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Selection of the Best Alternative of Heating System by Environmental Impact Assessment—Case Study

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Abstract: The Framework Directive 2009/28/EC on the promotion of the use of energy from renewable sources aims at developing the local and regional electricity market in order to reduce greenhouse gas emissions. A comparison study of the proposed activities of construction of a new biomass-fired power plant or reconstruction of an old one-gas power plant in town located in eastern Slovakia is presented in this paper. The method of the index coefficient was used for choosing the best alternatives. Multicriteria analysis proved that the construction of biomass-fired power plant is the most suitable solution chosen from three assessed variants (no activity is implemented, biomass power plant and modernized gas boiler).

Keywords: biomass-fired power plant; ecological criteria; economic criteria; multicriteria analysis; technical criteria and technological criteria

1. Introduction

The Cardiff summit in 1989 created the platform of coordinated action aimed at protecting the environment. The European Commission has progressively focused its attention on the development and integration of environmental aspects into the sectoral policies of transport, energy, industry, agriculture, industry, internal economic policy and fisheries. The first step was decision-making of the first integration strategy in the energy sector adoption in 1999, which was modified in 2001 and presented in Gothenburg, Sweden, before the European Council [1,2].

Directive 2001/77/EC [3] of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market and Directive 2003/54/EC [4] of the European Parliament and of the Council of 26 June 2003 have stability rules commune in terms of obtaining and distributing electricity. Another important document presented by the European Commission was "Green Paper on a secure, competitive and sustainable energy for Europe" [5], which was released in 2006. The aim of the EC was to create an integrated energy policy in Europe. The Commission Communication [6] of 10 January 2007 entitled "Roadmap for renewable energy—Renewable energies in the 21st century: building a more sustainable future" has demonstrated that a 20% target for the global share of renewable energy would be achievable targets and that a framework that includes binding targets should provide the business community with the long-term stability needed to make rational, sustainable renewable energy investments to reduce dependence on imported fossil fuels and increase the use of new energy technologies.

In December 2008, a wide range of measures in the European Union (EU) was adopted, which were aimed at reducing the impact of the EU states' activities on global warming and also reducing negative effects on the global climate, while ensuring adequate and reliable energy supply. The Framework

Directive 2009/28/EC [7] on the promotion of the use of energy from renewable sources aims at developing the local and regional electricity market in order to reduce greenhouse gas emissions.

Energy is one of the sectors that pollute and harm the environment the most. The alignment of energy and environmental conditions is at the moment one of the most serious strategic challenges to addressing global environmental problems. Therefore, the development of energy must strictly respect the principles of sustainable development. With a view to the future, the reduction of the negative effects of energy on the environment in Slovakia can be achieved by promoting the use of renewable energy sources as well as by promoting energy-saving measures [3].

From the point of view of sustainable development, the transition from the use of non-renewable energy sources to the use of renewable energy sources is necessary. To achieve this goal, it is necessary to change habits, practices and technologies not only in production but also in consumption. Total energy consumption is one of the main determinants of the impact of energy on the environment. Therefore, it is necessary to harmonize the relationship between energy and the environment through the introduction of technologies using renewable energy sources. All energy sources must be used not only with respect to the environment but also with respect to human health [8]. There are many Environmental Impact Assessments (EIA) of the thermal power plant worldwide. The energy strategy of the EU has become one of the most important factors influencing the development not only in the polity of the member states. Different mitigation measures for the control of pollution caused by thermal power as well as some new technologies are described in the paper by authors from India [9]. The Environmental Impact Assessment Report for the Tanda thermal power plant (in New Delhi) presents that the adverse environmental impacts due to construction and operation of thermal power can be mitigated to an acceptable level by implementation of various measures for mitigation [10]. In a paper by Pokale [11], the EIA of the thermal power plant and its effect, as well as a cost-benefit analysis, are presented and discussed. Studies not only from Italy [12], Bangladesh [13], China [14,15], Spain [16] or Turkey [17] confirm that the countries try to make every effort to respect the principles of sustainable development. Moridi et al. (2015) [18] presented a Multi-Criteria Decision-Making analysis method (MCDM) with the aim to select and prioritize appropriate technologies based on key criteria including cost, design, maintainability, and size and filtration efficiency in their paper. They were searched for optimal technologies for the treatment of air pollutants emitting from industrial complexes, especially petrochemical industries. EIA is a necessary step also during the early planning stages of environmental structures in order to gain clear insights into the structures' probable impacts with respect to the different components of the total environment. Likewise, the use of appropriate EIA techniques can aid decision-makers in formulating appropriate actions based on informed decisions in light of project urgency and limited resources, which are common constraints in developing countries [19].

This paper is based on legislative and methodological documents relating to the assessment process of environmental impact—Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 [20] on the assessment of the effects of certain public and private projects on the environment (only Act in the following) (the Environmental Impact Assessment, or EIA Directive) [20] and exactly Act No. 24/2006 Coll. on Environmental Impact Assessment as amended [21]—national Law in Slovakia (only Act in the following). The purpose of this Act is to ensure the procedure for the overall expert and public assessment of construction, and other activities determined under the Act (see Act Annex) prior to the decisions on the permission thereof under special provisions, and also for the assessment of proposals for certain development policies and generally binding legal directives from the point of view of their presumed effect on the environment.

