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FUNCTIONING OF AGRICULTURAL BIOGAS PLANTS FROM THE PERSPECTIVE OF TRANSACTION COSTS – A CASE STUDY

Key words: transaction costs, new institutional economics, agricultural biogas plant, bioenergy, bioeconomy

ABSTRACT. Agricultural biogas plants transform organic waste into a valuable source of renewable energy, necessary for the energy transition. The institutional environment of agricultural biogas plants shapes the specific operating conditions. It also influences several aspects of the operation, from ensuring the quality of the raw materials used for energy production to selling the energy produced. The main objective of this article is to present the transaction costs incurred by an exemplary agricultural biogas plant and to indicate their impact on the company's operations. To collect primary data, a structured interview was conducted with the owner of an agricultural biogas plant located in the Lubelskie Province in July 2023. The investigated company generates electricity and heat from agricultural biogas in a cogeneration system. The study concludes that transaction costs influence the choices made within the agricultural biogas plant and translate into its operation. The relevance of the information provided and the level of trust between the different participants in the transaction is indicated. This avoids in most cases an increase in the level of transaction costs as well as negative consequences for the operation of the agricultural biogas plant. The transactions concluded indicate that agricultural biogas plants primarily operate within a region and a local community. The study is a contribution to further research into the area of transaction costs occurring in agricultural biogas plants.

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INTRODUCTION

The explosive growth in energy demand, which began in the 19th century with the Industrial Revolution, resulted in a surge in energy production and thus in the use of fossil fuels: coal, oil, and natural gas. The development of economies and individual societies that has taken place is undeniable, with negative consequences for the climate. As climate change increasingly affects economies and societies through droughts, violent storms, and other atmospheric phenomena unprecedented in certain latitudes, the energy transition has become a key challenge for modern societies and economies. Thus, the ever increasing demand for energy, together with the need to modernise energy sources, creates challenges for individual countries. The reduction of fossil fuel-based energy production in production structures makes alternative ways of producing energy – renewable energy sources (RES) – gain in importance. As simulation models indicate, by 2050, the main RES will be wind and solar energy [IEA 2021]. One of the important renewable energy sources is bioenergy, which is defined as energy coming from the conversion of biological material (biomass) into electricity and heat [Williams et al. 2015, Muench, Guenther 2013]. As Mingxin Guo and his team [2015] point out, global bioenergy production will increase both under the influence of climate policy-making and progressive climate change. One of the important actors influencing the development of RES, including bioenergy, are combined heat and power plants using agricultural biogas – agricultural biogas plants.

Agricultural biogas plants are becoming an interesting field for researchers, which is observed by the increase in the number of publications covering the area of agricultural biogas production. A significant number of papers on biogas operators have focused on technological [Kuboń et al. 2023, Bumharter et al. 2023] and biotechnological [Lebuhn et al. 2014, Stolze et al. 2015, Tabatabaei et al. 2020] as well as environmental [Fuchsz, Kohlheb 2015, Hijazi et al. 2016, Møller et al. 2022] aspects. In contrast, relatively little attention has so far been paid to economic issues, particularly in terms of transaction costs. As pointed out by Ivanete Daga Cielo et al. [2023] transaction costs being an element of the New Institutional Economics (NIE) indicate several factors affecting the operation and efficiency of agricultural biogas CHP plants.

MATERIAL AND METHODS

The main objective of this article is to present the transaction costs incurred by a sample agricultural biogas plant and to identify their impact on the business. The study uses the approach proposed by Alcido E. Wander [2014] and is supplemented by the broader study of M.A.B.S. Splinter and L.K.E. Dries [2023] and Francesco Riccioli et al. [2023]. To collect primary data, a structured interview was conducted in July 2023 with the owner

of an agricultural biogas plant located in the Lubelskie Province. During the interview, the business owner was asked about:

- information on the agricultural biogas plant,
- processes related to obtaining information on available offers and transaction terms,
- issues related to the conduct of negotiations,
- adherence by existing business partners to the agreed contractual terms and conditions,
- factors determining transaction costs.

