An investigation on wind energy potential – a future option for Albania?

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Abstract: *The aim of this work is to investigate the potential of wind energy for the future power supply in Albania. The level of information available about wind zones in Albania requires highly reliable data supplied by our institutions. However, no significant investments have been recorded in the sector in the recent years. A number of studies published a wind map with wind speeds over 5 m/s and its annual number of hours. Based on this data and a boundary layer model with the roughness of the landscape as an input, maps of wind speeds at 50 m and 100 m (typical elevation heights of modern wind hubs) are developed. In order to estimate the potential yield of the most promising Albanian locations, the density of the annual energy output assuming different wind turbine characteristics and wind speed distribution have been carried out. In this paper a basic cost analysis based on simple payback method is performed. Cost of electricity generation from wind power and payback period have been determined.*

Keywords: RENEWABLESWIND ENERGY, WIND SPEED, ENERGY POTENTIAL, ALBANIA

1. Introduction

In Albania the renewable energy sources target up to 2020 was 38%, although this objective was mostly accomplished by 35%. According to the National Energy Strategy 2018-2030 this target is 42.2% [1]. Electricity generation in Albania is dominated by hydropower with a total installed capacity of 2,275 MW by December 2019. Comparing to 2018 an increase of 71 MW installed capacity was recorded. Total generation capacity of public company KESH sh.a is 1448 MW, or 63.47 % of the total generation capacity of the country. Private companies operating in this sector share 827 MW, or 36.23% of the total generation capacity. Total electricity generation for the year 2019 was 5,200 GWh, which is 57.3% of the total electricity generation [2]. The rest of the electricity generation was realized by private hydropower companies. However, the average electricity demand in the country is around 8,000 GWh. For Albania, due to its high dependence on hydropower and therefore rainfalls the gap between electricity demand and generation is covered by import supply. According to KESH sh.a records show 2010 as the most productive year for electricity generations. Power generation from photovoltaics for the year 2019 is 22,196 MWh. Due to its geographical position in the Mediterranean solar irradiation values varies from 1450-1500 kWh/m2.year. Most parts of Albania have 300 days of sunshine a year or the average amount of sunshine for Albania is 2400 hours of sunshine per year, whereas the Western Lowlands, including the Karavasta Lagoon and Myzeqe area, where the photovoltaic plant will be built, have 2700 hours of sunshine a year. In the recent months in the photovoltaic sector in Albania significant investment contracts are signed, such as Karavasta Photovoltaic Park with a capacity of 140 MW [3]. Wind energy resources constitute a potential opportunity for power production in Albania. According to AKBN (National Agency of Natural Resources) the major problem of establishing wind power plant in Albania, is the lack of consecutive measurements of the velocity and wind duration. The main directions of wind in our country are northwest-southeast and southwest-northeast, with dominant direction towards land. Albania's coastline is 345 km north-south direction, where a part is the coastal lowlands and the other coast very close to the south seaside mountain. Inside the territory, the direction and intensity of wind from area to area varies in time [4].

2. Wind speed characteristics in Albania

The level of information available about harness wind speeds zones in Albania is poor. The only measurements for wind speeds are done by meteorological stations [5] and it should be pointed that these measurements are not so trusty because these meteorological station are not only to measure the wind speed but and other atmospheric factors. Also, in Albania there are some zones that are known from the inhabitants as zones with high-speed levels but there are no done wind speed measurements available. In this study 6 zones have been investigated for annual wind speed hours. In Fig.1 the map gives not only the locations with wind speeds above 5 m/s but also the annual number of hours.

