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Using of Multicriteria Method for Choosing the Best Alternative of the Heating Power Plant

Martina Zeleňáková[1], Vlasta Ondrejka Harbuľáková[1], Adrián Olejník[2]

[1]Technical University of Košice, Civil Engineering Faculty, Institute of Environmental Engineering, Slovak republic, e-mail: martina.zelenakova@tuke.sk, vlasta.harbulakova@tuke.sk
[2]Technical University of Košice, Civil Engineering Faculty, Institute of Construction Technology and Management, Slovak republic
e-mail: martina.zelenakova@tuke.sk

Abstract

The paper presents construction of heating system in Trebišov town in alternative solution and its environmental impact assessment (EIA). Choosing the best alternative consider zero variant (if no activity is done - present state of the environment) and another two alternatives assessment using the method of the total indicator of environmental quality. Nine selected criteria were divided into four groups according to their character – economic, technical, ecological and social. Based on evaluation of the construction of biomass-fired power plant seems to be the best solution of heating system for Trebišov town.

Key words: Biomass power plant, Energy policy, Total indicator of environmental quality**.**

1 Introduction

The first strategic document relating to the energy sector in Slovak Republic has been "Updated energy concept for the Slovak Republic" which was adopted on September 30, 1997 by the resolution of the Government No. 684/97 [1]. New trends in liberalization of energy within Europe, difficulties in electro-energy sector and heat generation as well as application of the Act No. 70/1998 Coll. on energy were initiated by an adoption of “Energy Policy for the Slovak Republic” in 2000. The policy was approved by Resolution No. 5/2000 of the Slovak Republic´s Government [2] and its framework and had three base pillars for the purpose of change:
- preparation for integration into internal market of the European Union,
- a security of energy supply,
- sustainable development.

The “Concept of using of renewable energy sources” adopted in April 2003 laid the basic framework for a progress in utilization of the Slovakia´s renewable energy sources [3]. The potential of development in renewable energy sources is analyzed in a “Renewable energy sources action plan for 2002-2012”, which was prepared in 2002.

Subsequently in 2004, Slovakia had approved the document "Renewable energy sources (RES) review report" by its resolution No. 667. In the report, the national indicative target for RES electricity in the final electricity consumption in 2010 was set up for 19% [4]. The program creates also the legislative and economic conditions necessary for the fulfillment of indicative targets contained in European Parliament Directive 2003/30/EC. In January 2006, it was necessary to develop a new energy policy mainly because Slovak Republic has been applied for entry into the European Union and we had been forced to adopt a new EU directive on energy. Another reason was the economic growth and liberalization of the energy sector across whole Europe [5].
Slovak energy policy is also a starting point for further development of thermal energy, electricity, gas, coal, oil extraction and processing of its transport and also point to renewable energy utilization. Elaboration of this policy is for a period of 25 years. The Slovak Government approved in 2007 the "Strategy for higher utilization of renewable energy sources" [6], in which it is stated to develop and submit the "Action plan for utilization of biomass for the years 2008 to 2013" [7]. It is focused on meeting the objectives which would have a significant positive impact on the environment and would contribute to improvement of climate conditions, reduction of greenhouse gasses in atmosphere, and diversification of energy sources at increasing energy security. The objective of the "Energy security strategy of the Slovak Republic " developed in 2007, is to achieve competitive energy, which would be ensuring safe, reliable, and effective supply of all forms of energy at reasonable price while talking the customer protection, environment protection, perpetually sustainable development, safeness of supplies, and technical safety into the account [6]. Another document in the energy sector approved by the Slovak government in 2007 was "The concept of energy efficiency by 2016", which outlined a goal to reduce the energy intensity to the average level of the original 15 members states of the EU [6]. "Energy efficiency action plan for the years 2008 to 2010" from October 2007 identified existing and newly developed energy-saving measures and defined procedures for ensuring the implementation of the proposed measures and their monitoring [6]. Implementation of EU legislation into Slovak law the "Act no. 250/2012 Coll. on regulation in network industries [5] and "Act no. 251/2012 Coll. Energy" enabled Slovakia's accession to the EU internal market. In Slovakia there is a limited amount of primary energy sources (PES), nearly 90% of all primary energy sources must be imported from abroad. Fossil fuel reserves consist of brown coal and lignite. A comparable situation is also in gaseous and liquid energy sources, while domestic production is only about 5%. Dependence of Slovakia on import of these resources was about 64% in 2011 [5].
Considering that the amount of produced energy and the environmental impacts are directly proportional so the most appropriate measure to reduce the negative impacts is rationalization of energy interests. Energy saving can be achieved by [8]:

