The Use of Renewable Energy Sources and Mainly Wind Energy for the Production of Electricity in Albania

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Abstract

Electricity production in Albania is dominated by hydropower plants, Vau i Dejës, Koman and Fierzë with a capacity of 1,350 MW. The total net domestic electricity production realized for 2021 was 8,962,699 MWh, of which: 5 343 974 MWh was

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produced by the power plants owned by the public company KESH sh.a.; 3 618 725 MWh was produced by other power plants (INSTAT, 2021). This production was realized by public hydropower plants to the extent of 59.6%, by private and concessionary hydropower plants to the extent of 39.9% and by other producers (Photovoltaics) to the extent of 0.5% of the net domestic electricity production. The gross import of electricity (energy in receipt) reached the value of 2,253 GWh from 3,239 GWh that was a year ago, marking a decrease of 30.4%. The gross export of electricity (energy in delivery) reached the value of 2,800 GWh from 963 GWh, marking an increase of 2.9 times. Wind energy is a renewable energy such as energy produced from water, solar and biomass. Thanks to the progress in the reconstruction of modern wind energy converters, wind energy is becoming one of the main factors in providing electricity from renewable energies.

Keywords: *Renewable energy, Wind energy, Wind turbine, Rated turbine power.*

1.Introduction

Accelerating greenhouse gas emissions pose a growing threat to climate change, with potentially devastating human consequences. The use of Renewable Energy Sources together with the improvement of the efficient use of energy by users can contribute to the reduction of primary energy consumption, the reduction of greenhouse gas emissions and thus to the prevention of dangerous climate changes.

The main focus of the paper is on Renewable Wind Energy which offers many advantages which explains why it is one of the fastest growing energy sources in the world. Research efforts are aimed at addressing challenges for greater use of wind energy.

In recent years, Albania has struggled to meet all the electricity demand of its citizens due to a combination of factors, including: the lack of primary energy sources; lack of interconnected gas networks; high levels of electricity losses especially in the distribution system; limited generation and interconnection capacities and high consumption of electricity for heating and cooking. 37% of a household's annual energy consumption is only for two final uses of energy: space heating and air conditioning. (ERE[3], 2021).

In the graph of Figure 1, the structure of the use of Albania's energy resources (INSTAT, 2021) is presented.

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[3] Energy Regulator Authority

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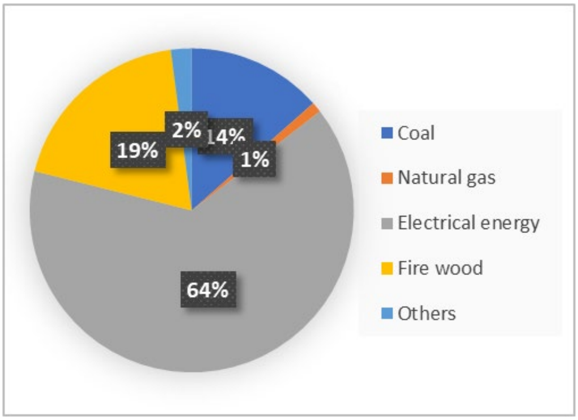

Figure 1. The structure of the use of Albania's energy resources.

2.Wind Turbines

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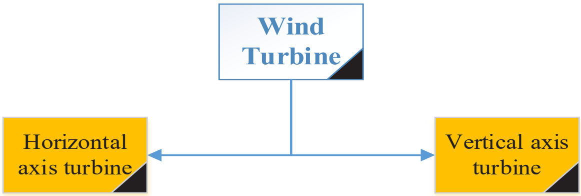
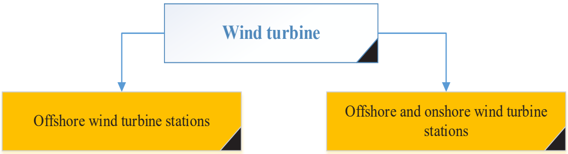
[1] Energy Regulator Authority

Wind turbines can be classified based on the orientation of their axis of rotation in relation to the wind current, into two types:



According to the installation location, wind turbines are divided into:



2.1 Nominal power of a wind turbine.

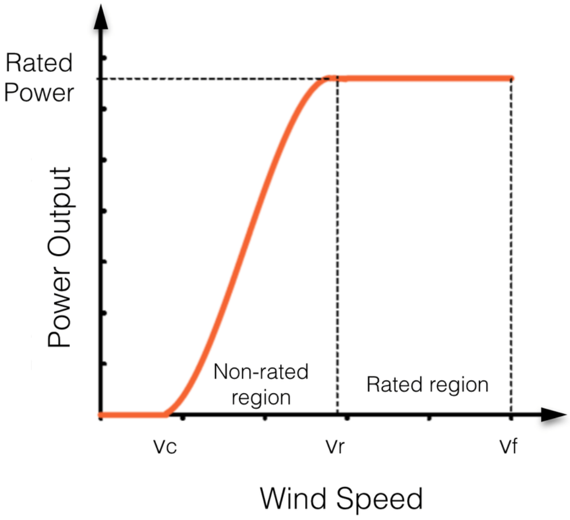
A steady supply of acceptable strong wind is a necessary requirement for harnessing wind energy. The maximum power with which wind turbines are designed is called "nominal power" and the wind speed at which it is reached is called "nominal wind speed". This is chosen to match the field wind regime and is often about 1.5 times the average field wind speed. The Beaufort scale, a classification of wind speed, gives a description of the effect of the wind. It was originally designed for mariners and described the state of the sea but has been modified to include the effects of wind on land.

The power obtained from the wind depends on a multitude of factors, such as the type of turbine and rotor, or blades with more sophisticated designs. In reality, this figure is typically around 45% (maximum) for a large power generation turbine and around 30%-40% for a wind pump. So, by modifying the formula for "Wind Power" we can say that the power produced by wind turbines is given by the equation:

$$P_T = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot V^3$$

Where:

P_T → is the available power (W) that the turbine has.
C_P → is the coefficient of performance of the wind turbine, also known as the Betz[2] limit.
ρ → Air density, ρ=1.225 kg/m^2.
A → is the area included in contact with the wind, given as the area of the circle formed by the turbine blades.
V → wind speed.