The main steps of the EIA process in Slovakia according to National Council of the Slovak Republic 2005 are presented in Figure 1 [22].

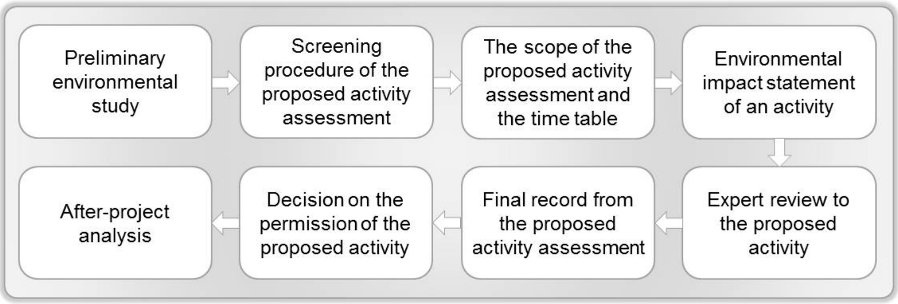

Figure 1. Main steps of the Environmental Impact Assessments (EIA) process in Slovakia (National Council of the Slovak Republic 2005) [22].

The 2006 EIA Act introduced no major changes in EIA procedures; it tightened certain procedural time limits and better delineated EIA responsibilities between the Ministry of the Environment and the regional and district environment offices. The Act was amended many times to respect all requirements of European Union; the last amendment was in June 2017, which was devoted to public participation in the EIA process [22].

There is a direct proportion of energy production and impact of the assessed activity on the environment. Effective and rational use of energy seems to be the best solution how to decrease the negative impact [8].

In the Act, the term "activity" is defined as an operation (structure, facility or others) that by its properties, localization or cooperation with other factors can affect the environment and cultural heritage. To implement such an activity, the permission (approval) or other decision according to specific regulations is necessary.

The Act consists of six parts and sixteen annexes. Annex 8 presents a list of activities subject to environmental impact assessment. It is divided into part A, presenting activities subject to obligatory evaluation, and part B, presenting activities subject to screening.

Variant solutions which are subject to assessment are mostly different in terms of capacity, technology, time of realization, construction costs and maintenance costs. When comparing variants, the result should be in the order of suitability for implementation with regard to human health and the environment. The economic and technical aspects of implementation are the most distinct. The economic aspect is not required by Act 24/2006 [21] to be considered, therefore, in many intentions it is only advisory. Comparing of variations mostly only provides information on the impact of individual variants on the environment and human health [6].

The proposed activity is the construction of a new biomass-fired power plant or reconstruction of an old one-gas power plant in the Trebišov town district in Slovakia. The result is a comparison of the proposed activities with the current state of the area using index coefficient method and finally the selection of the best alternatives of the heating system of Trebišov city.

2. Materials and Methods

2.1. Description of the Study Area

Impact assessment on the environmental compounds of the proposed power plant for heating in Trebišov city in Slovakia (Figure 2) was done according to Act 24/2006 Coll. as amended [21]. Trebišov is situated in the southeast part of Slovakia. It is surrounded by the Slanské Mountains that affect the air circulation. Southwest to northwest winds prevail in this territory. Average annual wind speed in the lowlands of Slovakia is relatively homogeneous. Minimum wind speed is usually connected with situations of temperature inversion, especially in the winter season.

Trebišov district is separated into three climatic areas. Part of the district lies in warm and moderately warm climatic areas and one part lies in cold climatic areas (higher than 800 m a.s.l.) [23].

The study area according to temperature is characterized by two areas. Specifically, part of the district is situated in a warm and dry area with cold winter (January ≤ -3 °C) and part belongs to warm and mildly dry area with cold winter (January ≤ -3 °C).

Long-time average air temperature measured at the Milhostov weather station is 9 °C, and during the vegetative season, the temperature reaches 16.5 °C. The duration of the vegetation period is 200–220 days. The average number of summer days is 67 [23,24].