- elimination of energy prices distortion,
- motivation inhabitants to higher energy saving,
- availability and clarity of information about energy-saving options,
- mandatory energy audits,
- tighten existing and establish new standards of consumption limits,
- mandatory labelling of electrical appliances.

European Union countries are obliged under legislation issued by the European Commission to assess each of the implemented actions that could have any negative impact on the

environment. It is ordered by Act 24/2006 Coll. on environmental impact assessment and on amendments and supplements [9].
Papers deals with calculation and selection of the best alternative of heat power plant construction (zero variant, new biomass-fired power plant, reconstruction of gas power plant) considering 9 selected indicators. For the comparison of the best solution in Trebišov town the method of the total indicator of environmental quality was used.

2 Material and Methods

2.1 Study area

Trebišov town is located in the southwestern part of the Eastern lowlands. It is surrounded by Slanské Mountains (Fig. 1). Slanské Mountains affect the air circulation significantly and determines the wind direction from north to south. This phenomenon is confirmed by the observation at station Milhostov from the years 1961-1999. North wind occurs mainly on the east of Slanské Mountains. Wind of the other directions is negligible. In region of Trebišov windless situation occurs in average 31 days of the year. In winter, an increased occurrence of ground inversion negatively affects the dispersion of emissions into larger distances. Consequently it causes air pollution even in the areas where the emission source is not situated [10].

Figure 1: Location of study area within Slovakia

In this region, north wind is strong and prevailing. The wind dries the region and brings cold weather. South wind is milder than the north and it warms the area. West wind most often brings precipitations. There is the weather station in Trebisov and also the ombrometric station, which is used to measure the rainfall. The measured average rainfall values in the Trebišov district is about 530-700 mm in lowlands and 700 to 1000 mm per year in the mountains. The greatest incidence of rainfall is mainly during the summer months of June and

July. Rainfall in these months is approximately about 60 mm. Most rainfall is usually in June with average value of precipitation are 72 mm [10].
The largest rivers in the Trebišov district are Ondava river and Latorica river. River Trnávka which is 35 km long, rises in Slanec Mountains and flows into Ondava river flow on the east of the town. River Trnávka has many tributaries in selected area. There are no mineral water sources and no thermal water sources in the area. From the climate point of view Trebišov town can be characterized as sufficiently warm, dry, with adequately cold winters, when the temperature is on average around -10 °C.
Long-time average air temperature measured at the weather station Milhostov is of 9 °C and during the vegetative season temperature reaches 16.5 °C. The duration of the vegetation period is 200-220 days. The number of summer days in average is 67 [10].
According to altitude selected region is divided into three climatic zones, namely: Zemplín, Eastern Lowland and Beskydské foothills. These three zones are located in the climate area referred as “warm”. Warm climate region involves in Ondavská and Laborecká Highlands. Areas which are situated under 800 m a.s.l are located in a region referred to as “moderately warm”. Areas that are higher than 800 m a.s.l. are situated in the “cold climate”.
Trebišov town district has slightly dry warm climate and cold winter. The average temperature during the year is around 9-10 °C. Average temperatures in January are in range from -1 to -4 °C in the lowlands and in the hills range -5 to -7°C. Average temperature in July in the lowlands is around 18.8 to 20.5 °C and from 12 to 16° C at higher altitudes [10].
From the geomorphological aspect the locality is situated in Matransko - Slanská area and in Eastern lowland. Western Carpathians belongs to Matransko - Slanská area.
From geological point of view, in the vicinity Trebišov town there are not significant mineral or ore deposits. Mainly nonmetallic materials as andesite (used mainly as a building stone, as gravel, as a cobble stone…) occur here.
Environmental impact assessment of the proposed activity – power plant for heating in Trebišov town in Slovakia according to Act 24/2006 Coll. as amended was implemented [9].