3. Albania and its energy potential

Albania ranks among the countries with the highest hours of sunshine in Europe per year that can be used to generate solar electricity and heat water with the continuous installation of solar thermal panels.
In addition, cost-effective solar and wind potential is estimated at more than 7 GW, more than three times the country's total installed electricity capacity, the report notes.
About 616 MW of this wind power could be installed by 2030.
Although due to large hydropower resources, Albania has the highest share of renewable energy in South-Eastern Europe, it is still highly dependent on annual rainfall – resulting in high sensitivity to climate externalities.

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[2] Betz's law indicates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow.

In 2020, the country was forced to import nearly 40% of its energy needs due to low rainfall, at a cost of $240 million. Diversifying the energy mix will mitigate Albania's exposure to external factors and build stability.

Plants located in the coastal lowlands account for about 30 GWh/year (about 0.7% of domestic energy production). The studies presented by AKBN[3] have shown that these areas have sufficient sources of wind energy to be considered suitable areas for the placement of turbines.

The average annual wind speed is estimated to be around 4-6 m/s at a height of 10 m (with an average energy density of 150 W/m). The limited meteorological service information currently available represents only a preliminary assessment of wind energy potential in Albania.

However, the Institute of Geosciences has counted on 22 meteorological stations throughout the country for 30 years, but only 4 stations (Durrës, Kryevidh, Gllavë and Xarrë) have detailed data about wind speed and its duration. Long time periods are analyzed for 22 stations across the country.

3.1 Wind sources in Albania.

The data show steady winds with an annual average speed of about 4 m/s. The economic limit for the implementation of wind energy is calculated for an average annual speed of about 5 m/s. Based on these criteria, from the four stations represented by the table, the station in Xarrë seems like an optimal opportunity, as it is closer to the economic limit to implement wind turbine plants, but the other stations also present interest for the application of wind turbines.

These data are based on measurements performed by specialists (anemometers) calculated at a height of 10 m at ground level.

But it is already known that the higher we climb, the stronger the wind speed becomes. As a result, for a 30% increase in wind speed, which is assumed to be reached at a height of 50 m above ground level, a height that is quite suitable for the installation of wind turbines.

A preliminary assessment of wind energy resources is shown in Figure 5. There the areas are shown according to the number of annual hours with a speed of more than 5m/s. Wherever opportunities exist, areas for wind energy utilization are labelled and shown in the figure.

Considering the period of 4500 hours/year as economically satisfactory, the areas with the highest premium are those of Xarra and Sheqeras. Other possible stations are the Durrës,

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[3] The National Agency of Natural Resources (AKBN) has as its object of development, supervision of rational use of natural resources, according to the government policy, and monitoring of their post-exploitation in mining, petroleum and energy.

Glavë, Kryevidh and Pukë areas. Areas in the Mati valley or in the Western Lowlands are also considered important study and investment stations.

It should be noted that the meteorological stations are located in places where the climate factor is taken as the primary criterion. Consequently, the natural potential of wind energy should be even greater.

Month	**Durrës**	**Kryevidh**	**Tepelenë**	**Sarandë**	**Vlorë**
January	4.2	5	5.8	4.9	5.1
February	4.2	5.1	5.7	4.9	5.2
March	4.2	4.6	5.9	4.8	4.5
April	4.1	4.5	4.3	4.6	4.4
May	3.6	3.7	4.6	4.3	4.1
June	3.4	4.1	4.4	4.5	4.1
July	3.3	4.3	3.5	4.6	3.9
August	3.2	4	3.5	4.4	3.8
September	3.3	4.3	4.1	4.1	4
October	3.6	4.7	5.3	4.5	4.5
November	4.2	4.9	4.7	4.7	4.6
December	4.4	5.1	5.6	5	5
Average	3.833	4.525	4.783	4.608	4.433
Density (W/m^2)	75-150	100-230	100-235	110-250	100-230

Table 1. Wind speed during the months of the year in some areas in Albania.

Wind speed [m/s]	3-4	4-5	5-6	6-7	>7
Place (where the measurements were taken)					
Durrës	5694	4906	3416	2453	1752
Gllavë	5256	4380	3679	2716	2365
Kryevidh	6132	5081	4117	2891	2190
Pukë	5781	3942	3066	2540	2115
Sheqeras	7008	5957	4643	3066	1577
Xarrë	7709	7096	5256	2453	1752
	Total annual number of hours for 6 areas				

Table 2. Number of annual hours in six areas in Albania.

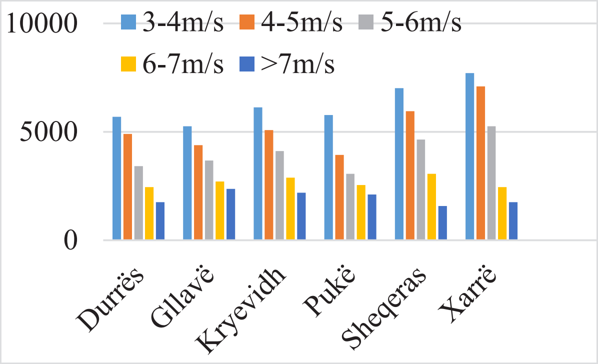

Figure 2. Distribution of the annual number of hours with different wind speeds.

3.1 Average annual wind distribution in Albania.

Five different average speed zones can be defined, these are named A, B, C, D and E in accordance with the Figure below.

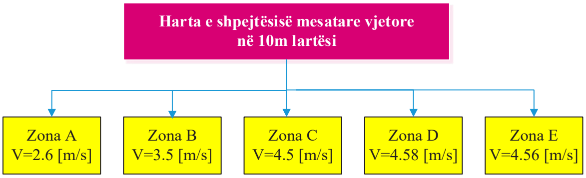

Figure 3. Breakdown chart of wind distribution map of Albania.

