Prof. Saša Žiković
Faculty of Economics University of Rijeka
I. Filipovic 4, Rijeka
Phone: 00385 51 355 111
E-mail address: szikovic@efri.hr

Ivan Gržeta
Faculty of Economics University of Rijeka
I. Filipovic 4, Rijeka
Phone: 00385 51 355 111
E-mail address: igrzeta@efri.hr

Ivana Tomas Žiković
Faculty of Economics University of Rijeka
I. Filipovic 4, Rijeka
Phone: 00385 51 355 111
E-mail address: itomas@efri.hr

EMPIRICAL ANALYSIS OF WIND POWER GENERATION PROFITABILITY IN CROATIA*

EMPIRIJSKA ANALIZA ISPLATIVOSTI ULAGANJA U VJETROELEKTRANE U HRVATSKOJ

ABSTRACT

There is an ever-growing importance of renewable energy sources in today's world. The need for the renewable energy emerged due to the perception of scarcity of fossil fuels, their high costs, as well as their geopolitical concentration and oligopoly of certain companies and countries. One of the renewable energy sources, which is very popular in Croatia, is the wind power. A significant hurdle in assessing the viability of investing in wind farms is the stochastic nature of wind, variable and often hidden costs of construction and maintenance, which depend on the position of wind farms, as well as their relatively low efficiency. All of these factors make the wind farms completely dependent on the heavily subsidized renewable electricity prices. When calculating the cost-effectiveness of a complex project such as the wind farm, it is not possible to use traditional methods of valuation, such as the method of net present value and internal rate of return. Under the national strategy of promoting renewable energy, wind farms have been given top priority as an alternative energy source, but due its unpredictability, investors are not fully confident in the viability of such projects. The purpose of this paper is to investigate the reality of assumptions behind the classical valuation of wind farm projects by using Monte Carlo simulation. Unlike the traditional methods, Monte Carlo simulation provides a broader and a more realistic view of the project valuation and provides an insight into the key variables that determine the investment's profitability. It also provides us with input/output flexibility, and possibility to adapt to market changes. Our results show that investing in wind farms in Croatia, under the current circumstances, is only marginally profitable. Although traditional valuation methods suggest the opposite, detailed analysis shows a lot of critical points and project viability seems highly questionable.

* Financial support from the Croatian Science Foundation under Grant number IP-2013-11-2203 and University of Rijeka Grant number 13.02.1.3.05 is gratefully acknowledged.

Key words: *Profitability analysis, Energy, Wind power, Renewable energy, Croatia*

SAŽETAK

Obnovljivi izvori energije u današnjem svijetu imaju izuzetno veliku važnost obzirom da je rezultat korištenja fosilnih goriva veliko narušavanje prirodne ekosfere i povećanje antropogenske emisije stakleničkih plinova. Potreba za obnovljivim izvorima energije javila se zbog percepcije oskudnosti fosilnih goriva, visoke cijene, kao i njihove geopolitičke koncentriranosti i oligopola pojedinih kompanija i zemalja. Jedan od obnovljivih izvora energije, koji je veoma popularan u Hrvatskoj su vjetroelektrane. Veliki problem kod ocjene isplativosti projekata izgradnje vjetroelektrana je nepredvidivost vjetra, teško odredivi i često skriveni troškovi izgradnje i održavanja koje ovisi o položaju vjetroelektrana, te njihova relativno niska efikasnost koja uvelike ovisi o subvencioniranim cijenama otkupa električne energije. Pri izračunu isplativosti kompleksnog projekta kao što je izgradnja i eksploatacija vjetroelektrane, nije moguće koristiti tradicionalne metode vrednovanja investicija, kao što su npr. metoda neto sadašnje vrijednosti i interne stope rentabilnosti. U nacionalnoj strategiji poticanja obnovljivih izvora energije vjetroelektrane su dobile veliki značaj kao alternativni izvor energije, no zbog njene nepredvidivosti povrata uloženih sredstava, investitori nisu u potpunosti sigurni u isplativost takvog projekta. Upravo zbog toga, svrha ovog rada je istražiti realnost klasičnog vrednovanja projekata izgradnje vjetroelektrana korištenjem Monte Carlo simulacije distribucija vjerojatnosti. Monte Carlo simulacija, za razliku od tradicionalnih metoda, pruža širi i realniji uvid u vrednovanje projekta te također daje uvid u kritične varijable na koje treba obratiti pozornost, a koje imaju najveći utjecaj na profitabilnost ulaganja. Također daje mogućnost fleksibilnosti inputa i outputa, odnosno mogućnosti prilagođivanja (korigiranja prvobitnih odluka) u skladu s tržišnim promjenama. Na temelju izračuna isplativosti ulaganja u vjetroelektrane na prostoru Hrvatske zaključeno je da je ova vrsta projekata granično isplativa. Iako nam tradicionalne metode izračuna isplativosti sugeriraju suprotno, detaljnijom analizom vidljivo je da projekt ima puno kritičnih točaka što i samu isplativost ulaganja čini veoma upitnom.

