# VALORIZATION OF POTENTIALS OF WIND ENERGY IN MONTENEGRO

## by

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Investments in energy sector are usually long term processes both in construction and exploitation phase, and therefore require many conditions to be satisfied, mostly from legislative and technical sector. While the legislative can change in accordance with economy activities in the country, technical data (on-site measurements) which are the main base for energy facility design, need to be reliable as much as possible. Wind energy has a significant global potential which exceeds the world's electrical energy consumptions. This paper presents the estimation of wind energy potentials in Montenegro, based on all previous available studies in this field. The wind energy potential in Montenegro is based on a combination of 3-D numerical simulations of wind fields on the entire territory, and comprehensive on-site measurements. The preliminary studies show that there is a potential of areas with high and mean values of a capacity factor about 400 MW, and annual production of 900 GWh of electric energy. The share of wind parks in the total installed power in Montenegro is planned to be about 8%, while an adequate ratio of wind parks in an annual production from renewable sources (large hydro power plants are included here) is estimated to be 11.4%. The paper presents the current state of art in the field of building of wind parks in Montenegro. A particular attention was paid to the legislation framework and strategic documents in the energy area in Montenegro.

Key words: wind, wind energy, estimation of potential, wind generator, wind park

#### Introduction

Within the global economy, dominated by a trend of fast changes, the ability of selfsatisfying of energy needs has a significant role in the planning of future in each country. For the purpose of reduction of reliance on fossil fuels and foreign sources of energy, many countries have initiated programs of researches and development in the field of renewable energy sources (RES). Wind energy is one of the renewable sources whose global potential exceeds several times the need for electrical energy [1, 2].

As one of candidate countries for EU accession, Montenegro is obliged to meet certain EU standards, *i. e.* to adjust its regulations and legal system, in all sectors, including energy.

This paper describes all the activities that are realized in Montenegro with the goal of valorization of wind energy potential through the harmonization of national with EU legislation. The paper also presents all analyses (based on theoretical studies, numerical simulations, and measurements) carried out to assess the wind energy potential in Montenegro. The paper also

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presents basic information for the two projects: wind park Krnovo (72 MW) which is completed and Mozura wind park (46 MW) which is in its initial stage of construction.

#### Energy policy of the EU and Montenegro

#### The current state and developmental trends in the EU

In order to protect the environment and to reduce GHG effects, permanent efforts related to increasing of use of electrical energy from renewable sources are made. In 2001, the EU member states adopted the guidelines for the increasing of the number of RES in the total consumption from 6% to 12% in 2010. The European Parliament in 2005 approved the recommendation for further increasing of share of renewable sources in the total consumption to 20% in 2020, with saving of energy of 20% and the reduction of production from fossil fuels to the level of 20%.

The wind energy has a dominant share between all RES in the EU countries. The increasing of total installed power of wind power plants in the EU countries and the rest of the world for the period from 2000 to 2015 is presented in fig. 1. At the end of 1995 there were 4.800 MW capacities installed, and 59.000 MW installed at the end of 2005 (increasing of 12 times for 10 years). In the period between 2000-2007, the biggest increasing of installed capacities is related to gas power plants (76.6 GW), followed by wind parks (46.8 GW), while the increase of installed capacity of thermo-electrical power plants, heavy-oil power plants, and nuclear power plants is rather smaller (32.2 GW in total). In accordance with the EU recommendations in 1997, the plan was to have 40 GW of wind parks until 2010, and this goal had already been achieved in 2005, fig. 1. The European Wind Energy Association (EWEA) increase this goal to 80 GW. Such a trend can be compared only with the increase of the computing or nuclear industry in 1960s and 1970s.