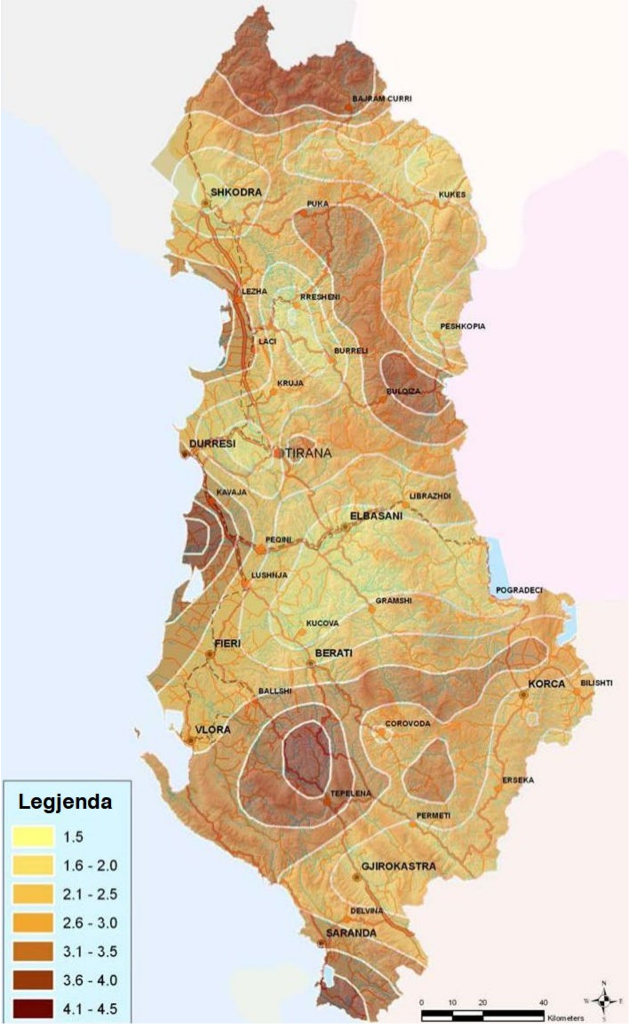

Figure 4. Map with average wind speed in Albania

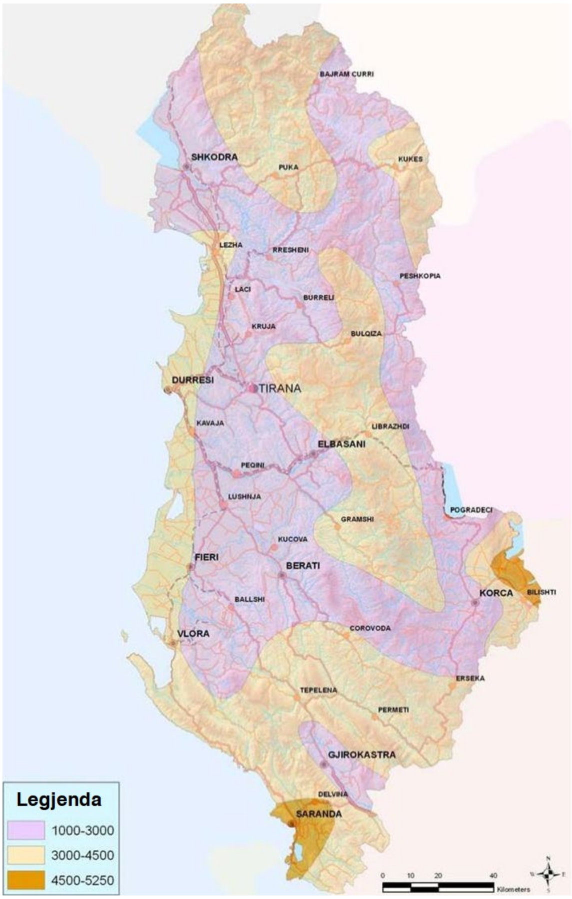

Figure 5. Territorial velocity of the annual amount of wind hours

3.1 Quantitative measurement of Albania's wind resources.

Severity class 3 was chosen for all calculations. The most likely areas for the installation of wind turbines in Albania are characterized by villages, small towns, agricultural areas. Thus, the corresponding length of the roughness is z_0=0.4 m.

Based on this summary, average annual wind speeds can be calculated for different altitudes. Of interest is the calculation of the wind speed above 50m height because the rotor centres of modern wind turbines are above this height.

Based on 10-meter height data, the Table below shows the calculated values of wind speeds at different height levels for the five map areas A, B, C, D, E.

	Hight [m]												
AREA	10 m	20 m	30 m	40 m	50 m	60 m	70 m	80 m	90 m	100 m	110 m	120 m	130 m
Area A	2,6	3,16	3,49	3,72	3,9	4,05	4,17	4,28	4,46	4,46	4,54	4,61	4,67
Area B	3,5	4,25	4,69	5,01	5,25	5,45	5,62	5,76	5,89	6	6,11	6,2	6,29
Area C	4,5	5,47	6,04	6,44	6,75	7	7,22	7,41	7,57	7,72	7,85	7,97	8,09
Area D	4,58	5,57	6,14	6,55	6,87	7,13	7,35	7,75	7,71	7,66	7,99	8,12	8,23
Area E	5,56	6,76	7,46	7,95	8,34	8,65	8,92	9,15	9,36	9,54	9,7	9,85	9,99
	v [m/s]												

Table 3. Calculated values of wind speeds at different altitude levels.

4.Potential profit of wind energy from typical Albanian sites

4.1Annual Energy Produced (AEO).

One of the measures of the cost efficiency of a wind turbine is the power it produces. Calculations of the annual energy produced require knowledge of the frequency distribution of wind speed as well as the system of produced power as a function of wind speed. Also, any forecast of the annual energy produced is specific to the location, the number of surrounding turbines, air flow, turbulence and air density. The required distribution frequency is the wind speed at the height of the rotor hub.