Ključne riječi: *Analiza isplativosti, Energetika, Vjetroelektrane, Obnovljivi izvori energije, Hrvatska*

1. Introduction

A wind power plant uses wind as its fuel for the production of electricity and is seen as a source of energy that does not emit greenhouse gases in the generation phase. Unfortunately it is often overlooked that in the machinery production and wind farm construction phases a significant amount of greenhouse gases are emitted and therefore we can say that wind power plants are "quasi CO_2 neutral". A wind farm (WF) consists of several components: pole, blades, housing, rotor, brake, power transmitter, control and monitoring systems, substations, transformers, cables, wires and other associated structures. The wind power plant converts the kinetic energy of the wind into mechanical energy, and through the generator it is converted into electrical energy. The harnessing of wind power as a renewable energy source has gained popularity in Croatia during the last several years. The technological feasibility of employing large WFs to produce electricity, together with the large amount of available wind energy, is the source of their attractiveness. Given the relatively high starting investment costs, volatile nature of the wind and technological limitations of wind power generators the realization of this potential becomes constrained by financial considerations. Besides the popularity of "green" and "renewable" energy and the positive consumer perception of companies promoting such trends and technologies the main driver of investing into renewable energy in Croatia is the feed-in tariff system. Croatian feed-in tariff system pays out a premium over the market price to the investors in order to promote investments into this sector. Since Croatia does not produce wind turbines, blades, poles etc. from a strictly macroeconomic perspective this sort of financial incentives do not create any benefits for the state but represent only expenses. Furthermore, the import of equipment worsens the country's trade balance and since a lot of investors are foreign the funds paid through the feed-in tariff are eventually siphoned from the country. Besides the general concern for the environment the only logical reason for giving a privileged position and incentives to WFs as opposed to the traditional power generators are the European 2020 renewable energy goals.

Despite the wide range of studies and policy statements about the capital cost estimates and guarantied returns the question remains whether investing in WFs is profitable when taking into account all of the critical. In order to answer this question we investigate the viability of WFs in Croatia. Building on the previous studies in this area we extend the classical profitability analysis by performing Monte Carlo simulations of all the critical factors and evaluate their impact on the profitability of WFs. The rest of the paper is organized as follows: in the Section 2 we present the technical boundary conditions of the analyzed wind power generators. Section 2 continues with the analysis of WF construction and operational costs. In section 3 we set up our simulation model used to analyse the profitability of WFs and present our results. Final section concludes.

2. Wind power and wind farms

Given that wind energy is one of the renewable energy sources, its purchase price is co financed by the state. This is the practice in most EU countries including Croatia. This means that the state is obligated to buy the electricity produced from renewable energy producer at a predetermined price. Currently Croatia has a feed-in tariff system under which the state pays a predetermined price for electricity produced from renewable sources depending on the type of the source and the installed power. The purchase price for electricity produced from wind is 0.72 HRK(0.0973 €)/kWh for plants up to and including 1 MW, while for power plants larger than 1 MW of installed power the price is 0.71HRK(0.0959 €)/kWh (HROTE, 2014).

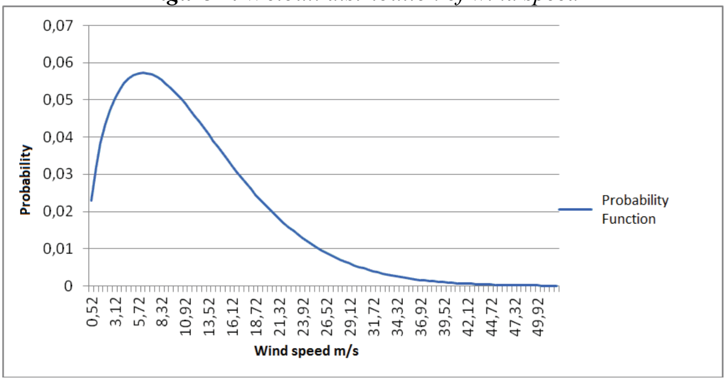
Croatia has tens of locations suitable for WFs. Measurements of speed, direction and frequency of wind showed that the utilization of wind potential is more suitable in the Adriatic coast than in the continental Croatia. The most interest was shown for the locations around Zadar, Sibenik, Knin, Split and Dubrovnik. Currently there are 16 WFs that supply electricity to Croatian power system. Their installed capacity is 339.25 MW and they annually deliver around 730 GWh of electricity, which accounts for 79% of electricity produced from renewable sources (HROTE, 2014).