Whereas the use of wind energy is followed by big investments, the increase of production of electrical energy from wind energy is an exponential one. The forecasts up to 2030 say that this trend will be continued (according to the projections by EWEA of 2007) or mildly slowed down (according to projections by the European Commission of 2006), fig. 2. The same figure gives the estimation of the impact of the new wind parks on the CO<sub>2</sub> reduction in percent, at some particular time points. It can be seen that the reduction of CO<sub>2</sub> emissions, which are the



Figure 1. Cumulative wind power capacity 2000-2015 [3, 4]



Figure 2. Projection of growth of installed power of wind generators in the EU and a corresponding effect on the reduction of CO<sub>2</sub> emission [5]

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main reason of the global warming, can be expected only in the next period, when the wind park capacities become more significant and its use become constant.

Although the industry of wind energy equipment has been most dynamic in Europe and North America so far, new markets are being opened in Asia (India and China) and South America (Brazil). Figure 3 gives the data about the installed power of wind generators in the world in 2015 [4].



Figure 3. Cumulative installed capacity in December 2015 [4]

Mainland locations for the mounting of wind generators in some countries are almost entirely used and wind parks are being installed offshore. Germany and Denmark achieved a particularly big advancement in this filed.

### Wind energy in the strategy of energy development in Montenegro by 2030

In March 2011, The Government of Montenegro adopted the updated and amended Energy policy of Montenegro [6]. This document is a basis both for the preparation of the strategic energy development in Montenegro by 2030 [7] and for the action plan for its realization [8]. New energy policy defines the aims of energy development of Montenegro by 2030 as well as the main priorities and key strategic trends. The main priorities are: reliability of power supply, development of competitive energy market, and a sustainable energy development. Based on the priority directions in the EU, the state's goals in the energy area are the growth of the reliability in the power supply, growth of use of energy from renewable sources, improvement of the energy efficiency, investment attraction and the development of market competition in the area of energy. Based on the presented results of the analysis of potentials of wind energy, the development of wind parks was planned by the strategy of development in Montenegro by 2030. According to the reference scenario, the first wind park should have been put into operation (in 2014), and the additional capacities of wind parks should have been put into operation in already in 2015. The overview of the planned development of the wind parks by 2030 is given in tab. 1.

The development of the total installed power of the energy system of Montenegro by 2030 is presented in fig. 4.

Projections of using of RES for electrical energy production according to the aims of Directive 2009/28/EC are presented in fig. 5.

Planned wind parks	Start of the realization of the project	Installed power [MW]	Annual production [GWh]
Wind park Mozura (Bar/Ulcinj)	2014	46	105.8
Wind park Krnovo (Niksic)	2015	50	115
Wind park Krnovo (Savnik)	2015	22	50.6
Wind parks (undefined location)	2016	7.5	17.2
Wind parks (undefined location)	2020	25.7	59.2
Wind parks (undefined location)	2025	17.1	39.3
Wind parks (undefined location)	2030	21.4	49.2
Total	2030	189.7	436.3





Type of	Installed capacity [MW]								
power plant	2016	2017	2018	2019	2020	2022	2025	2030	
Thermal	225	225	575	575	575	800	800	800	
Hydro (HP)	781	803	861	1099	1267	1268	1267	1267	
Large	708	708	729	967	1135	1135	1135	1135	
Small	74	95	132	132	132	132	132	132	
Wind	125	125	125	125	151	151	168	190	
Photovoltaic (PV)	6	7	8	9	10	15	22	32	
Biomass	9	14	18	19	29	30	32	39	
Total	1146	1174	1587	1827	2032	2264	2289	2328	

Figure 4. Development of installed power in EES in Montenegro by 2030 [7] (for color image see journal web site)



Type of DES	Electric energy production [GWh]							
Type of KES	2015	2020	2025	2030				
Hydro (HP)	1957.4	3153	3153	3153				
Large	1720	2731	2731	2731				
Small	237.4	422	422	422				
Wind	271.4	347.8	387.1	436.3				
Photovoltaic (PV)	5.3	16.5	36	52				
Biomass	23.1	101	144.2	187.8				
Total	2257.2	3618.3	3720.3	3829.1				

Figure 5. Electrical energy production from renewable sources by 2030 [8] (for color image see journal web site)

In accordance with data presented in figs. 4 and 5, the ratio of wind parks in the total installed power in this period will increase from 8% up-to the 11%. In this scenario, the wind parks will take third place regarding the installed power, after large hydro and thermal power plants. The long time projection for wind parks until 2030 is about 190 MW of installed power, with an annual electricity production of 440 GWh.

