ENVIRONMENTAL AND ECONOMIC ASPECTS IN DECISION MAKING OF THE INVESTMENT PROJECT "WIND PARK"

Janekova J., Fabianova J., Rosova A.*

Abstract: The current competitive environment puts on companies still increasing demands and their success is more uncertain. They are forced to implement many changes and challenges in limited terms with limited resources. An effective solution to this situation is the project management. Its principles are applied in this paper at deciding on acceptance or rejection of the investment project wind park. The decision making is carried out from an environmental and economic point of view. Within the environmental assessment it is a comprehensive assessment of impacts of the wind park construction on the population, geological environment, soil, flora, fauna and their habitats, on the country and its infrastructure, etc. Assessment of the investment from an economic and financial point of view is realized by dynamic methods. Their selection is chosen so that the investment was assessed in three ways, its profitability, liquidity and risk. The emphasis is taken on risk, which is analysed using Monte Carlo simulations.

Key words: investment, wind energy, risk analysis, Monte Carlo simulation

DOI: 10.17512/pjms.2016.13.1.09

Introduction

Wind power is becoming an important resource among renewable energy sources. Due to rising fuel costs, wind power might become the least expensive source of power. Its environmental and economic effects make wind farms an important investment area in the energy sector. However, the generation of electricity from wind energy poses a high level of uncertainty affecting its profitability. Project management of a large investment project, such as wind power construction, requires an assessment of economic, environmental and risk aspects. The issue of wind power exploitation, investment in wind power plants and investment risk is dealt with in numerous scientific publications.

Wind power generation is influenced by the stochastic nature of wind. So wind power forecasting plays a key role in uncertainty management. A review of the current methods and advances in wind power forecasting and prediction was introduced in (Foley et al., 2012). Wang et al. (2011) presented a review on comparative analysis on the foremost forecasting models, associated with wind speed and power. Optimization of production processes in area of alternative power sources using quantitative methods of operational analysis was performed by

* **Jaroslava Janeková,** Ing. PhD., Faculty of Mechanical Engineering, **Jana Fabianová,** Ing., PhD., Faculty of Mining, Ecology, Process Control and Geotechnology, **Andrea Rosová,** doc. Ing. PhD., Faculty of Mining, Ecology, Process Controland Geotechnology, Technical University of Kosice

✉ Corresponding author: jaroslava.janekova@tuke.sk

✉ jana.fabianova@tuke.sk; andrea.rosova@tuke.sk

Teplicka et al. (2015). Makipelto (2010) analysed the decision-making process and competitive priorities of investment strategies from wind power investors' point of view and compared the findings with the opinions of wind power unit suppliers. Montes and Martin (2007) studied factors that had the greatest short-term impact on the economic viability of wind energy projects. They found that the inherent risk within the sector can become a real obstacle in terms of development and short-term financing. Impact of public policy uncertainty on renewable energy investment was studied by Barradale (2010) and Sutherland (1991) researched market barriers to energy-efficiency investments. Integrating the risk profitability assessments is important for investors. Statistical simulation methods to incorporate risks from stochastic wind speeds into profitability calculations were presented in Gass et al. (2011). Zuobin and Yang (2010) proposed the evaluation index system of wind power investment risk and used fuzzy comprehensive evaluation method to evaluate the investment plan risk. A risk-constrained multi-stage stochastic programming model to make optimal investment decisions on wind power facilities along a multi-stage horizon was proposed by Baringo and Conejo (2013). Risk evaluation of wind power project based on fuzzy weigh and SVM was described in Li et al. (2011). Liu and Jiang (2010) analysed the risk factors including natural disaster risks, technology risks, economic risks and policy risks and constructed a fuzzy comprehensive evaluation model. Monte Carlo simulation enables planners to model many factors that may contribute to uncertainties and risks. The nature and relevance of Monte Carlo simulation was briefly described in Raychaudhuri (2008). Khedr (2006) and Daoyuan (2010) presented an application of Monte Carlo computer simulation in investment risk analysis. Lorenzo et al. (2012) described the economic-modelling methodology using Monte-Carlo simulation of investment integrity and value for power-plants. Montes et al. (2011) analysed the profitability of windfarm projects using Monte Carlo techniques. It was demonstrated that Monte Carlo sampling represents an excellent approach to economic risk management. Gillenwater (2013) presented results from a model of a wind power investor's decision making process using a Monte Carlo simulation of a project financial analysis.
Also non-coastal countries like Slovakia have possibilities to provide ecological and low-cost electricity production from wind power. Mountainous terrain with windy climate offers this alternative but at the same time creates constraints. Further barriers are of economic and technical nature. This article deals with investing in a wind park in a selected area in Slovakia.

