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ANALYSIS OF ALTERNATIVE SOLUTIONS FOR THE UTILIZATION OF WIND ENERGY USING BENEFIT/COST METHOD

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ABSTRACT
Wind energy is a transformed form of solar energy that arises as a result of solar radiation. The good side of wind energy utilization is the high reliability of the operation of a plant that does not pollute the environment and works without the cost of fuel. The bad sides are high construction costs and wind speed variability. The paper use the benefit cost analysis for the evaluation and selection of economically profitable project solutions in order to select the most optimal wind power plant.
Keywords: benefit/cost, wind power plant, alternative.

1. INTRODUCTION

Wind energy is a transformed form of solar energy, which is induced by solar radiation. It is estimated that 1-2 % of the energy comes from the sun in converted into wind energy.

When converting the kinetic wind energy into mechanical energy, only the difference of wind speed at the input and output of the wind farm is exploited. The wind farm starts when the wind speed increases above 3 m/s. Electricity production is very small at that speed. Maximum energy production is obtained at a wind speed of about 12 m/s, with further increase of a wind speed, the quantity of produced energy no longer increases. When the speed increases above 25 to 30 m/s, the wind turbine turns off because it cannot withstand mechanical loads caused by such high wind speeds. Locations with an average annual wind speed of less than 5.5 m/s are considered economically unjustified to use wind energy.

As a good side of the use of wind energy, high reliability of operation of the plant, which does not pollute the environment and operates without fuel costs, is emphasized. Bad sides are high construction costs and wind speed changes (the delivery of energy cannot be guaranteed).

Although the subject of this paper is to evaluate and select the most optimal of the three offered alternatives of the wind farm, from the public sector viewpoint, the project can be observed and analized from the perspective of the private sector as well. The method based on the assessment of the private sector project differs from the method for assessing the public sector project. Within the framework of public sector projects, the interests of the city, people, the state and the region are intertwined. In order to present a realistic economic analysis of public interest projects, an analysis model, that takes the benefit/cost ratio as the main parameter, has been developed [1, 3, 5].

2. THE CONCEPT OF BENEFIT/COST ANALYSIS

When assessing the justification of the realization of an investment project, one should always bear in mind the effects that the project brings to other organizations or the wider community. Some investments are, by their nature, such that they must be considered and evaluated primarily from a wider social aspect - traffic, energy, defence, natural, social, etc, due to their great contribution to the country as a whole. Cost-benefit analysis should take into account all benefits and costs, regardless of who or what benefits from them; apart from the cost, it is necessary to take into account the lost benefits, as well as benefits and costs reduction. The main objective and steps of the B/C analysis are [2]:

- The first step of analysis involves the process of identifying the fundamental differences between the public and private sectors alternatives.
- Step 2 evaluates individual projects for the B/C analysis method.
- In the third step, the best alternatives between two and more alternatives in the option are chosen.
- The fourth step involves a spreadsheet for performing B/C analysis of alternatives.

Public sector projects are financed by the citizens of any state level, while private sector projects are financed by individuals, associations or partnerships. There are significant differences in the characteristics of the public and private sectors alternatives:

- Public sector projects often require higher financial investments, projects can last up to several decades, often do not make a profit and can have unintended consequence (damages).
- Sources of funds for financing public projects are taxes, contributions, fees and donations.
- Interest rates for public sector projects are called discount and they are always lower than for private sector alternatives.
- The public sector viewpoint of analysis must be determined prior to the determination of costs, benefits and damages. [2]

3. MODEL B/C ANALYSIS FOR PROJECTS WITH TWO OR MORE ALTERNATIVES

To carry out an economic assessment of the public sector project, it is necessary to establish a relationship and transfer into a common counter value the total costs with the total benefits at a discount rate.

An additional B/C analysis of two or more alternatives involves the determination of an additional B/C relationship between the two alternatives. If $\Delta B/C \geq 0$, the alternative with higher costs is chosen. Otherwise, the alternative with lower costs is chosen. Also, it should not be neglected, if the two alternatives have an equal time period and an initial investment, and the other has higher annual equivalent costs, then the second must be further estimated in relation to the first one.

4. APPLICATION OF B/C ANALYSIS ON THE GENERATOR SELECTION EXAMPLE FOR WIND FARM

Data for the C/B analysis in this paper were taken from a study conducted by the eminent consulting house using the European Wind Atlas Methodology, integrated into the WaSP software. Analysis of the wind energy potential of the target region was done on the basis of two-year measurements. The average monthly wind speeds were measured at 77.5 m above the ground. Monthly average wind speeds range from 5.33 to 9 m/s. The average annual wind speed is 7.02 m/s. The highest average wind speeds occur during the period from March to December.

According to the law on renewable energy sources and cogeneration, wind farms with a capacity exceeding 10 MW are entitled to a guaranteed price for a period of 15 years if the producer sells electricity in analized region. Sales on analized market is defined by the connection place. If the connection place is outside the territory of the country coward by the research, the project cannot be qualified for the guaranteed purchase price and so the electricity would be sold at the market price. According to the current regulations on purchase prices, guaranteed purchase price 0.1466 KM/kWh (market - reference price 0.0570 KM/kWh).

