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## Article

# An approach to the large-scale integration of wind energy in Albania

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## An Approach to the Large-scale Integration of Wind Energy in Albania

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### ABSTRACT

Recently, the Albanian government has compiled national energy strategy with a special focus on promoting the use of renewable energy sources (RES) which identifies a target of 42% of the final energy consumption from RES by 2030. In this paper, analyses are conducted in order to investigate to which extent and way the absorption capacity of the power system from RES electricity can be improved. As an effective approach of implementing wind power, fostering the accommodation of renewable energy sources, especially on large-scale, a detailed techno-economic analysis of the 164 MW installed grid-connected wind farm, considered as a potential source, Korça district is analyzed. Conjoining two different types energy tools, RETScreen, a tool used on plant scale level and EnergyPLAN model applied for large energy system on national level including all energy sectors an optimization process is notably focused to attain 42% of the final energy consumption from RES by 2030, which was highly preformed in EnergyPLAN model. The results execute in EnergyPLAN identifies that the wind power capacity should be at least 1850 MW and an installation cost not more than 1.1m€/MW considering a bench mark price of electricity €76/MWh. The results of the study highlight the importance of high levels of RES integration which not only reduces greenhouse gases but will technically favor the creation of a flexible and sustainable energy system over time. Finally, the need for a sustainable and clear national energy model is inevitable, reshaping key points factors that hamper the integration on large-scale of wind power in Albania.

**Keywords:** Wind Power, Techno-economic Feasibility, Albania, EnergyPlan, RETScreen

**JEL Classifications:** Q4, Q42

### 1. INTRODUCTION

Considerable interest in renewable energy sources and significant increases in cost of imported oil have compelled various countries to search for low-cost energy sources and improved technologies such, wind turbines, and synergies between systems to achieve lower cost of electricity generation. Under the pressure of an increased awareness of the importance of environmental issues, technological progress and the liberalization of the energy market, in the last 15 years there has been rapid progress in the development of wind exploitation technologies in Europe. The implementation of wind turbines must take local interests into

consideration as the socio-economic aspect is one of the main issues for the rural zones especially. The total capacity of all wind turbines installed around the globe by the end of 2018 amounted to 597 GW, referring to 2017, 50.1 GW of new installed capacity is added in 2018 (Pitteloud, 2018).

Wind energy systems convert the kinetic energy of moving air into electricity or mechanical power (David, 2009). They can be used to provide electricity to central or isolated grids. Wind turbines are commercially available in a wide range of installed capacity and sizes (Wiser et al., 2016; U.S. Department of Energy, 2018).

Based on (ERE, 2018; Strategjia Kombëtare e Energjisë, 2018-2030) the total annual energy consumption in our country is 24 TWh/year, meanwhile electricity occupies only 31% of its total demand which is generated mainly from domestic hydro sources 60% (389.15 ktoe) and the rest is imported into the regional energy market (250.66 ktoe) (ERE, 2018). The leading sector in electricity consumption is the Residential Sector occupies around 55% of the total electricity. To reduce import of electricity, improve its security of supply and to attain the Paris Agreement, the responsible ministry and its subordinate institutions has drafted and adopted the national energy strategy 2018-2030, which proposes several possible scenarios of transition of the energy system. According to this strategy, the share of RES is intended to reach a target of 42% of the total energy consumption in 2030 as actually this contribution is around 30%. In line with EU objectives 20–20–20, its commitment is to reach a reduction of 11.5% of CO<sub>2</sub> emissions in 2030, compared to the baseline scenario in 2016. Based on these obligations, this study strongly supports the renewable energy resources (RES) in compliance with the requirements of the National Strategy 2018-2030. This study presents an ambitious goal, as at present there are no wind projects developed in the country, meanwhile there are given from authorities 11 wind farm licenses in Albania. From different measurements performed historically in Albania, on the potential of renewable sources for electricity generation wind and solar resources result of high interest.

### 1.1. Site Background

For any wind turbine installation, there are certain additional activities (e.g., construction of foundations and access roads, electrical connections, site erection, as well as project development

and management) that must be undertaken. The study area covers a land of 4905 ha located in the communes of Cerava (1640 ha), Vreshtaz (780 ha) and Center Bilisht (2485 ha) of Korça District. The topographic works have provided 82 points for the placement of aero-generators 48 in the Petrushe Subzone and 44 in the Kapshtica Subzone, respectively. Alternative distribution points of aero-generators is evaluated to maximize the annual electricity production, facilitate road access and solve problems with land ownership if any (Figure 1).

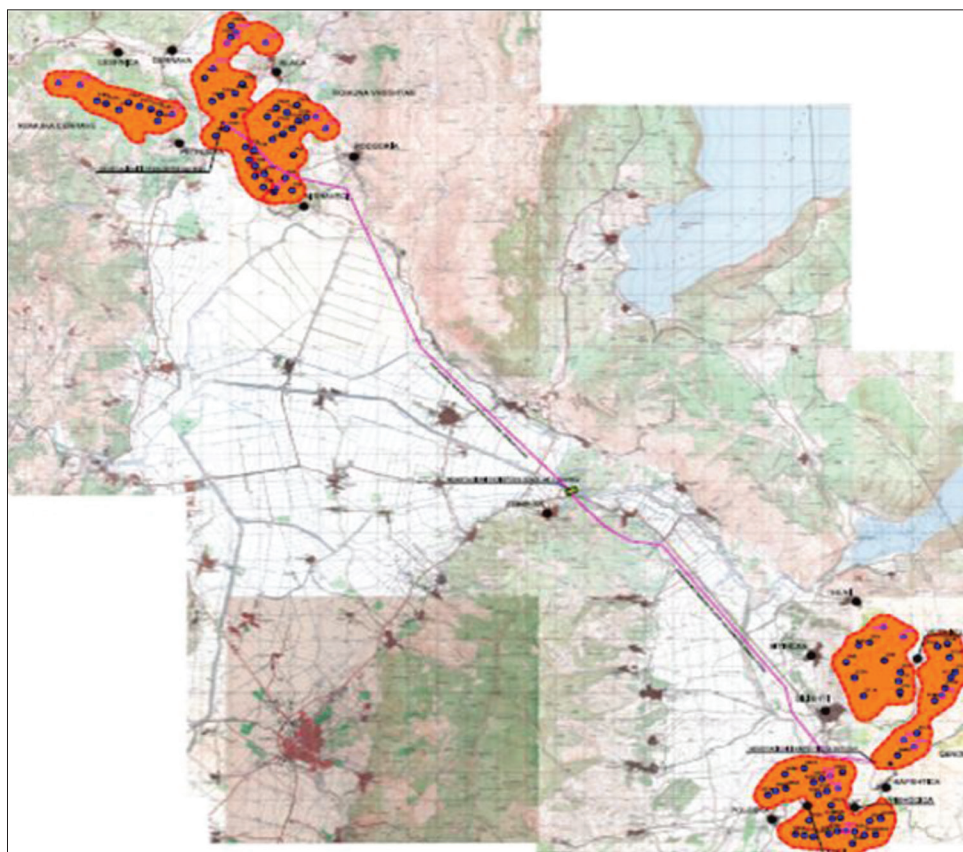
## 2. MATERIALS AND METHODS

The RETScreen® International Energy Project Model, is a reliable software to estimate power generation, life cycle costs and mitigation of GHG. It is used for different energy project including RES for isolated and off-grid electricity networks, which is validated with EnergyPLAN tool. Six worksheets (energy type, energy model, cost analysis, emission analysis, financial analysis and risk analysis) are the steps of developing Wind Power Project in RETScreen.

Before starting the technical analysis, a set of data is required to calculate with a high accuracy level the annual electricity generated by the proposed wind power plant. By selecting the construction site of the wind farm, the RETScreen model needs to populate the energy model with climate data, the air mean velocity at hub height and wind shear exponent.

First is analyzed the capacity and structure of the various wind power systems and then select the most suitable turbine type and

**Figure 1:** Map of the two sub-zones of the proposed eolic project



model, based on recommendations and trends. Generally, from authors (Nagababu et al., 2016; Gao et al., 2014; Adaramola et al., 2014) a rigorous assessment requires specific surveys of the region where the wind farm will be placed. There are three major markets for the field of global wind power generation: Europe, USA and China (Kaplan, 2015). This selection is made taking into account both technical and economic context, such as wind potential in the area affecting tower height, installed capacity, rotor diameter and specific yields (Figure 2).

### 2.1. Wind Speed Distribution

Wind speed distribution, when required in the model is calculated in RETScreen as a Weibull probability density function. This distribution is often used in wind energy engineering, as it conforms well to the observed long-term distribution of mean wind speeds for a range of sites. In some cases, the model also uses the Rayleigh wind speed distribution, which is a special case of the Weibull distribution, where the shape factor (described below) is equal to 2. The Weibull probability density function expresses the probability  $p(x)$  to have a wind speed  $x$  during the year, is given in equation 1 and based on (Hiester and Pennell, 1981):

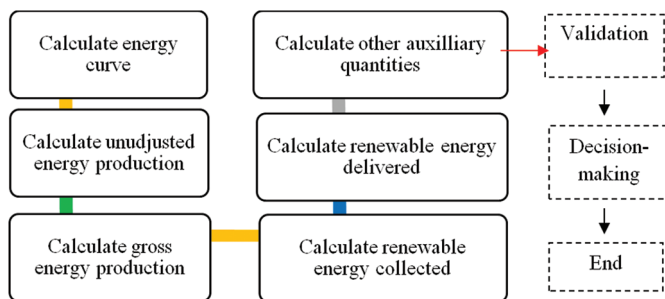
$$p(x) = \left(\frac{k}{C}\right) \cdot \left(\frac{x}{C}\right)^{k-1} \exp\left[-\left(\frac{x}{C}\right)^k\right] \quad (1)$$

The mathematical expression (1) is valid for  $k > 1, x \geq 0$ , and  $C > 0$ .  $k$  is the shape factor, specified by the user. The shape factor will typically range from 1 to 3. For a given average wind speed, a lower shape factor indicates a relatively wide distribution of wind speeds around the average while a higher shape factor indicates a relatively narrow distribution of wind speeds around the average. A lower shape factor will normally lead to a higher energy production for a given average wind speed (Gipe, 1995; Li and Priddy, 1985).  $C$  represents the scale factor (Hiester and Pennell, 1981) and calculated the following equation (2):

$$C = \frac{\bar{x}}{\Gamma(1 + \frac{1}{k})} \quad (2)$$

where  $\bar{x}$  is the average wind speed value and  $\Gamma$  is the gamma function.

