Review of Wind Energy Potential and Experiences from Operation of the First Wind Park in Republic of Macedonia

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Abstract: Wind energy as renewable energy source with the highest growth rate in the last two decades, is considered as a very important source of electricity for the future. According to the study WIND FORCE which is funded and conducted by the EU, the share of wind energy in the global world electricity generation in 2020 is estimated at 12%. Following a study and atlas of wind energy prepared by AWS Truewind, projected installed capacity at four most favorable locations in Macedonia varies from 20 MW to 30 MW per location. First wind park installed and operated by the state-owned electricity producing company (JSC Macedonian Power Plants - ELEM), started with operation in April 2014, on a location near Bogdanci. Analysis and experiences from its operation in terms of investment costs, operation and maintenance costs, electricity production and return on investment period, taking into account current feed-in tariffs for wind energy production in the country are also presented in the article.

Key words: wind, energy, investment, electricity, production

1. Introduction

With its geographical location, Macedonia has plenty of sun, wind and other natural resources needed to produce a renewable energy. In the eastern parts of the country, 130 to 170 days per year are windy, with wind speed averaging 3.5 m/s. Macedonia can theoretically secure 7% of its annual electricity needs by utilizing wind as a source. To reduce the high dependence on fossil fuels that reaches 80% of total electricity production in the country, as well as to reduce impact on climate change and prevent environmental pollution, Macedonian Government took some steps in the direction of renewable energy utilization. Based on the Preliminary Atlas of winds for Republic of Macedonia prepared by AWS Truewind in 2005, [1], four measuring stations with high-quality testing equipment in four different locations with sufficient wind energy potential were installed.

With the preparation of the feasibility study completed in 2010, information on physical characteristics, economic and financial feasibility, environmental, social and other impacts of the wind farm project were obtained, [2].

In April 2014, the first wind park installed and operated by the state-owned electricity producing company (JSC Macedonian Power Plants - ELEM), started with operation on a location near the town of Bogdanci.

According to the Strategy for utilization of renewable energy sources in Republic of Macedonia till the year 2020, Energy Law and the Decision of the Energy Regulatory Commission of the Republic of Macedonia, the maximum planned installed capacity of wind power plants in the electric power system is from 150 to 180 MW, with expected annual electricity production ranging from 300 to 360 GWh [3, 4].

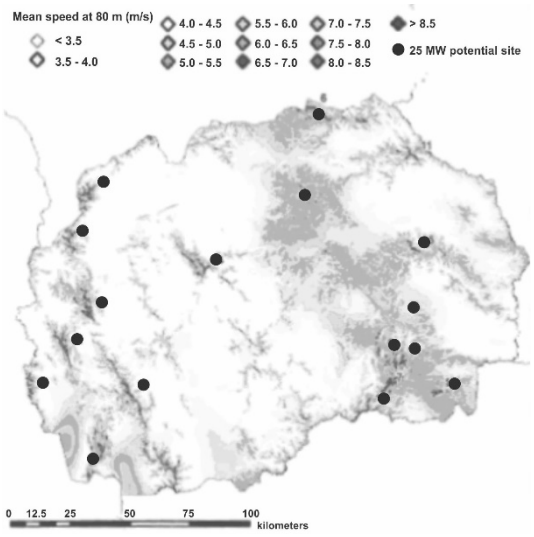


Figure 1. Map of most favorable locations for building of wind farms, [1]

2. Cumulative wind power capacity in EU and in the world

Wind power continues to expand worldwide, reflecting the reduced cost of turbines, expanding policy support and growing investor recognition of the positive characteristics of wind generation. In 2014, wind power reached more than 3% share of the world's electricity supply, [5]. In 2015, China led this development with installed capacity additions of 32.9 GW, followed by the United States with 8.6 GW and Germany with 4.9 GW, [6]. International Renewable Energy Agency (IRENA) in its report REmap 2030 has indicated that of the total electricity production in 2030, estimated at 37 thousand TWh, wind energy will account for 12%, i.e. 4.4. thousand TWh, [7].