Qualitative data (subjective opinions of those providing information) were obtained and quantified using a 5-point Likert scale.

RESULTS

BIOGAS PRODUCTION FROM A POLITICAL ECONOMY PERSPECTIVE

Renewable energy sources are gaining increasing importance in response to the growing need for green energy production solutions. As Floris Van Foresta [2012] points out, technologies using waste as well as energy crops to produce and use biogas are being increasingly developed in Europe. Energy generated from biogas is an alternative to energy generated from natural gas. To produce energy from waste, it must be processed using anaerobic digestion of biomass. The resulting biogas consists of approximately 50-70% methane, 30-35% carbon dioxide, and a small percentage of oxygen, nitrogen, and hydrogen sulphide [Weiland 2010]. The produced biogas can then be burned in gas-fired boilers or cogeneration engines to generate electricity and heat [Majewski et al. 2016]. The literature identifies the primary sources and feedstocks from which biogas is extracted [Scarlat et al. 2018. Holewa-Rataj, Kukulska-Zając 2022]:

- landfills, primarily municipal waste,
- waste water treatment plants, including sewage sludge,
- agricultural biogas plants, including waste from the agricultural and food industry, as well as energy crops.

It can be seen from the above that the biogas production possibilities are extensive, with agricultural biogas plants being key from the perspective of this study. As Bohdan Stejskal [2008] points out, compared to other RES, agricultural biogas plants are characterised by a high stability of energy production. Thanks to the possibility of constant cogeneration of electricity and heat, CHP plants using agricultural biogas are an important element in building a sustainable energy system for a country. The use of waste from the agricultural and food industry positions agricultural biogas plants in areas of permanent access to specific energy raw materials (substrates). As indicated by Cornelis Bumharter et al.

[2023] agricultural biogas plants support local rural societies, leading to a certain degree of self-sufficiency of rural municipalities. The results obtained by Aleksandra Lubańska and Jan K. Kazak [2023] confirm that in Poland the majority of functioning agricultural biogas plants are local. Despite the functioning of agricultural biogas energy producers in particular on the local market, it is important to extend this perspective due to the similar difficulties faced by local green energy producers. One of the best developed markets for agricultural biogas is the European market. Germany leads the way in technological development and the use of agricultural biogas for energy production [Ignatowicz et al. 2023]. It is worth mentioning that, as Dariusz Kusz and his team [2023] point out, Poland belongs to the group of countries with a high potential for biogas production, however, due to many barriers this potential is not fully exploited. Anita Bednarek et al. [2023] emphasise the importance of several constraints such as the lack of proper funding programs for the construction of agricultural biogas plants or the high operating costs of agricultural biogas plants. The results of studies from the Polish market are partly consistent with those obtained for the German market, where the importance of the contribution of agricultural biogas plants to the development of the energy and district heating system is also emphasised [Thrän et al. 2023]. In addition, the authors emphasise the importance of stable legal regulations for renewable energy sources.

The European Green Deal (EGD), which is a package of policy initiatives, creates challenges and forces individual EU Member States to adopt legal regulations regarding, among other things, renewable energy sources. In Poland, the production of agricultural biogas including its use is regulated by the Act of 20 February 2015 on renewable energy sources. On 13 July 2023, the Act on facilitation of investments in agricultural biogas plants and their operation was passed. The introduced provisions are intended to accelerate and streamline investments as well as the operation of agricultural biogas plants in Poland. Current legal regulations [Journal of Laws of 2023, item 1436, with amendmends] indicated several requirements relevant to the operation of CHP plants using agricultural biogas. To be able to produce electricity and heat, each agricultural biogas plant is required to be registered in the register of agricultural biogas producers kept by The National Support Centre for Agriculture (pl. KOWR). The law also imposes the need to make periodic reports on the raw materials used for energy production and make them available to KOWR. Another area of importance is the possibility of selling the electricity generated. Entrepreneurs have several options available in this case: feed-in tariffs, certificates of origin, and auctions for the sale of energy from renewable sources. The issuing of certificates of origin and the auctions involving the sale of energy are supervised by the Energy Regulatory Office (ERO).