Wind Energy use in Slovakia and other European Countries

Wind power is used minimally in Slovakia. There are currently only two wind parks operating in Slovakia. The lack of suitable sites is the main reason why wind energy is so little used. Localities with good wind conditions (wind speed of at least 5 m/s) are found mostly in protected areas and national parks. According to the Wind Energy Association of Slovakia the actually exploitable potential of wind energy is estimated at 600 MW, what would be able to cover about 3% of electricity consumption. The world's leading country in the wind power use is Denmark. Wind power in Denmark provides about 39 percent of Danish domestic electricity. Poland is a very fast developing country in wind energy production – in 2015 the share of energy from wind in the total energy production has reached 6.21%. Due to the environmental effects, the intention of the EU member states is to increase the share of energy from renewable sources. According the European Wind Energy Association (EWEA) renewable energy accounted for 77% of all new EU power installations in 2015. Germany was the largest market in 2015 in terms of annual installations, Poland came second, France was third and the UK fourth.

Implementation of Project Management at Deciding on the Investment Project "Wind Park"

Resolution of the investment project wind park is made in accordance with the principles of project management. Activities of the project in terms of time sequence are divided into three phases – pre-investment, investment and implementation. Subject of the review is the pre-investment phase. The focus is on its key area, i.e. environmental and economic-financial evaluation of the project, including risk management. Nowadays, accompanied by rapid changes and uncertainties in all spheres of life, the way of risk management decides on results of the project.

The object of investment is a wind park for electricity generation. The location of the wind park, the village near Cerová Highlands, is in the district of Rimavská Sobota. The place is suitable due to weather conditions. The wind park consists of five wind turbines REpower 3.2 M114 equipped with an aerodynamic rotor blade RE 55.8. Wind turbines are placed on hybrid towers 123 meters high. A part of the investment is the realization of the power lines which will ensure the supply of electricity from wind power stations into the power grid and transformer. Individual stations are spaced at a distance between two of them of minimum 500 meters. The wind park is distanced at least one kilometre away from the inhabited area. The graphic display of the wind park is shown in Figure 1.

Figure 1. The model of the wind park *(Mikulcová, 2013)*

The Environmental Aspects of the Investment Project

Under the Act on Environmental Impact Assessment No. 24/2006 the investment project has to be assessed on the effects and their impacts on individual components of environment. Both positive and negative environmental impacts identified on the basis of the law and also according to generally known facts about wind power plants are listed in the register of the impacts (Table 1).

Table 1. Register of the construction and operation impacts of the wind park on the individual components of the environment

Impact mark	Impacts of the wind park	Period
V1	**Population**	
V11	Noise and vibrations from construction equipment and waste production	Construction
V12	Work for 15 workers	Construction
V13	The increase in charges to the budget (local tax)	Operation
V14	Electricity production	Operation
V15	Noise	Operation
V16	Stroboscopic effect	Operation
V17	Work for 2 workers	Operation
V2	**Geological environment, raw materials, water, air**	
V21	Air pollution from internal combustion engines	Construction
V22	Pollution of surface and groundwater	Operation
V23	Saving of fossil fuels	Operation
V24	Prevention of production of waste heat released into the air or water	Operation
V25	Prevention of CO_2 emissions	Operation
V26	Prevention of SO_x, NO_x emissions	Operation
V27	Prevention of dust generation	Operation
V28	Prevention of solid and liquid wastes generation	Operation
V3	**Soil**	
V31	Soil contamination only in accidental situations (leakage of oil and hydraulic fluids from construction machineries)	Construction
V32	Potential industrial accidents - leakage of the whole volume of operational oil from wind turbines into the soil	Operation
V33	Temporary occupation of agricultural land during construction	Construction
V34	Permanent occupation of agricultural land	Operation
V4	**Flora, fauna and their habitats**	
V41	Bird mortality (collisions with masts and rotating blades)	Construction and operation
V42	Migratory birds and bats mortality	
V43	Negative effects of noise on wild animals	

