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Agricultural Biogas Plant Location Selection Using MCDA Methods †

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Abstract: Agricultural biogas plants are an investment that benefits both investors, inhabitants of a given region, as well as the natural environment. Such a project, despite many economic, environmental, and social advantages, is also associated with the emission of unpleasant odors or noise. That is why selecting the location of an agricultural biogas plant is a particularly important task. The investment location was selected using multicriteria decision-making (MCDA or MCDM) methods. Of the three variants, the most favorable in terms of the adopted criteria was selected using both analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) methods.

Keywords: agricultural biogas plants; multicriteria decision aid; investment location

1. Introduction

The role of agricultural biogas plants has increased in the recent years. This was due to the draft program developed in the Ministry of Economy "Innovative Energy—Energy-Related Agriculture". The intention of this document is to detail the creation of an agricultural biogas plant in each municipality by 2020. Such biogas plants use biomass produced not in sewage treatment plants but that originates from plant. High-yielding raw materials are energy crops, such as corn (silage), rye (silage), sugar beets, or potatoes. Natural fertilizers, including manure, are supplements for these. In the methane fermentation process of such biomass, agricultural biogas—i.e., gaseous fuel—arises. It is worth mentioning that the byproduct of this process, compost, can be used for fertilizing arable fields [1].

Agricultural biogas plants bring benefits not only to investors or residents of a given area, but also to the natural environment. These installations are characterized by low emission of harmful substances, thus contributing to the reduction of methane emissions and, through the use of the hygienization process, they contribute to the elimination of pathogens, which translates into a reduction in the risk of surface and underground water pollution [2].

Despite many environmental, economic, and social benefits of such installations, their location is related to the impact of agricultural biogas plants that is influenced on the environment, including the emission of unpleasant odors (whereby the odor mostly depends on the type of the used substrate), noise, etc.

2. Description of the Issue

The aim of the research is to select the most favorable location of agricultural biogas plant in the commune from three options, taking into account economic, spatial, and environmental criteria, which were divided into stimulants and destimulants. Among many methods of multicriteria decision-making (referred to by the abbreviation MCDA or MCDM), two were selected: AHP (analytic hierarchy process) and TOPSIS (technique for order preference by similarity to ideal solution).

The first one is based on the utility function and is characterized by hierarchy in the approach to the problem. In the AHP method, the decision-maker assesses the criteria by comparing them in pairs according to the 9-point Saaty's scale (1980), where 1 means equal significance, 3 means a slight advantage, 5 means a strong advantage, 7 means a very strong advantage, and 9 means the absolute advantage. The influence of the decision-maker on the assessment of criteria and the creation of comparisons by the matrix makes these judgments subjective. The final stage of the procedure in the AHP method is to determine the ranking of the options from the most to the least favorable [3].

The TOPSIS method is one of the most popular methods used for decision problems. In it, the considered variants are compared with reference solutions—a positive and negative ideal solution. When determining the order, the distances of a given variant should be calculated from the reference solutions, while taking into account the weightings of the criteria and the normalization of the evaluation. This allows for finding the value of a synthetic meter, by means of which a ranking of variants can be created [4].

Choice of the criteria used to evaluate the variants is very important. The criteria have to be a good representation of the criteria from a given group, they must provide a lot of information, and they cannot be repeated. Three groups of criteria were selected: environmental, economic, as well as spatial. These criteria include:

1. Distance to residential areas (C1)—destimulant;
2. Distance to the energy crops (access to them) (C2)—stimulant;
3. Distance to the protected habitats (C3)—destimulant;
4. Distance from the national or provincial roads (C4)—stimulant;
5. Cost of the land (C4)—destimulant.

The analyzed subject consists of three different locations (alternatives) situated in Miastkowo municipality. The commune is dominated by agriculture and has many lands with potential substrates which are energy crops. The mentioned commune has many protected areas, that is why the distance to these should be as far as possible. The chosen locations were in three different parts of Miastkowo (Figure 1). The first, plot No. 175, is situated in village Leopoldowo (east part of the commune), and it is in close range to the forest, which gives this location a great advantage as trees will become a natural shield against potential odor spread, noise, or air pollution, while the second is located in Czartoria (northern part), and the last one is the village Łuby-Kurki (central part).

(**a**) (**b**) (**c**)

Figure 1. Selected locations: (**a**) variant 1—plot No. 175 in village Leopoldowo (V1); (**b**) variant 2—plot No. 193 in village Czartoria (v2); (**c**) variant 3—plot No. 189 in village Łuby-Kurki (V3). (Source: [5]).

According to the mentioned location variants and selected criteria, a decision table was made. As shown in Table 1, the property in Łuby-Kurki is situated the farthest from the residential areas, is also the closest in distance to potential energy crops, and is located next to the national road. The cheapest, as well as the smallest, plot is situated in the village Leopoldowo, though it is also the closest to residential areas and the farthest from the national/provincial rode is the plot in Czartoria (V2), which gives this alternative a huge disadvantage in the upcoming analysis.

Table 1. Decision table. (Source: own work).

V/C	C1 (m)	C2 (m)	C3 (m)	C4 (m)	C5 (thousands)
V1	560	100	6230	1800	3978
V2	860	150	887	2560	7137
V3	1030	50	5610	0	975

Using the presented methods, one of the most favorable location variants was selected in each of the given installations, and then they were combined with each other. The selected, most advantageous location of the agricultural biogas plant is optimal due to all designated spatial, economic, and environmental criteria.

The analysis showed that the results also differ according to the different methods. In the AHP method, in which weights of the given criteria were estimated, the best variant was the land in Czartoria, and the worst was the first alternative, the property in Leopoldowo, although the second method, TOPSIS (1), used same weights as in previous analysis, and the results show that the best variant is the one located in the village of Łuby-Kurki. Interestingly enough, the worst was the one in Czartoria, where the same thing happened in TOPSIS (2) (Table 2). TOPSIS (2) was used with weights estimated by rank weights: C1—1st rank, C2—3rd rank, C3—2nd rank, C4—5th rank, C5—4th rank.

Table 2. Final ranking of alternatives in used methods: analytic hierarchy process (AHP), technique for order preference by similarity to ideal solution (TOPSIS) (1), using AHP weights and TOPSIS (2) using rank weights. (**Source:** own work).

Rank	AHP	TOPSIS (1)	TOPSIS (2)
1—best	V2	V3	V3
2	V3	V1	V1
3—worst	V1	V2	V2

3. Conclusions

MCDA methods, especially AHP and TOPSIS, are useful for choosing the location of an investment that can impact on the local environment, people, economy, and landscape. The study presents three different variations of agricultural biogas plant sites that were evaluated using the mentioned methods. Undeniably, the performed analysis demonstrated that the different methods, as well as subjective choices while estimating weights of the criteria, had a huge impact on the presented results. The two used methods have many differences, especially in their algorithms of action; therefore, to gain reassurance in the final choice, perhaps another analysis should be conducted using other MCDA methods. Nevertheless, only one decision-maker had an influence on the estimation of criteria's weights. That is why to objectify the results, a group of experts should make the decision, rather than one subjective decision-maker.

The choice of location is not only dependent on the criteria, but also on the policy of the given municipality. Many communes do not expect any industrial areas to be created in their region. Therefore, the construction of such installation in each municipality mentioned in the draft program "Innovative Energy—Energy-Related Agriculture" might be impossible to implement in the real life.

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