After some calculations of the Raleigh distribution, we find the frequency of the wind speed distribution during the year.

We can also present the total annual energy produced at a wind speed.

$$\Delta E_{a,k} = c_P P_w \Delta t \eta_T = c_P \frac{1}{2} \rho A v^3 \Delta t \eta_T \qquad \left[\frac{\text{kWh}}{\text{year}}\right]$$

The general equation for calculating the annual energy produced is presented.

$$AEO_g = \sum_{k=1}^{k} \Delta E_{a,k} = \sum_{k=1}^{k} P_k \Delta t_k \qquad \left[\frac{\text{kWh}}{\text{year}}\right]$$

AEO_g Annual energy produced (kWh/year)
k Wind speed index from 1 to k
$\Delta E_{a,k}$ Total energy produced for one speed (kWh/year)
P_k Average power produced per wind speed in turn (kW)
Δt_k Time accumulated wind speed at rotor hub height $\Delta t = 8760 * h_{Ray.distr}$ [hours/year]

After being interested in large wind turbines we received information from various companies about the large wind turbines that these companies manufacture and sell. In Tab. 4 below, a summary of several different turbines is made with all the parameters they have, such as launch speed (cut-ins), stop speed (cut-out), control type, etc.

PRODUCER	**Enercon GmbH**	**Vestas**	**Sudwind**	**Vescraft I/S**	**WEST/ENEEL**
Type	E-66	V-63	S70/1.5 MW	NTK1500/ 60	Range 60WE/504/86-T
AXIS	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Optimum power	1800kW	1500 kW	1500 kW	1500 kW	2000 kW
Node height	65,85,98,114 m	60 m	65 m	60 m	66 m
Rotor diameter	70 m	63 m	70 m	60 m	60 m
Number of rotor blades	3	3	3	3	2
Rotor speed	Var. 10-22 rpm	Obsessed 21 rpm	10.6-19 rpm	obsessed 19.2 rpm	Var. 15-55 rpm
Release speed		4.5 m/s	3 m/s	4 m/s	4 m/s

Optimal speed		16 m/s		16 m/s	14.5 m/s
Stopping speed		25 m/s		25 m/s	27 m/s
Power control	Electric self-checking	Sheet self-rotation	Sheet self-rotation	Fixed Control (Stop)	Active guidance system
The generator		1500 kW induction	Asynchronous	2 x 275 kW induction	Synchronous
Mechanical brakes	Active hydraulics. Positioned on the low-speed shaft	Active hydraulics. Positioned on the low-speed shaft		Active spring. Positioned on the high-speed shaft	Active hydraulics. Positioned on the low-speed shaft
Aerodynamic brakes	Electrically active	Hydraulic self-rotating blade		Active spring brake	Hydraulics with active orientation
Tower and weight		73000 kg		98000 kg	110000 kg
The slope		5 deg		4 deg	6 deg

Table 3. Summary of different wind turbines with their parameters

4.2 Annual Energy Produced (AEO) from typical Albanian sites using modern wind turbines.

After seeing all the turbines given in the table, we can choose between five types of wind turbines. Before we choose, we must base ourselves on the wind conditions in Albania, and as we said in the previous chapters about the wind conditions in Albania, Albania does not have high levels of wind speed, always keeping in mind the reason they were made for the energy use of wind but from meteorological institutes. Considering the aforementioned fact, we can say that the ENERCON wind turbine, E-66 is the best option for us because:

- Low cut-in wind speed

- Low rated wind speed

- High cut-out wind speed

- There is no gearbox

But we can still compare the potential profit of these turbines. It should be noted that the yield for all turbines was obtained η = 0,9 and the power coefficient c_P= 0.435, the comparison was made assuming all turbines with the same height, except for their real height.

		Type of wind turbine		
		Vestas 63	**NTK 1500/60**	**Enercon66 (Supposed)**
		AEO [MWh/Vit]	AEO [MWh/Vit]	AEO [MWh/Vit]
Areas at 60m height	A60	840.0132141	740.4360762	958.1183647
	B60	2091.36593	1873.431813	2314.945913
	C60	4437.420085	3931.695678	4896.699064
	D60	4687.728671	4232.944444	5173.971898
	E60	8228.76668	7448.897994	9194.532286
Totali [MWh/Vit]		**20285.29**	**18227.41**	**22538.27**
Areas at 70m height	A70	921.0826111	813.241884	1044.500227
	B71	2293.62561	2057.218833	2536.47427
	C70	4866.0979	4284.065854	5371.890464
	D70	5131.070576	4635.71437	5666.487023
	E70	8959.347018	4236.366977	10058.55786
Totali [MWh/Vit]		**22171.22**	**16026.61**	**24677.91**

Table 4. Annual energy produced for three types of turbines at the same height

From Table 5 we can see which one is better, but it should be taken into account that these wind turbines do not have the same power capacity. The factor on which AEO depends is the rotor surface because the other factors (v,gh, ρ,c_P) are taken constant.

To calculate the Annual energy produced (AEO) we will do the calculations for the ENERCON wind turbine:

- Turbine type E-66/1.8 MW

- Rotor diameter 70 m
- The height of the node is 85 m
- Optimum wind speed. 12.5 m/s

Table 6 shows the percentage distribution throughout the year for wind speed values higher than the optimal wind speed for the ENERCON turbine, this is done to show how often this turbine works during the year at full capacity.