Expansion of wind power generation in the upcoming years is expected, because in addition to the great interest of investors, by joining the EU, Croatia has to meet obligations under the EU Commission Directive 2013/18/EZ which demands that by the end of 2020, the minimum share of the electricity produced from renewable energy sources is 20% of the total final consumption of electricity (HROTE, 2015).

2.1. Technical boundary conditions of the wind turbines

For the purposes of this study, the expenditures and revenues are projected from the already existing WF Vratarusa (installed power 42 MW). We have taken WF Vratarusa as our starting point because the construction, operation and production of electricity are very similar to other planned projects on the Adriatic coast. The WF Vratarusa uses 14 Vestas V90 wind turbines, each with 3MW of nominal power. We analyse a WF with just two Vestas V90 wind turbines. According to the official technical specification wind turbines start producing at a wind speed of 3.5 m/s, and shut down at 25 m/s. Wind turbine achieves the maximum power at a wind speed of 15 m/s and that output level is maintained up to 25 m/s when it shuts down. Wind speed can be best described by the Weibull distribution and as such it is the most widely used distribution to display the probability distribution of the meteorological phenomena (Poje, 1996, 6; Jeromel, Malačić, Rakove, 2009, 94). The average annual wind speed at 80 meters height in the area we analyse is 7.31 m/s (MHS, 2013). Weibull distribution of our wind speed data is given in figure 1.

***Figure 1:** Weibull distribution of wind speed*



Source: Authors

2.2. Wind farm building expenditures

Almost 75% of the total WF costs are connected to the investment costs, such as: turbines, foundations, electrical equipment, land rent, connection to the power grid etc. Obviously the fuel and labour costs have almost no effect on the price, so we can say that WFs are capital-intensive compared to conventional technologies such as gas fired power plants. The following table shows the typical expenditures of building WFs.

***Table 1:** Expenditure structure of a typical 2MW wind farm installed in the EU*

	INVESTMENT (€1000/MW)	SHARE IN TOTAL COSTS %
Turbine	928	75,6
Connection to network	109	8,9
Foundations	80	6,5
Land rent	48	3,9
Electrical installations	18	1,5
Consultans	15	1,2
Financial expenses	15	1,2
Road construction	11	0,9
Control systems	4	0,3
TOTAL	1227	100

Source: Windenergie, 2009, p. 9

When these investments are added to the cost of operation, maintenance, administration, insurance and other costs we get the total cost of production of electricity from wind power. The investment in the construction of WF Vratarusa averaged 4,428,571 € (at 7.4 HRK/€ rate 32.771.425 HRK) per wind turbine. Croatian Bank for Reconstruction and Development offers special interest rate of lending for renewable energy projects. The interest rate on these loans is fixed at 4% per year, with a fee of 0.8% and the loan can be approved for up to 75% of the total investment (HBOR, 2015).
Wind turbines, just like all other industrial equipment, need maintenance which constitutes a large share of the annual operational costs. Maintenance costs are comprised of: insurance, regular maintenance, repairs, spare parts and administration. While costs such as insurance or regular maintenance are relatively fixed because they can be planned, costs which include spare parts and repairs are much harder to predict and identify. According to the experience from Germany, Spain, Great Britain and Netherlands, costs are estimated to be between 0.012 and 0.015 €/kWh. Approximately 60% of these costs are connected to the maintenance of turbines (Wind Energy,