#### Potential of wind energy in Montenegro

A proper evaluation of renewable energy potential has a main importance for sustainable energy policy of any country, where the wind energy is one of observed factors. Evaluation studies of wind energy potentials for the countries of the former Yugoslavia can be found in: Poje and Cividini [9] for Croatia, Zlomusica [10] for Bosnia and Herzegovina, Dimcev *et al.* [11] for Macedonia. The first theoretical analysis of wind potentials for the territories of Serbia and Montenegro was given by Mikičić *et al.* [12]. In this analysis, the estimation of the wind energy potential was obtained based on anemographic on-site measurements in meteorological stations. These data were used for the estimation of a degree of similarity of winds in Serbia and Montenegro, to the winds in Denmark and Germany, and on the basis of which the estimation of winds in Serbia and Montenegro was executed in a comparative analysis. Knowing that the technically usable potential of winds that at the height of 10 m above the surface have an average annual mean speed higher than 5.1 m/s, only these values of wind speeds were used in the comparative analysis.

The first detailed study in which the wind potential in Montenegro was analysed [13] was based on the results of the simulations obtained by the use of a 3-D macroscopic numeric model that are afterwards calibrated with the results obtained on the spot. The estimation of energy potential of wind for the entire territory of Montenegro was performed first. The results of this analysis are presented as wind maps presenting the theoretical mean wind speed, fig. 6, and theoretic mean wind potentials, fig. 7, on reference height of 50 meters above the ground.



Figure 6. Theoretic mean wind speed [13] (for color image see journal web site)

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Figure 7. Theoretic mean energy wind potential [13] (for color image see journal web site)



Figure 8. Real mean wind speed [13] (for color image see journal web site)

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Figure 9. Real mean energy wind potential [13] (for color image see journal web site)

After this, the correction of the results was performed in order to obtain a real mean wind speed and real mean energy wind potential. The correction by using an adequate factor obtained by comparison of the simulated and measured wind speed, was firstly executed. Then, after the detailed analysis, the corrections taking into account all relative limits influencing the reduction of usability of energy wind potential were executed. These limits include the terrain topography, accessibility of the location, distance from the road network and connection to the electrical grid, closeness of settlements and natural parks, *etc.* The final results of these corrections are the maps presenting the real mean wind speed, fig. 8, and a real mean energy wind potential, fig. 9, on the height of 50 meters.

These analyses showed that the wind speeds at the largest part of Montenegro are below 5 m/s. The building of wind parks mainly is not economically viable in cases of these wind speeds. Although, it has been shown that some areas have a significant potential for utilization of wind energy and these places, at the same time, are situated in the vicinity of traffic and electrical networks. First of all, it purports to the coastal area where wind speeds have a range from 5-7 m/s, and at some locations along the coastal areas these wind speeds have values 7-8 m/s (mountain massif Rumija, hinterlands of Petrovac, mountains in hinterlands of Herceg Novi and Orahovac). Except the seaside, an important wind potential is found in the region of Niksic city, where the mean values of wind speeds range from 5.5 to 6.5 m/s. The analysis has shown that other locations characterized by big wind speeds are not attractive for the time being for the building of wind parks because these are positioned on high mountain regions, at mountain

slopes, or these are far from the existing road and power supply infrastructure. The problem of the connection of wind parks in Montenegro to the adequate electric grid is particularly pronounced. For the biggest part of Montenegro, the typical real mean energy wind potential is within the limits of 100 to 300 W/m<sup>2</sup>, while in the mentioned areas in the seaside and around Niksic it exceeds the level of 400 W/m<sup>2</sup>.

