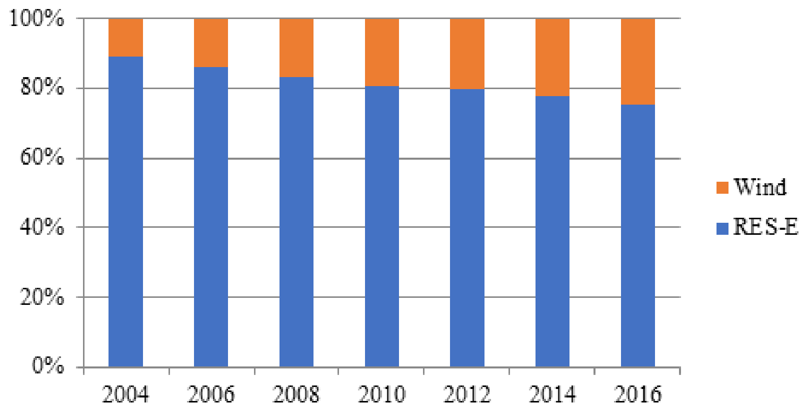



**Fig. 2 Wind's contribution to RES electricity production.**
Source: EC 2020, adapted by author.

**Table 1 Forecast for the expansion of installed capacities for the generation of electricity from RES.**

| Estimated capacity (MW) for energy production from RES | 2015-2020 | 2018-2020 | 2019-2020 |
|---|---|---|---|
| Hydro | 750 | 600 | 57 |
| PV | 50 | 120 | 490 |
| Wind | 30 | 70 | 150 |
| Biomass | 0 | 8 | 41 |
| Total | 830 | 798 | 738 |

Source: Energy Community 2020, adapted by author.

sources and reduce import dependence. It also directly affects economic growth, employment and reduces the discharge of pollutants into the atmosphere, which are contributing to the warming of the planet and the greenhouse effect.

The main policy document in the energy sector is the National Energy Strategy 2018-2030, where one of its main objectives is the diversification of energy sources, aiming for the contribution of RES to total energy consumption to be 42%, while GHG emissions against the total are to decrease by 11% until 2030 [13].

The National Action Plan for RES, which defines the supporting measures for achieving the national objectives, has been revised twice since its creation. What is observed is a growing trend in the planning of energy produced by wind and photovoltaic PV plants [14].

The interest of local and foreign investors in the use of RES has always been on the rise in the last 10 years. About 88 applications for the construction of PV with a capacity of up to 2 MW have been submitted to Ministry of Industry and Energy, of which 12 have been authorized with a total installed capacity of 24 MW. The largest plant is under construction in Akërni Vlorë, with an installed capacity of 100 MW. As for wind energy, there were about 70 applications, of which 3 were authorized for the construction of wind parks up to 3 MW with an installed capacity of 41 MW [15].

The most important entry point to drive investment is to create incentives and secure financing for wind projects that produce electricity at above-market prices. These incentives must be supported by a legal and institutional framework that guarantees RE producers both the ability to connect to the grid and the ability to sell energy.

The new law on RES approved in 2017 provides energy producers for installations above 3 MW for wind parks with the sale of energy for 15 years to Electricity Distribution Operator. Also, the law promotes new support schemes, such as the tariffs regulated today (feed in tariff) and those where the "Contract for Difference" concept (feed premium) is

**Table 2 Price for electricity production from RES plants.**

| The RES technologies that are applied | Tariffs (feed in) €/MWh |
|---|---|
| PV modules with installed capacity of electricity up to 2 MW | 100 |
| Wind turbines with installed capacity of electricity up to 3 MW | 76 |
| Small hydropower plant with installed capacity up to 15 MV | 69 |

Source: ERE 2020, NREP 2018-2020.

applied in the future. These schemes are expected to support the producer when the price of electricity produced by wind farms is above the market price. The price for the production of 1 MWh from wind plants with an installed capacity of over 3 MW is €76 (feed in tariff) [16].

## 2. Material and Methods

*2.1 Study Area*

In the Synej area of the municipality of Kavaja, it is planned to build a wind park with a capacity of 14 MW, which envisages the installation of 7 turbines each with a power of 2 MW. The turbines are expected to be of the Vesta 110 type and will be placed at a height of 85 m. The closest distance from the residential center is 9 km. The height of the turbines is 85 m.

Fig. 3 shows the map of the area with the distribution of the average wind speed at a height of 100 m, and Table 3 provides the main technical data of the project.