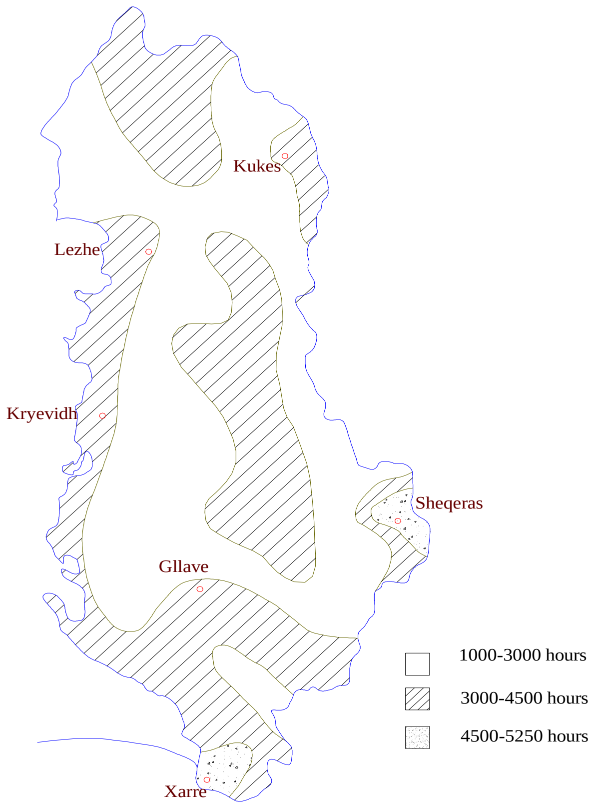

***Fig.1**. Albania's map on annual hours with wind speed >5 m/s* [6]

Figure 2 shows the distribution of the annual number of hours for different wind speeds. In a clear way one can observe the difference of hours between the locations considered: E.g., Gllave has many hours with wind speeds above 5 m/s but also the other locations have approximately the same amount of hours. The measurements of wind speed were done by the meteorological stations at 10 m elevation, i.e. at an elevation of 10 m the anemometer of the station was positioned.

The quantification of the local wind energy resources can be done by their annual *average wind power density:*

$$p_{w,a} = \frac{0,5\rho}{8760} \int_{Year} v^3 dt \qquad (1)$$

with

Annual average wind power density [W/m^2]

t Time [hours]
v Horizontal component of wind speed [m/s]
ρ Air density (ρ = 1.225 [kg/m^3] at normal atmospheric conditions).

The international wind power classes according to [2] based on the mean wind speed v or the annual average wind power density

have been investigated. Tab.1 shows the international wind power classes according to [7] based on the mean wind speed v or the annual average wind power density .

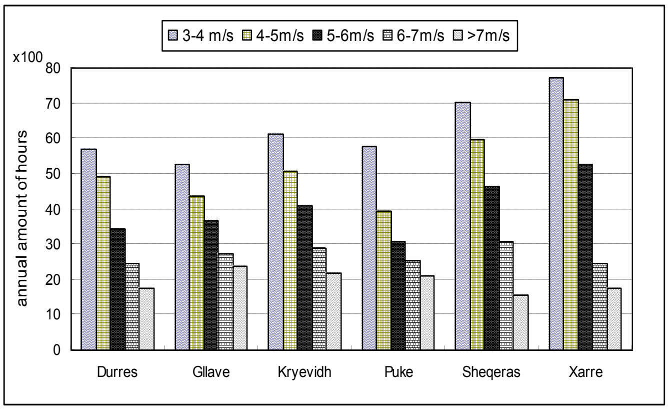

Fig.2 *Distribution of the annual hours with various wind speeds in the six zones*

Table1. *Wind Power classes* [6]

Wind power class	$p_{w,a}$ [W/m^2]		Equivalent mean wind speed v [m/s]	
	10-m elevation	50-m elevation	10-m elevation	50-m elevation
1	0-100	0-200	0,0 - 4,4	0,0 - 5,6
2	100-150	200-300	4,4 - 5,1	5,6 -6,4
3	150-200	300-400	5,1 - 5,6	6,4 - 7,0
4	200-250	400-500	5,6 - 6,0	7,0 - 7,5
5	250-300	500-600	6,0 - 6,4	7,5 - 8,0
6	300-400	600-800	6,4 - 7,0	8,0 - 8,8
7	400-1000	800-2000	7,0 - 9,4	8,8 - 11,9

The roughness of the surface of the landscape determines the boundary of the wind speed profile and thus the change of wind speed with elevation. According to [8] E.g., the open sea has the roughness class 0 and the corresponding roughness length is almost 0, too. That means that the terrain does not influence the wind speed and the energy index corresponding to this roughness class is 100 %. Based on a reference elevation z_{ref} one can estimate [9] the wind speed profile and thus any wind speed at different elevations employing:

$$v = v_{ref} \frac{\ln(z / z_0)}{\ln(z_{ref} / z_0)} \qquad (2)$$

with

v Wind speed at elevation z [m/s]

$v_{z_{ref}}$ Reference wind speed at elevation z_{ref}

z_0 Roughness length [m]

z Reference elevation, i.e. the elevation where we know the exact wind speed v_{ref}

The roughness class influences the wind speed profile (i.e. in terms of basic fluid dynamics: the boundary layer profile) as shown in Fig 3. It clearly shows that that zones with low roughness classes (i.e. small roughness lengths) have the highest values of wind speeds and vice versa. The horizontal wind speed is zero at the earth's surface and increases with altitude in the atmospheric boundary layer. The turbulent fluctuations caused by the characteristics of the terrain influence the profile quite dramatically. The variation of wind speed with elevation is referred to as the vertical profile of the wind speed. The variation of wind speed with elevation above ground level has important influences on the both assessment of wind energy resources and design of wind turbines.