**Figure 2:** The flowchart of the algorithms used to calculate on annual basis, the energy production of wind energy systems in RETScreen model validated in EnergyPLAN model



In some cases, the model calculates the wind speed distribution from the wind power density at the site rather than from the wind speed. The relations between the wind power density WPD and the average wind speed  $\bar{v}$  are:

$$WPD = \sum_{x=0}^{25} 0.5 \cdot \rho \cdot (\bar{x})^3 p(x) \quad (3)$$

where 
$$\bar{v} = \sum_{x=0}^{25} x \cdot p(x) \quad (4)$$

where  $\rho$  is the air density and  $p(x)$  is the probability to have a wind speed  $x$  during the year.

### 2.2. Energy Curve

It is specified the wind turbine power curve as a function of wind speed in increments of 1 m/s, from 0 m/s to 25 m/s. Each point on the energy curve,  $E_v$ , is then calculated as given in equation 1:

$$E_{\bar{v}} = 8760 \cdot \sum_{x=0}^{25} P_x \cdot p(x) \quad (5)$$

$P_x$  - Turbine power at speed  $x$

$p(x)$ -is the Weibull probability density function for wind speed  $x$ , calculated for an average wind speed  $\bar{v}$ .

### 2.3. Unadjusted Energy Production

RETScreen calculates the unadjusted energy production from the wind turbines. It is the energy a wind power plant will produce at standard conditions of temperature and atmospheric pressure. The calculation is based on the energy production curve of the selected wind turbine and on the average wind speed at hub height for the proposed site.

Wind speed at hub height is usually significantly higher than wind speed measured at anemometer height due to wind shear. The model uses the following power law equation to calculate the average wind speed at hub height (Gipe, 1995).

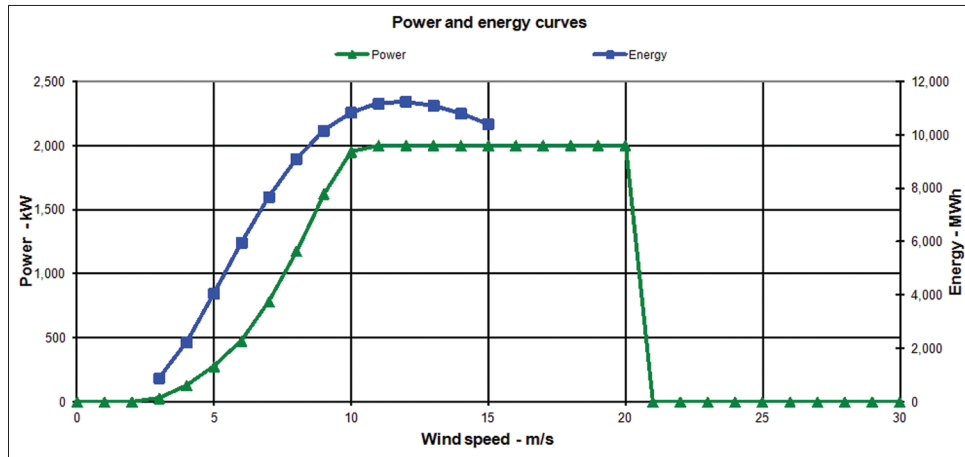
$$\left(\frac{v_{z(\text{hub})}}{v_{z(\text{aneom})}}\right) = \left(\frac{z_{(\text{hub})}}{z_{(\text{aneom})}}\right)^\alpha \quad (6)$$

It is first required to set the model the values of the respective wind velocities in the study area which may be represented by the monthly average values for the metering height and/or the annual average. Along with the height of the turbine setting, the wind shear exponent, which ranges from 0.1 to 0.4, must be set. Strongly supported on the real measurements provided through installation of tower masts a in different height levels (Figures 3-8) this dimensionless coefficient  $\alpha$  results 0.16.

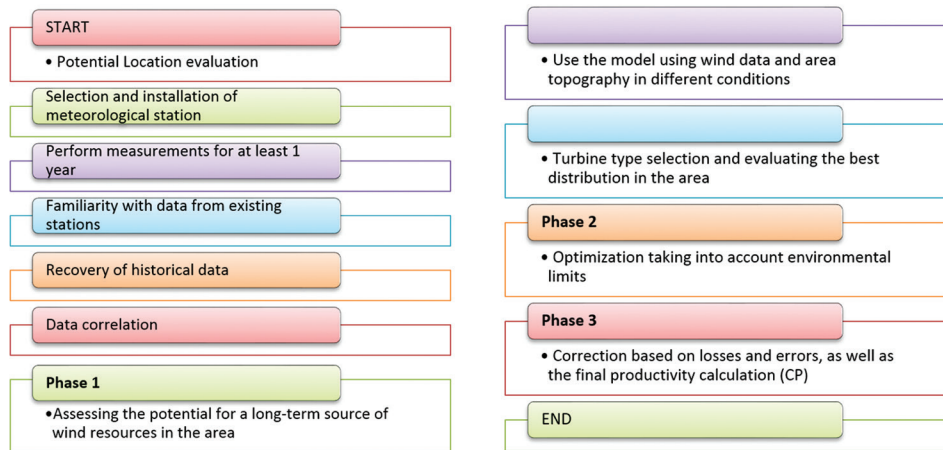
### 2.4. Gross Energy Production

Gross energy production is the total annual energy produced by the wind energy equipment, before any losses, at the wind speed,

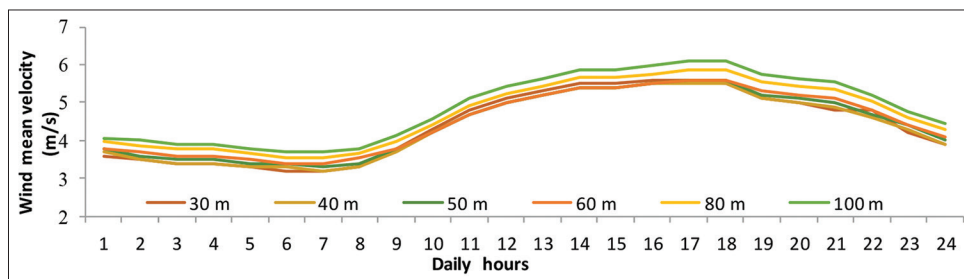
**Figure 3:** This graph provides a representation of the power (kW) and energy (in MWh) delivered by the selected wind turbine measured over a range of wind speeds



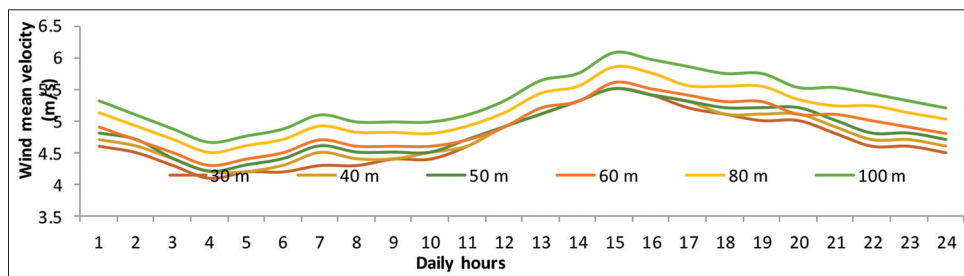
**Figure 4:** Algorithm of pre-feasibility wind farm projects



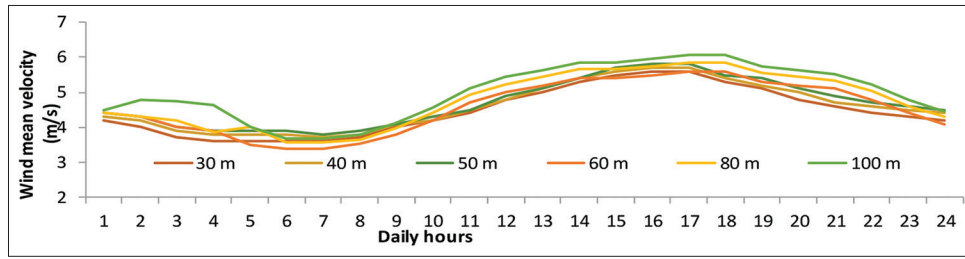
**Figure 5:** Daily variation of mean wind speed (m/s) measured at altitudes of 30, 40, 50, 60, 80 and 100 m, Kapshtica, Period 24.02.2008-5.02.2009 (ERE, 2018)



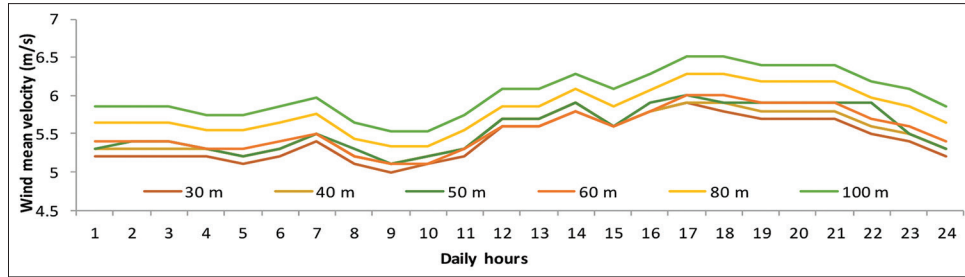
**Figure 6:** Daily variation of mean wind speed (m/s) measured at altitudes of 30, 40, 50, 60, 80 and 100 m, Petrushë, Period 24.02.2008-5.02.2009 (ERE, 2018)



**Figure 7:** Daily variation of mean wind speed (m/s) measured at altitudes of 30, 40, 50, 60, 80 and 100 m, Nizhaveci, Period 24.02.2008-5.02.20092009 (ERE, 2018)



**Figure 8:** Daily variation of mean wind speed (m/s) measured at altitudes of 30, 40, 50, 60, 80 and 100 m, Verniku, Period 24.02.2008-5.02.20092009 (ERE, 2018)



atmospheric pressure and temperature conditions at the site. It is used in RETScreen to determine the renewable energy delivered calculated by equation (7):

$$E_G = E_U \cdot c_H \cdot c_T \quad (7)$$

where  $E_U$  is the unadjusted energy production,  $c_H$  and  $c_T$  are the pressure and temperature adjustment coefficients calculated by the following equations:

$$c_H = \frac{P}{P_0} \quad \text{and} \quad c_T = \frac{T_0}{T} \quad (8-9)$$

where  $P$  is the annual average atmospheric pressure at the site,  $P_0$  is the standard atmospheric pressure of 101.3 kPa,  $T$  is the annual average absolute temperature at the site, and  $T_0$  is the standard absolute temperature of 288.1 K (Tables 1 and 2).