Basic data on the study of the construction feasibility of WF are shown in Table no. 1. Calculation of gross annual production with an estimate of losses made by experience, based on previous research and work of consultants on similar projects [4].

Table 1. Gross annual production calculation with estimation of losses of the wind farm

ALTERNATIVES	SIEMENS SWT-130-3.3 -G-	VESTAS V126-3.45 -H-	GENERAL ELECTRIC GE 130 -C-
INSTALLED CAPACITY	56,1 MW	58,6 MW	58,3 MW
GROSS ANNUAL PRODUCTION	182.629 GWh/ P.A.	189.108 GWh/ P.A.	194.931 GWh/ P.A.
WAKE - LOSSES	3,62 %	3,26 %	3,24%
	-6611 GWh/ P.A.	-6667 GWh/ P.A.	-6316 GWh/ P.A.
IDEAL NET PRODUCTION	176017 GWh/ P.A.	182941 GWh/ P.A.	188615 GWh/ P.A.
TOTAL LOSS AND CORRECTION (11%)	-19362 GWh/ P.A.	-20123 GWh/ P.A.	-20414 GWh/ P.A.
NET ANNUAL PRODUCTION (P50)	156655 GWh/ P.A.	162817 GWh/ P.A.	167868 GWh/ P.A.
EQUIVALENT WORK TIME WITH NOMINAL POWER	2792 h	2778 h	2879 h
FACTOR CAPACITY %	31,87%	31,72%	32,86%

4.1. B/C analysis on the generator selection, example for wind farm

The conceptual solution of the wind farm consists of 17 pillars which enables the exploitation of the maximum wind potential in this area. Table 2 contains basic information on three types of wind turbines for which the project analysis is done in order to select the most optimal project solution for the wind turbine.

Table 2. Basic characteristics of wind turbine test

MODEL	ELECTRIC POWER (MW)	ROTOR DIY (m)	PILLAR HEIGHT (m)	WIND CLASS
SIEMENS SWT-130-3. 3 MW	3.30	130	110	IEC IIA
VESTAS V126-3.45 MW	3.45	126	117	IEC IIA
GENERAL ELECTRIC GE 130- MW	3.40	130	110	IEC IIB

The investment budget includes investments in wind turbines and its installations, foundations, electrical installation at the site, substation at the site, power lines and connections, construction works, development costs and contingency costs.

For total losses and corrections, 11 % of the ideal net production of the wind farm is taken (i.e. gross annual production minus loss due to passing through and around the rotor depending on the wind farm model). Maintenance costs for these models are taken from 1.5 to 2.0 %, 1.5 % of the total investment per year is adopted.

Wind turbine components are usually designed to be operative for twenty years, so we can say that there are basis to achieve an economic-technical compromise.

From Table 3, using B/C, we can conclude that each of these alternatives is cost-effective. Of the considered alternatives, C is chosen as the most cost-effective, the GENERAL ELECTRIC GE 130-3.4 MW wind turbine model. Compared to initial costs, this is the most expensive alternative, but at the same time it provides the highest annual profit for the planned period of 15 years.

Table 3: Application of B/C analysis for wind turbine project for analized wind farm

ASSESSMENTS	B/C CATEGORY	ALTERNATIVES		
		SIEMENS SWT-130-3.3 MW -G-	VESTAS V126-3.45 MW -H-	GENERAL ELECTRIC GE 130 MW -C-
PW of the initial investment, KM	Cost	64285000.00	65050000.00	658500000.00
Annual maintenance cost KM/ p.a	Cost	964275.00	975750.00	987750.00
Annual billing KM/p.a	Benefit	25804092.20	26819150.60	27650959.00
Annual losses KM/ p.a	Loss	2838469.20	2950031.80	3041510.20
Cost PW, KM	Cost	74293844.75	75177951.33	76102507.23
Annual billing PW	Benefit	267837653.02	278373612.10	287007498.85
Comparison			H with G	C with H
PW of ΔB			-10535959.1	-8633886.7
PW of ΔD			111562.6	91478.4
PW of ΔC			884106.6	924555.9
Δ(B-D)/C			12.0	9.4
Justified increment			YES	YES
Chosen Alternative			H	©
B/C for individual proj.		3.6	3.7	3.7

Transferring costs and benefits to the current point of time is done using the current value method. The method is based on the concept of equivalent values of all cash flows which refers to a basic or starting point at the present. All those cash inflows and outflows are discounted at the current point of time at the interest rate that is generalized for the minimum acceptable rate of earning rate.

5. CONCLUSION

This paper presents the possibility of applying the B/C analysis of the conceptual design of the wind farm. Three types of wind turbines are compared economically. The usual procedure is used with the help of the Excel software package. GENERAL ELECTRIC GE 130 - 3.4 MW is selected from three considered wind turbines, which is the most expensive alternative to the initial costs, but at the same time it provides the highest annual profit for the planned period of 15 years.
The development of wind farm projects can be considered as an attractive investment with a sustainable long-term return thanks to premiums and guaranteed purchase of electricity for a period of 15 years. The project would be financially sustainable even without the incentives, but not too attractive if it is considered from the private sector perspective. If we consider the wind energy exploitation as a public interest project, we can assess it as completely justified and desirable.

6. REFERENCES

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