Table 4 summarizes the technical information for the area of Synej, Kavaja. The area presents an average speed of about 5.25 m/s. However, the wind speed is distributed in the area in different values, which vary from 5.25-6.1 m/s. Meanwhile, in 10% of the best windy areas in this region, an average speed of 5.93 m/s at a height of 100 m is identified.

The power density in the top 10% of areas in this region at a height of 100 m is 322 W/m$^2$. The dominant wind direction is South-East. The wind speed index is higher during the period January-March and November-December. These are the best periods for using wind energy in this region.

Tables 6, 7 and 8 summarize the results of the energy analysis for the proposed project in Synej Kavaja [17, 18].

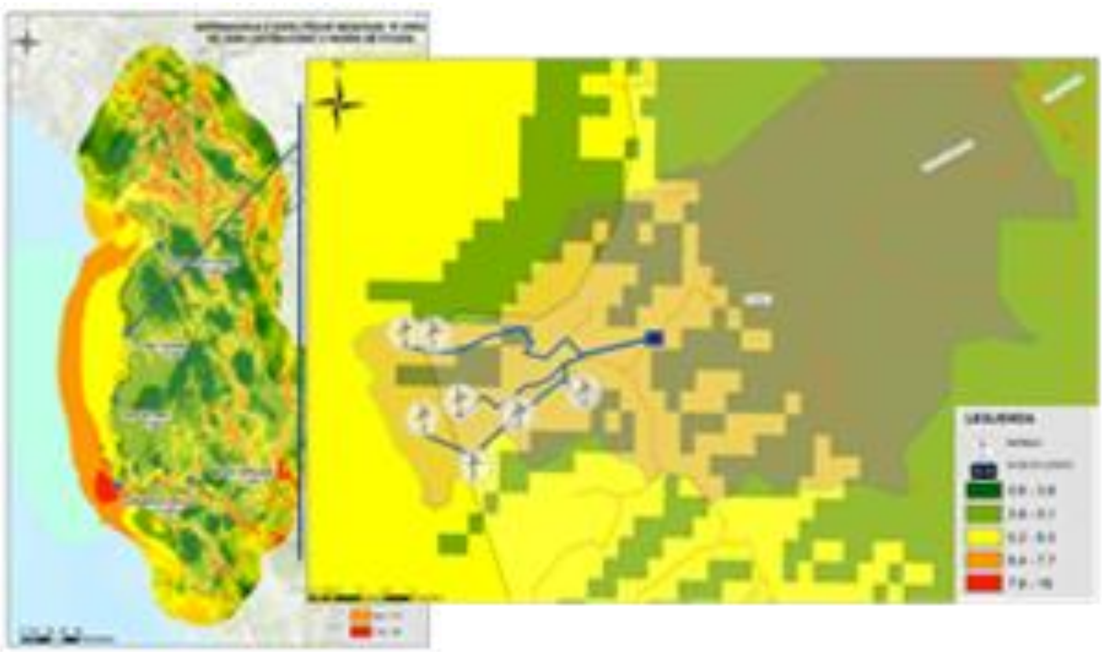


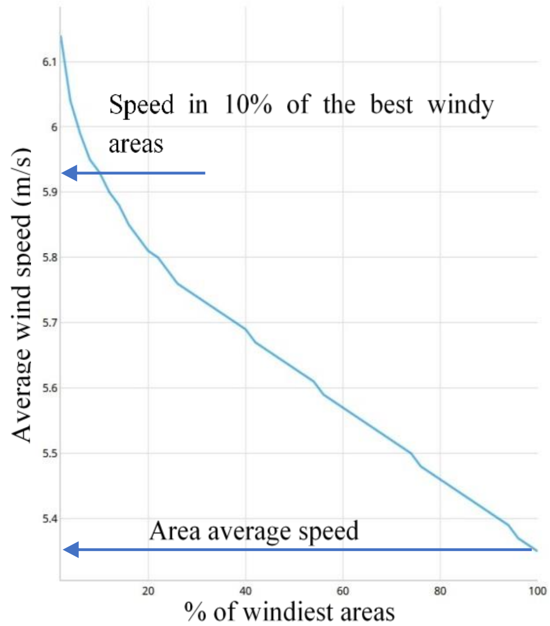
**Fig. 3 Distribution of average wind speed at 100 m height in the area of Synej, Kavaja.**