Total cumulative wind power capacity installed in Europe by the end of 2016 was 161330 GW with a share of EU-28 countries of about 153729 GW (Germany – 50018 GW; Spain – 23074 GW; UK – 14543 GW; France – 12066 GW; Italy – 9257 GW; Sweden – 6520 GW; Turkey – 6081 GW; Poland – 5782 GW; Portugal – 5316 GW; Denmark – 5.228 GW; Netherlands – 4328 GW; Romania – 3028 GW; Ireland – 2830 GW; Austria – 2632 GW; Belgium – 2386 GW and the rest of Europe (Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Faroe Islands, Macedonia, Hungary, Iceland, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Norway, Romania, Russia, Switzerland, Slovakia, Slovenia, Ukraine) – 8241GW, [6].

In the world, global installed wind power capacity by the end of 2016 was 486749 GW. In Figure 2, global cumulative installed wind capacity in the world from 2001÷2016 is shown.

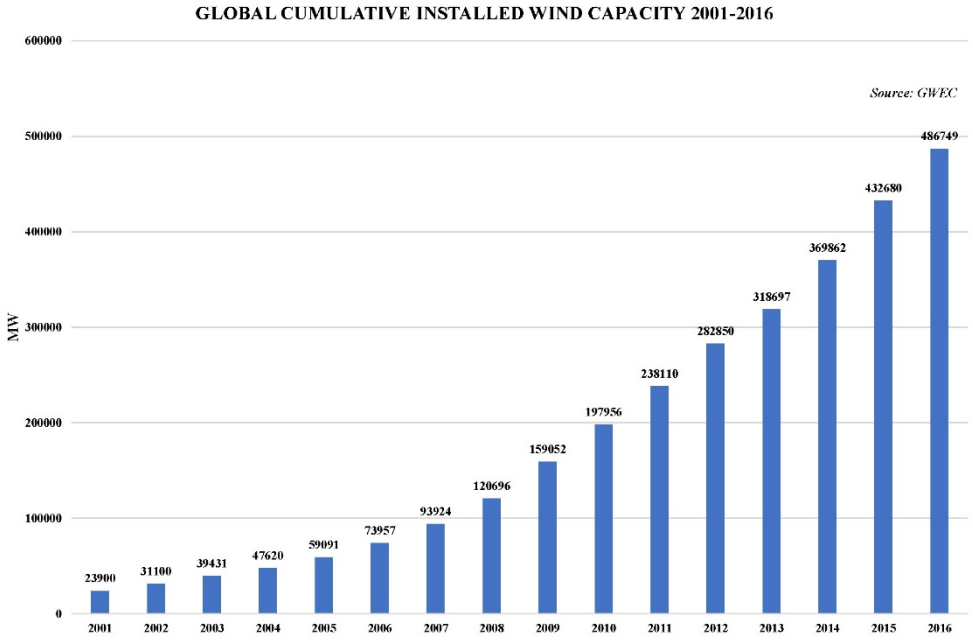
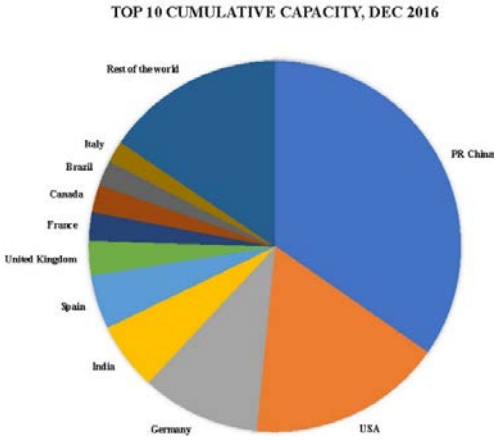