Height [m]	**Zone**				
	A	B	C	D	E
65	0.15	2.99	12.3	13.19	25.57
85	0.29	5.71	15.12	16.22	29.3
98	0.39	4.98	16.69	17.81	31.16
	Percentage [%] of wind speed with v>12.5 [m/s] where: 12.5 [m/s] - the optimal speed of E-66				

Table 5. Percentage (%) of wind speeds in different areas of Albania with v>12.5 (m/s)

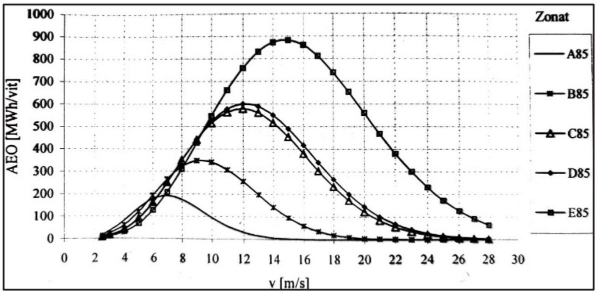

Figure 6. Annual energy produced (AEO) of the ENERCON wind turbine (E-66 70 m rotor diameter),
at 85 m height.

We have made the calculations based on only one E-66 installed, and it has been assumed that this type of turbine is installed on all five (A, B, C, D, E). This is done to compare the potential profit of these areas, to see how the AEO varies from one area to another. For the calculations made, it should be made clear that some factor values were obtained as follows:

c_p- Power coefficient $c_p = 0.435$ because large modern turbines strive for high efficiency.

p- Air density.

The efficiency of the wind turbine is:

$$\eta_T = \eta_{mek}\eta_{elec}\eta_{aerodyn} \qquad \eta_T = \frac{P_{el}}{P_T}$$

η_{elec} = Generator efficiency (depends on generator type) $\eta_{elec} = (60 - 90)\%$.

η_{mek} = Gearbox and gearbox efficiency (95%).

$\eta_{aerodyn}$ = Wind turbine aerodynamic efficiency.

Finally, the power produced by the wind turbine is given in the following equation.

$$P = c_p P_{wind} \eta_T$$

A summary of the annual energy produced at different heights is presented in Table 7, the ENERCON wind turbine was used.

Enercon E-66		
		AEO [MWh/Year]
Areas at 65m height	A65	1.093,74
	B65	2.707,66
	C65	5.091,57
	D65	5.275,55
	E65	7.466,16
Total [MWh/Year]		**21.634,678**
Areas at	A85	1.280,5998

	B85	3.311,3509
	C85	5.654,1921
	D85	5.862,9
	E85	8.040,0214
Total [MWh/Year]		**24.149,064**
Areas at 98m height	A98	1.382,397
	B98	3.589,5358
	C98	5.951,514
	D98	6.156,1843
	E98	8.314,7602
Total [MWh/Year]		**25.394,391**

Table 6 Summary of annual energy produced at different altitudes for different areas (E-66 is used)

In addition to ENERCON, which is the best variant, calculations were also made for VESTAS 63 and NTK 1500/60. These two turbines have the same node height but a difference of three meters in the diameter of the rotor, and this difference certainly influences the annual energy produced. After some calculations we can find and present the graph of AEO, Fig.8, and Fig.9, as for:

Vestkraft I/S, type NTK1500/60 at 60m height.

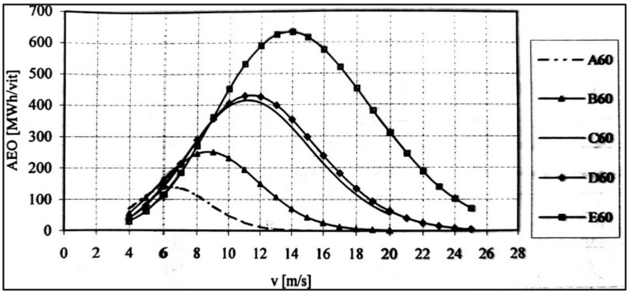

Figure 7. Annual energy produced (AEO), by Vestkraft I/S, type NTK1500/60

Vestas V63 at 60 m height.

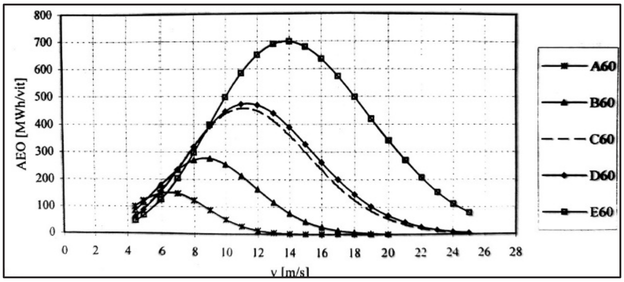

Figure 8. Annual energy produced (AEO), from VESTAS V63.

From the chart we clearly see the difference between the AEO produced by Vestas and Vestkraft I/S, this has to do with the existence € difference in rotor diameter (difference = 3 meter)

4.3Annual Energy Density produced.

To create an idea about the potential profit from typical Albanian countries it was necessary to calculate the annual energy produced. These calculations were done for three different types of turbines so we were dependent on the type of turbine. To see in an independent way the potential profit that means not depending on the type of turbine, we can calculate the annual energy density produced at different heights. To do this in the formula for the annual energy produced (AEO) the area of the rotor A is not entered, and the yield (not including the yield means that there is no loss). The values are presented in a table and in a graph that refers to this table.

	Zonat				
Height [m]	A	B	C	D	E
60	0,3033	0,7451	1,5803	1,6695	2,9325
70	0,3315	0,8173	1,7331	1,8276	3,1930
80	0,3588	0,8801	1,8723	1,9713	3,4211
90	0,3822	0,9413	1,9945	2,1053	3,6334
100	0,4066	0,9951	2,1133	2,2277	3,8176
110	0,4291	1,0510	2,2194	2,3370	3,9827
120	0,4495	1,0982	2,3200	2,4490	4,1383
	Annual energy density produced [MWh/m^2]				

Table 7. Annual energy density produced in five different areas for different altitudes

Below is presented the chart that refers to table 8.