For the selected turbine Vestas, model V110-2.0 MW<sup>TM</sup> IEC IIIA, characteristics and technical-economic indicators are represented in Table 3. The total electricity generated by the wind farm is calculated for a mean annual speed 5.4 m/s while the pressure measured at the hub height results 92 kPa according to the hydrostatic equation, the perfect gas law and the stepwise linear temperature variation assumption, the hydrostatic equation yield (10):

$$\frac{\partial p}{\partial z} = -\rho z \rightarrow p = p_0 \left[ 1 + \frac{L_0}{T_0} (h - h_0) \right]^{\frac{g_0 M}{R L_0}} \quad (10)$$

- $P_0$  = static pressure (pressure at sea level) [Pa]
- $T_0$  = standard temperature (temperature at sea level) [K]
- $L_0$  = standard temperature lapse rate [K/m] = -0.0065[K/m]
- $h$  = height about sea level [m]
- $h_0$  = height at the bottom of atmospheric layer [m]
- $R$  = universal gas constant = 8.31432 (Nm/molK)

**Table 1: Main technical indicators of the two selected turbines**

	Unit	VESTAS V110-2.0 MW <sup>TM</sup> IEC IIIA	W. TO EN W2E-100-2000-100
		Value	
Power	MW	2.0	2.0
Number of turbines	Pcs	82	82
CF	%	23.5	22
Annual energy production	MWh	337448	316751
Rotor diameter	M	110	100
Hub height	M	95	100
Swept area	m2	9503	7854

**Table 2: Typical Breakdown of O&M costs in %**

Components	Recommended costs (%)	Accepted cost (%)	Annual cost (€)
Maintenance	65-80	75.0	2,608,252
Salaries	4-10	7.0	243,437
Materials	4-10	8.0	278,214
Others	5-10	10.0	347,767
Total		100	3,477,670

$g_0$  = gravitational acceleration constant = 9.80665 ms<sup>-2</sup>  
 $M$  = molar mass of Earth's air = 0.0289644 [kg/mol]

From hydrostatic equation (10) pressure calculated at 95m of hub height results 92kPa.

Renewable energy collected is equal to the net amount of energy produced by the wind energy equipment given in equation (11):

$$E_C = E_G \cdot c_L \quad (11)$$

**Table 3: Techno-economic indicators of VESTAS turbine model V110-2.0 MW™ IEC IIIA**

Components	Value	Unit
Installed capacity	2	MW
Turbine Nr.	82	
Capacity factor	23.5	%
Annual wind speed	5.4	m/s
Production	337448	MWh/year
Sales price	76	€/MW
Investment cost	1,100	€/kW
Discount rate	6	%/year
Inflation	2.5	%/year
% e Credit	70	%
Inflation rate	3.0	%
Credit duration	15	Year
Turbine lifespan	20	Year
(O&M) cost	10	€/MWh
Land lease	35,000	€/ year

where  $E_G$  represent the gross energy production and  $c_L$  - the losses coefficient, given in equation (12):

$$C_L = (1 - \lambda_\alpha) \cdot (1 - \lambda_{s\&i}) \cdot (1 - \lambda_d) \cdot (1 - \lambda_m) \quad (12)$$

where  $\lambda_\alpha, \lambda_{s\&i}, \lambda_d, \lambda_m$  specify array losses, soil and icing losses, downtime and miscellaneous losses respectively taken into account to calculate the net energy production.

The wind plant capacity factor PCF represents the ratio of the average power produced by the plant over a year to its rated power capacity. It is calculated as follows (Li and Priddy, 1985):

$$CF = \left( \frac{E_c}{WPC \cdot h_y} \right) \cdot 100 \quad (13)$$

where  $E_C$  is the renewable energy collected, expressed in kWh,  $WPC$  is the wind plant capacity, expressed in kW, and  $h_y$  represent the number of hours in a year (8760). According to Betz's Law, no wind turbine can convert more than 59.3% of the kinetic energy of the wind into mechanical energy transformed at the rotor ( $C_p \leq 59.3\%$ ). that is, only 59.3% of the energy contained in the air flow can theoretically be extracted by a wind turbine (Thomas and Cheriyan, 2012; Oliveira, 2008; Yu et al., 2012).

Wind energy project plant capacity factors have also improved from 15% to over 30% today, for sites with a good wind regime (Rangi et al., 1992).

The graph is based on values from the power curve data and energy curve data columns. This study was conducted in the Korça region, divided into two sub-zones: Petrushe sub-zone and Kapshtice sub-zone.

By calculating step by step each parameter, the annual electricity generated by the selected wind turbine V110-2.0 MW™ IEC IIIA guarantee an optimal capacity factor  $CF = 23.5\%$ , corresponding to 337,448 MWh/year of electricity generation.

### 3. RESOURCES: WIND RESOURCE ASSESSMENT

This analysis is highly performed using wind characteristics and data from the wind towers installed in the site. This data set was developed as a high spatial and high temporal (10-min) resolution data set for wind energy applications. It differs from wind resource data used previously in Albania because the model's period of record is long enough to capture some interannual variability but not long enough to be representative of the long-term. The HMI network now has 8 automatic weather stations (VAISALA, SIAP-MICROS and Theodor-Friedrich Combilog). Thanks to this technology it was possible to obtain detailed information on wind speed every 10 min. In (Wang et al., 2017), it is emphasized that wind speed prediction plays a vital role in the management, planning and integration of the energy system. In previous studies, most forecasting models have focused on improving the accuracy or stability of wind speed prediction. However, for an effective forecast model, considering only one criterion (precision or stability) is insufficient. This information is enough to run and develop the reference model in the RETScreen tool. In the case where a pre-feasibility study indicates that a proposed wind energy project could be financially viable, it is typically recommended that a project developer take at least a full year of wind measurements at the exact location where the wind energy project is going to be installed (Brothers, 1993; Canadian Wind Energy Association (CanWEA), 1996; Lynette and Ass, 1992; Draxl et al., 2015).

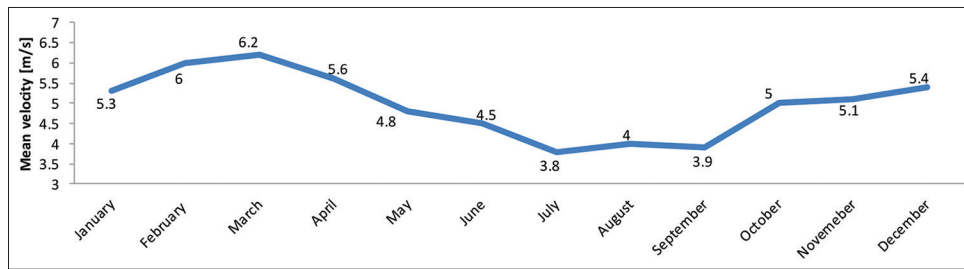
From the data available, using Origin 8 software the variation of the average daily velocity based on 2008-2009 wind data measured on site (providing 10-min information to average 15-s measurements for both speed and direction).

The wind regime in the area is based on the analysis of all the data collected by measurements towers installed in the proposed construction site. Analyzing the gathered information, the indicators and parameters of the wind speed regime and its direction have been estimated. Figure 9 shows the average monthly wind speed performance. The highest values are observed during the cold season of the year, while the lowest values are observed in the summer months. The highest value 6.2 m/s is reached in March, while the lowest value 3.8 m/s is reached in July (Figure 9).

Based on the measured data, wind climatological statistics such as monthly and annual average velocity, wind probability (8 main horizon directions are being evaluated and re-evaluated), it is concluded that the area presents a great potential for wind power generation and the yearly mean velocity is evaluated at a rate of 5.4 m/s.

#### 3.1. Wind Turbine Type Selection

The selection of the turbine must meet different criteria simultaneously given in (David, 2009; Wiser et al., 2016; Hiester and Pennell, 1981; Gipe, 1995; Thomas and Cheriyan, 2012; Rangi et al., 1992; Wang et al., 2017; Canadian Wind Energy Association (CanWEA), 1996).

**Figure 9:** Measured annual average wind speed by months

The following table shows the main key indicators for to different potential turbines selected in the study. From the database of RETScreen model and the information provided from the manufacturer, comparisons were made to determine the most efficient turbine. The selected turbines are Vestas-model V110-2.0 MW<sup>TM</sup> IEC IIIA and Wind to Energy - model W2E-100-2000-100.

Table 1 are shown some important indicators generated by RETScreen tool that will influence in the final decision-making in regard turbine type selection. As a result Vestas Model V110-2.0 MW<sup>TM</sup> IEC IIIA turbine has a capacity factor of 23.5% while the Wind To Energy turbine has a production factor of 22%. Capacity factor (CF) is the most technical criterion in selecting the type of turbine as it directly influences the annual energy generated by the turbine system. As it can be seen from Table 1 an increase of 6% of CF increase in the same rate the annual energy production (Figures 10 and 11).

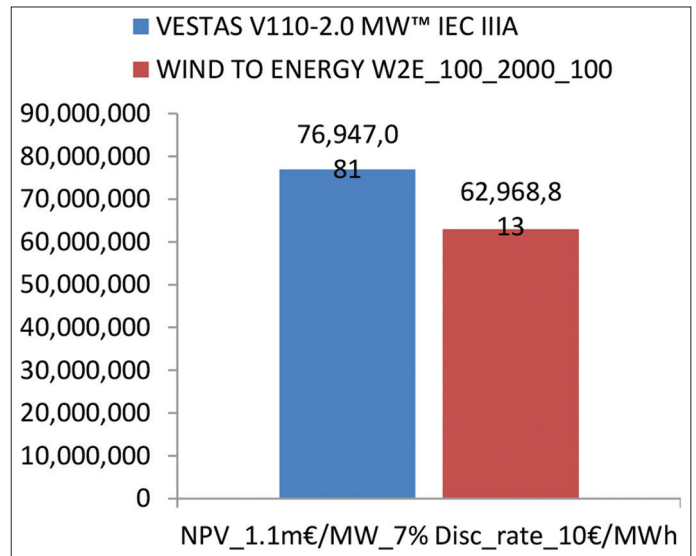
### 3.2. Techno-economic Selection of Turbine

The technical aspects of turbine type selection directly affect the annual revenue generated by each turbine. Based on various studies and reliable references (David, 2009; Wisser et al., 2016; Hiester and Pennell, 1981; Gipe, 1995; Thomas and Cheriyan, 2012; Rangi et al., 1992; Wang et al., 2017; Canadian Wind Energy Association (CanWEA), 1996). It is very important to achieve CF at least 20% for the system to be efficient. In the case of this study the Vestas Model V110-2.0 MW<sup>TM</sup> IEC IIIA turbine achieves the greatest capacity factor of 23.5%, as discussed earlier.