Figure 2. Cumulative wind power installations in the world from 2001-2016

By the end of 2016, China remained in the world with the largest cumulative capacity of 168690 GW or share of 34.7%, followed by the USA with 82184 GW (16.9%), Germany with 50018 GW (10.3%), India – 28700 GW (5.9%), Spain – 23074 GW (4.7%), the UK – 14543 GW (3.0%), France – 12066 GW (2.5%), Canada – 11900 GW (2.4%), Brazil – 10740 GW (2.2%), Italy 9257 GW (1.9%) and the rest of the world with 75577 GW or share of 15.5%. It can be concluded that total top ten cumulative capacities by the end of December 2016 share about 84% or 411172 GW. Unfortunately, in this global card Republic of Macedonia is not present due to its relatively small wind power installations.



Country	MW	%Share
PR China	168690	34.7
USA	82184	16.9
Germany	50018	10.3
India	28700	5.9
Spain	23074	4.7
United Kingdom	14543	3.0
France	12066	2.5
Canada	11900	2.4
Brazil	10740	2.2
Italy	9257	1.9
Rest of the world	75577	15.5
Total TOP 10	**411172**	**84**
World Total	**486749**	**100**

Source: GWEC

Figure 3. Top ten cumulative capacity by December 2016

3. Installation, operation and maintenance costs

Installation costs together with operation and maintenance (O&M) costs are the main elements of electricity production cost from wind energy. For onshore wind, turbine costs dominate, while the rotor blades and tower account for nearly half of the total cost of a turbine. Major factors in reducing the LCOE (Levelized Cost of Electricity) for wind power are larger turbines and large-scale installation of wind farms. The levelized cost of electricity (LCOE), also known as Levelized Energy Cost (LEC), is the net present value of the unit-cost of electricity over the lifetime of a generating asset, [8]. Because larger turbines harness strong wind at higher altitudes, they produce more electricity per unit of installation area, thereby reducing both the number of turbines and the land area needed per unit of output. Large-scale installation of wind farms increases the economies of scale and reduces costs for transport, installation and O&M. For onshore wind, the regional weighted average installed cost in 2014 was between 1128 EUR per kW and 2018 EUR per kW. O&M costs typically account for 20-25% of the LCOE for onshore wind, ranging from 0.0044 EUR per kWh to 0.022 EUR per kWh1, [9].

Table 1. Capital cost for onshore wind power systems

Cost share of:	Onshore (%)
Wind turbine	64 – 84
Grid connection	9 – 14
Construction	4 – 10
Other capital	4 - 10

4. Wind energy utilization in Macedonia

Wind energy as a renewable energy source with the highest growth rate in the last two decades, is considered as very important source of electricity production in future. The forecasts for development of wind energy are highly optimistic and state that this type of energy will be really important in the future. In order to obtain more realistic picture of the true wind energy potential, and also to stimulate broader support for the development and use of the renewable energy sources, further research and measurements on determined locations are required, [10].

Preliminary Atlas of winds determined that the best wind resources in Macedonia are on the mountain tops, whereas on the plains and in the valleys wind has lower average velocity. Nevertheless, the hills along the river Vardar, in the area between towns of Kavadarci and Gevgelija (southeastern part of Macedonia), prove that even areas where the altitude is lower having potential for wind resources. The average velocity of the wind in this area is 7 to 7.5 m/s on an altitude of 500-800 meters above sea level. Taking into account the measurements performed and previous meteorological data regarding winds blowing in this area, including wind rose, Figure 4, location for the first wind was determined.

[1] Calculations are made in accordance with average exchange list of USD vs EUR at National Bank of the Republic of Macedonia on 05.07.2017

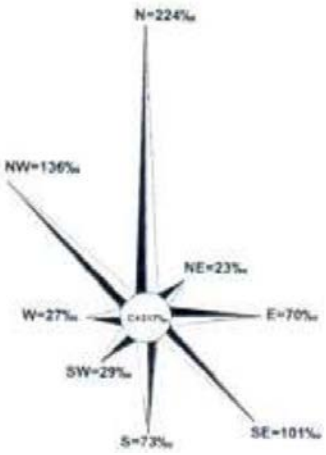


Figure 4. Wind rose for the chosen location

In 2013, state owned electricity production company 'Elektrani na Makedonija - ELEM' started to build the first wind farm near the city of Bogdanci.