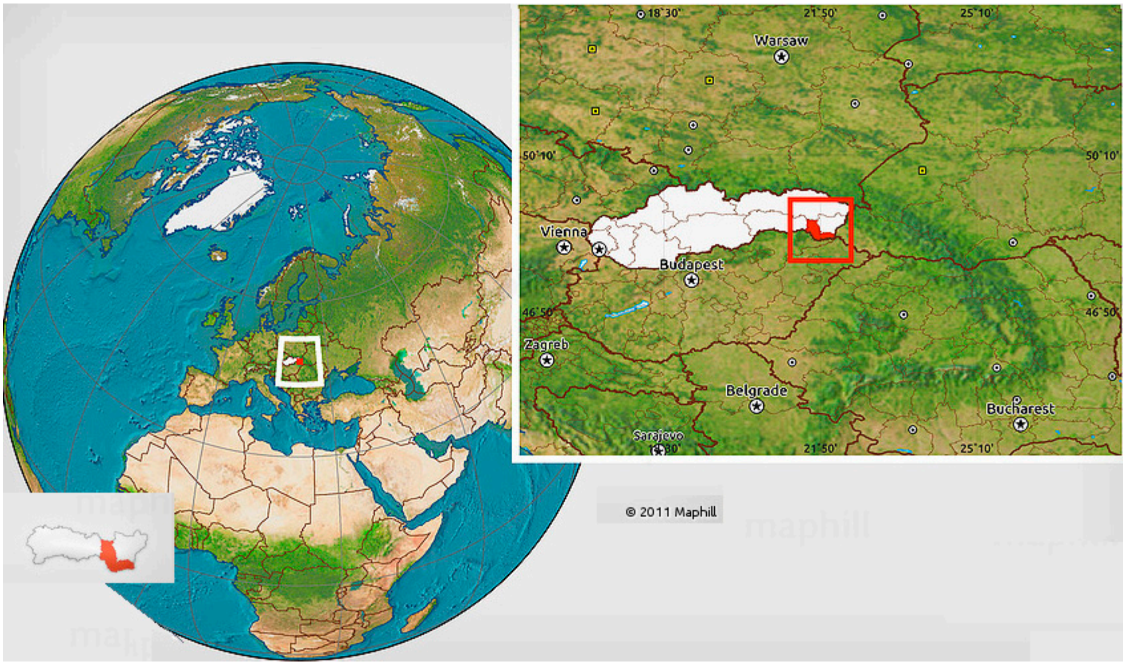

Figure 2. Location of Slovakia and Trebišov district within the European Union (adapted from maphill.com) [25].

The rivers in the Trebišov district are the Ondava River and Latorica River. There are no areas of water bodies which are under the protection. Very important water sources are the Ondava River and Trnávka River, as well as Ruskovský Pond situated in this study area [26]. From the geomorphological division, the study area is located in the Matransko-Slanská area (The Western Carpathians) and in the Eastern Slovakian Lowlands. There are no more significant deposits of ore minerals in the vicinity of Trebišov. There are mainly non-toxic raw materials here as andesite (mainly), which is used primarily as a building material, gravel or paving stone. In particular, the Slanské Hills are covered with andesite volcanoes and stratovolcano.

In the cadastral area of the Trebišov town, the following soils are found: black, brownish and bottomland occurring as subtypes of the black soils and brownish soils [27]. From the agricultural point of view, the most valued are brownish soils. They are more harvested and used for cereal growing. The acidity of the soil is weakly alkaline and has a pH value of 7.3 [27].

2.2. Description of the Project

A brief description of the technical and technological solution is as follows. The central energy source of heating for Trebišov town has two possibilities:

- biomass-fired power plant (alternative 1; wood chips and straw);
- modernization of existing natural gas boiler (alternative 2).

A technological solution of biomass-fired power plant consists of the boiler house (SO 01), a handy storage of straw (SO 02) and technical annex (SO 03). Individual objects are connected structurally and technologically. Objects of power supply are located in the northern part of the plot.

The boiler construction consists of a steel hall with three boilers, one for combustion of wood and two for burning straw. The building object SO 02—a straw storeroom—consists of a single store. There is a firewall designed between the boiler room and the straw storeroom. The building object SO 03—the technical annex—consists of two above-ground floors. Construction of the technical pavilion is built of Porotherm walls. In the technical pavilion, there is the operator, the equipment and the administration of the boiler room [23,24].

2.2.1. Biomass-Fired Power Plant

Wood Chips Combustion

Uncontaminated wood chips will be used as fuel. The preparation of fuel is ensured by cleaving of waste wood (wood-based residue from wood extraction) [23,24]. The fuel will be transported to the boiler room by means of a lorry with a trailer on which two containers are attached with volumes of $2 \times 35\ m^3$. The cars enter via gate No. 1 to the building and the fuel is emptied to a biomass-wood storage site (building SO 04). It is an uncovered, three-sided (height of 2.5 m) concrete walls bounded space. The entrance of fuel into the landfill, as well as its storage, is illustrated by the red arrows, and the transfer of fuel from the biomass landfill to the charging press is illustrated by the blue arrows in Figure 3. Ash removal from the burning process is illustrated by the green arrows. The task of the fuel store exchanger is to gradually add the accumulated quantity of feedstock (wood chips) to the feed press and through it to the inlet part of the boiler in order to ensure the continuous supply of the boiler to the fuel.

Figure 3. The direction of the fuel handling (source: by authors).

Straw Combustion

As a fuel, the straw used in agriculture as cereal crops will be used. Fuel is provided by packing into large straw bales in the fields.

The fuel will be transported to the boiler room by means of a lorry on which straw bales are stored. The straw is stored on the car; in one layer there are 10 parcels and, in the case of an assumed package with a width of 1200 mm, height 900 mm, length 2200 mm, weight 261 kg, can be placed in three layers. One trailer car carries 60 straw bales for a total weight of 15.66 t [23]. The cars enter via gate No. 1 and the fuel is transported either directly to the straw storeroom (SO 02) or to the straw landfill (SO 05). The placement decision will be based on the fulfilment of both stocks. The unloading is carried out using a forklift truck. The transport of fuel to the boiler house and to the warehouses is illustrated by the red arrows in Figure 4.