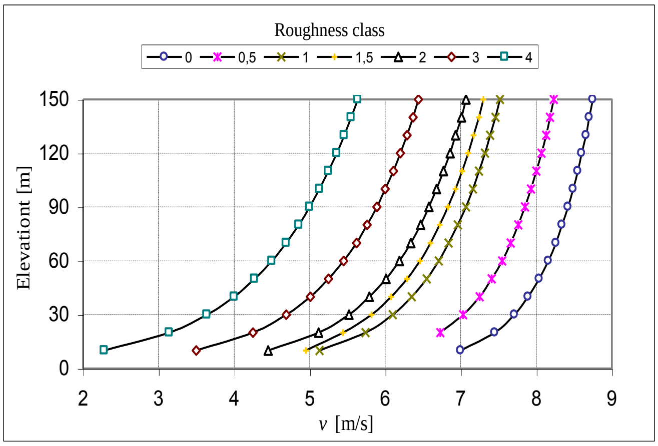

Fig.3 *The influence of the roughness class on wind speed profile*

3. Annual Distribution of the wind speed

Analyzing the Fig.1 at 10 m elevation can be defined 6 zones with annual average wind speeds. Zone A with wind speed v=2.6 m/s, Zone B with wind speed v=3.5 m/s, Zone C with v=4.5 m/s, whereas zone D with v=4.58 m/s and Zone E with v=5.56 m/s. For all calculations a roughness class 3 was selected. The most probable locations for wind turbines in Albania are characterized by villages, small towns, agricultural land with many or tall sheltering. Thus the corresponding roughness length is Z_0 =0.4 m. Based on this assumption the annual average wind speeds at different elevations can be calculated. Of special interest is the wind speed above 50 m elevation because this is the elevation of the hub of large modern wind turbines.

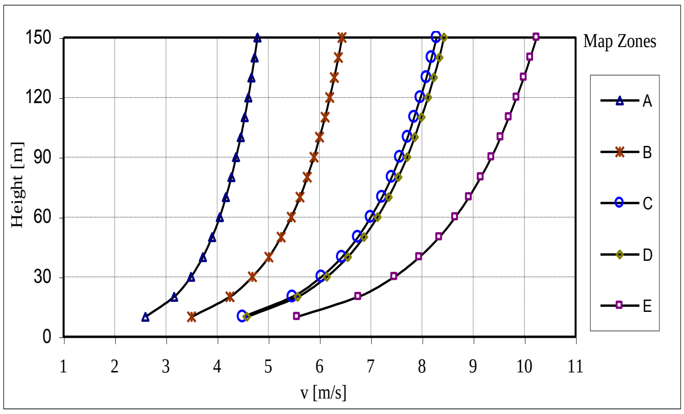

Fig. 4 *Vertical profile of wind speed for different zones in Albania*

To find the annual wind distribution we refer to the maps of the annual average speeds at 10 m, 50 m, and 100 m elevation. At least for some Middle European countries the annual wind distribution can be model quite accurately by a Raleigh distribution function [9]

$$h=\frac{\pi}{2\bar{v}}\varepsilon\cdot e^{-\frac{\pi}{4}\varepsilon^{2}} \quad (3) \quad \text{with } \varepsilon=\frac{v_i}{\bar{v}} \quad (4)$$

$\bar{v}$ Annual average wind speed [m/s] (the values of $\bar{v}$ are taken in the average wind distribution map) v_i Wind speed [m/s]

Because of lack of information, the Raleigh function is also used to estimate the annual wind speed distribution in Albania.

In Figs.5-7, the Raleigh distribution at different elevations and the earlier defined zones are shown. In Fig 5 is shown the percentage of the Raleigh distribution in different zones (zone C10 and D10 have almost the same values for *v* and *h*).