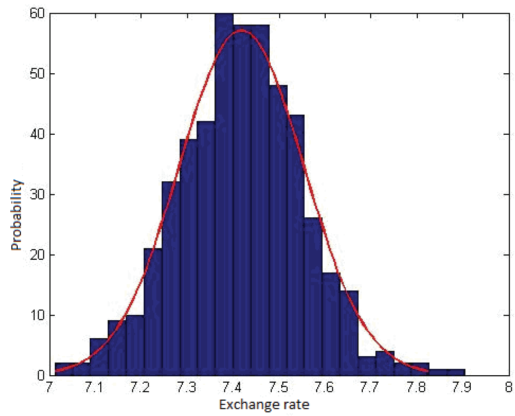
2013, 9). A Bloomberg (2012) survey disclosed that the average cost of installed MW of wind power is 19.200 € which is more than 50% less compared to just the maintenance costs in 2001, while these costs are 38% lower than they were in 2008. According to the Bloomberg (2012) survey, which was conducted with 38 major wind turbine manufacturers and maintenance service providers, there are two reasons for such a drastic decline; First, the average price of the total maintenance services has declined due to the increased competition, the desire of the manufacturers to sign service maintenance contracts and greater durability of new turbines. Second, the average duration of contract has risen from 4.5 years in the 2008 to 6.9 years in 2012, since the producers want to lock in the long-term contracts. Part of the reason for such a large drop in maintenance costs also lies in the increased demand for wind turbines, thus achieving greater competition and economies of scale. Number of installed WFs in the EU grew considerably over the past years, from 814 MW in 1996 to 128.8 GW in 2014, which is an annual growth of 30.5% (EWEA, 2015, 3).

3. Investment evaluation under uncertainty conditions

Monte Carlo simulation is a simulation using random number generator and is useful for forecasting, estimation and risk analysis. Its' basic principle is the calculation of the distribution function of random variables. It is necessary for each random variable to generate a set of samples to be subjected to a given theoretical distribution, then for each set of samples we calculate the part of the function being simulated. The simulation starts with the selection of key variables and determining their probability distributions. Having determined the parameters of the probability distribution for each variable all the variables are combined with each other by calculating the net present value. This process is repeated several hundred times until we get a representative probability distribution of possible future net present values. The mean distribution is the expected value of the project, while the standard deviation of the distribution is a measure of volatility for the evaluation of the project (Žiković, Fatur, 2011, 177).

In case of WF our revenues consists of the guaranteed purchase price and the total production of electricity. However, when using Monte Carlo simulation we have to account for the likelihood of the speed of wind, which we do by using the Weibull distribution. Our total production of electricity is the probability function of wind speed and technical characteristics of the wind turbine. The expenditures consists of capital expenditures and variable/operational costs. Repayment of the loan needed for the investment has a Euro currency clause, meaning that the loan annuities change depending on the HRK/€ FX fluctuations. Monthly HRK/€ exchange rates are obtained from the official website of the Croatian National Bank (CNB, 2015). Based on the log likelihood results of fitting different distributions to the monthly FX data we find that normal (Gaussian) distribution give a very good fit to the empirical data. The empirical distribution of HRK/€ FX rate with a superimposed normal distribution (mean = 7.42, st. deviation = 0.13497) can be seen in the following figure.

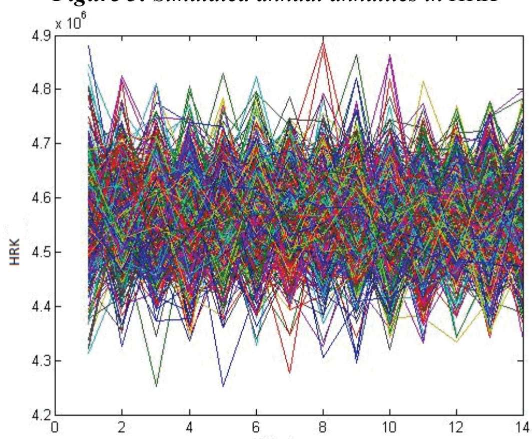
Figure 2: *Empirical and the normal distribution of HRK/€ exchange rate*



Source: Authors

We multiply the annuity in € with the HRK/€ FX distribution to obtain the distribution of the value of annuity in HRK. Simulated annual annuity movements are shown in the following figure.

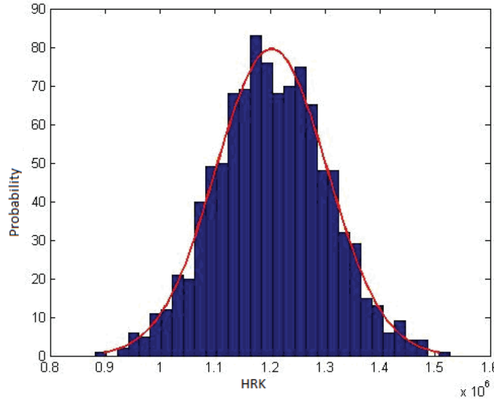
Figure 3: *Simulated annual annuities in HRK*



Source: Authors

For the yearly operational costs normal distribution, with the mean of 1.2 million HRK and standard deviation of 100.000 provided a very good fit to empirical data, which is visible from the following figure.