**Table 3 Technical data for the proposed project in the Synej, Kavaja area.**

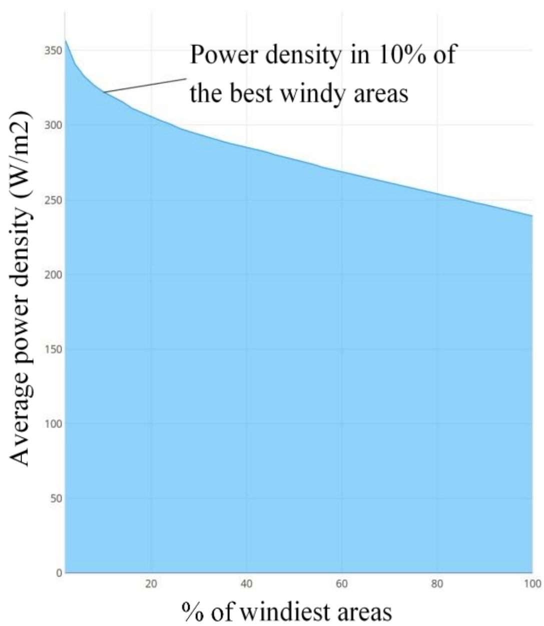
| Zone | Synej Kavaja |
|---|---|
| Installed capacity | 14 MW |
| Number of turbines and their capacity | 7 × 2 MW |
| Type of turbines | Vesta 110 |
| The height of the turbines | 85 m |
| Rotor diameter | 110 m |
| Average speed in 100 m | 5.35 m/s |
| Average speed in the best areas | 5.93 m/s |
| No. of wind hours | 1,916 |
| Dominant direction | J-L |
| Connection point and distance from the network | 110 kV Kavaja, 9 km |

**Table 4 Average speed, frequencies, wind density at 100 m height and their variability in the Synej, Kavaja area.**

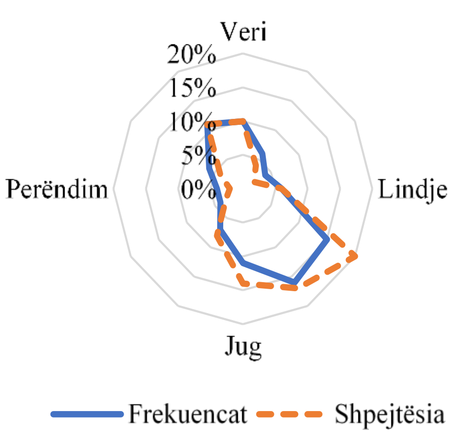
The average speed at 100 m height




Average power density at 100 m height




The Wind Rose




Speed variability by month

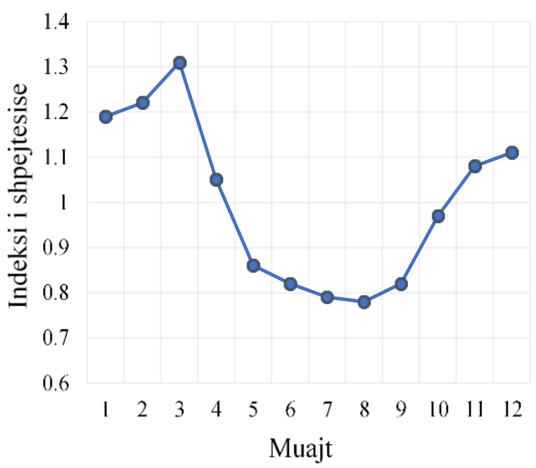


**Table 5 Analysis of initial costs for small and large wind farms.**

| Type of cost | Small plants | Large plants |
|---|---|---|
| Feasibility study | 1%-7% | < 2% |
| Development | 4%-10% | < 1%-8% |
| Engineering | 1%-5% | 1%-8% |
| The electrical system | 47%-71% | 67%-80% |
| System balancing | 13%-22% | 17%-26% |
| Others | 2%-15% | 1%-4% |

Source: RETScreen.

*2.2 Methodology*

The calculations of all technical, economic and environmental parameters were carried out with the RETScreen Expert program. The analysis carried out using this program is sufficient for first studies—the applicability in which very detailed calculations are not required [19]. For the area studied through this program, the following parameters were analyzed.

2.2.1 Energy Analysis

The net energy (MWh) produced by the wind is calculated with the following expression:

$$E_{neto} = E_{gross} \times C_{losses}$$

The gross energy (MWh) that a turbine produces is calculated by multiplying the instantaneous power of a turbine, according to its power curve, by the probability distribution of the speed.

$$E_{gross} = (24 \times 365) \sum_{v=0}^{25} P_v f(v)$$

The loss coefficient takes into account losses as a result of mutual influence (1.5%), air losses (1%), technical losses (3%) and losses due to the absence or inadequacy of the network (0.03%).

$$C_{losses} = (1 - 0.15) \times (1 - 0.01) \times (1 - 0.03) \times (1 - 0.0003) = 0.816$$