TRANSACTIONS COSTS IN THE OPERATION OF BIOGAS PLANTS

The institutional environment of agricultural biogas plants shapes the specific operating conditions. It also influences several aspects of the business from ensuring the quality of the raw materials used for energy production to selling the energy produced. The institutional environment of enterprises contributes to the research for the New Institutional Economics (NIE) doctrine. Institutions are meant the rules governing human conduct, taking the formal form of legislated law and the informal ones based on the culture of a country [Aoki 2001]. The research tool used within NIE is transaction costs, which were defined by the creator of the concept Ronald Harry Coase [1937] as the costs of using the price mechanism. Despite the rather long history of the concept itself, transaction costs have not lived up to a single accepted definition. Emerging definitions focus on various aspects related to the market mechanism [Coase 1937, Arrow 1969], property rights [Demsetz 1995], or the operationalisation of transactions [North, Wallis 1986]. About transaction costs, mention should also be made of the definition proposed by Oliver Williamson [1998], who indicated that these are the comparative costs of planning, adapting, and coordinating the execution of tasks within different management structures.

The variety of approaches in defining transaction costs influences the typologies and research approaches used. The most common and at the same time very general distinction of transaction costs is their division into ex ante and ex post costs [Gruszecki 2002]. Another equally frequent division is the classification of transaction costs taking into account where they arise, where managerial, market, and public transaction costs are distinguished [O. Kyzenko, D. Kyzenko 2016]. However, both of these classifications are not precise enough. Depending on the adopted research topic, different costs may be included within transaction costs. Therefore, economists using transaction cost theory in their research use a more detailed distinction between them. Alcido E. Wander [2014] proposes the following division of transaction costs:

- costs of information: defined as the costs of searching for and obtaining information about transaction partners and their terms and conditions,
- costs of negotiation: referred to as costs associated with the negotiation process,
- costs of control and monitoring: are costs focused on ensuring compliance with the terms of the agreed contract,
- costs of adaptation: relating to costs arising from the enforcement of contract amendments during the contract period.

A slightly less extensive classification was proposed by Evy Mettepenningen and team [2009], where categories of transaction costs such as search costs, negotiation costs, and implementation costs were identified. The two indicated divisions of transaction costs cover the range of activities that make up the execution of a transaction and, consequently,

the conclusion of a contract between two entities. The classifications indicated are based on the main stages of entering into and carrying out a transaction. The key aspect is the transactions themselves and it is about them that transaction costs should be considered.

In contrast to the definition of transaction costs, the literature agrees on the factors affecting the level of transaction costs in a firm. Oliver Williamson [1998] points to three attributes affecting the level of transaction costs: asset specificity, uncertainty, and opportunism, as well as the frequency of transactions. Asset specificity means the uniqueness of the asset in the context of the transaction. Uncertainty, on the other hand, together with opportunism, emphasises the psychosocial aspect of the transaction and the involvement of individual agents – people – in it. The fact that the transaction is made by people significantly influences the transaction. Researchers [Diaz et al. 2023, McManus 2023] highlight the impact of people's bounded rationality and uncertainty on transaction costs. Alcido E. Wander [2014] complements this with information being a key factor, being an extremely important element at every single stage.