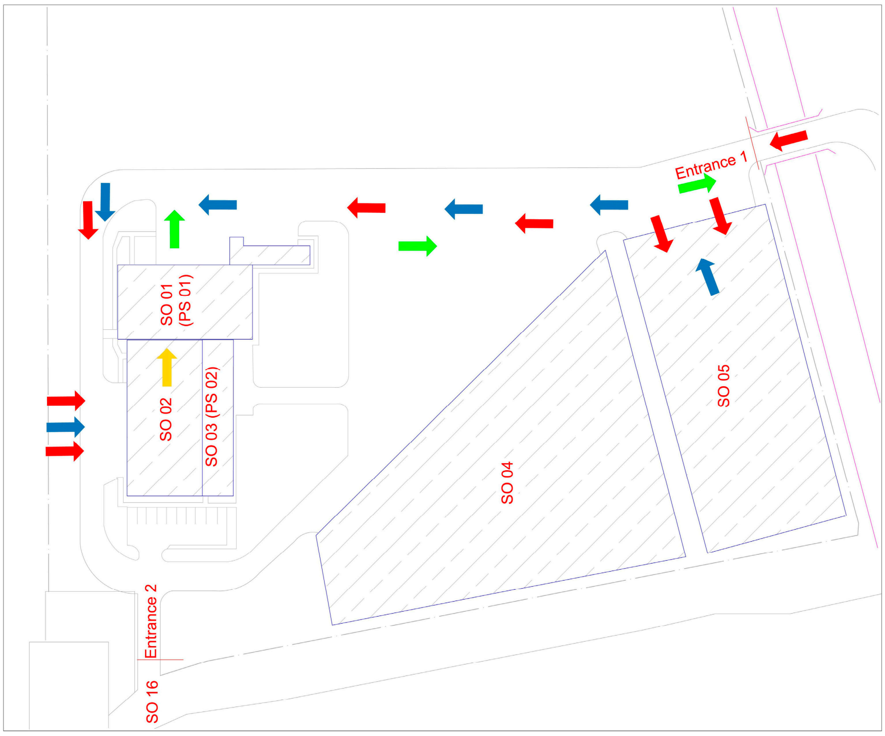

Figure 4. The direction of the straw handling (source: by authors).

The covered straw landfill (SO 05) only serves as a temporary storage to overlap a failure in the fuel supply logistics to the boiler house. In the case of emptying the straw storeroom (object SO 02), straw bales will be taken from the covered straw landfill (object SO 05) using a forklift truck. The transport of fuel from the covered straw landfill to the straw storeroom is illustrated by the blue arrows in Figure 4.

In the case of direct straw removal in the straw storeroom (object SO 02), the packages are stacked on top of a precisely drawn place on the store floor. Storing exactly in place is important for handling straw bundles using an automatic crane. The bridge crane located on the crane track, which will be located on the building of the hall, ensures the transport of the straw package as required by the boiler automation and its placement on the conveyor, which ensures delivery of straw to the boiler. The fuel transportation within the interior spaces is represented by a yellow arrow and ash removal from the burning process is illustrated by the green arrows (Figure 4). Just before entering the straw bales into the boiler, the conveyor ensures that it is rotated to the vertical position. In this position, the straw bundle is cut into three parts by means of the cutting device and transported to the boiler itself, where it burns [23].

2.2.2. Modernization of Existing Natural Gas Boiler

Atmospheric natural gas-fired water tube boilers are used in old central boiler houses. These boilers using the combustion gas transfer the heat to the primary heat exchanger, then it 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 [23,24,28]. They produce dry combustion products which reach a temperature of 120 °C to 180 °C. Hot combustion products are discharged to the chimney, thereby loss of heat appears. Waste gas contains latent heat which is 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 the chimneys. They have a high temperature and steam having a high energy flows through the chimney without further use.

When gas is heated, large amounts of flue gas are generated and released into the atmosphere through the chimneys. They have high temperature and water vapor, which has high energy, escapes the chimney without any further use. With conventional gas boilers, the connection of the condensate hose to the waste is complicated. The hose may clog or freeze, and the condensate can enter the boiler and cause a boiler failure. Sewage water can also be pushed out into the boiler [28,29].

2.3. Application of the Methodology

A lot of methods (tools) have been utilized over the last decades to meet the different actions required in the conduction of impact studies. The objectives of the different actions vary, as do the usable methods for each. These methods are described for example in [30] or [31,32].

Guidelines of European Commission [33] provide information on methods and tools that were selected from case studies and literature research. These generally fall into two groups:

- Scoping and impact identification techniques—these identify how and where an indirect or cumulative impact or impact interaction would occur—Network and analysis; Consultation and questionnaires; Checklists, Matrices; Expert opinion.
- Evaluation techniques—these quantify and predict the magnitude and significance of impacts based on their context and intensity—Matrices; Expert opinion.