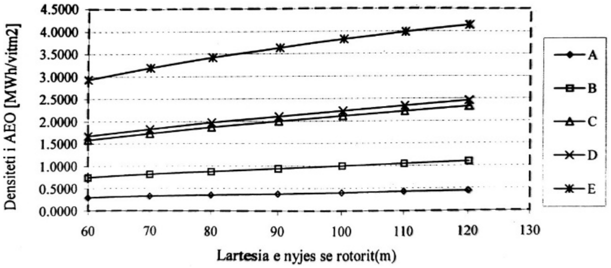

Figure 9 AEO density at different rotor hub heights.

4. ASSESSMENT OF THE POTENTIAL OF WIND UTILIZATION.

The multi-year measurements on the wind parameter have had the main goal of using wind data for meteorological forecasts, but after the 1990s and especially the last decade, one of the main goals of wind monitoring is the assessment of its energy potential. Currently, in Albania, steps have been taken in the direction of generating electricity from wind energy sources, and concretely, for the next few years, it is expected that around 2000 MW will be produced.

Based on studies on the average wind speed, it turns out that this parameter reaches over 5 m/s in the coastal areas, in the mountain ranges in the north of the country as well as in many mountainous areas of Southern and Northeastern Albania (meteoalb). It is worth highlighting some areas in Albania such as Velipoja, Hasi, Kukësi, Shëngjin Island, Tale, Balldre, Ishëm, Porto Romano, Kryevidh, Seman, Karavasta, Vlorë, Sarandë, Korçë and Tepelena, which present a high wind energy potential. The evaluation of the energy potential of the wind is based on the measurement and analysis of several parameters such as the distribution of the average wind speed according to the directions, the daily and annual progress of the wind speed, the distribution of the wind speed for different thresholds, the number of hours with a speed of certain wind, etc.

As a result of these measurements, it turns out that the coastal area is dominated by westerly winds that change direction in the depth of the territory with an average annual speed that fluctuates from 0.8 to 6.6 m/s (measurement made at 10 m height from the ground). Specifically, in Albania there are many areas where the average annual wind speed varies from 6 to 8 m/s and consequently the energy generated by these speeds is estimated to be around 250-600 W/m2. These results can be significantly improved if one tries to optimize the wind speed by performing measurements at higher altitudes. The above measurements and results apply to the heights of 45, 50, 55 and 60 meters above the earth's surface, but a better result would be obtained if we increase the height of the wind exploitation, based on the fact that the wind speed increases with the increase in height. Aiming to evaluate the potential of this resource, it has been estimated that the production level of wind farms planned for construction in Albania is about 2400 MW

During the period 2010-2021, the granting of licenses continued and until the end of December 2021, in Albania, their total amounts to approximately 2500 MW, based on the information provided by the Ministry of Energy and Industry, with an energy production potential of approx. 5 twh/year. The capacity of the Albanian electrical system to transmit and absorb wind energy has been estimated at approximately 180–200 MW.

The identification of the most suitable areas for the development of power plants based on the use of wind energy has been carried out, thus representing a preliminary assessment that must also be matched with the support of the competent authorities of Albania.

The main obstacles that exist (height, land ownership, infrastructure, natural protected areas, power) were applied to the current wind speeds and its potential map, in order to provide an assessment of the wind exploitation potential in Albania.

The maps obtained by applying the simulation codes, the corrections made to the corresponding data on the ground, quite clearly show the areas with the most wind potential, unfortunately not entirely suitable for wind plants, this is due to natural, economic, or financial limitations. In order to evaluate the areas of use, the following limitations, whether positive or negative, have been taken into account:

- Altitude above sea level (areas lower than 1,800m)
- Natural protected areas
- Road network (distance from national roads or good gravel roads less than 5 km)
- Electrical power supply system (distance from the electrical power supply system less than 10 km).

Taking financial factors into account, suitable areas for wind energy production are limited to those areas that are not too far from main roads and the energy supply system, and that have promising capacity factors (e.g. the ratio between the actual energy produced in a given period and the hypothetical maximum) thus making it an opportunity or potential to invest. In order to identify these areas, the restrictions described above are superimposed on the wind maps, considering only the characteristic areas with average annual wind speed at a height of 50m above ground level, between the values of 5.5m/s and 7.0m/s, or even more.

This estimate is a simple indicator, to present a clear idea of the size and potential of installing wind plants in Albania.

Constraints on annual average wind speed are expressed through two different productivity scenarios. Possible scenarios: high productivity (HPP) and medium productivity (MPP). As shown in figure 10, suitable areas are divided into:

1. **Ridges**[4], for mountainous areas where wind plants are mainly located in a linear fashion along the highest ridges.
2. **Flat areas**[5], they are almost residential areas, where the installation of turbines can be done not only in a single row.
3. **Offshore areas**[6], although the possibilities for such a plant go beyond the scope and calculation of this study.

The most interesting areas for the use of wind energy in Albania, namely the ridges, and the areas shown in the figure, correspond to the final assessment:

- High Productivity Scenario (HPP) – 261.5 km ridge, 66.3 km2 mostly flat area.
- Medium Productivity Scenario (MPP) – 1329 km ridge, 1689 km2 flat area.

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[4] The red line
[5] Green areas
[6] Offshore areas, known as "blue areas"

Figure 10. High productivity potential

Figure 11. Medium productivity potential.

6.Economic evaluation of wind turbine

6.1Wind Turbine Economic Evaluation.

To make the economic evaluation of the wind turbine, we will use the financial methods of investment evaluation:

1. Payback method.
2. The net present value (NPV) method.
3. The internal rate of return (IRR[7]) method.

Payback method

It is known as the payback period of the initial investment and simply estimates how long it takes for a firm to recover its initial investment in a project, regardless of the time value of money.

If the payback period is less than the maximum acceptable period for the return of the initial investment, then the project is decided to be accepted.
If the payback period is greater than the maximum acceptable period for the return of the initial investment, then the project is rejected.

Net present value (NPV) method

NPV compares the sum of the present values of each year's inflows to the initial investment. Discounting can be done using cost of capital, opportunity cost and discount rate.