Taking into account the available financial resources of the company, it was agreed that the wind park will be installed in two phases:

first phase with installed capacity of 36.8 MW and net annual production of 90 GWh, and second phase with additional capacity of 13.8 MW and additional net annual production of 33 GWh.

For this purpose, a total of 16 wind turbines, each with installed capacity of 2.3 MW were installed, in order to achieve a total nominal capacity of 36.8 MW, which was expected to generate a total of 89.5 GWh per year. The layout of the wind farm consists of a total of 22 wind turbines which are oriented in one line, following the highest parts of the ridge. The layout of the complete wind park (with 22 turbines) is shown on Figure 5, [2].

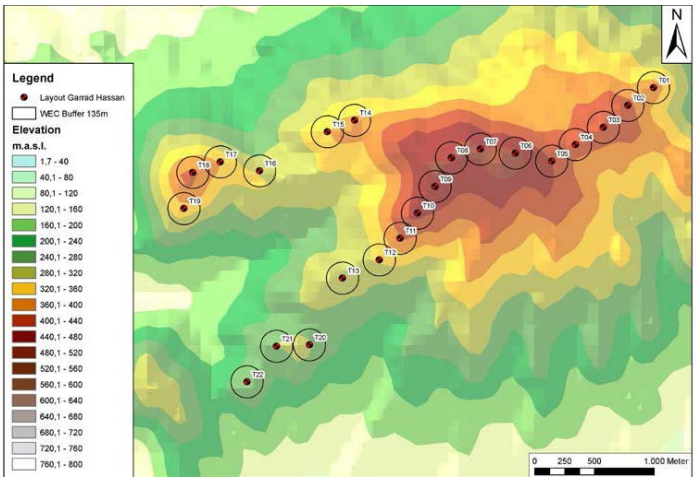


Figure 5. Layout of turbines for complete wind park

Most important technical characteristics of installed wind turbines, type Siemens 2.3 MW-Mk II are shown in Table 2.

Table 2. Technical specifications of Siemens 2.3 MW-Mk II wind turbine

Rotor		**Blade**	
Type	3 bladed, horizontal axis	Type	Self-supporting
Position	Upwind	Blade length	45 m
Diameter	93 m	Tip chord	0.8 m
Swept area	6800 m2	Root chord	3.5 m
Synchronous rotor speed	6 – 16 rpm	Material	GRE
Power regulation	Pitch regulation	Surface gloss	Semi-matt, <30/ISO 2813
Rotor tilt	6 degrees	Surface color	Light grey, RAL 7035
Generator		**Operational data**	
Type	Asynchronous	Cut-in wind speed	4 m/s
Nominal power	2300 kW	Nominal power at approx.	13 – 14 m/s
Synchronous speed	1500 rpm	Cut-out wind speed	25 m/s
voltage	690 V	Maximum 2s gust	55 m/s (standard version)
Frequency	50 Hz		60 m/s (special version)
Protection	IP54		

According to the wind map and measured values at 4 locations, projected installed capacity by location, varies from 20 MW to 30 MW. On the other site, measured data in Macedonia shows that the effective factor of wind farm with installed capacity of 30 MW is between 0.13-0.25. This means that expected annual generation of wind power park with average installed capacity of 25 MW ranges from 30 GWh to 55 GWh. It should be emphasized that from the beginning of the operation of wind park 'Bogdanci' estimated production of electricity was exceeded by 25%, thus providing justification for the realization of the second phase, but also for implementation of similar projects near Bogdanci or other areas with wind abundance in Macedonia. In meantime, ELEM acquired software for wind energy project design and planning windPRO, [11], for analysis of data regarding wind direction and speed, obtained from measuring stations.