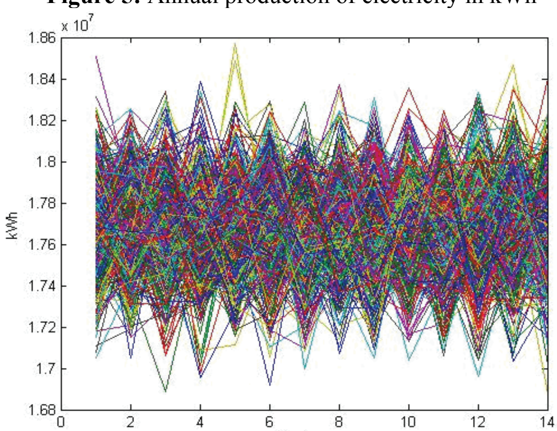
Figure 4: *Operational costs in HRK*



Source: Authors

Based on the Weibull distribution of wind speed and technical characteristics of Vestas V90 turbines we performed the Monte Carlo simulation. The results show that the production of electricity (in kWh), for the duration of the signed contract with the state (14 years), would range between 17 and 18.4 million kWh per year, which can be seen in the following figure.

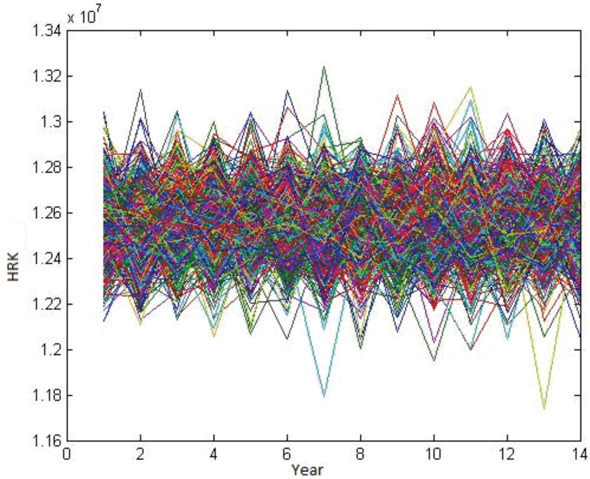
Figure 5: Annual production of electricity in kWh



Source: Authors

Total revenue would range, taking into account the purchasing price of electricity (0.71 HRK/kWh), between 12 and 13.1 million HRK. Annual revenues in HRK are shown in figure 6.

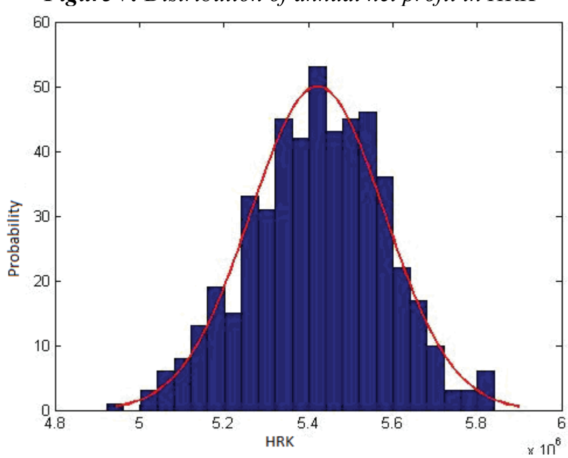
Figure 6: *Annual revenues in HRK*



Source: Authors

The annual net profit, after subtracting the distributions of operational costs, annuities and income tax, would be between 5 and 5.8 million HRK, as shown in figure 7.

Figure 7: *Distribution of annual net profit in HRK*



Source: Authors

With the obtained probability distribution function of annual net profits we can determine the central and extreme values of the internal rate of return (IRR) and the results are shown in table 2.