The variation of NPV and IRR as a function of initial total cost, O&M cost and discount rate  $r$ , are depicted in the following graphs shown Figures 12 and 13.

In both cases the NPV is calculated for a total investment of m€1.1/MW and O&M unit cost of €10/MWh. It results that by decreasing discount rate from 7% to 5%, NPV increases by 32.45% (25,870,798 in total) for the V110-2.0 MW<sup>TM</sup> IEC IIIA turbine and by 36.5% (23,543,604 in absolute value) for the Wind To Energy W2E.

Graph 13 absolutely shows that the Vestas V110-2.0 MW<sup>TM</sup> IEC IIIA turbine represents better financial performance than Wind To Energy W2E. The change in IRR is analyzed for each level of turbine's installation unit cost. Changing installation's unit cost from m€ 1.3/MW to the m€1.2/MW, IRR increases at a rate up to 20% for VESTAS model and 21.6% for the W2E model. By

**Figure 10:** NPV comparison for the two types of turbines obtained in the study,  $r = 7\%$ 

reducing again the installation unit cost from m€1.2/MW up to m€1.1/MW the IRR increases at a rate of 19.4% to 21% for Vestas and W2E model, respectively.

Based on these technical and economic indicators, that VESTAS V110-2.0 MW<sup>TM</sup> IEC IIIA turbine is more competitive and performs better than W2E turbine type.

## 4. ECONOMIC ANALYSIS

### 4.1. Economic Aspects of Wind Turbines

Based on the indicators influencing the selection of the type of turbine carefully performed above, it is definitively concluded that the detailed economic and financial analysis will be performed on model generated from Vestas V110-2.0 MW.

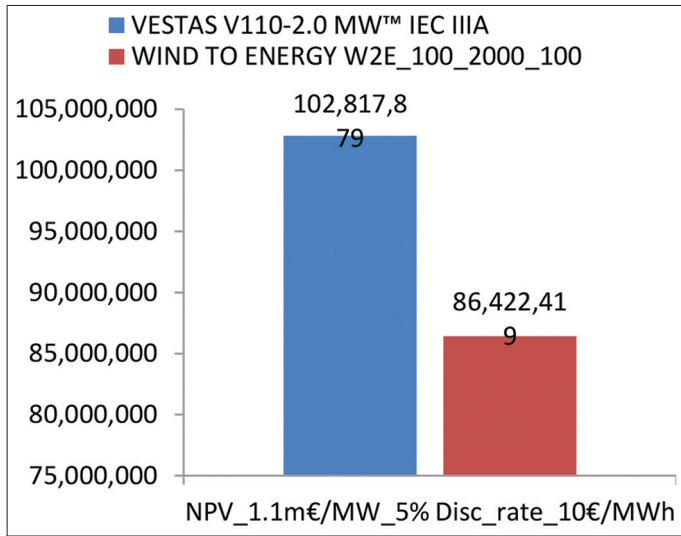
This section deals with the economic aspects of building a wind farm with an installed capacity of 164 MW and aiming to produce 337,448 MWh/year.

In order to determine the efficiency of the system as a whole, the following factors, variables and indicators of a techno-economic character should be analyzed:

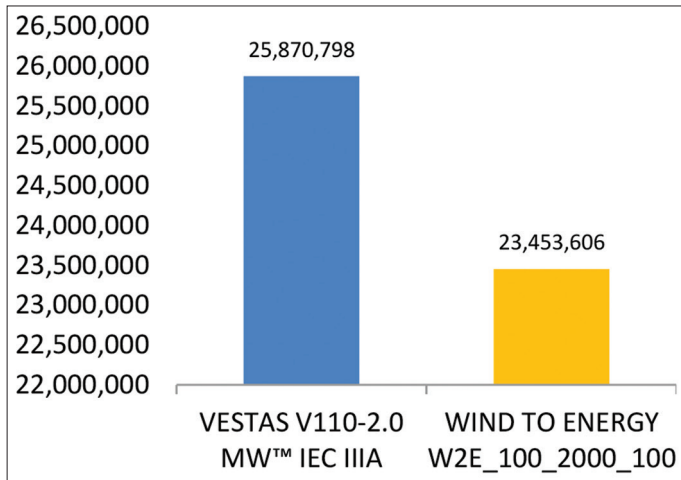
- Levelized cost of electricity (LCOE) in electricity production can be defined as the present value of the electricity price produced in c€/kWh, taking into account the economic life



**Figure 11:** NPV comparison for the two types of turbines obtained in the study,  $r = 5\%$



**Figure 12:** Comparison of NPV difference for the two types of turbines obtained in the study for  $r = 5\div 7\%$

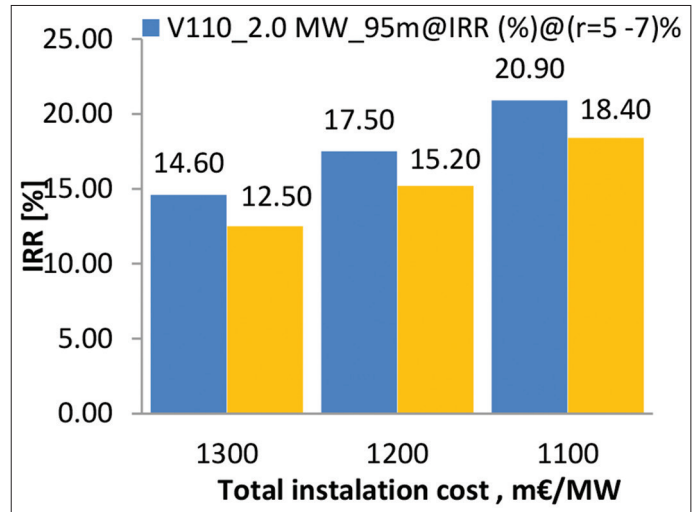


of the park and the costs incurred in construction, operation, maintenance, and for fuel. Along this line, the generation cost during construction and production periods can be given expression (14) (Bruck et al., 2016):

$$LCOE = \frac{\left[ \sum_{N=1}^{t-1} \left( \frac{I_t}{(1+r)^t} \right) \right]_{foundation} + \left[ \sum_{t=0}^{t=n-1} \left( \frac{F_t + O \& M_t - D_t + T_t}{(1+r)^t} \right) \right]_{prod}}{\sum_{t=0}^{t=n-1} \left( \frac{G_t}{(1+r)^t} \right)_{prod}} \quad (14)$$

- Discount rate ( $r$ ) is chosen depending on the cost and source of available capital, taking into account a balance between equity and debt financing, estimating the financial risks involved in the project and the context of the country.
- The net present value of a project is the value of all payments,

**Figure 13:** IRR graphical representation for the two types of turbines obtained in the study for  $r = (5\div 7\%)$



deducted from the beginning of the investment. If the net present value is positive, the project has a real rate of return which is greater than the real interest rate. If the net present value is negative, the project has a lower rate of return. The net present value is calculated by taking the first annual payment and dividing it by  $(1+r)$ . The next payment is then divided by  $(1+r)^2$ , the third payment by  $(1+r)^3$ , and the  $n^{\text{th}}$  payment by  $(1+r)^n$ , as expressed in equation (15).

$$NPV = \frac{P_1}{(1+r)^1} + \frac{P_2}{(1+r)^2} + \frac{P_3}{(1+r)^3} + \dots + \frac{P_n}{(1+r)^n} \quad (15)$$

- Internal rate of return IRR is the value of discount rate that makes the net present value of a project zero.

$$0 = \sum_{n=0}^N \left( \frac{C_n}{(1+IRR)^n} \right) \quad (16)$$

where  $N$  is the project life in years, and  $C_n$  is the cash flow for year  $n$  (note that  $C_0$  is the equity of the project minus incentives and grants; this is the cash flow for year 0).

- The benefit-cost ratio, (B-C) is an expression of the relative profitability of the project. It is calculated as a ratio of the present value of annual revenues (income and/or savings) less annual costs to the project equity as expressed in the following formula (17):

$$B / C = \frac{NPV + (1 - f_d) \cdot C}{(1 - f_d) \cdot C} \quad (17)$$

$f_d$  is the debt ratio

- Debt payment, Debt payments are a constant stream of regular payments that last for a fixed number of years (known as the debt term). The yearly debt payment  $D$  is calculated using the following formula (18):

$$D = C \cdot f_d \frac{i_d}{1 - \frac{1}{(1+i_d)^N}} \quad (18)$$

Where  $C$  represent the total initial cost the of the project,  $f_d$  is the debt ratio and  $i_d$  is the effective annual debt interest rate and  $N$  is the debt term in years.

- Installation costs include costs for the extension of the grid and the armature of the grid. Installation costs can vary with location, road construction and network connection. These can amount to about 30% of the cost of the turbines.

High installation costs can be borne, usually when there is a good wind source as the power produced by a wind turbine is proportional to the wind speed in third power.

- Operation and maintenance (O&M) expressed in €/MWh or in % of total investment cost (it depends on energy model applied).

### 4.2. Project Costs

Although the cost of wind energy has dropped dramatically in the last 10 years, technology requires a higher initial investment than traditional fossil fuel generators. Approximately (65-75%) of the cost goes to equipment purchase and the rest is construction costs (U.S. Department of Energy, 2018; IRENA International Renewable Energy Agency, 2018; Connolly et al., 2012).

### 4.3. Capital Investment Cost

Based on (U.S. Department of Energy, 2018, IRENA International Renewable Energy Agency, 2018; Connolly et al., 2012.) the distribution of cost is graphically presented in Figure 14.

In Figure 15, it is shown that the tower cost occupies approximately 24% of the total turbine cost. Referring to official data published by (Li and Priddy, 1985), the trend of total installation cost of wind turbines has experienced a significant decline in time, due to many factors influencing in the reduction of the production cost, including technological improvements and reduced cost of materials (Connolly et al., 2012).