The study [13] analyzed several scenarios of use of wind potential in Montenegro. The most windiest areas that are most convenient for the building of wind parks (wind speeds bigger than 7 m/s, namely the capacity factor bigger than 30%, fig. 10), have a capacity of about 100 MW. The areas with mean values of wind speeds and a capacity factor (wind speed from 6.4-7 m/s and capacity factors from 25-30%) have an additional capacity of 300 MW. By exploitation of the mentioned potential of 400 MW in total, the annual production of electrical energy of 900 GWh would be accomplished, what approximately correspond to one fourth of consumption of electrical energy in Montenegro. Note that all the mentioned analyses were conducted for the height of 50 meters and the use of higher towers, namely wind generators with higher installed power would enable use of bigger wind speeds, and a bigger capacity factor could be obtained.

Since 2007, besides the mainland area of Montenegro, Italian, Croatian, and Albanian partners, in co-operation with the ministries responsible for energy, have been working on the project of the estimation of wind potentials at the Adriatic Sea within IPA Adriatic Program of a cross-border co-operation [14]. This project is focused on the estimation of offshore wind potential through the elaboration of a numerical model, as well as the placing of measuring devices on coasts for the purposes of calibration of obtained results. The mean wind speeds for 2012 at the part of the Adriatic Sea by the Montenegrin coast are presented in fig. 11.





Figure 11. Real mean wind speed at the part of Adriatic sea by the Montenegrin coast [14] (for color image see journal web site)

Similar project was also performed within the 6<sup>th</sup> Framework Program of the European Commission which was finished in 2015 [15]. One of the results of this project is the wind maps for the territory of republics of former Yugoslavia.

The Danish manufacturer of wind generators made the map of winds in Montenegro which gives the wind speeds at the height of 80 meters [16].

Note that the Institute of Hydrometeorology and Seismology of Montenegro has also been performing a systematic on-site measurements of hydrometeorology parameters for its own needs, as well as the wind parameters for more than 20 years. The data are measured in the points that are situated in urban environments (mostly in towns), and that are mostly in lower areas and valleys. Many data that are obtained and analyzed in this way are mostly intended for the purposes of various analyses and studies that are conducted in the Institute of Hydrometeorology and Seismology of Montenegro.

Wind speed in the lower layers of the atmosphere is affected by terrain configuration, vegetation and buildings. As it can be noted, different studies use different reference height above ground, *e. g.* 50 m, 80 m, *etc.* It is possible to compare those data on different heights, considering that the roughness effects in the atmospheric boundary layer can be described using logarithmic profile:

$$\frac{V_m(z)}{V_m(z_{\text{ref}})} = \frac{\ln z - \ln z_0}{\ln z_{\text{ref}} - \ln z_0} = \left(\frac{z}{z_{\text{ref}}}\right)^{\alpha} \tag{1}$$

where z represents the height above the ground,  $z_{ref}$  – the reference height,  $z_0$  – the roughness height, and  $\alpha$  – the terrain roughness coefficient. Typical values of  $z_0$  and  $\alpha$  can be found in [17].

# The current state in the building of wind parks in Montenegro

Relying on data from study [13], four companies obtained the permission from the responsible ministry for on-site measurements and researches of wind potentials at the Montenegrin territory. The reports of analysis of collected data of wind potentials have been submitted for two locations so far: Krnovo and Mozura [18], [19]. Based on the results of measurements in December 2009, a public bid for these two locations was announced and the contracts about the land rent and building of wind parks for these two locations, Krnovo and Mozura, were signed latter.