2.2 Technical and technological solution

2.2.1 Alternative 1

Technological solution of biomass-fired power plant consists of building object BO 01 - boiler house, BO 02 - a handy storage of straw and BO 03 - technical annex. Individual objects are connected structurally and technologically. Objects of power supply are located in the northern part of the plot. Building object BO 01 - boiler room consists of one floor [11]. Construction of the boiler room consists of a steel hall, in which there are three boilers, one designed for burning wood chips, and two for the combustion of straw. Building object BO 02 - a handy storage straw consists of one floor, consisting of steel hall and storage of straw. The boiler room and handy storage straw is separated by the fire wall. Building object BO 03 - technical annex consists of two floors and is made of masonry walls Porotherm. The outbuilding is the technical staff, facilities and administration of the boiler.
Built-up area of the boiler house is 719.00 m^2 and built-up area of the foundations and outbuildings is 214.35 m^2. Total built-up area is 933.35 square meters. The boiler room also includes a handy storage straw that built-up area is 1,981.65 square meters (consist also handy storage of straw and technical annex) [11].

Uncontaminated timber will be used as a fuel. Fuel preparation ensures chipping wood waste (residues after logging). In the boiler house are three boilers for biomass combustion with a nominal output of 3x4 MW. Two of the boilers are intended for combustion of straw, one is boiler for combustion of the timber purposes [11].

2.2.2 Alternative 2

Atmospheric natural gas fired watertube boilers are used in old central boiler houses. These boilers using the combustion gas transfers the heat to the primary heat exchanger, which heats the heating water and consequently the water is cooled to about 120 °C. Then from the primary heat exchanger water is distributed to the secondary circuit and through pipes to the heated objects. At the secondary circuit is installed a heat meter which measures the heat consumption [12].
Convention boilers are designed to produce dry combustion products. These products reach a temperature of 120 °C to 180 °C. The lowest temperature of the water entering the boiler is 60 °C. The temperature is ensured by mixing valves of heated water and the return water or the boilers are tapped into direct heating incoming water. This is necessary due to condensation of the combustion products. This condensation is aggressive because exchangers and boilers are made of sheet steel so exchanger can become wet with dew and cause surface corrosion [12]. Hot combustion products are discharged to the smokestack thereby heat loss appears. Waste gas contains latent heat bound to water vapor resulting from the combustion of natural gas. From the total heat energy gained from natural gas combustion only 80% is used for water heating.
This combustion of natural gas forms a large amount of exhaust gases emitted into the atmosphere through smokestacks. They have a high temperature and steam having a high energy flows through the smokestack without the further use.

2.3 Multicriteria analysis

Multicriteria evaluation of alternatives is based on the creation of decision-making situations where there is a known quantity of variants and the set of sub-criteria which serve as a basis for evaluating individual alternatives [13].
Summary quality of the environment for the geographical regions is determined, by substantial (cardinal) properties of the individual components of the environment, the quality of which we can assess by the available analytical and diagnostic indicators. These partial indicators can create a catalog of indicators criteria (character) whose values are precisely determined analytically using the scientific bases of prognosis or experimental estimation [14].
Total indicator of environmental quality (*TIEQ*) method is used to determine the value of the most suitable variant of power plant construction in Trebišov town district. Total indicator of environmental quality (*TIEQ*) method is used to determine the value of a comprehensive land use in terms of humanly influenced environment quality. It is calculated according to equation (1):