By means of the formula it can be presented:

$$\mathrm{NPV} = \frac{\mathrm{CF1}}{1+\mathrm{K}} + \frac{\mathrm{CF2}}{(1+\mathrm{K})^2} + \cdots + \frac{\mathrm{CFN}}{(1+\mathrm{K})^{\mathrm{N}}} - \mathrm{I}_0$$

---

[7] The internal rate of return (IRR) is a metric used in financial analysis to estimate the profitability of potential investments. IRR is a discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis.

$$\mathrm{NPV} = \mathrm{CF1} * \mathrm{PVIF}(1;\mathrm{k}) + \mathrm{CF2} * \mathrm{PVIF}(2;\mathrm{k}) \ldots. + \mathrm{CFn} * \mathrm{Pvif}(\mathrm{n}:\mathrm{k}) - \mathrm{I}_0$$

While in the case where the annual flows are equal, then the formula can be used:

$$\mathrm{NPV} = \mathrm{CF} \cdot \mathrm{PVIFA}_{(\mathrm{n;k})} - \mathrm{I}_0$$

Where:

CF_t is the expected income for year t (1, 2, 3,…,n).

I_0 is the initial investment in period zero.

K is the cost of capital or **PVIF (k;n)** the actualization factor for year t.

The steps followed in using this technique are:

- Using the present value table to find the present value of each annual entry.
- We collect the actual values in order to find the actual value of all inputs for all the years of the life of the project we are studying.
- From this found value, we subtract the initial investment.
- Accept or reject the proposed project.

To make the decision whether the proposed project should be accepted or rejected, we act according to the following rule where:

If **NPV>0** Project Accepted.

If **NPV<0** the Project is Rejected.

Internal Rate of Return (IRR)

The internal rate of return (IRR) is perhaps the most widely used and sophisticated capital budgeting technique.

The Internal Rate of Return (IRR) is that discount rate that equates the present value of outflows to the present value of inflows.

It is the compounded annual rate of return that the firm will earn if it invests in the project and receives the given inflows. IRR is the specific rate of return for the project.

The price of electricity is calculated for a period of 15 years, therefore it is underlined:

After the request of the company OSHEE, OST and KESH to increase the price of electricity on average by 12%, the independent unions reacted. According to the trade unionists, the increase in the price of energy is not justified by an increase in costs, and in these conditions, they request the intervention of the government so that this price increase does not happen.

Currently, the price of electricity for household consumers is charged 0.1 $ for kilowatt/hour.

Energy evaluation and determination of the total energy produced by the turbine.

The energy assessment aims to determine the total energy produced per year by the turbine we have chosen and compare this value with the monthly need of a family for electricity.

Power Coefficient C_p and Betz Criterion:

$$\mathbf{C_p} = \frac{\textbf{Electricity produced by wind turbines}}{\textbf{Total wind energy}}$$

Albert Betz was a German physicist who calculated that no type of wind turbine can convert more than 59.3% of its kinetic energy into mechanical energy of rotor movement. This is known as the limit, or Betz criterion, and is the maximum theoretical power factor for any type of wind turbine.

Wind Energy:	Energy Used:
100%	40.7%

Conversion to electricity:

70% and 59.3% of wind energy.

In the diagram above, the wind turbine converts 70% of the Betz criterion into electricity. In other words, the C_p of the wind turbine will be $0.7 \times 0.59 = 0.41$. So, wind turbines convert 41% of total energy into electricity. This is a satisfactory power factor.

Quality wind turbines mainly fluctuate in the values of 35-45%.

The calculation is based on the following formulas:

$$P_T = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot V^3$$

The power that goes into producing electricity.

$A = \pi r^2$, Wind contact surface.

C_p =0.41, Performance coefficient.

Air density **ρ=1.225 kg/m^2.**

V wind speed.

Energy is calculated as the product of power times time.

$E = P_T \times t$ Unit: (kWh/month) or (kWh/year).

CASE STUDY

Installation of a wind turbine in a private house in Durrës.

The characteristics of the annual wind hours, at a height of 10m, serve to calculate the energy produced by the wind turbine, installed in a private house in the city of Durrës.

Hours/ Years	10 m		50 m		75 m	
	m/s	W/m2	m/s	W/m2	m/s	W/m2
6230	> 3	30	3.9	60	4.5	100
5000	> 4	70	5.2	160	6	250
4300	> 5	150	6.5	300	7.5	500
3100	> 6	250	7.8	550	9	800
1400	> 7	400	9.1	830	10.5	1300
V_{ave}; Dens.	4.5 m/s	100	6.0 m/s	250	7.0 m/s	400

Table 8 Characteristics of annual wind clocks.

The turbine is calculated to be placed at a height of 10m. The selected turbine is a 10 kW turbine model: NE-10k G which has the following specifications:

Figure 12. Illustrative photo, 10 kW wind turbine generator / Estonia

Product Name (Turbine):	Ten-High
Type:	Wind power generator
Voltage (V) / Power (P) [kW]	240/10
Initial working speed [m/s]	3
Average working speed [m/s]	11
Material of sheets (blades):	Glass fiber
Rotor diameter [m]	6.3
Maximum power [kW]	11
Safety speed (Break) [m/s]	50
Working speed [m/s]	3-45
Weight [kg]	480 kg
Tower height [m]	12/15

Table 9. Characteristics of the NE-10k G model wind turbine

Installation Costs:

Wind Plant Parts:

1- Turbine and Tower	4000$
2- Battery Controller	70$

3- The regulator	50$
4- Fuse Box	20$
5- Discharge Resistor	400$
6- Battery	700$
7- Inverter	120$
8- Electric Socket	20$
9- Transportation cost	2000$
10- Installation cost	500$
Total in $	7,880$

Table 10. Wind Plant Parts and Costs

Maintenance costs are calculated around $200/year.

Calculations:

We find the total Energy according to the table:

$$P_T = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot V^3$$

The power that goes into producing electricity.

