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UTILISATION OF WIND ENERGY POTENTIAL IN MONTENEGRO

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ABSTRACT: *Research on the potential of wind energy in Montenegro was conducted by the Italian Ministry for the Environment, Land and Sea. Results are presented in the study - Assessing the potential of renewable energy sources (2007), where Montenegrin coast and area around Nikšić were recognized as potential sites for the construction of wind farms. If we consider only the areas that have a capacity factor of over 25%, we conclude that Montenegro has wind energy potency of 100MW. If we take into account the medium potential zone this value reaches 400MW. By using the aforementioned energy resources to produce electricity 20-25% of annual energy consumption in Montenegro could be provided. Up to now, studies of wind potential for two sites, Krnovo and Možura, have been submitted to Ministry of Economy. At the site Krnovo, construction of the wind farm began in May 2015, while the beginning of construction on the site Možura is still ahead. Montenegro also participates in the project of coastal wind farms, POWERED, which aims to explore the potential of wind in the Adriatic Sea for the construction of offshore wind farms.*

Keywords: *wind power,Krnovo, Mozura,POWERED, Montenegro*

INTRODUCTION

In modern conditions of intense population growth and increasing consumption of fossil fuels, primarily oil, coal and natural gas, there are significant changes in the environment. By burning fossil fuels, gases with a greenhouse effect are released, which at the same time change the natural composition of the atmosphere. As a consequence, there is global warming and climate change (Rajović, Bulatović, 2013).Climate change, as the main ecological problem of the world community, was discussed at numerous international meetings and many declarations were made. Although there is no single solution to prevent climate change, it has been observed that greater use of alternative energy sources can significantly reduce carbon dioxide (CO2) levels and slow them down. The wind is recognized as one of the more attractive alternative sources of energy. Wind power has been used for navigation, pumping water, running mills, etc. since ancient

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times. With the development of electricity production, the use of wind for these purposes has also been developed. Wind energy was initially used by larger objects away from the central power grid and the farm, in order to join the massive construction of wind turbines of various sizes, located on land and water. The advantages of using wind power are the lack of gasses that pollute the environment, relatively inexpensive maintenance, and the fact that wind farms do not require additional energy sources for their work (Mikičić et al., 2006).

It is estimated that today at least 80 countries use wind energy for electricity generation. At the end of 2014, there were more than 268,000 wind generators that participated in the total electricity production with 3% (GWEC, 2015). At the level of Europe, Denmark and Spain have the highest potential for wind energy use, where by 2025, production is expected to increase by 50%. Europe is at the forefront of the construction of wind turbines on water, with 90% of the world's total wind turbines of this type (GWEC, 2011).Thanks to them, the release of 12.2 Mt CO2 into the air was avoided. So far, about 57,000 workers have been directly and indirectly engaged in their construction, and it is projected that this number will increase nearly four times by 2020. By using wind energy, employment at the EU level has increased by 30%, and the income from production was € 23 billion by 2010. According to a survey conducted in 2013, 70% of the EU's citizens believe that the future of electricity production is in alternative sources (http://www.ewea.org/wind-energy-basics/facts/). According to Reyers et al. (2016), wind potentials are decreasing from northern and central Europe, to southern Europe and the Mediterranean, based on the CMIP5 model that they used for the period up to 2100.

Analyzing the areas of higher altitudes in South-East Europe, besides solar energy, wind energy is characterized by significant potential as the energy of the future (Ban et al., 2013). Starting from the experience of EU member states, it is necessary to pay more attention to wind energy in the framework of national energy strategies (Mikičić et al., 2006). One of the priorities of Montenegro's energy policy, which is in line with the EU's energy policy, is sustainable energy development. It involves exploring the potential of renewable energy sources and increasing their share in total energy production. Pursuant to the Law on Energy and the Energy Development Strategy of Montenegro until 2030, the National Action Plan for the use of energy from renewable sources by 2020 was adopted. This plan defines the dynamics of the use of natural resources, as well as the planned use of technologies needed to meet the national target of 33% of the share of energy produced from renewable sources in the total final energy consumption.