$$TIEQ = U_j = \sum_{j=1}^{n} f_j \left(P_j^{(N)}\right) W_j^{(N)} \tag{1}$$

Where U_j is function of benefit, P_j is criterion, W_j is the weight [14]. *TIEQ* structure is hierarchical, adaptive and allows to select the preferred option of a conventional set of alternatives or to give a preferential position of alternatives to a given set of criteria.
For evaluation and comparison of the alternatives, the set of nine criteria were established. The selected criteria are divided into qualitative and quantitative ones.

3 Results and Discussion

The assessment is made for two alternatives which are assessed in comparison with zero alternative:

- The zero alternative – Alternative 0 – if no activity is implemented.
- Alternative 1 - the environmental impact assessment of the central energetic source (biomass-fired power plant) in Trebišov district.
- Alternative 2 - the environmental impact assessment of the modernized natural gas boiler.

The comparison of alternatives of the proposed activity and the proposal of optimal alternative is based on multicriteria method. The first step of this evaluation is creating a set of criteria and determining their importance (weight) for the selection of the optimal alternative. We have defined a total of nine criteria (Catalogue of criteria), which we have divided into four groups according to their character – economic, technical, ecological and social (Tab. 1).

Table 1: Catalogue of criteria

Criteria	**Alternative 0**		**Alternative 1**		**Alternative 2**	
	Value	**Points**	**Value**	**Points**	**Value**	**Points**
Economic						
Total cost of construction	0 €	9	3.8 mil €	3	2.6 mil €	8
Annual operation cost	0 €	8	535 000 €	6	650 000 €	5
Technical						
Duration of construction	0 months	10	9 months	2	3 months	8
Land occupation	0 m^2	8	1,981.7 m^2	3	1,249.4 m^2	6
Output of 3 boilers	0 MW	0	14 MW	9	10 MW	8
Ecological						
Waste production	no	8	yes	5	yes	4
Emission production	0 %	7	0 %	7	6.5 %	6

Social						
Extra boiler room need	0	0	8	9	6	7
Job opportunities	yes	0	no	8	no	8

The points (0-10) associated with each criterion were stated based on three different experts' suggestions with the aim to get the most objective results (Table 1). In this evaluation the highest score is the best possible. Proposals were discussed with professionally qualified persons working in the field of environmental impact assessment as well as civil engineers.

For the optimal alternative determination it is important to calculate the weight of each criterion. The ranking method was used to state the weights of criteria. Fuller´s triangle was used for the weight criteria importance. By this procedure the referee must deal with the triangle scheme in which the couple of the individual criteria are expressed. It is clear that each pair can be displayed only and exactly once. From each couple is chosen one which is more important than the other one. Such a criterion must be emphasized – e.g. by a circle. It can happen, of course, that the two criteria have the same importance. In such a case the referee must encircle both. If the number of the indications for the *i* - the criterion is P_i, we can again get for the weight criterion estimation [15]. Calculation of Fuller´s triangle and estimation of preferences is described in detail in [16].
Once we have identified preferences, so we can calculate the final weight of the criteria. The resulting weight is ratio of individual preference with the sum of all preferences, when the sum of all weights $\Sigma w_j = 1$.
In Table 2 all criteria and its final weight is shown. Standardized weights that are used to calculate the optimal alternative method using (*TIEQ*) are also presented in Table 2. Calculation of the normalized weight is little bit different from the method of paired assessment. Standard weight is calculated from the equation (2):

$$W_j^{(N)} = \frac{w_j}{\sum_{j=1}^{n} w_j} \tag{2}$$

where

$$\sum_{j=1}^{n} w_j = 1 \tag{3}$$

The resulting calculation is the same as using the method of paired assessment criteria w_j but weight is not determined by Fuller´s triangle but is determined as the sum of the point's evaluation which gets each criterion when compared to alternatives 0, 1 and 2.