The graph in Figure 16 shows that turbine prices have fallen sharply in 2018, 53% less compared to 2015 (IRENA International Renewable Energy Agency, 2018; Connolly, 2012). This is a very positive indicator as in the financial analysis initial cost will be restricted up to 1.3 m€/MW.

As can be seen from the graph in Figure 17 capacity factor increases from 20% in 1983 to 29% in 2017, thus 45% more performance increase on CF. This is due to the increased performance of wind turbines using more advanced constructive technologies, increased

tower height, increased rotor diameter and, of course, wind sources in the planned area.

### 4.4. Operation and Management Costs

The operation and maintenance of Wind Power Plants is 1.5-1.7% of the total initial cost, which is a recommended value in the strategic energy document in our country (ERE, 2018). It is important to note that references used in our study are obtained from RETScreen database, EnergyPlan database and data collected from studies in the field of renewable energy sources. The following are the management costs (O&M) - Vestas V110-2.0 MW™ IEC IIIA.

Considering the above recommendations, it is calculated the monetary values expected to be spent during the operational phase.

### 4.5. Calculations

Table 4 gives a detailed distribution cost of which components of the wind farm in terms power installed capacity, €/kW.

## 5. FINANCIAL ANALYSIS

Three reference prices assumed in the feasibility study according to current trends are given in Table 5.

In addition, the inflation rate (2.5%), debt rate 70%, maturity 20 years, debt repayment level 15 years, debt interest rate (3%), the benchmark electricity price 76 €/MWh, O&M costs 10 €/MWh and 2% of contingencies are accepted and assumed in the light of the methodology used by the designer and the best experience

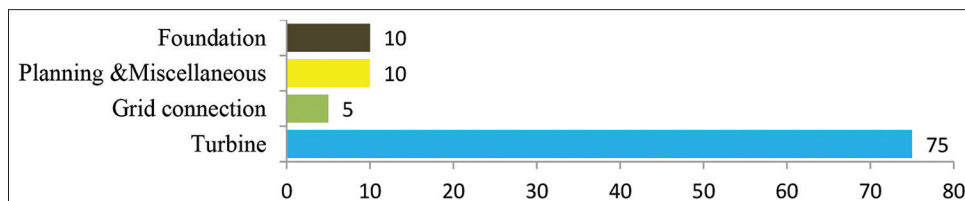
**Table 4: Investment cost allocation by item in%**

Components	Cost (%)	(%)	Cost (1,100 /kW)
Turbine	65-80	75.0	825
Foundations	4-10	4.0	44
Elect. installations	4-10	4.0	44
Grid connection	5-10	5.0	55
Road construction	1-5	3.3	27
Land acquisition	0-6	0.0	0
Permissions	0-2	1.0	11
Projection costs	3-5	3.0	33
Financial costs	3-5	3.0	33
Infrastructure	1-5	2.5	28
Total		100	1,100 €/kW

**Table 5: Total initial investment cost per MW of installed capacity**

Installation price levels	1.3 m€/MW	1.2 m€/MW	1.1 m€/MW
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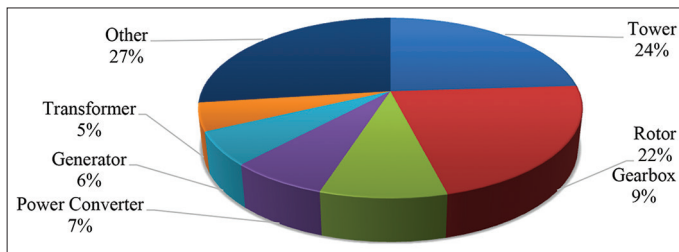
**Figure 14:** Typical Breakdown of Costs for Modern Wind Farms (U.S. Department of Energy, 2018; IRENA International Renewable Energy Agency, 2018; Connolly et al., 2012)



in the design of wind turbine power generation plants. On the basis of these parameters, the estimation of other economic and financial indicators was performed by simulations performed on the interest rate ( $r = 5, 6, 7\%$ ) and the total installation price according to the chosen range shown previously. RETScreen model generates values for each scenario, thus obtaining the final economic feasibility indicators such as NPV, B/C ratio, IRR, VAT summarized in Table 6. In order to have a clear idea of the correlation between the key indicators and the financial variables that influence the feasibility study, graphical representations of the key functions are of interest.

From graphs in Figures 18 and 19 and simulations performed in RETScreen model it is observed that NPV increases as the installation cost varies. Decreasing the total investment unit cost from 1.3 m€/MW to 1.2 and to 1.1 m€/MW, NPV increases by 27,

**Figure 15:** Typical Breakdown of Costs distribution of the wind turbine by constructive elements (U.S. Department of Energy, 2018; IRENA International Renewable Energy Agency, 2018; Connolly et al., 2012.)



6% and 55%, for an assumed discount rate  $r = 7\%$  and by 20.4% and 40.8%, for  $r = 5\%$ , respectively.

From the graph in Figure 20 it is clearly seen that project is profitable and NPV is calculated for each level of investment costs for the whole variation scale of discount rate,  $\Delta r (5-7\%)$  represents a linear relationship. Lawfulness of linear interpolation can be applied.

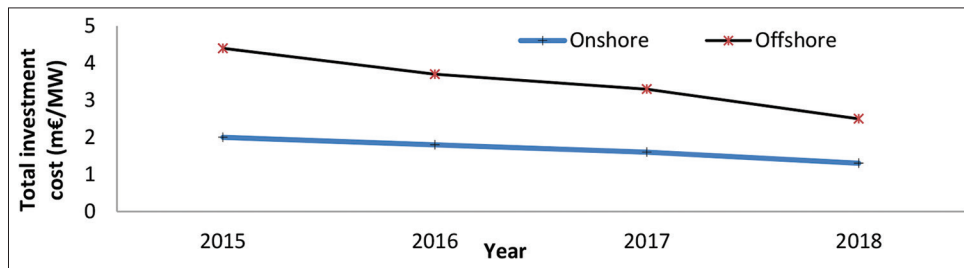
The graph in Figure 21 shows the difference of B/C and PBP for each investment level at a discount rate of  $r = 7\%$ . From the analysis performed it is concluded that B/C ratio is inversely proportional to the unit price of the investment, while PBP is proportional to the price. Considering that B/C ratio must be greater than two, it is seen that total unit investment should not exceed 1.1 m€/MW.

While at a discount rate of  $r = 5\%$ , B/C results  $>2$  in all scenarios (Figure 22).

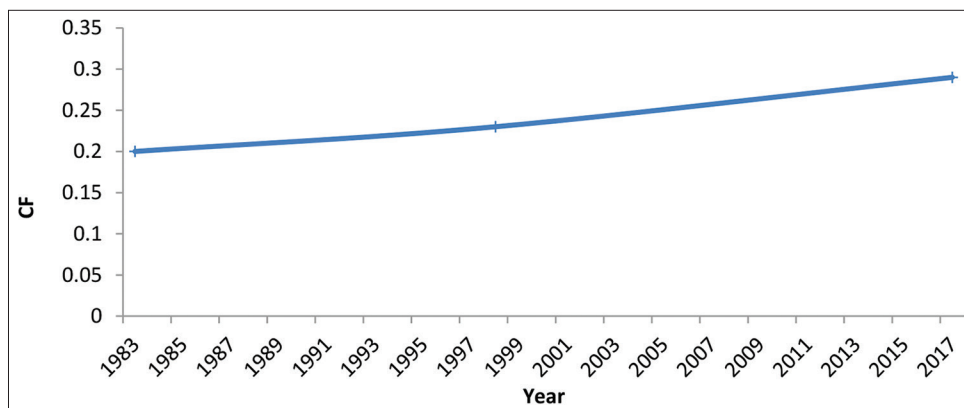
The Pay Back Period is calculated on different financial parameters assuming a fixed installation cost of 1.1 m€/MW, electricity export rate 76 €/MWh, discount rate 5%, inflation rate 2.5%, debt ratio 70%, debt interest rate 3%, debt term 15 years and a project life of 20 years.

As it is seen from the graph in Figure 23 the Simple Pay Back Period results 8.1 years while the Equity Pay Back results 4.7 years. In other hand Benefit-Cost ratio results 2.9, a good suggested value that will generate 102.817.879€ and the energy production cost of 51.55€/MWh. The above-mentioned analyses are given

**Figure 16:** Capital expenditure per MW financed in wind energy, 2015-2018 (€/MW) (U.S. Department of Energy, 2018; IRENA International Renewable Energy Agency, 2018; Connolly, 2012.)



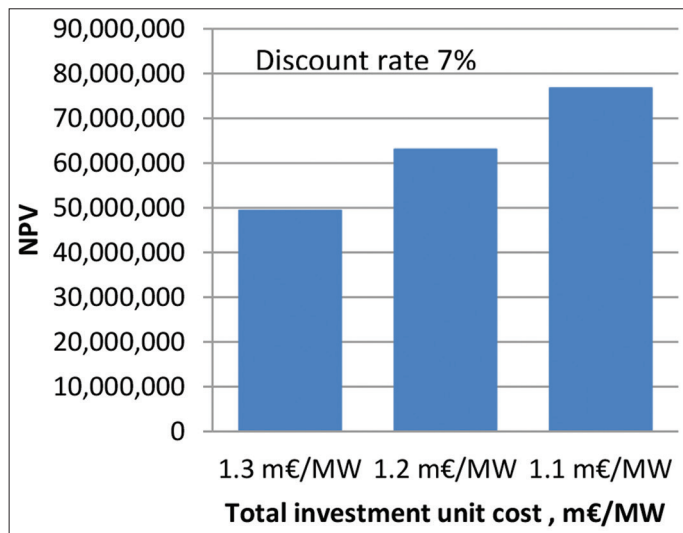
**Figure 17:** Tendency of “Capacity Factor” in years (U.S. Department of Energy, 2018; IRENA International Renewable Energy Agency, 2018; Connolly, 2012)