The aim of the paper is to present the potentials of wind energy in Montenegro based on previous research by the relevant institutions, then present the energy revenue and utilization of wind energy at the plants currently installed, as well as to present an exhaustive analysis of the use of wind energy with countries in the region.

PREVIOUS EXPLORATION OF WIND POTENTIAL

Research on the potential of wind energy use in Montenegro was carried out by the Ministry of Environmental Protection, Land and Sea of the Republic of Italy. The results were presented in the Assessment of Renewable Energy Potential Study, 2007. The analysis was first determined by theoretical mean wind speed and theoretical average wind potential at a reference height of 50 m. On the basis of the relationship between the measured and simulated wind speeds, the real mean velocity and actual average wind potential in Montenegro at a height of 50 m were obtained (figure 1).

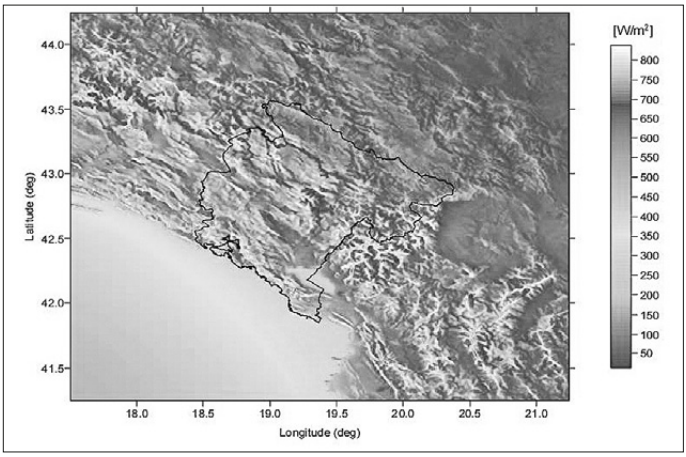

Figure 1: Actual wind potential in W/m2 at 50m.
Source:CETMA, 2007.

A more detailed analysis was carried out, which included potential constraints, such as the relief of the site, its accessibility, the road network, proximity to protected areas, railroads, electricity networks and settlements. Based on this analysis, it has been concluded that Montenegro has significant potential for using wind energy in certain localities (figure 2). On most of the territory, wind speed is less than 5m/s, which is typical for the territory of Central Europe. However, the speed increases further to the coast where it reaches a value of 7-8 m/s. In addition to the coast, the area around Nikšić is interesting, where the wind speed reaches values of 5.5-6.5m/s.Due to the developed network of transmission lines and roads, both areas are recognized as potential sites suitable for the construction of wind farms. The most vivid are mountain peaks where the real energy potential of the wind is over 400W/m2. However, according to all other characteristics, these sites are not suitable for exploitation. Of all national parks, only NP Lovćen can be suitable for the use of wind energy due to developed infrastructure and high wind speed (Ministry of Environmental Protection, Land and Sea of the Republic of Italy, 2007).

Due to the insufficiently developed transport infrastructure (except for several convenient locations), it would be most appropriate to choose smaller turbines, due to the easier transportation of their components. On the other hand, the installation of larger generators would produce a higher amount of electricity, which would depreciate the

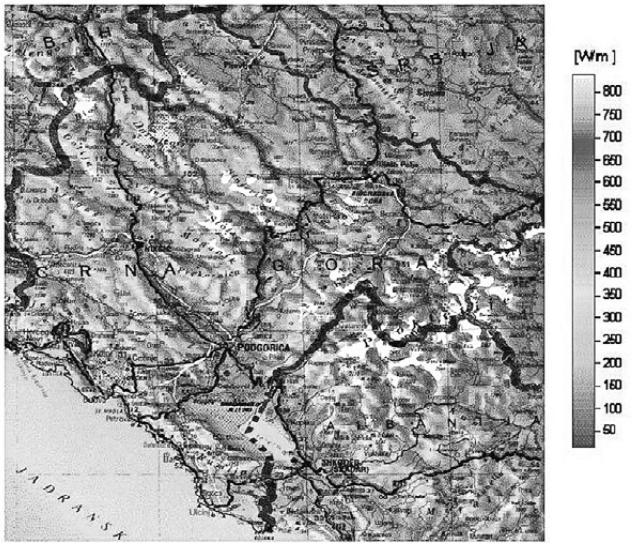

Figure 2: Actual wind potential in W/m2 at 50m with relevant restrictions

Source: CETMA, 2007.

costs of improving the road infrastructure. Furthermore, a preliminary analysis of economic parameters in case of concrete construction of wind turbines in Montenegro was carried out. Various scenarios for different capacity factors (20,25,30%) were analyzed corresponding to different mean wind speeds (6.1.6.4 and 7 m/s) for wind power generators with a nominal power of 850kW.

