Application of Multi-Criteria Analysis in Environmental Impact Assessment [†]

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Abstract: A very important element of environmental impact assessment is the selection of investment options. There are many methods of choice, including Multi Criteria Decision Aid methods, which allow for multi-criteria assessment of investment alternatives. The aim of this paper is to assess the alternatives of agricultural biogas plants. Variants were assessed using three approaches—equal criteria weights, economical, and environmental—using the TOPSIS method. This allowed us to define the differences between investors' points of view and choose the best suited alternative.

Keywords: environmental impact assessment; agricultural biogas plant; MCDA; TOPSIS

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1. Introduction

Environmental impact assessment is a procedure based on the assessment and interdisciplinary identification of the impact of various types of investments on the environment, as well as on all processes occurring within it. Although there are many methods of assessment, multicriteria decision aid methods are popularly used when choosing both technological and location variants. There are many types of agricultural biogas plants, and various alternatives are considered when choosing the best alternative. In connection with the program “Innovative Energy—Energy-Related Agriculture”, more and more agricultural biogas plants should be created in municipalities.

Biogas is formed as a result of the transformation of organic compounds through anaerobic microorganisms in methane fermentation. Appropriate conditions for correct biogas formation consist of constant optimal temperature as well as moist surroundings, anaerobic conditions and sufficient availability of organic matter [1]. Biogas is obtained in a pro-ecological way, which is why energy obtained in biogas plants will result in reduction of exhaust emissions as opposed to energy gained by use of hard coal. This leads to the reduction of smog pollution. Thus, the process of construction and operation in such investments should not have a negative influence on the environment. Therefore, according to the Act of 3 October 2008 on the Provision of Information on the Environment and Its Protection, Public Participation in the Environmental Protection and Environmental Impact Assessments [2], a report of the Environmental Impact Assessment of an agricultural biogas plant is prepared [3].

In accordance with the principle of sustainable development, growth and development should take place in a way that maintains a natural balance and thus provide future generations with no less access to natural resources than we have nowadays. Worldwide consumption of fossil fuels, environmental pollution, and climate change are the reason scientists search for new, pro-ecological ways of obtaining energy.

2. Description of the Issue

The aim of our research consists of selecting between two technological variants of agricultural biogas plants in accordance with three different approaches. The first weighs the chosen criteria equally (impartial approach), whereas the second one is focused on to the environmental impact of such an investment. The last approach—economical—focuses on financial losses and gains. The second and third points of view weigh criteria differently in order to show how investors' objectives may influence the selected optimal alternative.

Out of the multi-criteria decision-making methods, the author decided to use the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method to carry out the assessment using rank weights. All Multi Criteria Decision Aid (MCDA) methods consist of three stages [4]:

1. definition of attributes and variants;
2. selection of variants and criteria (division of stimulants and destimulants);
3. processing values and ranking alternatives.

The TOPSIS method is commonly used for multi-criteria decision problems in which chosen alternatives are compared with a negative as well as positive ideal solution [5]. TOPSIS is a distance method as the variants are assessed by designating their distances to referenced solutions. The preferential string requires taking into consideration the weight of criteria and then standardizing the assessment of alternatives in light of mentioned attributes [6–8]. Lastly, the value of a synthetic meter is created, which results in the ranking of variants [5].

Criteria chosen to evaluate the alternatives should be selected wisely as representations that carry a lot of information. Usually these attributes can be divided into groups, i.e., spatial, environmental, or economical. During the process of selection in this research, the following criteria were chosen:

1. overall income (C1)—stimulant;
2. purchase of substrates (C2)—destimulant;
3. quantity of biogas generated (C3)—stimulant;
4. total efficiency (electricity and heat) (C4)—stimulant.

The analyzed subject is hypothetically going to be located on a previously chosen plot in Miastkowo municipality, in the village of Łuby-Kurki, selected by an assessment using the TOPSIS method [9] (Figure 1). The analysed variants consist of two agricultural biogas plants with a capacity of approximately 0.999 MW. The first one (V1) uses mainly slaughter waste as substrates, whereas the other one—variant 2 (V2)—uses only vegetable substrates, mainly maize silage.

Figure 1. Selected location—plot No. 189 in the village of Łuby-Kurki (V3). **Source:** [9,10].

With the mentioned technological alternatives as well as the selected attributes, a decision table was created. Table 1 presents how each variant changes according to the criteria shown. It can be observed that although the first alternative generates more income annually (C1), it is less efficient than the second variant. This will have an impact on the evaluation process.

Table 1. Decision table.

V/C	C1 [M PLN]	C2 [PLN/Mg]	C3 [m ³ /Year]	C4 [%]
V1	7.24	0	4,169,760	51
V2	6.26	2.73	4,174,218	88

Source: own work—estimation of C2, other data based on Refs. [3,11].

Using the TOPSIS method, one of the two alternatives was selected as the most optimal because it was most favourable in each approach according to all selected criteria (financial as well as environmental).

The conducted analysis categorized the options into two factions—the optimal, as chosen, and the suboptimal, as a slightly less favorable choice. As presented in Table 2, all assessments were carried out using rank weights, which were changed in relation to our objective. To ensure an impartial approach, in TOPSIS 1st all weights were equal, and in TOPSIS 2nd (environmental approach) ranks were as follows: C1—4th rank, C2—3rd rank, C3—1st rank, and C4—2nd rank. Finally, in third approach (economical), TOPSIS 3rd, the ranks were as follows: C1—2nd rank, C2—1st rank, C3—4th rank, and C4—3rd rank. Both alternatives were quite alike, so in each approach the value of the synthetic meters were similar, but as shown in Table 2, the most optimal option in every assessment was the second variant, which was an agricultural biogas plant with substrates of organic origin—mainly maize silage.

Table 2. Final ranking of alternatives using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method: TOPSIS 1st, using an impartial approach; TOPSIS 2nd, using an environmental approach; and TOPSIS 3rd, using an economical approach.

Rank	TOPSIS 1st	TOPSIS 2nd	TOPSIS 3rd
1—optimal	V2	V2	V2
2—suboptimal	V1	V1	V1

Source: own work.

3. Conclusions

The TOPSIS method is often used in Environmental Impact Assessment analysis. The study presents two different technological variations of agricultural biogas plants, which vary in used substrates as well as efficiency and annual income. Both options are commonly used, however, the alternative that utilizes substrates of plant origin is the most optimal in both economical and environmental approaches.

Often, the preferences of investors, who might be mostly focused on financial gain, show a lack of care for the natural environment. However, in this case, with these particularly selected criteria, perception of reality as well as the processes occurring and a different system of values did not have a great impact on the final decision. However, multi-criteria decision support methods are tools that allow a decision-maker to balance different attitudes in order to find a satisfying, compromising solution.

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