Table 2: *Simulation based internal rate of return for the WF project*

Year	min	mean	max
0	-53.864.286	-53.864.286	-53.864.286
1	5.001.325	5.422.100	5.805.157
2	5.001.325	5.422.100	5.805.157
3	5.001.325	5.422.100	5.805.157

Year	min	mean	max
4	5.001.325	5.422.100	5.805.157
5	5.001.325	5.422.100	5.805.157
6	5.001.325	5.422.100	5.805.157
7	5.001.325	5.422.100	5.805.157
8	5.001.325	5.422.100	5.805.157
9	5.001.325	5.422.100	5.805.157
10	5.001.325	5.422.100	5.805.157
11	5.001.325	5.422.100	5.805.157
12	5.001.325	5.422.100	5.805.157
13	5.001.325	5.422.100	5.805.157
14	5.001.325	5.422.100	5.805.157
IRR	**3,7%**	**4,9%**	**6,0%**

Source: Authors

When calculating the IRR of this project in the classical way, with constant values, the obtained IRR equals 5.7%. From the table 2 we see that the average IRR obtained by using the Monte Carlo simulation is lower than given by the classical approach. The IRR value of 5.7% given by the classical method of calculating the profitability of the project, in our simulation is only possible under the best case scenario, a set of assumptions that has a low probability of occurring. The most likely internal rate of return will amount to 4.9%, which is 0.8 percentage points less than given by the classical calculations of the cost-effectiveness of the project. If we assume a discount rate of 5% we can conclude that the net present value of this project will only be positive under the best case scenario. The most likely outcome (4.9%) would give us a marginally negative net present value. The results obtained by using the Monte Carlo simulation are different from the classical calculation of profitability, and based on Monte Carlo simulation results it is possible that the investor could withdraw from the project.

4. Conclusion

The efficiency of WF construction project has been assessed using the Monte Carlo simulation based calculation of internal rate of return (IRR). Based on the classical evaluation of the project by the internal rate of return, using constant values and estimates, we obtain an IRR of 5.7% which would yield a positive net present value if using a 5% discount factor. However, the classical, constant value approach fails to evaluate an important fact, namely the production possibilities of wind generators, the characteristics of the wind speed in the area, exchange rate fluctuations and changes in variable costs. Taking these variables into account, we see that the project is less profitable, and that the expected internal rate of return equals 4.9%. On the positive side the internal rate of return of the lower limit (worst case scenario) is also positive and amounts to 3.7%. However, the net present values are negative, except in the best case scenario version. Taking this into account, investors should carefully reevaluate the investment in WFs and all the risks that they entail. With no additional government incentives related to the co-financing of interests or co-financing land rents, investments in WFs in Croatia can be considered only marginally profitable.

REFERENCES

Bloomberg, (2012): ***Wind farm operation and maintenance costs plummet,*** https://www.bnef.com/PressReleases/view/252

DHMZ, (2015): ***Croatian wind atlas,*** http://mars.dhz.hr/web/index.htm

EWEA, (2015): ***Wind in power: 2014 European statistics***, http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2014.pdf

HBOR, (2015): ***Program kreditiranja projekata zaštite okoliša, energetske učinkovitosti i obnovljivih izvora energije,*** http://www.hbor.hr/sec1406

CNB, (2015): ***FX rates,*** http://www.hnb.hr/tecajn/

HROTE, (2015): ***Annual report 2014***
http://files.hrote.hr/files/PDF/OIEIK/GI_2014_HROTE_OIEiK_web.pdf

HROTE, (2015): ***Nacionalni akcijski plan za obnovljive izvore energije do 2020.godine,*** *http://files.hrote.hr/files/PDF/Dokumenti/NAP/Nacionalni%20akcijski%20plan%20za%20OIE%20do%202020..pdf*

Jeromel, M., Malačić, V., Rakove, J., (2009): ***Weibull distribution of bora and sirocco winds in the northern Adriatic Sea,*** Geofizika, Vol. 26, No. 1, pp. 85 – 100

Poje, D. (1996): ***Distribution functions and the estimation of wind power,*** Croatian meteorological journal, Vol. 31, pp. 1-13.

Vestas, (2015): ***V90-3.0 MW,***
http://www.vestas.com/en/wind-power-plants/procurement/turbine-overview/v90-3.0-mw.aspx#/vestas-univers

Windenergie, (2009), ***The Economics of Wind Energy; A report of the European Wind Energy Association,***
http://www.ewea.org/fileadmin/files/library/publications/reports/Economics_of_Wind_Energy.pdf

Wind energy, ***Operation and Maintenance Costs of Wind Generated Power,***
http://www.wind-energy-the-facts.org/images/chapter3.pdf

Žiković, S., Fatur, T. (2010): ***Practical application of real option method to valuing investment projects,*** Računovodstvo i financije, Vol. 12, pp. 168-182.