If we consider only areas with a capacity factor of over 25%, we conclude that Montenegro has an energy potential of 100MW. Considering the mid-potential zones, this value reaches 400MW. By using this energy potential for the production of electricity, 20-25% of the annual energy consumption in Montenegro could be provided (CETMA, 2007).

LOCATION OF WIND FARMS IN MONTENEGRO

By the competent Ministry, several permits were issued for the measurement and research of wind potential in the territory of Montenegro. These companies are:Fersa Energias Renovables[1] (license for the municipalities of Tivat, Bar, Ulcinj, Podgorica and Budva), Ivicom wind[2] (Krnovo, Niksic), NTE[3] (Rumija, Bar) and Dekar (Rumija, Bar).

[1] Fersa Energias Renovables SA is one of the world's leading alternative energy companies, based in Barcelona, Spain. They own and are planning to build new wind farms in: India, Panama, Spain, China, France, Italy, Hungary, Montenegro, Poland, Estonia and Russia.

[2] IVICOM Consulting GmbH is a consultancy, design and construction company in industrial plants. It was founded in 1991, based in Vienna.

[3] Nord-Trøndelag Elektrisitetsverk AS (NTE) is a power generation company, based in Stykkhor, Norway. They own 28 hydropower plants and two wind farms, and are the leading company for the construction of wind generators along the coast of Norway.

So far, the Ministry of Economy has submitted the reports of the analysis of the wind potential for two sites, Krnovo and Mozura. In addition, the Institute of Hydrometeorology and Seismology of Montenegro performs measurements of wind speed and direction at a height of 10m at the automatic stations in Podgorica, Bar, Nikšić, Kolašin, Žabljak, Pljani, Herceg Novi and Ulcinj (www.oie-res.me).

Montenegro is also a participant in the cross-border IPA Adriatic project - POWERED. The aim of the project is to explore the potential of wind in the Adriatic Sea. It is realized by setting an anemometer network along the coast of the Adriatic Sea. The analysis of the obtained data will recognize the most favorable locations for the installation of wind turbines (www.powered-ipa.it).

LOCATION KRNOVO

Krnovo is a grassy plateau, surrounded by branches of the Vojnik, which steps down to the Nikšić polje (Radojičić, 2015). It is located in the territory of three municipalities: Niksic, Savnik and Pluzine. The planned project included 26 wind turbines (tabel 1), two overhead transmission lines (Krnovo-Brezna and Brezna-Kličevo), two new substations (Krnovo and Brezna) and buildings for the management of a wind farm. The construction began in May 2015, and the works were completed in October 2016. At the moment, the usage permit is being processed, after which the wind farm will be put into trial for two to three months (www.bankar.me). The wind power output will be 72 MW, and the planned annual output is 200 to 230 GWh. Wind farms are located at an altitude of about 1500 m, while wind generators are at a relative height of 85 m. Near the location of the wind farm there are houses and other facilities used as huts. The nearest village is Grozd (2.3 km), while the nearest town is Šavnik (6.5 km). Transmission line passes through several villages. Six houses are up to 200m from the corridor, and the nearest is only 88m away. The minimum allowed distance from the transmission line corridor is 60m.

Table 1. Results of wind speed measurement (m/s) for the period 09.09.2008-09.09.2009.