It is possible to apply at the outset to define the problem, establish the terms of reference, design the overall EIA process, and set the study boundary. Scoping helps to reform EIA institutional arrangements by focusing on each EIA activity and documents (impact identification and prediction, public and agency consultation and other), as well as subsequent proposal acceptance or rejection [34].

During the EIA process usually, a combination of techniques is used, or approaches are adopted at different stages of the project. Examples of both categories are set out below, in Figure 5.

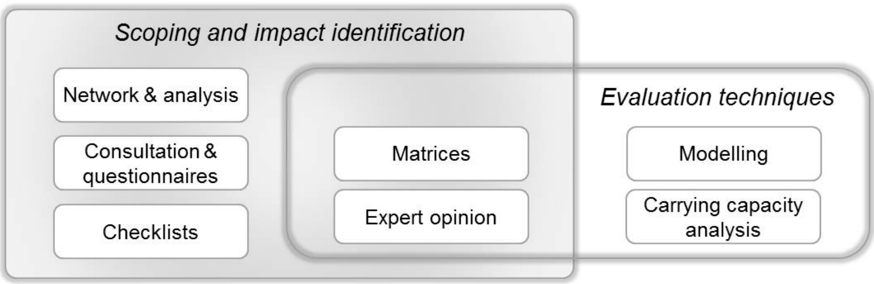

Figure 5. Methods and tools for assessment of indirect and cumulative impact as well as impact interaction (after Walker and Johnston 1999) [22].

The next differentiation of methods in the EIA process is given also in Zeleňáková and Zvijáková (2017) [22]. Table 1 presents the recommended methods suitable for impact assessment in the preliminary impact study, environmental impact statement and methods of multicriteria analysis.

Table 1. Methods for impact assessment in the preliminary impact study, environmental impact statement and methods of multicriteria analysis (after Kozová et al. 1996) [22].

Group of Methods	Methods
Recommended methods suitable for preliminary impact study	Ad hoc methods Checklists and catalogues of criteria Tables and matrices, expressing the causes and the effects Networks and system diagrams Decision trees Overlay mapping
Recommended methods suitable for environmental impact statement	Prognostic methods • Modeling - mathematical models - simulation models - experimental in situ or laboratory models • Comparative methods
Multicriteria analysis	Method of utility function Total Environmental Quality Indicator (TIEQ) method Methods for determining weights of criteria • Ranking method • Allocation method • Grading method • Pairwise comparison method • Dual method ALO-FUL

Multicriteria analysis considers the assessment of the impact on the environment. Objective assessment is based on the use of quantitative factors—objective technical, technological, social and economic units. Qualitative assessment includes [35,36]: indicators; indices; intervals; categories; classes. Indicators can be represented by its description. Indices and intervals can express the magnitude or quality of parameters using the index function. Categories and classes use usually the subjective assessment of the features of interval and/or ratio scales. Formalized workflow involves ensuring that detection of an impact is done using a single method, and prognosis of induced changes is carried out on a scientific basis.

The selection of the optimal alternative is enjoyed by various methods, particularly by multicriteria analysis. The general procedure of multicriteria evaluation of alternatives includes six relatively discrete steps [8]:

- The creation of a purpose-oriented set of evaluation criteria;
- Setting the weights of the evaluation criteria;
- Assessment of the results (consequences, benefits, but also potential damages or losses of alternatives), it is a partial assessment of the alternatives;
- Assessment of the risks associated with implementing the alternatives;
- Determination of the preference order of alternatives and selection of the best option.

Multicriteria analysis is used to determine the value of a comprehensive land use in terms of the quality of the environment affected by humans. Multicriteria method utilizes the catalogue of criteria [8,37,38]. Its structure is hierarchical, adaptive and, basically, the whole society allows you 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.

In the EIA process, it is always necessary to consider at least two alternatives to the proposed action:

(I) zero alternative—if there is no activity (current state of the environment); and
(II) alternatives of the proposed activity—variants of the activity that usually differ in the locality (site of construction), used technology, time of implementation, etc.

The purpose should be to find the optimal solution, in practice a choice called "preferred option". The selection of the optimal alternative is enjoyed by various methods, particularly by multicriteria analysis [36].

The evaluation presented in a previous paper [39] was done using the method of the Total Environmental Quality Indicator (TIEQ) to calculate the optimal variant. The TIEQ method is a modified utility function. The principle of this method is that the assessed impacts represented by the relevant indicators can be considered from the point of view of quantity and quality and transformed into partial utility functions and these values can already be compared [37]. According to this method alternative of biomass-fired power plant, (A1) is the best one [39]. However, due to the extent of the project, the demand for proof of this fact by another method was required. It makes the calculation more objective and has a higher value. The index coefficient method was chosen as the next method of multicriteria analysis for assessment and for selecting the best option for boiler construction in Trebišov city.