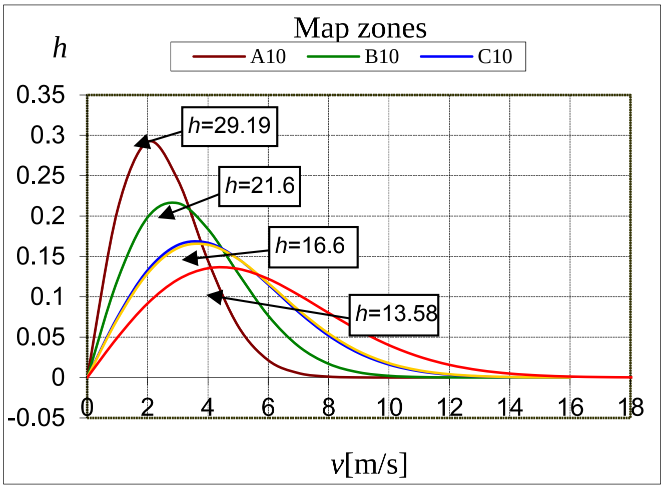

Fig. 5 Raleigh distribution for 10 m elevation

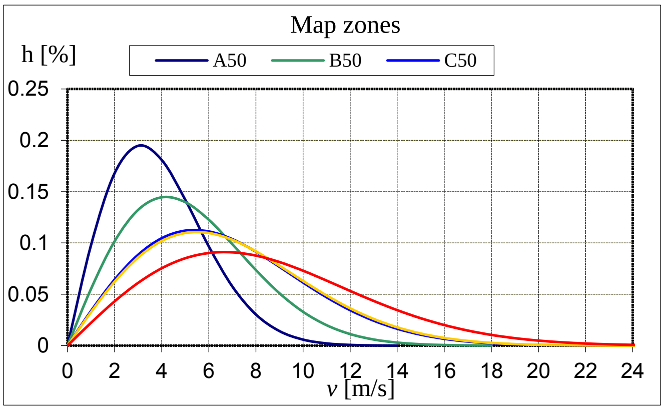

Fig. 6 Raleigh distribution for 50 m of elevation

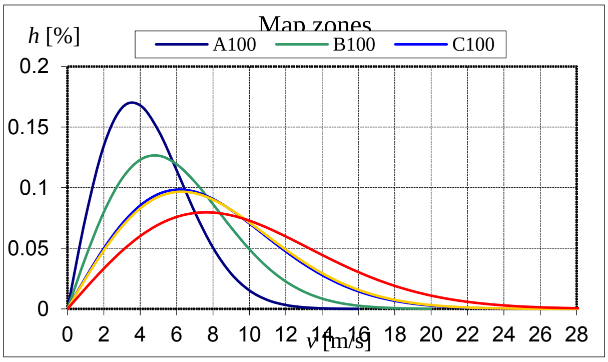

Fig.7 Raleigh distribution for 100 m elevation

4. Annual Energy Output

A significant measure of the cost-effectiveness of a wind turbine is its production of energy. Calculation of annual energy output requires knowledge of the *wind speed frequency distribution* and the system power output of each turbine as a function of wind speed. Furthermore every prediction of annual energy output is site specific, depending the local wind flow patterns and turbulence the number and the type of neighboring turbines and the air density [10]. After the calculations of the Raleigh distribution, can evaluate the frequency distribution of the speed over the year. Also, we can display the gross annual energy output in the wind speed [10]

$$\Delta E_{a,k}=c_p P_w \Delta t \eta_T = c_p \frac{1}{2}\rho A v^3 \Delta t \eta_T \qquad \text{[kWh/year]} \quad (5)$$

The general equation for calculating gross annual energy output is eq.6 (output exclusive of energy consumed for station-keeping, down-times losses, array effect etc). [11]

$$AEO_g=\sum_{k=1}^{k}\Delta E_{a,k}=\sum_{k=1}^{k}P_k \Delta t_k \qquad \text{[kWh/year]} \quad (6)$$

AEO_g Annual energy output [kWh/year]

k Index of wind speed from 1 to k

$\Delta E_{a,k}$ Gross annual energy output in the wind speed [kWh/year]

P_k Average power out put over the wind speed range [kW]

Δt_k Cumulative time the wind speed at the elevation of the centre of the swept area

$$\Delta t = 8760 * h_{Ray.distr} \qquad \text{[hours/year]}$$

To estimate annual energy output (AEO) we will do our calculation based on ENERCON wind turbine [12].