Month	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Year
Grozd	6.22	5.29	5.58	8.11	6.66	9.09	8.66	5.01	5.61	5.24	5.34	6.07	7.74	6.24
Bukovik	6.01	4.77	5.22	6.93	5.12	8.46	7.53	4.44	4.99	4.18	4.33	5.15	7.52	6.47
Konjsko	4.29	3.96	4.51	6.89	4.68	6.75	6.55	3.89	4.48	No data				5.66

Source: http://www.oie-res.me/uploads/archive/Izvjestaj%20o%20mjerenjima%20-%20Krnovo.pdf

The project, worth 120 million euros, is realized by Ivicom wind and Akuo Energy, Krnovo Green Energy is responsible for the construction, and the financiers are EBRD, German Development Bank and French Investment Company for Promoting Economic Cooperation Proparco (www.bankar.me).During construction, all standards related to environmental protection and working conditions have been met. The existing asphalt roads have been reconstructed and new roads have been built, which are expected to increase in the future the increase in the number of tourists and sports activities in this

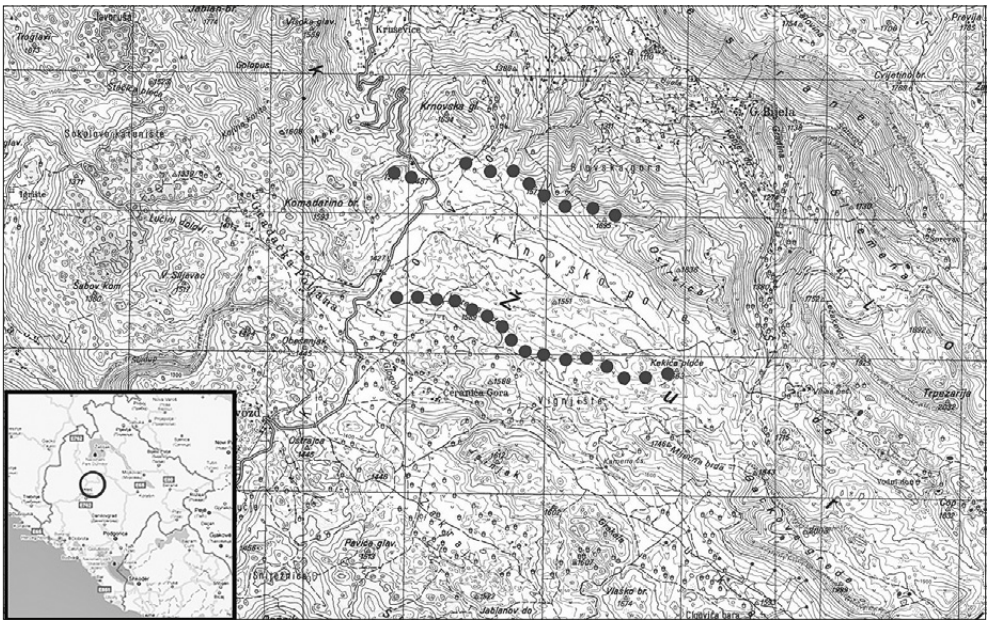

Figure 3: Position of the wind turbine inside the wind farm Krnovo

Source: KGE,2015

region. The project employs a large number of workers, which contributes to the development of the local community.

Possible negative impacts expected during the phase of the operation are: damage to roads during construction works and transport of wind turbines, possible negative impact of wind turbines on birds and blind mice, and noise production during the operation of wind turbines (KGE, 2015).

Despite the listed negative effects, the project has great importance for the economy and sustainable development of Montenegro. The largest wind farm in the Region will significantly contribute to achieving Montenegro's energy goals by 2020, which obliges 33% of total consumption to be from renewable energy sources.

LOCATION MOŽURA

Možura hill (622 m) is located on the coast, between Bar and Ulcinj (figure 4). Due to the rich biological diversity it has been declared as an area of special importance.

In the period from 2008-2009 on this site, observations were carried out for the needs of the construction of a wind farm by Fersa Energias Renovables. Wind speed was measured at altitudes of 40,60 and 68 m. The obtained results were presented in the Report of the analysis of the wind potential measurement at the Možura locality, 2009 (table 2).