V44	Vegetation disturbance	
V5	**Country and its infrastructure**	
V51	Landscape infrastructure changes	Construction and operation
V52	Visual landscape changes	
V6	**Other effects**	
V61	Restrictions for agricultural production	Construction
V62	Traffic loading	Construction
V63	Impacts on protected areas	Construction and operation

Evaluation of the individual environmental impacts (both positive and negative) is carried out using risk matrix "probability x impact".

The possibility of risk occurrence expressed in the form of scales may be described verbally or numerically. In our case, the occurrence probability is assessed on the 3-point scale and related to duration of the impact. High (H) probability means that the impact will occur with probability of 70 to 100% and is of a permanent nature. Medium (M) probability means that a lasting impact will occur with probability 40-70% or the impact is periodically repeated. Low (L) probability represents probability of a short-term impact, i.e. the impact will occur only during the construction period of the wind park, resp. the impact will occur with probability of less than 40%. Impacts are rated also in terms of their significance. Low, medium and high significance of the impact is assessed by points 1-3. The number of points increases with significance (Figure 2).

Probability										
	H	3	**3**	**6**	**9**	**9**	**6**	**3**	3	H
	M	2	**2**	**4**	**6**	**6**	**4**	**2**	2	M
	L	1	**1**	**2**	**3**	**3**	**2**	**1**	1	L
			1	2	3	3	2	1		
			L	M	H	H	M	L		
			Impact							
			Negative (N)			Positive (P)				

Risk		
= 9		High (H)
		Medium (M)
≤ 3		Low (L)

Figure 2. Risk matrix „P x I“

The value of the risk posed by individual environmental impacts is calculated as:

$$R = P \times I \qquad (1)$$

where:

R - value of the risk,
P - occurrence probability of the impact,
I - significance of the impact.

So the risk takes the value from 1 to 9. Based on the calculated values of the risk, the impacts are assessed as risk impacts of varying degrees in either positive or negative sense (Table 2).

Table 2. Assessment of the construction and operation impacts of the wind park on the individual components of the environment

Impact	Assessment of the impact								Value of risk
	Impact		Significance			Probability			
	P	N	H	M	L	H	M	L	
V11		×	×					×	**3**
V12	×		×					×	**3**
V13	×		×			×			**9**
V14	×		×			×			**9**
V15		×			×	×			**3**
V16		×			×		×		**2**
V17	×				×	×			**3**
V21		×		×				×	**2**
V22		×		×				×	**2**
V23	×			×		×			**6**
V24	×				×	×			**3**
V25	×			×		×			**6**
V26	×			×		×			**6**
V27	×			×		×			**6**
V28	×			×		×			**6**
V31		×		×				×	**2**
V32		×		×				×	**2**
V33		×		×				×	**2**
V34		×			×	×			**3**
V41		×		×			×		**4**
V42		×		×			×		**4**
V43		×			×	×			**3**
V44		×			×			×	**1**
V51		×			×	×			**3**
V52		×			×	×			**3**
V61		×			×			×	**1**
V62		×			×			×	**1**
V63		×			×			×	**1**

The evaluation assessed the state of land use and carrying capacity of the natural environment, the importance of expected positive impacts on the environment including the impact on the territory and population. Based on the impact assessment of the proposed activity on the environment, it can be concluded that the investment project wind park is environmentally acceptable. The final value of positive risk impacts (54) was higher than the negative ones (42). The identified negative impacts are of low respectively medium level of risk and need to be monitored and addressed. By the Act No. 24/2006, the one who will perform the proposed activity is required to ensure the monitoring and evaluation of environmental impacts. The scope and period of monitoring and evaluation is determined by the authorizing authority.