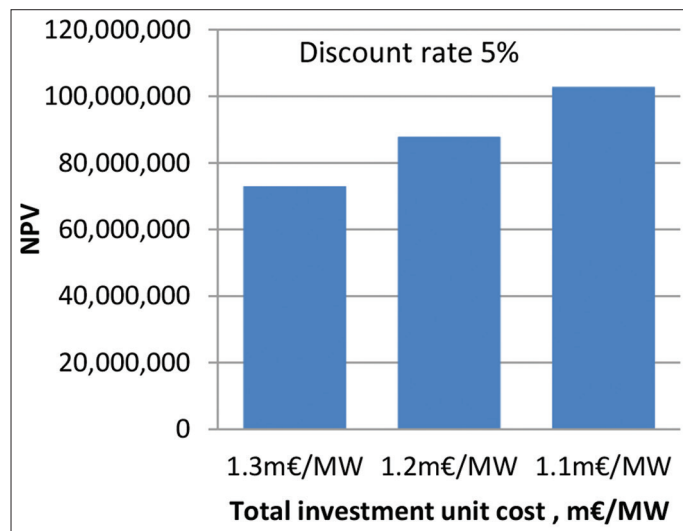
**Table 6: Important economic and financial indicators calculated**

Main indicators						
Annual electricity generated (MWh/year)	337,448.00					
Electricity price (€/MWh)	76*					
Discount rate (%)	5	5	5	7	7	7
Total investment cost (m€/MW)	1.1	1.2	1.3	1.1	1.2	1.3
IRR (%)	20.9	17.5	14.6	20.9	17.5	14.6
B/C Ratio	2.9	2.4	2.14	2.42	2.07	1.78
Pay back period (year)	4.7	5.7	6.8	4.7	5.7	6.8
NPV (€)	102,817,879	87,916,381	73,014,833	60,484,643	76,947,081	63,268,544

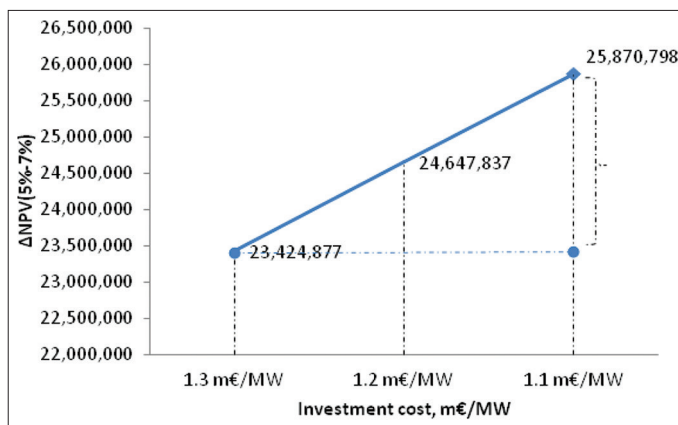
**Figure 18:** Graphical representation NPV = f (total unit cost of installation; r = 7%)



**Figure 19:** Graphical representation NPV = f (total unit cost of installation; r = 5%)



**Figure 20:** Graphical representation ΔNPV = f (total unit cost of installation; Δr = 5-7%)



of possible financial indicator outcomes is generated by using randomly selected sets of values as input parameters, within a predetermined range, to simulate possible outcomes.

The sensitivity analysis was executed on model assuming a fixed installation price of m€1.1/MW, discount rate r = 5% and sensitivity ranges up to 35%. Graph in Figure 24 shows the correlation between the unit cost of installation and the LCOE. It is apparently seen that an additional increase of the installation cost by 18% and 35% has a negative effect on the financial parameters of the project. NPV becomes negative -37,742,885 € and -66,428,268€, respectively (Table 7).

Under these conditions the sensitivity analysis provides accurate information to the determination of the electricity benchmark price.

The analysis clearly shows that the sale price should be at least over €76/MWh. The design calculations of the wind farm assume a fixed benchmark price of electricity € 76/MWh, and the detailed financial analysis highlights the fact that the system is ineffective unless a sustainable agreement should happen and reached between the investor and responsible ministry to favor the purchase of electricity produced from renewable wind sources.

This price should be adjusted in accordance with the legal framework that supports the installation and electricity generation from wind farms with an installed capacity over 3 MW (Wiser et al., 2016).

Table 8 summarizes the results of risk analyses obtained from the simulations in RETScreen model, which are performed on NPV at sensitivity range of 35%.

in detailed in sensitivity analysis extended over a range of 35% performance of variables.

### 6. SENSITIVITY ANALYSIS

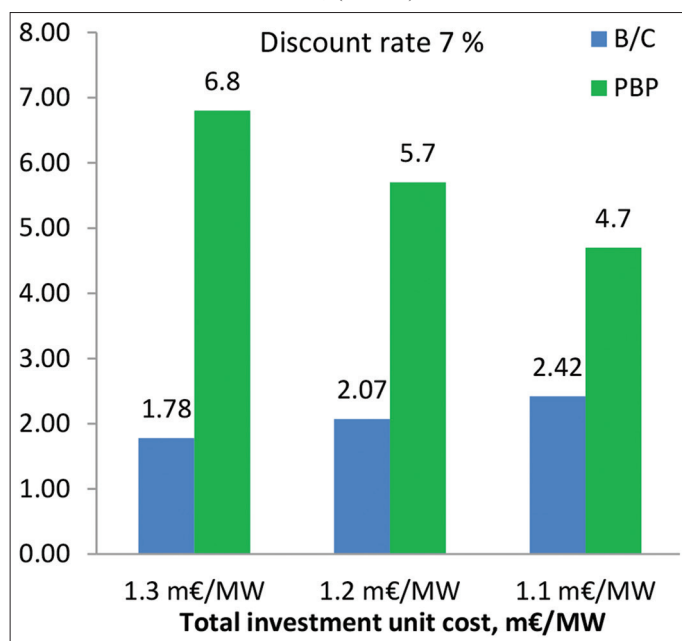
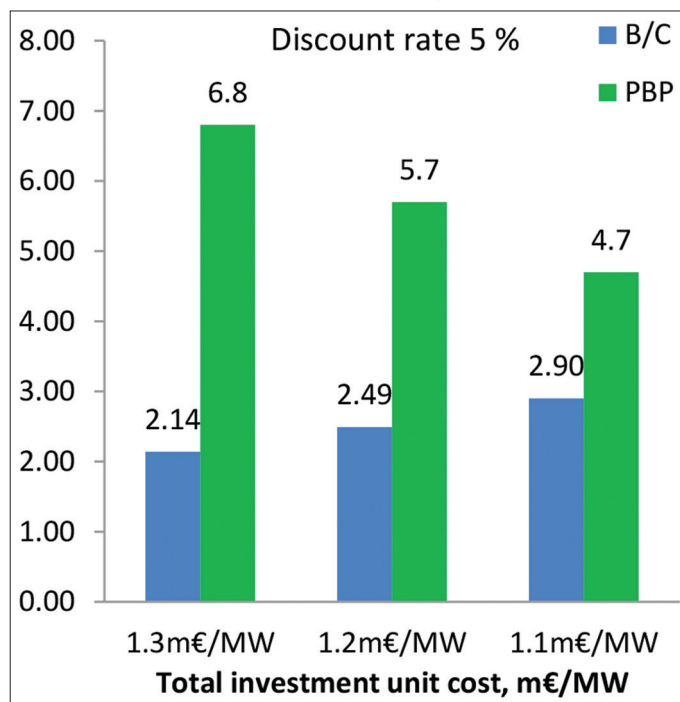
The Risk Analysis Model in RETScreen is based on a “Monte Carlo simulation,” which is a method whereby the distribution

**Table 7: Risk analyses performed for selected turbine**

		Initial costs				€
Electricity export rate		117,260,000	148,830,000	180,400,000	211,970,000	243,540,000
€/MWh	%	-35	-18	0	18	35
49.40	-35	48,313,266	19,627,882	-9,057,501	-37,742,885	-66,428,268
62.70	-18	104,250,956	75,565,572	46,880,189	18,194,805	-10,490,578
76.00	0	160,188,646	131,503,263	102,817,879	74,132,496	45,447,112
89.30	18	216,126,336	187,440,953	158,755,569	130,070,186	101,384,802
102.60	35	272,064,026	243,378,643	214,693,259	186,007,876	157,322,492

**Table 8: Risk analysis reflecting the different key parameters**

Perform analysis on	Parameter	Unit	Value	NPV		
				Range (±)	Min	Max
	Initial costs	€	180,400,000	35%	117,260,000	243,540,000
	O&M	€	3,374,480	10%	3,037,032	3,711,928
	Electricity export rate	€/MWh	76.00	35%	49.40	102.60
	Debt ratio	%	70%	35%	46%	95%
	Debt interest rate	%	3.00%	35%	1.95%	4.05%
	Debt term	Yr	15	10%	13.5	16.5

**Figure 21:** Relationship of B/C and PBP with total unit installation cost; (r = 7%)**Figure 22:** Graphical layout [B/C and PBP] = f (total unit cost of installation; r = 5%)

The parameters considered are initial and annual costs, debt ratio, debt interest rate, discount rate, O&M cost and electricity export rate.

As it is shown in the depicted graph in Figure 25, the largest impact on the LCOE of onshore wind comes from the initial investment costs. In contrast, financial parameters are found to have a comparatively little effect on LCOE. The sensitivity analysis shown was computed for the location of Korca, assuming an average annual wind speed of 5.4 m/s and 1.1 €/MW of total investment costs.

## 7. VALIDATION

Numerous experts have contributed to the development, testing and validation of the RETScreen Wind Energy Project Model. They include wind energy modelling experts, cost engineering experts,

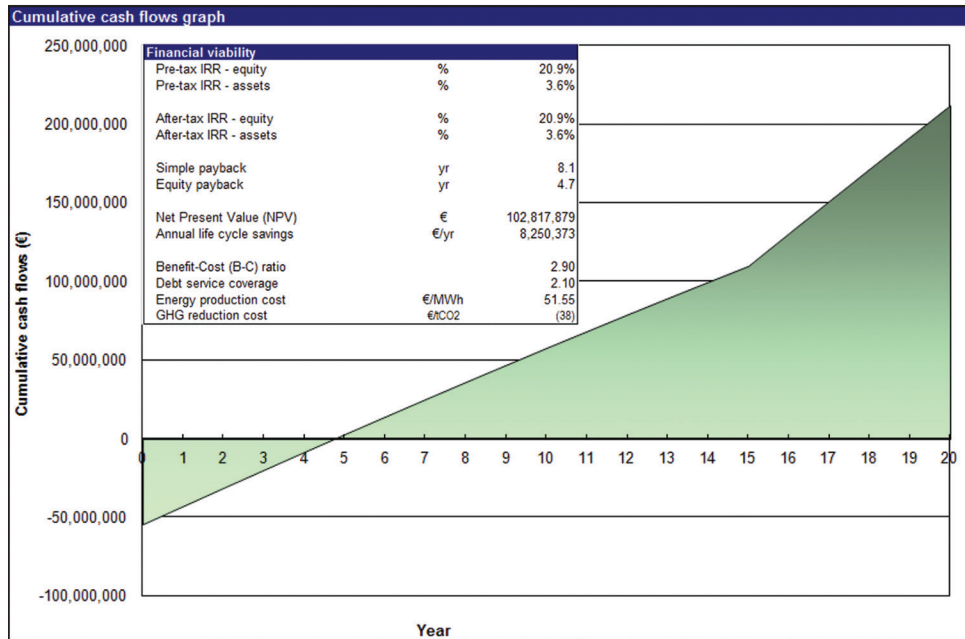
greenhouse gas modelling specialists, financial analysis professionals, and ground station and satellite weather database scientists.