The capacity factor of the plant is calculated as the ratio of the net energy produced with the production of the capacity of the plant with the number of hours per year.

$$CF = \frac{E_{neto}}{(24 \times 365) \times Cap.Plant}$$

The specific output of the plant (kWh/m$^2$) is used to determine the performance of the turbine according to the wind regime, and is defined as the ratio of the net energy to the output of the number of turbines and the surface of the rotor.

$$Y = \frac{E_{neto}}{(No._{turbines} \times Area_{rotor})}$$

To realize the energy performance in each area studied, regional climate data according to Global Wind Atlas (GWA) were used, which were corrected where possible with field measurements and technical data of the turbines proposed by the project developers.

2.2.2 Economic Analysis

The program analyzes in detail initial costs, annual costs, annual savings and periodic costs. To orient the user to the initial costs that are also the largest costs, the program suggests the percentages that each of these costs occupies in the total cost of a project for a large or small capacity wind farm.

2.2.3 Environmental Analysis

This analysis is based on two scenarios. The baseline scenario calculates the net emission of GHGs that would be emitted into the atmosphere if the same amount of energy were produced in an alternative way from a conventional plant. In this scenario, it is assumed that the entire amount of energy produced in the area comes from an imaginary plant that works with fuel in the ratio of 30% natural gas and 70% diesel.

This scenario is taken as a reference and compared with the scenario of producing energy from wind. In the end the reduced GHG emissions produced by the proposed project throughout its life cycle are calculated. The analysis takes into consideration to calculate the GHG reduction, $CO_2$, $CH_4$ and $N_2O$ emission factors of 234.5 kg/GJ, 0.0083 kg/GJ and 0.057 kg/GJ respectively.

2.2.4 Financial Analysis

This analysis through financial indicators provides information on the viability of a project. It uses these parameters as input data; inflation, discount rate, project life, grants or incentives, loan level, loan, capital, loan interest rate, loan duration and its payment.

In all cases considered, we have assumed that the life of the project is 25 years, the inflation rate is 3%, the discount rate is 9%, the loan level is 50% of the initial investment, which is taken for a period of 15 years with 6% interest.

The program also calculates the annual income that the project realizes, both from the sale of electricity and from the reduction of GHG in case the project is supported by any incentive policy, for example that takes into account carbon credits. In all cases we have taken into consideration that the price of electricity produced by wind plants is 76 €/MWh. Also, the annual income takes into account only the income obtained from the sale of electricity.

The results of the financial analysis are: IRR (Internal Rate of Return), return on capital, net present value, life cycle savings, cost benefit ratio, debt coverage and energy production cost.

## 4. Results and Discussion

For the case taken in the study, it results that the areas have a considerable technical potential for the use of wind energy. At the end of the energy—environmental-financial analysis, we can say that the proposed project is financially viable. It has a positive net present value and a benefit-cost ratio greater than 1. Investment payback time is 8 years. The total amount of electricity produced by this plant is calculated at 25 GWh/year, with a cost of 0.06 €/kWh. The total emission reduction for all proposed projects is 477,500 $tCO_2$ per year. Tables 6, 7 and 8 and figure 4 summarize the energy, environmental and financial results.

**Table 6 Results of the energy analysis for the Synej project, Kavaja Municipality.**

| Energy production results for the proposed plant in Synej, Kavaja | |
|---|---|
| Net energy per turbine (MWh) | 3,860 |
| Loss ratio | 0.9 |
| Capacity factor (%) | 19.9 |
| Turbine efficiency (kWh/m$^2$) | 367 |
| Electricity produced annually by the plant (MWh/year) | 24,413 |

**Table 7 Results of the environmental analysis for the Synej project, Kavaja Municipality.**

| GHG reduction results for the proposed plant in Synej, Kavaja | |
|---|---|
| Amount of emissions for the base case ($tCO_2$) | 20,761 |
| Amount of emissions for the proposed case ($tCO_2$) | 1,661 |
| Reduction of annual emissions ($tCO_2$) | 19.100 |
| Reduction of emissions throughout the life cycle ($tCO_2$) | 477,493 |

**Table 8 Results of the financial analysis for the Synej project, Kavaja Municipality.**

| Financial results for the proposed plant in Synej, Kavaja | |
|---|---|
| Total investment cost (€) | 13,554,303 |
| Internal rate of return on capital IRR (%) | 14.2 |
| Internal rate of return on assets IRR (%) | 6.1 |
| Payback period of initial investment (years) | 8 |
| Years of capital return (year of positive flows in years) | 6.9 |
| Net present value (€) | 3,799,957 |
| Annual lifetime savings (€) | 386,823 |
| Benefit-cost ratio | 1.6 |
| Debt coverage (years) | 2.4 |
| Electricity production cost (€/kWh) | 0.06 |