$A = \pi \cdot r^2 = 3.14 \cdot 9.92 = 31.1 m^2$

C_p = 0.41 Performance coefficient (Betz).

Air density **ρ=1.225 kg/m^2**

V wind speed.

Energy is calculated as the product of power times time.

$E = P_T \times t$ [kW hours/month]

For each speed and each time period, we have respectively:

V_1=3m/s; V_2=4m/s; V_3=5m/s; V_4=6m/s; V_5=7m/s; $t_{1=}$ 6230 hour; t_2=5000 hour; t_3= 4300 hour; t_4=3100 hour; t_5=1400 hour.

$$E_{Totale} = \sum (E_1 + E_2 + E_3 + E_4 + E_5)$$

$E_1 = P_{T1} \times t_1$ =2130885 W hour /year

E_2=4053765 W hour /year
E_3=6809050 W hour /year
E_4=8482503 W hour /year
E_5=6083180 W hour /year
E_{Total}=27559380 W hour /year =27559.38 kW hour /year
E_{Total}= 2296 kW hour /month

Profit: 2296–500=1,796 kW hours/month, (it is assumed that a household consumes about 500 kW hours per month).
The lifetime of the Wind Turbine is about 15 years.
The price of electricity is about $0.1/kWh.

After finding the value of the annual energy obtained from the wind turbine, we also find its monetary value: E_{Total} = 27559.38 kW hours / year
The monetary value is: $27559.38 \cdot 0.1 = 2{,}755.9\ \$/vit$

To find the cash flow that will be benefited each year we subtract the annual maintenance cost:
CF = 2755.9 $/year – 200 $/year = 2735.9 $/year
I_0 = 7,880 $/year (Initial investment)

$$\text{Term of repayment} = \frac{7{,}880\$}{2735.9\ \$} = 2.88 \approx 3 \text{ vite.}$$

This investment is classified as a very good investment.

8.Conclusions and recommendations

8.1Conclusions

Referring to this study, Albania presents a fantastic wind potential, with wind speeds reaching 8-9 m/s in many areas. A number of interesting areas, mainly along the seacoast, and mountain ridges, with strong winds mainly in the South of the country, have been identified. The overall wind potential is estimated by taking into account factors that have a direct impact on wind plants (eg distance to roads, protected areas, electrical system, etc.).
The identification of the most suitable areas for the development of power plants based on wind energy has been carried out, thus making a preliminary assessment which will

require the cooperation of the relevant authorities of the Republic of Albania. Two potential uses are considered:

a. High productivity scenario (HPP) and
b. Medium Productivity Scenario.

Advantages of using wind turbines:

- Wind power is powered by the wind, so it is a clean source of energy.
- Wind energy does not pollute the air, like power plants that rely on burning fossil fuels, such as coal or natural gas.
- Wind turbines do not produce atmospheric emissions that cause acid, rain, or greenhouse gases.
- The current produced by the wind turbine does not release CO2.
- Wind is an inexhaustible resource.
- Wind turbines are cheap to maintain.
- Wind turbines can be built on farms. Farmers can continue to work the land, because the wind turbines use only a part of it.

The designated areas present a total installed power between 980 - 11700 MW, which corresponds to a total energy production of 3000 - 25800 GW hours/year.

The economic feasibility of installing Wind Plants in Albania shows that, with the existing tariffs, the financial feasibility is acceptable only for areas with high productivity (eg capacity factor 35%). A future possibility, based on incentives (such as the Italian Green Certificates), was included in this analysis, thus presenting a suitable ground to invest in the realization of Wind Plants.

- Environmental Viewpoint

  - Wind energy is an ecological, renewable and clean energy. However, when planning such a project, several environmental factors are taken into consideration, as follows:
  - Electromagnetic interference. Some TV waves are susceptible to interference from wind generators.
  - Noise. The rotor, gearbox and generator create acoustic noise as they operate, which must be considered when considering turbine placement.
  - Visual Impact. Modern wind machines are large objects, and therefore have a visual impact on the area around them. Some consider this influence positive, some do not.

- Investment of wind turbines for family consumption.

From the above analysis, we emphasized that Albania has a good wind energy potential, and seeing the stages that our country is going through on the road to Europeanization, it is worth noting that the price of electricity is increasing, this paves the way for the introduction of a newer technique, that of renewable energies, mainly wind, sun or water. It seems that the investment is satisfactory since in addition to covering personal (family) needs for energy, it also manages to sell it through an agreement with the distribution network. Also, such an investment paves the way for another technology, that of electric cars, which are charged by electricity, and thus breaks away from dependence on exhaustible resources such as oil, gas, etc.

8.2 Recommendations

In addition to families, such a technique can also be used by private businesses, hotels, complexes or even in transport, where it is seen as a potential use in traffic lights and lighting with solar energy or wind energy.

- It is recommended that in the family economy, the use of renewable energies is combined, in other words, solar panels for sanitary water and residential heating, and the rest in combination with wind energy, in order to meet family needs.
- Albania as a connecting part with Europe, and using its geographical position and its energy potential, to transform into a power of electricity distribution and production in the Balkans and beyond. Annual hours of wind, sunny days per year, the second place for water resources in Europe (after Norway) which are signs of a strong energy potential of Albania.

The European Wind Energy Technology Platform predicts that "in 2030, wind energy will be a major source of modern, reliable and cost-competitive energy in terms of cost per kWh". In addition, they predict that wind energy will contribute 21% to 28% of European Union (EU) energy demand, which is similar to the scenario described earlier for the United States. The European Wind Energy Technology Platform describes a long series of research and development improvements that will be necessary to make wind cost competitive by 2030. The reader interested in this multi-disciplinary research program is referred to the reference 5. There is no "major technology" breakthrough predicted for wind technology in the United States or Europe. However, many evolutionary steps executed with technical skill could cumulatively bring a 30% to 40% improvement in the cost-effectiveness of wind technology over the next two decades.

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