Montenegro has concluded a land lease agreement and the construction of a 46 MW installed power plant on July 5, 2010. With this contract, state land has been leased to Fersa Energias Renovables for a period of 20 years. In 2015, the Ministry of Sustainable Development and Tourism issued a building permit for the construction of a wind farm,

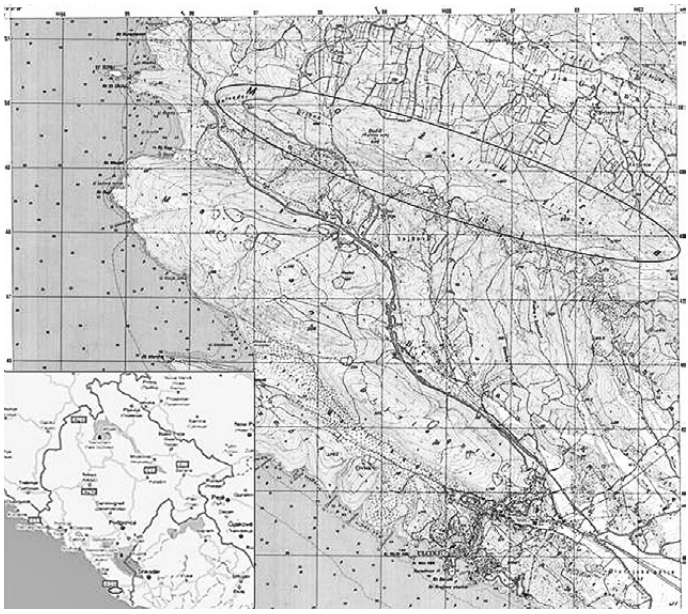

Figure 4. Location of Možura hill
Source: TK 1:25 000, Part of OTK, Ulcinj,VGI, 1980

however, the aforementioned company transferred the rights and obligations from the contract to Enemalta corporation, which showed great interest in investing in the energy sector in Montenegro. Currently, preparatory works are carried out on this site, which include the preparation of access road infrastructure, as well as the excavation of the terrain for future wind generators. The beginning of the main works is expected in the first months of 2017. The project envisages the installation of 23 wind power generators with 2 MW of installed power (www.bankar.me).

Table 2. Measuring height and wind speed for the period 22.05.2008-22.05.2009.

Hight	Retrieved saved data in %	Captures	U* max. m/s	U* min. m/s
68.0 m	100.0	52488	28.8	5.8
60.0 m	100.0	52488	28.6	5.7
40.0 m	100.0	52488	28.1	5.6

Source:http://www.oie-res.me/uploads/archive/Izvjestaj%20o%20mjerenjima%20-%20Mozura.pdf

AREA OF THE ADRIATIC SEA

Montenegro participates in the Coastal Wind Power Project, POWERED, which is financed through IPA Adriatica. The initiator and lead partner of the project is the province of Abruzzo in Italy. Other partners on this project are representatives of Montenegro, Croatia and Albania. The aim of the project is to explore wind potential in the

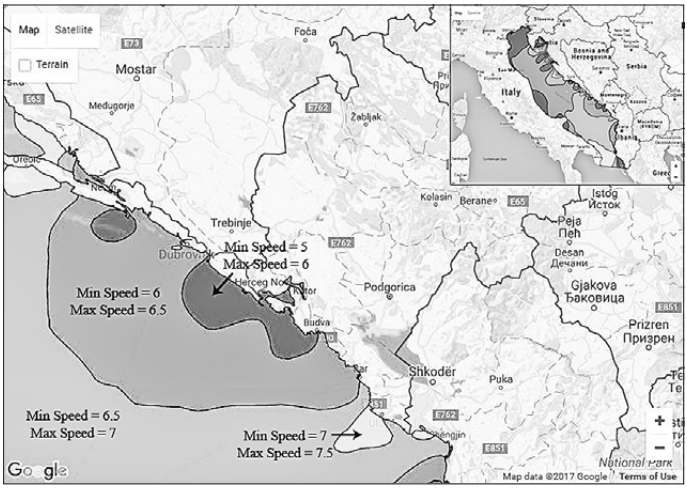

Figure 5: Map of the wind speed in the Adriatic Sea (territory of Montenegro) at a reference altitude of 90m

Source:http://www.powered-ipa.it/

Adriatic Sea to build possible offshore wind farms. For this purpose, the anemometers are located along the Adriatic Sea, on land and on the open sea, at a height of 40-60 m (www.oie-res.me).