4.1. Investment costs and financial analysis of the project

In 2014, the wind farm generated electricity of 70.387 GWh, which is 2.13 times greater than the planned 33.048 GWh. Instead of the planned 95.544 GWh, electricity generation reached 120.768 GWh in 2015, which is 26.40% more than planned. In 2016, electricity production was 109.458 GWh, i.e. 5.43 % more than planned 103.848 GWh for that year, [12].

In the first three months of this year, electricity production in wind park 'Bogdanci' was 28.066 GWh, or 14.87 % more than the planned 24.432 GWh, [13].

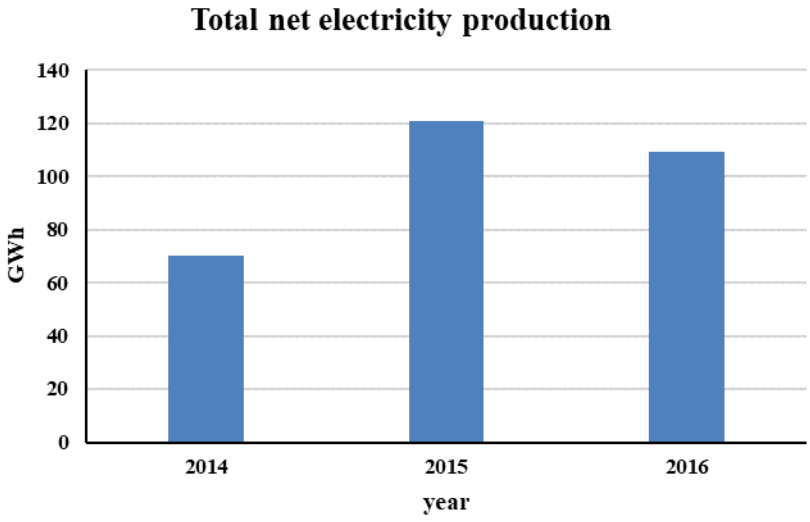


Figure 6. Total net electricity production from wind park for the period 2014 – 2016

Investment for the first phase totals 55.5 million EUR (MEUR), out of which 47.9 MEUR were provided by a loan from Germany's KfW bank, while the rest were funded of JSC ELEM. Investment of 24 MEUR is necessary for the realization of second phase, out of which 18 MEUR will be credited by a bank, and the rest will be funded from company's own resources. The entire administrative and logistical support for the second phase of the wind park 'Bogdanci' is already completed, including economic analysis, adopted investment decision on the continuation of the project, Ministry of finance has been addressed with a request for borrowing and also, KfW bank committed a mission, [14].

In accordance with the Energy Regulatory Commission of the Republic of Macedonia which has implemented a feed-in tariff of 89 EUR/MWh for buying and selling of electric energy produced and supplied by wind stations, [15], the profitability of this kind of projects and further development of this very important part of country's energy sector must be considered.

In this context, annual income from wind electricity production for 2014 was 6.26 MEUR, for 2015 – 10.75 MEUR and 9.74 MEUR for 2016.

Calculated average annual income from wind electricity production for this period (2014-2016) is 8.92 MEUR.

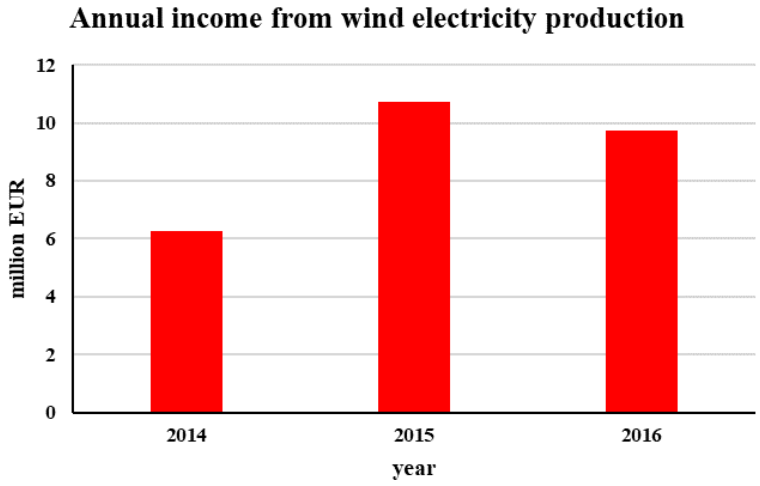


Figure 7. Annual income from wind electricity production in the Republic of Macedonia for the period 2014-2016