The index coefficient method determines the partial evaluation of the criteria through the calculation of the partial profitability through the index coefficient k_{ij}. The total profitability of the variant U_j (Equation (1)) is determined as the sum of the coefficients of the index coefficients k_{ij} (Equation (2)) and the criteria of the relevant variant and the weight of the i-th criterion [40]:

$$U_j = \sum P_{ij} = \sum k_{ij}.w_i \tag{1}$$

U_j is the overall profitability of the j-th variant; P_{ij} is the i-th criterion of the j-th variant; k_{ij} is the index coefficient of the i-th criterion of the j-th variant; w_i is the weight of the i-th criterion where $\Sigma w_i = 100$. The value of U_j determines the order of the advantage of the variants. There are also different possible methods for determining weights of criteria:

- Ranking method
- Allocation method
- Grading method
- Pairwise comparison method
- Dual method ALO-FUL

Pairwise comparison method by Fuller triangle was used in the presented case. The determined criteria were compared based on a number of preferences to each criterion. The total number of the pairs is n/2(n − 1); in our case, it is 9/2(9 − 1) = 36. The final weight for each criterion is calculated by a number of preferences to criterion divided by 36. The variation that achieves the highest value of overall performance is the best possible [40].

$$k_{ij} = \frac{H}{b_v} \tag{2}$$

The coefficient k_{ij} is determined by comparing the value of the criterion of the variant under consideration (H) with the value of the basic variant (b_v). A basic variant is a fictitious variant whose values of the criteria are theoretically the best (worst) or variants whose values for the criteria are predetermined according to the set goal. The principle of this method is that in a fictitious base variant we replace criterion values by number 1. The profitability of the criteria for the other variants is calculated using a coefficient as the ratio between the value of the calculated variance criteria and the original value of the base criterion. To determine the k_{ij} coefficient, two classes of criteria have to be distinguished. The first class is profit-type criteria, where higher values are preferred to lower performance levels (i.e., the higher the criterion value, the better). The second class is cost-type criteria where lower values are preferred to higher performance levels (i.e., the lower the criterion value, the better this criterion) [40]. Thus, criteria for increasing or decreasing preference are distinguished.

3. Results and Discussion

In the EIA process, considerations of two alternatives of the proposed action in comparison with zero alternative is usually taken in the assessment. In the presented case the study of considered alternatives are:

- Alternative 0—the zero alternative—if no activity is implemented.
- Alternative 1—the biomass-fired power plant in Trebišov district.
- Alternative 2—modernization of existing natural gas boiler.

Comparison of alternatives is done by multicriteria analysis. The beginning of this evaluation is creating a set of criteria and determining their importance (weight). We have chosen nine criteria described in Table 2. For evaluation and comparison, the criteria are divided into qualitative and quantitative ones.

Table 2. Description of criteria.

Aspect	Economic	Technical	Ecological	Social
Criteria (P_i)	the total cost of construction (P1)	time of construction (P3)	waste production (P6)	job opportunities (P8)
	annual operation cost (P2)	land occupation (P4)	emissions production (P7)	extra boiler room construction (P9)
		energy outputs of the power plants (P5)		
Character of assessment	quantitative	quantitative	qualitative	qualitative

The points (0–10) associated with each criterion (Table 3) were stated based on different experts' suggestions [23] (10 experts were involved) by brainstorming method with the aim to get the most objective results. The opinions of experts did not differ widely in most cases.

Table 3. Index coefficient method.

Criteria Pi/ Alternative Ai		P1	P2	P3	P4	P5	P6	P7	P8	P9	$\sum U_j$
b_v		9	8	10	8	9	8	7	9	8	
w_i		3	3	8	3	11	17	19	17	19	**100**
A0	value	0 €	0 €	0 months	0 m^2	0 MW	no	0%	0	yes	
	points	9	8	10	8	0	8	7	0	0	
	k_{i0}	1	1	1	1	0	1	1	0	0	
	$k_{i0}.w_i$	3	3	8	3	0	17	19	0	0	**53**
A1	value	3.8 mil. €	0.54 mil. €	9 months	2000 m^2	14 MW	yes	0%	8	no	
	points	3	6	2	3	9	5	7	9	8	
	k_{i1}	0.33	0.75	0.2	0.375	1	0.625	1	1	1	
	$k_{i1}.w_i$	0.99	2.25	1.6	1.125	11	10.63	19	17	19	**82.6**
A2	value	2.6 mil. €	0.65 mil. €	3 months	1250 m^2	10 MW	yes	6.5%	6	no	
	points	8	5	8	6	8	4	6	7	8	
	k_{i2}	0.88	0.625	0.8	0.75	0.88	0.5	0.86	0.78	1	
	$k_{i2}.w_i$	2.64	1.875	6.4	2.25	9.68	8.5	16.3	13.26	19	**79.9**

Ecological criteria are the most important from an environmental perspective. The evaluation is influenced by subjective opinions of evaluators. The effects of operating variants cannot be measured, assessed and compared. Two criteria are evaluated (P6 and P7). A0 has the best results (no waste production) and A1 and A2 have broadly similar points (some waste production exists). During the combustion processes of biomass, the ash is produced and, in the case of modernized natural gas boiler, condensation and latent heat appear. A0 and A1 produce no emission, which is why they are better than A2.