Type of wind turbine	E-66 /1.8 MW
Rotor diameter	70 m
Hub height	85 m
Rated wind speed	12,5 m/s

From the investigations through turbine technology variants we can conclude which variant is better, although these turbines have not the same rated power. The factor that AEO depends is rotor swept area because other factors (v, η, ρ, c_p) are taken constant.

The calculations have been carried out based only in one E-66 installed, and is supposed as this type of wind turbine is installed in all the five zones (A, B, C, D, E).

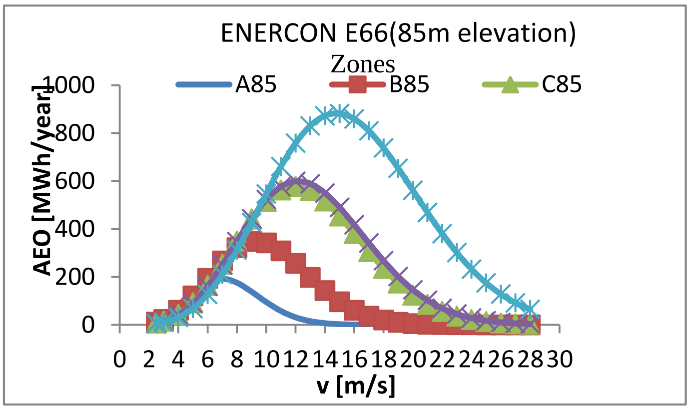

Fig. 8 Annual Energy Output of wind turbine ENERCON (E-66 70 m rotor diameter)

Table 2. Summary of annual energy out put in different hub heights for different zones with E-66.

ENERCON E-66		
		AEO [MWh/y]
Zones at 65m elevation	A65	1.093,74
	B65	2.707,66
	C65	5.091,57
	D65	5.275,55
	E65	7.466,16
Tot[.MWh/year]		**21.634,678**
Zones at 85m elevation	A85	1.280,5998
	B85	3.311,3509
	C85	5.654,1921
	D85	5.862,9
	E85	8.040,0214
Tot[.MWh/year]		**24.149,064**
Zones at 98m elevation	A98	1.382,397
	B98	3.589,5358
	C98	5.951,514
	D98	6.156,1843
	E98	8.314,7602
Tot[.MWh/year]		**25.394,391**

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5. Cost Analysis

The determination of total initial cost (TIC) generally involves the cost of wind turbines and installation cost. In the installation costs are involved, cost of roads, construction, transportation etc. In general, economics studies, wind turbine installed costs are often normalized to cost per unit rotor area or cost for rated power installed. The price of wind turbines is very difficult to determine because it depends on many factors such as:

- Wind speed and conditions
- Site where the wind turbine is going to erection
- Location
- Foundation
- Number of turbines utilized.

Operation and maintenance costs are an important requirement for all energy production facilities accounting for a significant portion of the unit costs.

Operation and maintenance cost are expressed in a number of different ways and it can be confusing to understand the data. However, there are two main ways of presenting the data:

- As a percentage of purchase price (€/kW installed); for operation and maintenance (AOM) 2-3% of capital costs are required annually;

The cost of energy (COE), delivered to the customers, contains the following three general elements:

- Capital cost
- Operating and Maintenance cost
- Annual Energy Output

According to [13] the following formula can be used for estimating the cost of energy:

$$COE = \frac{TICxFCR + AOM}{AFxAEO} \quad (7)$$

where

COE Unit cost of electricity [€/kWh]

TIC Total initial cost of the wind turbine system [€]

FCR Levelized fixed charge rate [1/year]

AOM Annual cost of operation and maintenance [€/year]

AF Availability factor accounting for system downtime [kWh/year]

AEO Annual energy output [kWh/year]

Based on eq. (7), it can be estimated the cost of electricity COE [€/kWh] and the simple payback period SP [year] For estimating annual energy output AEO [kWh/year] in all harness zones of Albania (zone A is not a harness zone) the ENERCON E-66 wind turbine with different hub heights (three types, based in the hub height) are considered. It has to be pointed out that all calculations are done on the base of only one single 1,8 MW - turbine in each zone. The results are presented in Fig.9.