Economic and Financial Aspects of the Investment Project including Risk

Economic and financial evaluation of the investment project wind park is based on the most probable scenario. It is processed using a financial model created in MS Excel. The financial model includes:

- *Input data* required for the determination of cash flows of the project and quantification of the financial criteria. These include investment expenses (together EUR 20,893,876), annual production volumes and sales of energy (about 96,000 MWh), sales prices of energy (70.30 - 49.00 EUR/MWh), operating costs, personnel costs, income tax rate, discount rate, and others.
- *Project cash flows* which take into account the construction period and the period of operation of the wind park. The construction period of the project is set at three years. The economic life time of the project is identified with the depreciation period of wind turbines, i.e. set at twenty years. Financing of the investment is 20% from own funds and 80% from foreign sources. The loan can be drawn in the third year of construction of the investment at 5% p.a. interest rate and with its maturity in ten years.
- *Financial criteria* for assessing the financial stability of the project such as net present value (NPV), profitability index (IP) and discounted payback period (DPB). When calculating financial criteria the time factor is taken into account in cash income and also in capital expenditures calculation. Discounting is carried out at the initiation of the investment project construction. The calculated value of the above financial criteria is given in Table 3.

Table 3. Financial criteria of the project

Indicator	Unit	Value
NPV	EUR	20,893,876
IP	coefficient	2.90
DPB	year	7.99

From Table 3 it clearly results that the investment project is economically efficient. However, despite positive values of financial criteria, it is probable that the real development of input variables of the investment project deviate from the considered most probable values. For this reason a risk analysis of the considered investment project processed.

Risk analysis using Monte Carlo simulation is carried out in the Crystal Ball system, which is an extension of MS Excel. The output variable is NPV whose base case is determined by the traditional approach (Table 3). Risk factors of the project are determined using sensitivity analysis. They are followed in relation to the NPV at isolated changes of individual input variables by ± 10% from their most probable values. The results of the sensitivity analysis showed that the key risk factors include the volume of energy production, discount rate, and investment costs in the third year, sales price and the income tax rate. When illustrating the uncertainty of risk factors the following distributions are used normal distribution, lognormal distribution and BetaPERT distribution.

The Results of Monte Carlo Simulations

The primary outputs of the Monte Carlo simulations are the probability distribution of NPV and its statistical characteristics (Figure 3). Based on the values of statistical characteristics it is possible to mention the following conclusions. Mean value of NPV is by EUR 840,247 higher than the NPV calculated by traditional approach. With the probability of 95% the NPV of the project is expected in the range from EUR (-500,840) to EUR 36,182,613. The probability that the NPV of the project does not exceed the most probable scenario is 41.07%, which means that higher values than EUR 20,893,876 will be achieved with a probability of 100% - 41.07% = 58.93%. NPV probability distribution is approximately symmetrical; skewness has a negative value, indicating that it is slightly inclined to the left, i.e. towards lower NPV. Given that the probability distribution of NPV is approximately symmetrical, variability characteristics of standard deviation, variance and coefficient of variation represent good measure of risk of the project in relation to the NPV.

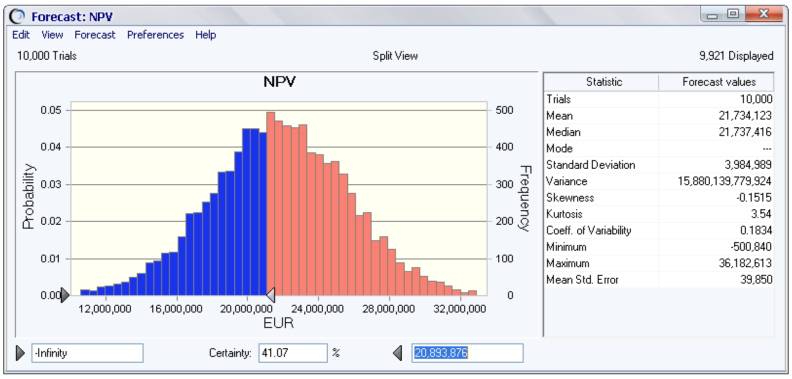

Figure 3. Forecast NPV

Another important output of the simulation is a sensitivity graph of NPV (Figure 4). It provides information about contributions of selected risk factors to the overall risk of the project in relation to the NPV, in both, graphical and numerical form.