On the territory of Montenegro an anemometric station is located in the vicinity of Ulcinj. It consists of eight meteorological towers, with five anemometers and four wind direction sensors, located at five different altitudes: 45, 40, 30, 20 and 10 m (http://www.powered-ipa.it/).

On the basis of the preliminary data obtained, a map of the wind velocity was made at a reference altitude of 90 m (figure 5).

DISCUSSION AND CONCLUSION

The production of electricity from renewable energy sources and the reduction of electricity production from plants using fossil fuels contribute to reducing the emission of harmful gases, primarily carbon dioxide (CO_2), and thus reducing the level of air pollution. Renewal and durability of wind power provides reliable and safe electricity supply, and the possibility of employment during the construction, operation and maintenance phase of the wind farm contributes to the development of the local community (KGE, 2015). At the same time, ecologically pure energy sources are introduced, i.e. Green energy (ESMAP, 2005; Mikičić et al., 2006; Rajović i Bulatović, 2013).

In addition to numerous positive features of wind use for electricity generation, there are also negative sides: initial capital investments are large, because they are built in isolated locations, the costs of transport are higher, and the approach is more difficult, which is especially characteristic for the territory of Montenegro. In addition to economic factors, it is also important to highlight the impact of wind farms on the environ-

ment. It is reflected in disturbing landscape, producing high noise and potential hazards for birds and bets.

Like all other mechanical devices, wind generators produce a certain amount of noise during operation. Much of this noise is masked by the sound of the wind. In recent years, the design of the wind turbine has been perfected so that the sound production is reduced to a minimum. In addition, during construction, the selection of an adequate location and insulation material is important in order to minimize the negative impacts.

Because they require open terrain, most wind generators are very noticeable and have a great impact on the landscape's appearance. However, their visibility does not necessarily diminish the aesthetic value of the area. This is where Location Selection Strategies help. One of these Strategies proposes that a smaller number of wind turbines be installed in different locations within a larger zone, and that larger and more efficient models are used during construction.

One of the biggest and most significant negative effects of the construction of wind farms is their impact on the mortality of birds and bats. Although this effect is related to the construction of other buildings such as chimneys, lighthouses, high buildings, radio and TV receivers, it is also the concern of the wind industry. What has attracted the attention of the professional public is the fact that in some wind farms a higher mortality rate is recorded, while in some it is completely absent. Consequently, numerous studies have been carried out on the movement, crashes and relevant behavior of birds and bats and possible mitigation measures. Designers are obliged to collect relevant data through the monitoring of the current situation and the Assessment of the impact of the planned state. In order to mitigate the negative effects, location selection is also important.

The wind turbines do not produce any exhaust gases and the only danger for polluting the environment is small amounts of oil used for lubrication, maintenance of hydraulics and insulation. Therefore, the possibility of contamination of soil and groundwater is minimal (http://windeis.anl.gov/).

It is estimated that today at least 80 countries use wind energy for electricity generation. At the level of Europe, Denmark and Spain have the greatest potential for using wind power. The Republic of Serbia (1300MW), Bosnia and Herzegovina (900MW) and Croatia (750MW) have the highest wind potential in the area of Southeast Europe. Montenegro has a wind power of 400MW, considering medium-potential zones. Also, the analysis of Ban and associates (Ban et al., 2013), the area of Montenegro has a moderate intensity of wind energy.

By using the mentioned energy potential in order to produce electricity, 20-25% of annual energy consumption could be provided. So far, the Ministry of Economy has submitted the reports of the analysis of the wind potential for two sites, Krnovo and Mozura. At the site Krnovo, the construction of the wind farm started in May 2015, while the start of work at the Mozura locality is expected in March this year. Montenegro, along with Croatia, Albania and Italy, participates in the POWERED Coastal Power Project, financed through IPA Adriatica, which will enable the definition of new sites suitable for the construction of wind farms, especially along the coastal part of the Adriatic Sea.

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