Economic criteria are important aspects of comparison. In this case, they determine and compare the costs spent on the construction (P1) and annual operation of the alternatives (P2). In our case, the cheapest variant is Alternative A0, while Alternative 1 (A1) is more expensive in the total costs of the construction compared to Alternative 2 (A2), but is more favourable in the annual operating costs.

Technical and technological criteria were evaluated quantitatively. Criterion as the time of construction (P3), land occupation (P4) and energy output (P5) of three boilers belongs here. In two criteria, A0 is more advantageous than A1 and A2, but in the comparison with the third criterion—the output of boilers—Alternative 0 is the worst. Comparing criteria of A1 and A2 at the time of construction and land occupation, A2 is the preferred option, but according to an aspect of energy output, A1 seems to be a better variant.

Social criteria are also qualitatively assessed. The rating is influenced by subjective opinions of evaluators as well. Social impacts directly interfere with the quality of the life of the population, in our case, the alternative which offers more job opportunities (P8) and where it is needed for extra boiler room construction (P9). Since boilers are designed for citizens, they are designed to improve the quality of their lives. In our case, it has been compared which alternative can provide more job opportunities and which alternative contains the residents' need to build their own home boiler room. In both alternatives mentioned above, A0 is the worst. A1 is better than A2 compared to the job opportunities. In terms of the second criterion, both alternatives are able to compensate for the home boiler to a sufficient extent so that residents do not have to build the home boiler rooms.

The second step was to determine the index coefficient k_{ij}. This is determined by evaluating criteria where the value of the highest criterion is replaced by a value of 1. Subsequently, the other values are calculated as the ratio of value 1 to the appropriate variant value. The basic variant in this step is those where number 1 is located. The total profitability was calculated based on Equation (1).

The construction of the biomass-fired power plant is the best of the three compared alternatives based on the selected criteria from the point of view of the environmental impact assessment (Figure 6).

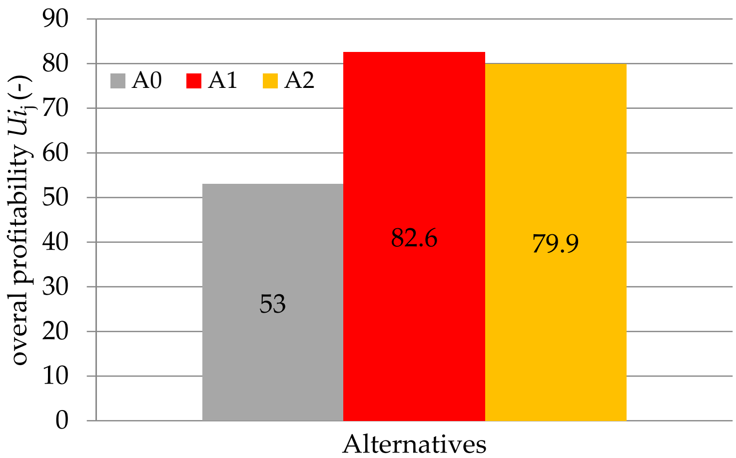

Figure 6. Summary comparison of the assessed alternatives.

The aim of the assessment was to make an overall investigation, description and evaluation of the direct and indirect environmental impacts of the activity on the environment, to determine measures that will prevent or mitigate pollution and damage to the environment, and to explain and compare the advantages and disadvantages of the proposed activity including its variants, in comparison also with the situation that would exist if the activity was not implemented. Biomass-fired power plant seems to be the better alternative (U_2 = 82.6) compared to modernizing the existing natural gas boiler (U_3 = 79.9) and compared to if no activity were implemented (U_0 = 53).

Alternatives 1 and 2 only have 2.7 points of difference. This difference is very low, so we made a sensitivity analysis of the different criteria, which are the criteria that have the real importance in the final decision. Sensitivity analysis of Alternative 0 is presented in Figure 7, Alternative 1 is presented in Figure 8 and Alternative 2 is presented in Figure 9 where criteria: P1—the total cost of construction, P2—annual operation cost, P3—the time of construction, P4—land occupation, P5—energy output, P6—waste production, P7—emissions production, P8—jobs opportunities, P9—extra boiler room construction.

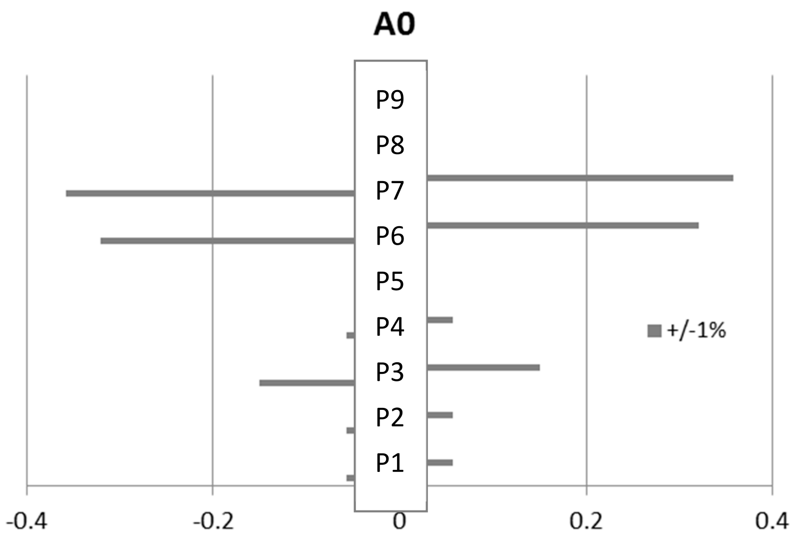

Figure 7. Sensitivity analysis of Alternative 0.