This section presents two examples of the validations completed. First, predictions of the RETScreen Wind Energy Project Model are compared to results from an hourly simulation program. Then, model predictions are compared to yearly data measured at a real wind energy project site. The comparison between RETScreen and an hourly model is performed in (Ramli et al., 2017; Lund, 2014).

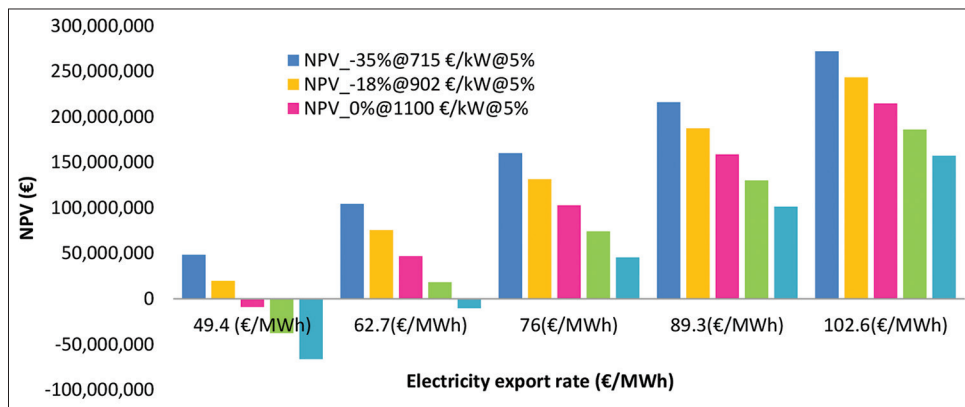
### 7.1. Validation of Wind Energy Model Compared with an Hourly Model

In this section predictions of the RETScreen Wind Energy Project Model are compared with an hourly model.

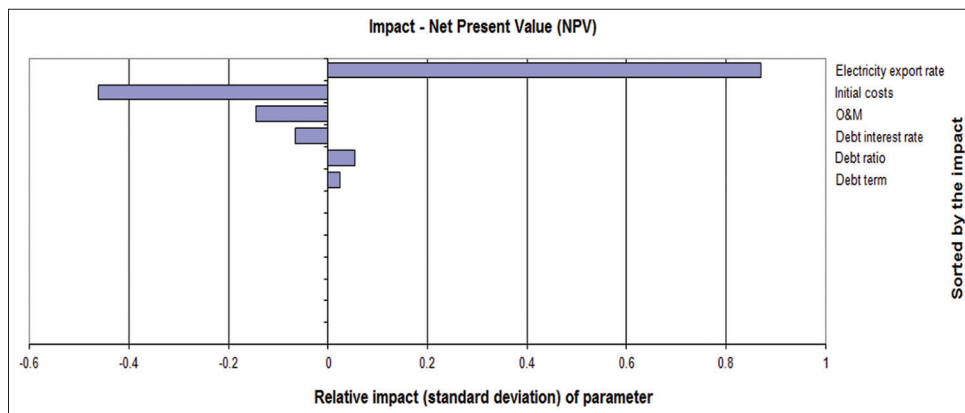
**Figure 23:** Graphical representation of Pay Back Period



**Figure 24:** Graphic representation NPV, LCOE = f (total installation cost 1.1 m€/MW; r = 5%)



**Figure 25:** Sensitivity analyses perform on NPV in a range up to 35%



The hourly tool used is EnergyPLAN, a deterministic model aims to identify optimal energy system designs and operation strategies using hourly simulations over a 1-year time period (Lund, 2014; Ringkjøb et al., 2018; Connolly et al., 2010). Both models have possibility on creating scenarios, are bottom-up tools, able to identify and analyze the specific energy technologies

and thereby assume investment options and alternatives (Lund, 2014) to generate economic optimisation, but RETScreen is not able to perform Operational Optimisation (Connolly et al., 2010). Operation optimization tools optimize the operation of a given energy system. Typically, operation optimization tools are also simulation tools optimizing the operation of a given system.

Compared to RETScreen model, the following characteristics of Energy-PLAN can be highlighted shortly in Table 9.

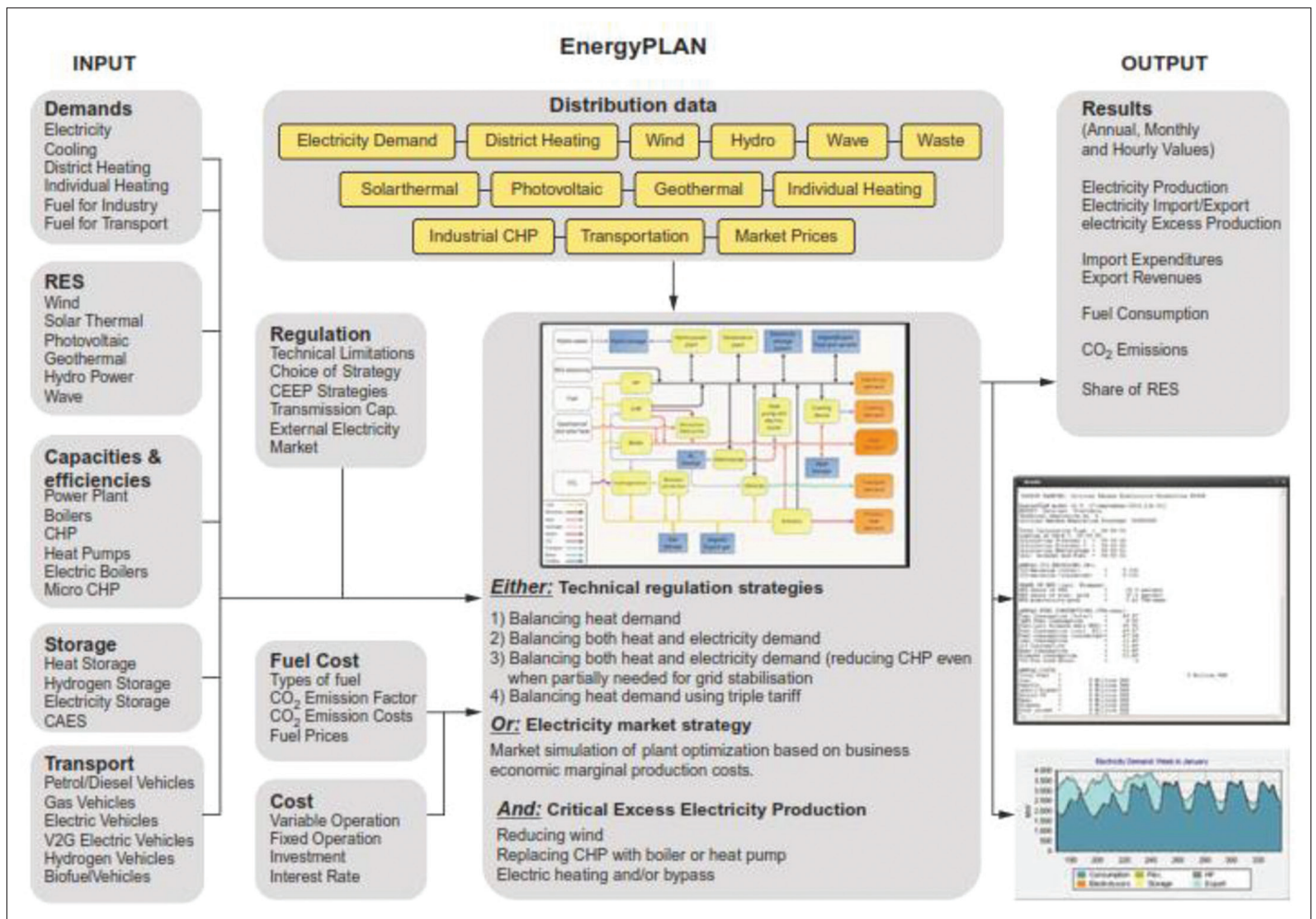
The EnergyPLAN model is a deterministic input/output model. General inputs are demands, renewable energy sources, energy station capacities, costs, and a number of optional different regulation strategies emphasizing import/ export and excess electricity production. Through this tool both technical, economic, investment cost and environmental based models at national or regional level can be created and validated considering electricity, heat and transport as main sectors, but are not seen part of this study work (Figure 26).

The total final energy consumption in Albania referring 2018 is 24 TWh where the consumptions by different sectors in Albania (Figure 27) was as follows: 4.8 TWh (industry sector), 5.52 TWh (household sector), 1.68 TWh (services sector), 1.2 TWh (agriculture sector), 9.12 TWh (transport sector) and 1.68 TWh (non-energy sector) (ERE, 2018; Strategjia Kombëtare e Energjisë 2018-2030). Indeed, the transport sector is by far the biggest consumer of energy 38% of PES in Albania (ERE, 2018; Strategjia Kombëtare e Energjisë 2018-2030) (Figure 28).