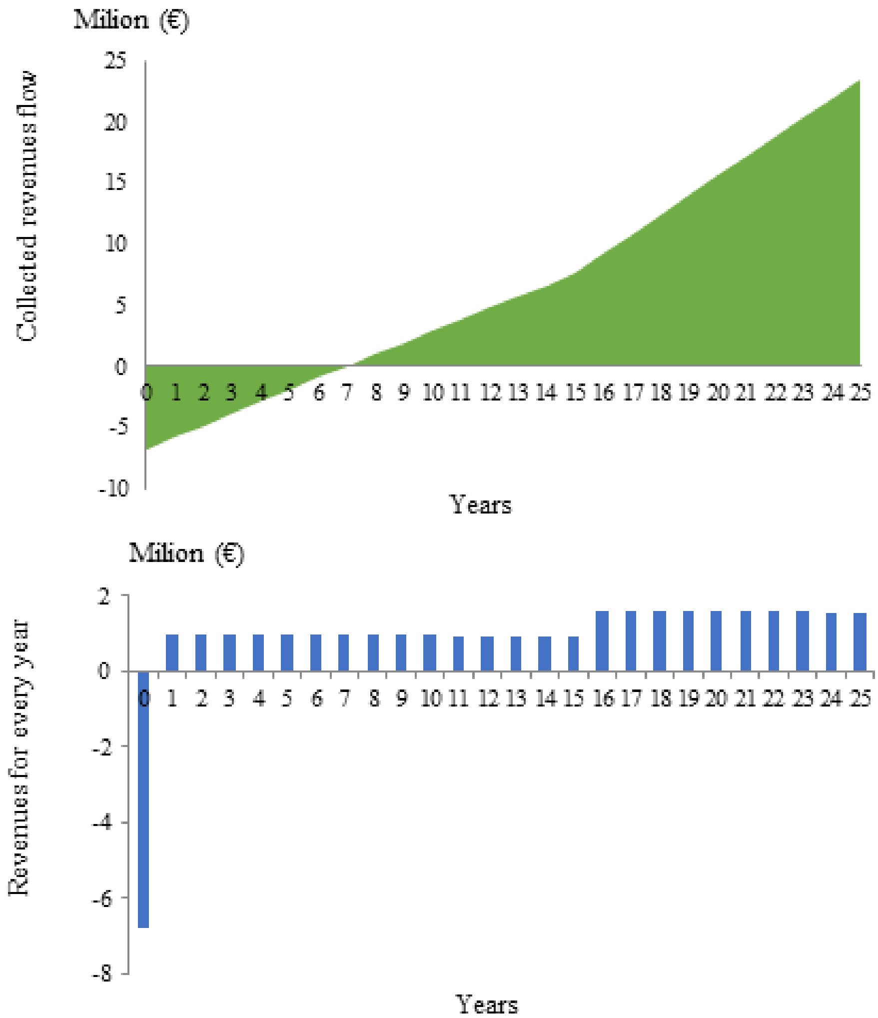



**Fig. 4 Income flows for the project in Synej, Kavaja.**

## 5. Conclusions and Recommendations

Wind energy, among all renewable energy sources, occupies a significant place in the energy market, experiencing during the last decade the greatest growth in the whole world. Among the main benefits of wind-generated energy are the environmental advantages it presents compared to energy generated from traditional fuels. Moreover, the cost of producing electricity from wind is among the cheapest compared to other energy sources, and it is more and more comparable to the costs of producing electricity from fossil fuels.

The use of the energy potential of the wind, as a renewable source of energy, for the production of electricity in Albania has not yet been started. Despite the increased interest presented to invest in this direction, it seems that the main barriers faced by investors are:

1. lack of long-term data and measurements in the areas of interest for the use of this energy

2. high investment costs and uncertainty about the income and expenses of these projects

3. lack of effective support schemes as long as the cost of wind power production is higher than the market price of electricity

Based on the results of this case study for further research in this field, is recommended:

1. The design and implementation of concrete projects aimed at a detailed assessment of the wind

source in the area studied as the most interesting for the use of this energy;

2. More detailed assessment of the wind source, based on monitoring with field measurements of wind speed. This is the main element to determine the financial viability of a wind energy project;

3. Drafting favorable policies for the use of RS in general and the wind source in particular, to create more security for investors;

4. Building effective financial support schemes and creating successful business models for wind resource utilization.

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