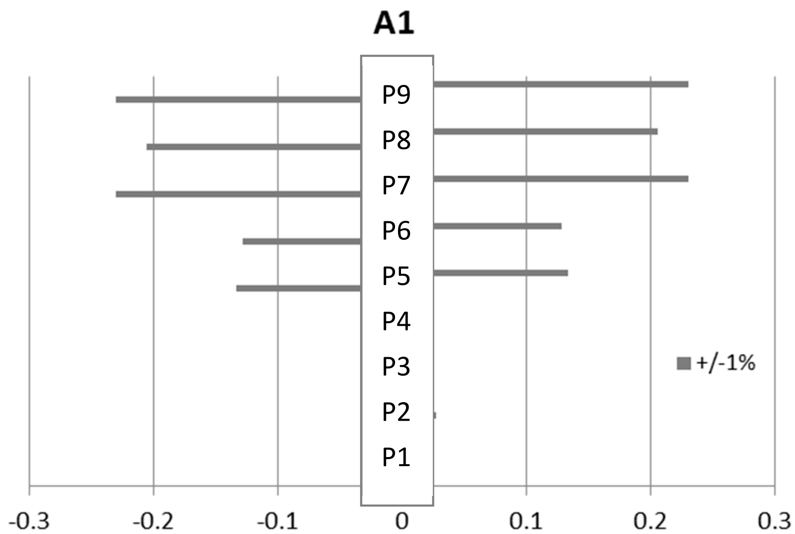

Figure 8. Sensitivity analysis of Alternative 1.

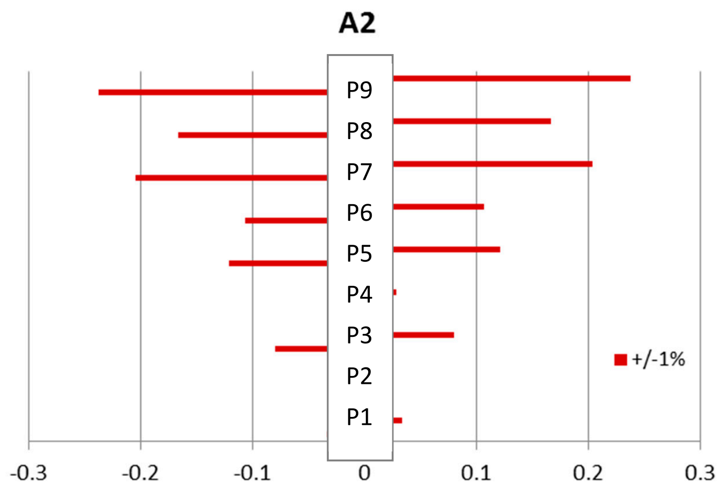

Figure 9. Sensitivity analysis of Alternative 2.

Figures 7–9 show results from sensitivity analysis as to how the model is sensitive to the choice of the criteria. The figures depict the effect on the selected activity (its alternatives) due to the different input data. Criteria: P7—emissions production and P9—extra boiler room construction have major influences on the selection of the best alternative. The assessment shows the highest sensitivity to these criteria. The proposed activity shows little sensitivity to all other criteria P1–P6 and P8.

4. Conclusions

The environmental impact assessment process for plants, structures, facilities and other activities has been applied in developed countries for several decades and is one of the main tools of preventive environmental protection and sustainable development.

The use of biomass in heating systems is beneficial because it uses agricultural, forest, urban and industrial residues and waste to produce heat and electricity with less effect on the environment than fossil fuels.

Coefficient index method as a tool of multicriteria analysis was used for proving that the construction of biomass-fired power plant is the most suitable solution chosen from three assessed variants (no activity is implemented, biomass power plant and modernization of existing gas boiler).

The index coefficient was used to state the weights of criteria. The points (0–10) associated with each criterion were stated based on ten different experts' suggestions with the aim to get the most objective results. In this evaluation, the highest score is the best possible. According to these points, Alternative A2 seems to be the best one (overall profitability of 82.6). Proposals were discussed with professionally qualified persons working in the field of environmental impact assessment as well as civil engineers.

The main contribution of the present paper is using theoretical knowledge of the issue, evaluation on the state of the environment in the area by the multicriteria analyses to select the optimal alternative of the action in the decision-making process in order to preserve environmental quality for further sustainable development of society in the study area. Most important for the assessment is the right selection of the criteria. In our assessment, we found out by a sensitivity analysis that the criteria that have the real importance in the final decision are P7—emissions production and P9—extra boiler room construction.

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