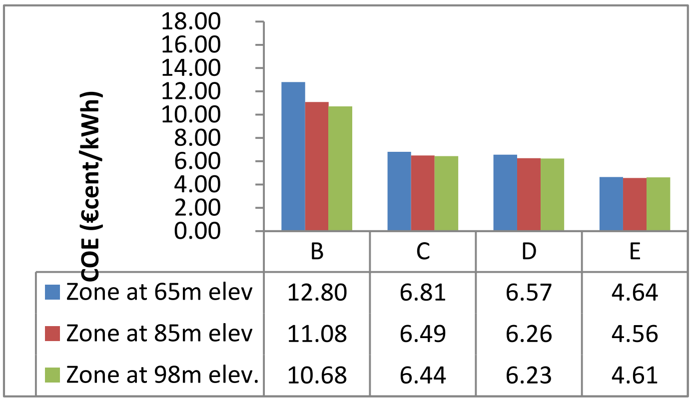

Fig.9 *Cost of electricity generation from E-66 wind turbine selection*

The payback period (in years) is equal to the total capital cost of the wind system divided by the average annual return from the produced power [14]. In its simplest form (simple payback period), it is expressed in equation form as

$$SP = \frac{TIC}{(AEOxPrice)} \quad (8)$$

It should be pointed out that the calculation of simple payback period omits many factors that may have a significant effect on the system's economic cost effectiveness.

Employing eq. (8) one gets the results shown in Tab.3, where the price of electricity included in the equation is the price that private customers. As we can see the SP varies from 6,4 to 17,97 years.

Table 3. *Simple payback period, SP (years) for different zones and hub heights for one E-66, 1,8 MW*

		TIC [€]	*Price* [€/kWh]	AEO [kWh/year]	AAR [€/year]	SP [years]
Zones at 65m elevation	A65	1.800.000				
	B65	1.800.000	0,0370	2.707.658,89	100.183,38	17,97
	C65	1.800.000	0,0370	5.091.568,23	188.388,02	9,55
	D65	1.800.000	0,0370 (6.1)	5.275.549,97	195.195,35	9,22
	E65	1.800.000	0,0370	7.466.162,25	276.248,00	6,52

Zones at 85m elevation	A85	1.906.000				
	B85	1.906.000	0,0370	3.311.350,94	122.519,98	15,56
	C85	1.906.000	0,0370	5.654.192,05	209.205,11	9,11
	D85	1.906.000	0,0370	5.862.900,02	216.927,30	8,79
	E85	1.906.000	0,0370	8.040.021,45	297.480,79	6,41
Zones at 98m elevation	A98	1.991.800				
	B98	1.991.800	0,0370	3.589.535,82	132.812,83	15,00
	C98	1.991.800	0,0370	5.951.514,00	220.206,02	9,05
	D98	1.991.800	0,0370	6.156.184,28	227.778,82	8,74
	E98	1.991.800	0,0370	8.314.760,20	307.646,13	6,47

6. Conclusions

The aim of this work was to investigate the potential of wind energy for the future power supply in Albania. The renewable energy sources in Albania have a considerable potential, since the energy demand is largely supplied by hydropower. Currently, do not exist significant wind energy investment in the country, however the government has taken steps forward in the field of photovoltaics. The level of information available about wind speed zones in Albania is poor. A wind resources map depicting wind speeds over 5 m/s and its annual number of hours has been published in the previous years. Based on this data and a boundary layer model, with the roughness of the landscape as an input, maps of wind speeds at 50 m or 100 m (typical elevation heights of modern wind turbine hubs) are developed. One can define five different zones of annual average wind speeds at different locations, A, B, C, D, and E, indicating an average speed of 2 to more than 5 m/s. Zone E with more than 5 m/s is located in the northeast of Albania, close to Kukes. Zones D and C correspond to Gllava and Kryevidh. The wind data correspond well to the ones found for comparable regions, e.g. the northern coast of Greece. A wind profile for three different elevation heights has been performed for the six wind zones studied in this article. A survey of some current large wind turbines with respect to rated wind speed, cut-in- and cut-out wind speed, efficiency, design features and cost is given. The wind turbine found suitable for this paper was considered to be the German ENERCON turbine E-66 (1.8 MW, 70 m rotor diameter). To characterize the potential earning of the most promising Albanian locations the density of the annual energy output is used. Calculations for the annual energy output assuming different hub heights, different types of wind turbines, rotor areas, efficiencies, power coefficients, and the wind speed distribution are carried out. The costs such as the total initial cost, the operation and maintenance costs and miscellaneous costs for wind turbines from various manufacturers are summarized. A payback period of 6,5 year is estimated for the zone E in Kukes. With a moderately increased price level also zones C and D (Gllava and Kryevidh) could be worth to be considered. In this calculation the costs of transportation, coonstruction and the connection to electric grid have not been considered.

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