Values necessary to express the weight of the criteria can be found in Table 2. Also adding the evaluation criteria and the final weights for each criterion can be found there ($TIEQ_0$ - $TIEQ_2$). It shows that that the highest weight by this method is criterion economic criteria - total cost of construction (P_1), technical criteria - time of construction (P_3) and ecological criteria - emissions production (P_7).

Table 2: Weight (w_j) and standardized weight $W_j^{(N)}$ of criteria

Criterion		Preference	Weight w_i preference/36	Weight w_j [%]	∑	Weight $W_j^{(N)}$
Economic	Total cost of construction (P_1)	1	0.028	3	20	0.123
	Annual operation cost (P_2)	1	0.028	3	19	0.117
Technical	Duration of construction (P_3)	3	0.083	8	20	0.123
	Land occupation (P_4)	1	0.028	3	17	0.105
	Output of 3 boilers (P_5)	4	0.111	11	17	0.105
Ecological	Waste production (P_6)	6	0.167	17	17	0.105
	Emission production (P_7)	7	0.194	19	20	0.123
Social	Extra boiler room need (P_8)	6	0.167	17	16	0.099
	Job opportunities (P_9)	7	0.194	19	16	0.099
		36	1	100	**162**	1

In Table 3 partial calculated total usefulness of alternatives (U_0, U_1, U_2) and consequently calculated final function of the benefit ($TIEQ_0$, $TIEQ_1$, $TIEQ_2$) for each criterion are presented. Total usefulness of alternatives is described in detail in [16].

Table 3: Partial and final function of the benefit

P_i	U_0	U_1	U_2	$TIEQ_0$	$TIEQ_1$	$TIEQ_2$
P_1	0.109	0.963	0.248	0.013	0.119	0.035
P_2	0.074	0.592	0.888	0.009	0.069	0.104
P_3	0.101	0.953	0.346	0.013	0.118	0.043
P_4	0.09	0.933	0.444	0.009	0.098	0.047
P_5	0.968	0.114	0.236	0.102	0.012	0.025
P_6	0.069	0.636	0.87	0.007	0.067	0.091
P_7	0.127	0.127	0.979	0.016	0.016	0.121
P_8	0.956	0.104	0.326	0.094	0.01	0.032
P_9	0.979	0.126	0.126	0.097	0.012	0.012
				0.36	**0.521**	0.51

The final step is the calculation of the total usefulness of each alternative. It is calculated by multiplying the standardized weights of the criteria ($W_j^{(N)}$) (Table 2) and partial usefulness of alternative (U_{ij}) (Table 3). Equation (4) presents the calculation of the *TIEQ*:

$$TIEQ_{ij} = w_j * U_{ij} \tag{4}$$

From the Table 3 is evident, that alternative 1 achieved the highest score among the three variants (A0 - no activity, A1 - biomass-fired power plant, A2 - natural gas boiler). Based on comparison of these alternatives - alternative A1 - biomass-fired power plant ($TIEQ_1$=0.521), means the optimal variant for assessed locality.

4 Conclusion

Slovak energy policy has started point for further development of thermal energy, electricity, gas, coal, oil extraction and processing of its transport and also point to renewable energy utilization. Energy belongs to sectors, which significantly pollutes the environment. Harmonization of energy and environment has become one of the most important and strategic tasks in solving the environmental issues. Every day, we are watching the deteriorating state of the environment. It is particularly important to focus on minimizing the negative impacts of human activities on the environment.
Biomass is friendly and renewable source of energy and it is expected that in the future the demand for this raw material in the field of thermal energy will grow because of trends in environmental protection gradually displace conventional heating methods.

The main target of the society should become the environmental protection, because without a healthy environment, humanity cannot live and develop properly. In Slovakia, future reduction of negative effects of energy using on the environment might be provided by promoting the usage of renewable energy sources and austerity energy solutions.

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