The area around the wind park Mozura is situated northerly from Ulcinj, at the coastal part of the mountain Mozura, far a little more than 5 km of airline from Ulcinj, at about 17 km far southerly from the nearest point of the Skadar Lake, and at about 17 km north-westerly from Ada Bojana. The mountain Mozura stretches along the southeast-northwest direction in length of about 8.5 km, and the height where the installation of wind generators is planned ranges to 622 meters above sea level. This location territorially belongs to the municipalities of Bar and Ulcinj. The projected installed power the wind park Mozura is 46 MW with the estimated annual production of about 100 GWh. The value of the project was estimated to be about 80 million €. The contract about land rent for the period of 20 years and the building of the wind park at the location of Mozura was signed in July 2010 with the consortium Fersa Energias Renovables, Barselona, Spain and Celebic, Podgorica [18]. After the providing of all necessary documents, the Ministry of Sustainable Development and Tourism issued the building permission for the building of the wind park in December 2014, however, the investors were interested to transfer their rights and obligations to the Enemalta Plc, II Marsa, Malta, what was latter realized. The estimated reduction of  $CO_2$  emission due to the building of this wind park is about 80,762 tonne per year.

The area around the wind park Krnovo is situated at the territories of Savnik and Niksic, at sea level above the 1500 meters. The projected installed power of the wind park Krnovo is 72 MW, and the estimated annual production is about 160 GWh. The value of the project was estimated to be about 120 million  $\in$ . The investor is the consortium of companies Ivicom Consulting, Wien, Austria and Akuo Energy, Paris, France. The estimated reduction of CO<sub>2</sub> emission due to the building of this wind park is 212,960 tonne per year.

For the first 12 years of operation, the contracts provide that the guaranteed purchase price for the energy produced in wind generators is  $95,99 \in /MWh$ . The purchase price is prescribed by the regulation for the stimulation of price of energy from renewable sources [20]. Table 2 gives the mean wind speeds measured at the locations of Mozura and Krnovo, while tab. 3 gives basic technical data for both projects.

т .:	Month												
Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Mozura	6.6	7.5	7.3	6.0	5.2	5.1	5.0	5.4	5.3	6.1	7.1	7.6	6.2
Krnovo	6.7	9.1	8.7	5.0	5.6	5.2	5.3	6.1	7.0	5.3	5.6	8.1	6.5

Table 2. Mean wind speeds [m/s] and measured at the locations of Mozura and Krnovo [18, 19]

Table 3.	Basic	technical	data	for	wind	parks	Mozura	and	Krnovo
								****	

	Wind park Mozura	Wind park Krnovo
Number of wind generators	23	26
Installed power	46 MW	72 MW
Rotor diameter, number of blades	do 121 m, three blades	do 103 m, three blades
Tower height	Up-to 90 m	Up-to 100 m
Year of manufacturing	115 GWh	220 GWh

The installation of wind generators at the location of Krnovo was done in September and October 2016, and the trial operation and the exploitation permission are planned to May 2017. For the location of Mozura, the preparations for the final works are planned for the beginning of 2017.

#### Conclusions

Based on the previous research, it can be concluded that Montenegro has a significant potential for building wind parks for electrical energy production. The preliminary studies based on the numerical simulations indicate that there is a potential of areas with high and mean values of a capacity factor about 400 MW, and that exploitation of this potential means an annual production of electrical energy of about 900 GWh, corresponding approximately one fourth of total consumption in Montenegro. However, further comprehensive research is necessary, especially in the field of measurements on the terrain in order to determine potential of energy more precisely. The strategy of energy development of Montenegro by 2030, provides the building of wind parks with total installed power of 190 MW and an annual production of 440 GWh. In this way, the share of wind turbines in the total installed power of the energy system of Montenegro is planned to be a little more than 8%, while an adequate share of wind parks in an annual production from renewable sources (large hydro power plants are included

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here) is estimated to be 11.4%. In case that planned scenario became true, the building of wind parks would have a significant role in the realization of goals prescribed by the directive 2009/28/EC, in sense of an increasing of the share of electrical energy produced by utilization of renewable sources, as well as in sense of reduction of emissions of GHG.

The project of the building of the wind on the location of Krnovo with the installed power of 72 MW has been finished and it represents the first concrete project that exploits potential of wind energy in Montenegro. The project of the building of the wind park on the locality of Mozura with installed power of 46 MW is in the phase of preparatory works. With the realization of these two projects, 60% of wind parks planned in the strategy of energy development of Montenegro by 2020 will be achieved.

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