Taking into account the regional weighted average installed cost in 2014 which was about 1589 EUR per kW or 1.589 MEUR per MW, [9], it is obvious that the average installed cost for 36.8 MW from the first phase is about 58.4752 MEUR.

On the other side, O&M for onshore wind, ranging about 0.022 EUR per kW or 22 EUR per MW, so weighted average O&M cost for the same 36.8 MW installed capacity is 810 EUR.

The payback period (also called Simple Payback – SP) of the project is calculated as (58.476 MEUR)/(8.92 MEUR) = 6.56 years. This is the length of time it takes for the initial investment to be repaid out of the net cash inflows from the wind farm installation.

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. It is calculated by the following formula:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

where: Ct – net cash inflow during the period t; C0 – total initial investment costs; r – discount rate; t – number of time periods.

A positive net present value indicates that the projected earnings generated by a project or investment (in present dollars) exceeds the anticipated costs (also in present dollars). Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss.

In our case, if we assume discount rate of 6%, [16], the NPV for the project is calculated as 7.176 MEUR. This summates all the cost and benefits over the twenty-year period of the project. This period corresponds to the duration of concession for feed-in tariff.

5. Conclusions

Renewable energy sources became very important and attractive in the last two decades. Power generation from renewable sources is growing from year to year and will continue to grow in the coming years. Republic of Macedonia is trying to attend this process and make big efforts to increase production of electricity from renewable energy sources. In this direction, the first wind park installed and operated by the state-owned electricity producing company (JSC Macedonian Power Plants – Elektrani na Makedonija, ELEM), started with operation in April 2014, on a location near the town of Bogdanci. Taking into account the available financial resources, it was agreed that the wind park will be installed in two phases: the first phase with installed capacity of 36.8 MW (estimated net annual electricity production of 90 GWh), and the second phase with 13.8 MW (estimated net annual electricity production of 33 GWh). When completed, this wind park will have total installed capacity of 50.6 MW and estimated annual electricity production of 120 GWh. Initial experiences from the operation of the wind park show that this was a good investment. If we exclude the first year of operation (2014), realized electricity production was, in average, around 16% higher than planned. Accordingly, the wind park has a status of privileged electricity producer from renewable energy sources and uses feed-in tariff of 89 EUR per produced MWh of electricity. Simple payback period of the project, with the average electricity production from the first three operational years is 6.56 years, while the Net Positive Value of the project is positive, calculated at over 7 million EUR, indicating that the risks associated with the investment were worth taking.

Furthermore, four measuring stations with high-quality testing equipment are installed in additional pre-determined locations across the river Vardar, near the wind park 'Bogdanci', in the areas of the villages Miravci and Davidovo. Realization of another wind park in some of these locations is even more feasible with the construction of the new highway section Demir Kapija – Smokvica, part of the pan-European corridor 10, thus making these remote locations more accessible. Potential for installation of another 100 MW of wind turbines is expected at these locations, if the results are similar to those obtained with measurements at the wind park 'Bogdanci', [17].

Installation of new wind parks would have positive implications for the Macedonian electric power sector, business climate, foreign investments and local economy. Measurements should also provide justification for the realization of the second phase of the first wind park in the country and for implementation of similar projects near Bogdanci. As far as Republic of Macedonia is concerned, having in mind positive experiences from the operation of the first wind park, it is necessary to continue and expand the exploitation of wind energy.

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