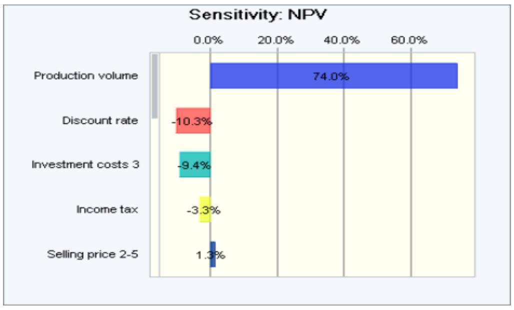

Figure 4. Sensitivity graph of NPV

Figure 4 it is obvious that the most significant factor is the amount of electricity produced, which contributes to the risk of the project by 74.0%. The second factor in order of importance is the discount rate that contributes to the project risk by 10.3%. The third important factor is the investment cost in the third year of construction, which contribution to the risk is 9.4%. The contribution level of other risk factors to the risk of the project is 3.3% or less. In the effort to reduce the risk of the project it is appropriate to focus attention on the first three risk factors. Monte Carlo simulation leads to a deeper knowledge of risk sites of an analysed project but its implementation is not a one-time issues. The simulation should be repeated every time when changes in the development of analysed risk factors of the project were determined or when new risk factors were recognized.

Summary

Recently theory and practice identify a number of various sophisticated methods and techniques for evaluation of efficiency of investment projects. Each of them has its limitations and neither of them works equally well in every condition. For this reason, there is no universal method of evaluation of investment projects efficiency. There are only recommended practices. The aim of this paper was to present one of the possible approaches to evaluate the efficiency of the investment project wind park including risk. The choice of methods considered the objectives and specifications of the project. From environmental point of view, the project is acceptable. Fond negative impacts are mostly low, medium level of risk needs to be continuously monitored and resolved. From economic and financial point of view, the project is effective in terms of risk and risk is acceptable. Further development of research in this field, we see in need to focus on risks, not only in the traditional negative meaning of "threats" but also "opportunity", because the discovery and utilization of opportunities for improvement of results can often balance the threats that cannot be avoided or which can occur (as well as new opportunities) during the lifetime of the project.

This work was supported by the Slovak Research and Development Agency under the grants VEGA No. 1/0216/13 and VEGA No. 1/0708/16.

References

Baringo L. Conejo A.J., 2013, *Risk-constrained multi-stage wind power investment*, IEEE "Transactions on Power Systems", 28(1).

Barradale M.J., 2010, *Impact of public policy uncertainty on renewable energy investment: Wind power and the production tax credit*, "Energy Policy", 38(12),

Daoyuan S., 2010, *The application of Monte Carlo computer simulation in investment risk analysis*, The 2nd International Conference on Information Science and Engineering.

EWEA, 2016, W*ind in power, 2015 European statistics*, Available at: *http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2015.pdf*, Access on: 23.3. 2016.

Foley A.M. et al., 2012, *Current methods and advances in forecasting of wind power generatio*, "Renewable Energy", 37(1).

Gass V. et al., 2011, *Assessing the effect of wind power uncertainty on profitability. "*Renewable and Sustainable Energy Reviews", 15(6).

Gillenwater M., 2013, *Probabilistic decision model of wind power investment and influence of green power market, "*Energy Policy, 63(1).

Khedr M.K., 2006, *Project Risk Management Using Monte Carlo Simulation*, AACE International Transactions, 2.1–2.10. Available at: *http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=22646765&site=ehost-live*, Access on 20.10. 2015.

Li W., Li S., Wang D., 2011, *Risk evaluation of wind power project based on fuzzy weigh and SVM*, Proceedings of 2011 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference.

Liu C.L.C., Jiang Y.J.Y., 2010, *Risk analysis and assessment of wind power project*, Emergency Management and Management Sciences (ICEMMS), 2010 IEEE International Conference.