The validation of model is complicated, since the two models are typically different as both of them require different input

data. The principle of validation is discussed RETScreen uses a computerized system with integrated mathematical algorithms. The model uses top to bottom approach. It provides a cost analysis, GHG emission reduction analysis, financial summary, and sensitivity analysis, and provides a low-cost preliminary assessment of RES projects. RETScreen requires less detailed information and less computational power while EnergyPLAN needs to create the reference scenarios for the hole national level to perform the scope of this study to attain 42% RES share of the total final energy consumption. Firstly, EnergyPLAN considers the three primary sectors of any national energy-system: electricity, heat, and transport. As the reference scenario is created in EnergyPLAN the validation of its outputs referring to (ERE, 2018; Strategjia Kombëtare e Energjisë 2018-2030; INSTAT) is be checked step by step. The validation procedure of EnergyPLAN is described in details (Lund, 2014). The electricity is generated from hydro plants which has a total installed capacity of 2,204 MW consists of the total capacity of public producers and the total installed capacity of private producers/concession of electricity of 755.2 MW which constitutes about 34.3% of the total installed capacity (ERE, 2018). From (ERE, 2018) dammed hydropower counts for 1770.4 MW versus 276.96 Run of River power plants. Electricity consumption including all sectors results 7.5 TWh/year, where 55% of this energy is consumed by the household sector (ERE, 2018; Strategjia

Figure 26: Input–output structure of the EnergyPLAN model (Connolly, D., H. Lund, B. et al. 2010.)



Kombëtare e Energjisë, 2018-2030). The import of electricity varies on weather conditions but historically 3 TWh/year is imported from regional market (ERE, 2018). EnergyPLAN offers a large number of distribution file representing a wide source hub, easily imported into the model. Distribution files for electricity demand/import are created by using data provided from TSO Albania (ERE, 2018; Strategjia Kombëtare e Energjisë, 2018-2030; INSTAT; Key, 2019). Also, as a wind distribution file “Zagreb hour wind distribution” is used and corrected up to a factor of (0.35) until it reflects the total annual production. The stabilisation factor was inputted as 0 because wind power does not contribute to grid stabilisation. Both models offer cost database library (Connolly, 2012) but one can change the values at the desire level. After ensuring that outputs from the reference model created in EnergyPLAN, distribution files and other inputs data are verified to that of the current energy system (ERE, 2018), it is fruitful to build strategies over a period of time. EnergyPLAN cost database consider investment costs for onshore wind are 1.2 m€/MW while the fixed O&M costs are 6 €/MWh (Connolly, 2012).

In Table 10 the differences between the two opposite energy models are evaluated. The energy production results with a very slight difference 1.6%. The mean installation cost differs only 8.33%. The operation and maintenance cost ranges between 20 up to 40% more in the case of RETScreen model. While the

**Table 9: A Comparison between EnergyPLAN and RETScreen Model (Connolly et al., 2010)**

EnergyPLAN	RETScreen
Internationally accepted	Internationally accepted
Regional/National system level	Project/Station System Level
Detailed hour-by-hour simulations	Aggregated annual calculations
Bottom-up model	Bottom-up model
1 Year scenario time frame (possibility of combining to create a scenario of multiple years)	Up to 50 years scenario time frame
Simulation	No
Operation optimization	No
Investment optimization	Investment optimization
One version	Many version
Free	Expert versions is not free of charge
Environmental Impact	Environmental Impact

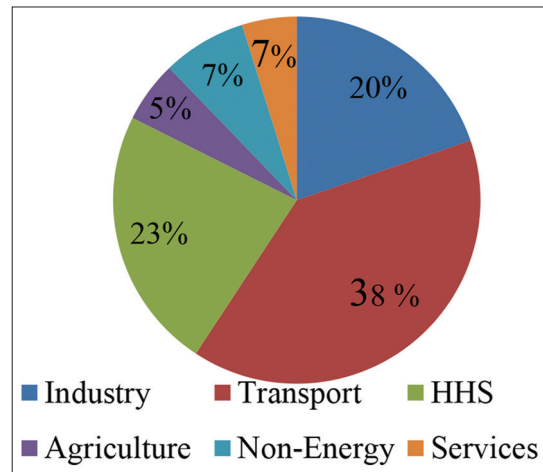
**Table 10: A comparison of the two energy model used in the study: EnergyPLAN versus RETScreen**

	RETScreen	EnergyPLAN	Diferencies (%)
Yearly energy production (MWh)	338 478	340000	1.6
Total investment cost (m€/MW)	1.1-1.3	1.2-1.3	8.33
Fixed O&M cost(€/MWh)	10	6-8	20-40
Capacity factor	23.5	23	-2.12
tCO <sub>2</sub>	129,910	141000	8.5

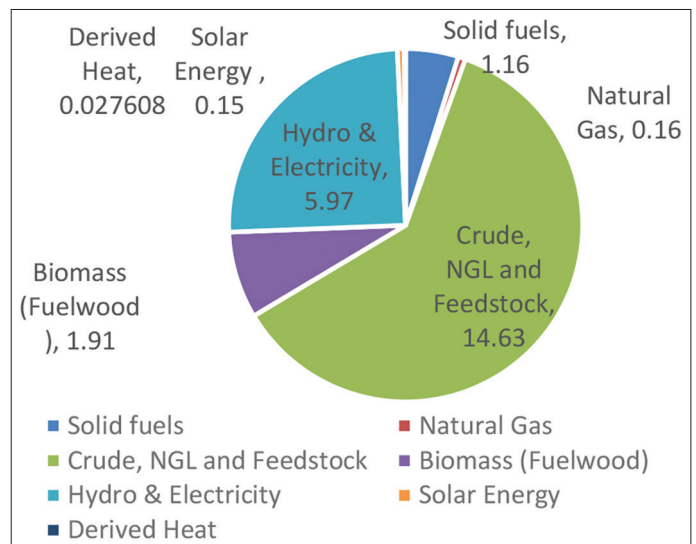
capacity factor in the case of EnergyPLAN results 23% versus 23.5% calculated in RETScreen. As a conclusion the closer result encourage us in the next scientific work to build long term scenarios using EnergyPLAN as the main tool. The annual emission effect of CO<sub>2</sub> in the case of RETScreen applying method 2 and supposing an efficiency of 50% for the base case power plant using natural gas as a fuel while in EnergyPLAN (PP1) power plant is with an efficiency of 50% is chosen. As it can be seen the differences of the total annual of CO<sub>2</sub> generated by both models is sharply small, 8.5%.

There are no obvious differences, so predictions for long interval are present and can be carried out without any doubt through the intertwined use of the models taken in the study. But in our case, without a clear energy roadmap in the country, definitively of full conviction EnergyPLAN model in any case should be the right tool to successfully achieve the objectives of a 100% renewable system.

**Figure 27: Annual energy consumption by sectors in Albania (ERE, 2018): Input values in EnergyPLAN model**



**Figure 28: Annual energy consumption by fuel type in Albania (TWh) (ERE, 2018): Input values in EnergyPLAN**





## 8. CONCLUSION

The results of the study highlight the importance of high levels of RES integration which not only reduces greenhouse gases but will technically favor the creation of a flexible and sustainable energy system over time. To better understand possible pathways to scaling the distributed wind market in Albania, we conducted a sensitivity analysis based on the scenarios created on RETScreen and EnergyPLAN model. Due to decreasing unit investment costs and increasing capacity factor in the future, wind power will become increasingly competitive against conventional power generation, reducing 129,910 tCO<sub>2</sub> in the base case scenario or 1,655,455 tCO<sub>2</sub> in the case of the high wind power integration of 1850 MW equivalent of 252,295 cars and light trucks not used, approximately 40% of the actual Albanian road car fleet.

From the simulation results from EnergyPLAN model of the reference scenario, the installed wind capacity to be fully in compliance with (Strategjia Kombëtare e Energjisë, 2018-2030) should be at least 1850 MW.

RETScreen model outputs compared to an hourly simulation program EnergyPLAN strongly shows that the results are of a high accuracy, thus the model is excellent in the stage of preparation of pre-feasibility studies, particularly given the fact that RETScreen only requires 1 point of wind speed data versus 8,764 points of data required by EnergyPLAN.

The annual electricity production of the proposed wind farm is 337.448 MWh, equivalent to 4.5% contribution to the total consumption of electricity in our country or 1.4% to the total final energy consumption.

Referring to (Strategjia Kombëtare e Energjisë, 2018-2030) installation cost of wind power plants varies between (1.250÷1.650) m€/MW. In this study the installation cost of 1.1 m€/MW should serve as the low recommended threshold, referring once again to (Strategjia Kombëtare e Energjisë, 2018-2030, Ministry of Infrastructure 2017) the scenario still is unprofitable as the energy production cost results 51.55€/MWh (Graph in Figure 23).

Multidimensional calculations to predict the electricity cost per Megawatt hour as a function of turbine output power, operating cost, and maintenance cost are included. The selling price of electricity, discussed in details in the financial analysis is assumed 76€/MWh. Considering a sensitivity range of ±35% this price strongly should be the low threshold for an installation cost of (1.1÷1.3) m€/MW. Referring to (Strategjia Kombëtare e Energjisë 2018-2030, Ag, Axpo Trading. 2019) the purchasing price of electricity generated from renewable energy sources especially from wind is 51€/MWh resulting unprofitable and NPV is negative (Figure 20). As a conclusion, as it is shown from the results of the study substantial intervention is needed in (Strategjia Kombëtare e Energjisë, 2018-2030; Ministry of Infrastructure, 2017) to attain the goals towards 2030.

In markets for electrical energy, the wholesale price varies considerably throughout the day and year and so the wind farm

electricity producer is likely to be exposed to changeable prices, leading to the need of supporting mechanisms, together with the markets for electrical energy, must be subject to very rapid change.

The approach is to create a long-term bilateral contracts between generators, large customers; a short-term market, at least 10 h ahead of delivery, between generators, customers and suppliers and a balancing mechanism, 10 h ahead of delivery, operated by the TSO and promoting the electricity storage technologies by integrating many flexible possible options on regional/national level.

Based on (Edmunds et al., 2019; De Alencar et al., 2017; Gross et al., 2017) power systems require a wide range of ancillary services in order to function and RES will be expected to provide such services in line with their increasing penetration energy policy is evolving to meet the requirements for ancillary services (AS) necessary to ensure the economic and reliable delivery of power with a high penetration of RES especially of wind power plants (System Operability Framework 2016; Key, A. 2019; Shakoor, Anser et al., 2017; Joos, Michael, and Iain Staffell., 2018).

## ABBREVIATIONS

The following abbreviations are used in this manuscript:

RES – Renewable Energy Sources  
 PES - Primary Energy Supply  
 O&M - Operation and Maintenance  
 NPV - Net positive value  
 IRR - Internal rate of return  
 CF - Capacity Factor  
 PBP - Pay back period  
 LCOE - Levelized cost of energy  
 B/C - Benefit-Cost ratio  
 TSO - Transmission System Operator  
 AS - Ancillary services.

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