Di Lorenzo G. et al., 2012, *Monte-Carlo simulation of investment integrity and value for power-plants with carbon-capture*, "Applied Energy", 98.

Makipelto T., 2010, *The competitive priorities of the wind power investment*, "International Journal of Management and Enterprise Development", 9(3).

Mikulcová M., 2013, *Analýza rizika pri investičnom rozhodovaní*. Košice: Technická univerzita v Košiciach, Strojnícka fakulta, 75.

Montes G., Martin E., 2007, *Profitability of wind energy: Short-term risk factors and possible improvements*, "Renewable and Sustainable Energy Reviews", 11(9).

Montes G.M. et al., 2011, *The applicability of computer simulation using Monte Carlo techniques in windfarm profitability analysis*, "Renewable and Sustainable Energy Reviews", 15(9).

Raychaudhuri S., 2008, *Introduction to Monte Carlo simulation*, [in:] 2008 Winter Simulation Conference. IEEE, 91–100. Available at: *http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=4736059*, Access on 20.11. 2015.

Sutherland R.J., 1991, *Market Barriers to Energy-Efficiency Investments*, "The Energy Journal", 12(3).

Teplická K., Čulková K., Železník O., 2015, *Application of Bayess Principle Optimum – Optimization Model for Managerial Decision and Continual Improvement*, "Polish Journal of Management Studies", 12(2).

Wang X., Guo P., Huang X., 2011, *A Review of Wind Power Forecasting Models*, "Energy Procedia", 12.

Zuobin W.Z.W., Yang T.Y.T., 2010, *The study on risk evaluation of wind power investment*, Advanced Management Science (ICAMS), 2010 IEEE International Conference, 1.

ŚRODOWISKOWE I EKONOMICZNE ASPEKTY W PODEJMOWANIU DECYZJI PROJEKTU INWESTYCYJNEGO „PARK WIATROWY“

Streszczenie: Obecne otoczenie konkurencyjne nakłada na firmy wciąż rosnące wymagania i ich sukces jest bardziej niepewny. Są one zmuszone do wprowadzenia wielu zmian i wyzwań w ściśle określonych warunkach z ograniczonymi zasobami. Skutecznym rozwiązaniem tej sytuacji jest zarządzanie projektami. Jego zasady są stosowane w niniejszym dokumencie przy podejmowaniu decyzji o przyjęciu lub odrzuceniu inwestycji projektu parku wiatrowego. Podejmowanie decyzji jest przeprowadzone ze środowiskowego i ekonomicznego punktu widzenia. W ramach oceny oddziaływania na środowisko dokonano kompleksowej oceny wpływu budowy elektrowni wiatrowej na ludność, środowisko geologiczne, glebę, florę, faunę wraz z siedliskami, na kraj i jego infrastrukturę, itp. Ocena inwestycji z punktu widzenia gospodarczego i finansowego realizowana jest za pomocą metod dynamicznych. Ich wybór został dobrany tak, że inwestycja została oceniona na trzy sposoby, jej rentowności, płynności i ryzyka. Nacisk został położony na ryzyko, które jest analizowane za pomocą symulacji Monte Carlo.
Słowa kluczowe: inwestycje, energia wiatrowa, analiza ryzyka, symulacja Monte Carlo

環境和經濟方面的投資項目決策中的“風電場”

摘要：目前的競爭環境穿上公司仍不斷增長的需求和他們的成功更加不確定。他們被迫實施了許多變化，並與有限資源有限的條件的挑戰。有效地解決了這個情況是項目管理。其原理本文在決定投資項目風電場的接受或拒絕申請。決策是從環境的觀點和經濟的角度開展。在環境評估是對人口風園建設的影響，地質環境，土壤，植物，動物及其棲息地進行了全面評估，對國家和它的基礎設施等。從經濟的觀點和金融點投資評估是通過動態方法實現。選擇他們的選擇，使得投資於三個方面，其盈利能力，流動性和風險評估。重點是採取的風險，這是利用蒙特卡羅模擬進行分析。
關鍵詞：風險分析投資，風能，蒙特卡羅模擬