CASE STUDY OF A BIOGAS PLANT IN THE LUBELSKIE PROVINCE

The agricultural biogas plant located in the Lubelskie Voivodeship has been in operation for more than 10 years and employs a total of nine people. The company has adopted the legal form of a limited liability company. The studied entity produces electricity and heat from agricultural biogas in a cogeneration system. In 2022, the average monthly revenue from electricity sales was between PLN 570,000 and PLN 700,000. Revenues were significantly impacted by the increase in energy prices in Poland in 2022. The nature of the company's business influences the number of collaborations with operators in the supply of substrates. This is due to the changing conditions and availability of energy raw materials near the agricultural biogas plant. The average distance from a supplier in 2022 was 71 kilometers, where the furthest supplier was a company 280 kilometers away. There were 34 different types of substrate used for agricultural biogas production in 2022, from 19 different suppliers. For the agricultural biogas plant under study, substrates are delivered several times a day. The company mainly uses waste from the food industry and, to a lesser extent, from the agricultural industry to generate electricity and cogeneration heat. The agricultural biogas plant has long-term contracts with major biomass suppliers ensuring continuity of substrate supply. Contracts with suppliers do not include contractual penalties. In the case of some suppliers, the audited entity incurs additional costs related to the transport of substrates. At the same time, the company takes advantage of opportunities in the local market by sourcing waste from the food and agricultural industries. In such situations, the surveyed entity does not enter into long-term contracts. At the same time, it is indicated that the agricultural biogas plant generates

additional revenue through this type of operation for the disposal of waste. The subject of the study concludes annual contracts for the sale of electricity. Contracts are concluded on the Polish Power Exchange. The agricultural biogas plant has concluded one contract for the collection of electricity. The technical maintenance of the installation is carried out in-house. The agricultural biogas plant does not need to enter into transactions with external parties for the technical servicing of the installation. The thermal energy generated in the cogeneration process is used for the company's own needs, including the drying services provided for agricultural products.

Costs of information. Gaining information on suppliers is primarily the responsibility of the owner of the agricultural biogas plant. Due to the long period of operation in the region, the entrepreneur knows and has established contacts with most potential substrate suppliers. When it is necessary to search for information on possible feedstock suppliers, suppliers from the agri-food industry in the region are sought. During the interview, it was pointed out that there are only a few new actors with whom cooperation could be established. It was also pointed out that if new suppliers do appear, they are mainly waste disposal contractors from further afield. The owner of an agricultural biogas plant regularly explores the market in the context of finding opportunities to acquire cheap substrates and actively participates in various conferences, industry events, or agricultural fairs. In this way, it establishes additional contacts for new substrate suppliers. Information on electricity traders, including proposed terms and conditions, is obtained from the Polish Power Exchange.

Costs of negotiation. Negotiations at the agricultural biogas plant under consideration are mainly conducted by the business owner. They take place primarily by telephone and most substrate supply arrangements are made by verbal agreement. Due to the long-standing cooperation with the main substrate suppliers, negotiation costs do not play a significant role. The organisation of the market for the sale of energy impacts the way and possibility of negotiating electricity generators. Due to the limited negotiation possibilities, the agricultural biogas plant did not incur significant negotiation costs in the field of electricity sales. Negotiation costs did not occur about the sale of thermal energy, as the dryer belongs to the same owner as the agricultural biogas plant.

Costs of control and monitoring. One person is fully delegated to handle the administration and verify the correctness of deliveries. It was indicated that there are at least monthly problems with the timeliness and volume of agreed substrate deliveries. During the survey, the owner indicated that any problems with suppliers are dealt with on an ongoing basis and that irregularities on the part of the business partners are for the most part rectified. At the agricultural biogas plant, laboratory tests are conducted periodically to verify the quality of the biomass supplied. The company also tests the dry matter content of the substrates. The company also has the equipment to measure the substrates in terms of their biogas production potential and profitability. Due to the time-consuming nature of the process, this measurement is carried out sporadically.

Table 1. Assessment of the impact of transaction costs on the functioning of an agricultural biogas plant

Transaction costs		Scale
Ex ante	costs of information	1 person, time rating: 5 (out of 5), impact rating: 5 (out of 5)
	costs of negotiation	1 person, time rating: 3 (out of 5), impact rating 2 (out of 5)
Ex post	costs of control and monitoring	3 persons, impact rating 5 (out of 5)
	costs of adaptation	1 person, impact rating 1 (out of 5)

Source: own elaboration

Costs of adaptation. Pre-agreement on changes in terms of dates, quantities, and price of delivered substrates is made in the form of a verbal agreement, which in turn is reflected in the contractual provisions and invoices issued. During the course of the study, no significant difficulties were indicated in the aspect of enforcing changes in delivery terms. Table 1 presents an assessment of the impact of transaction costs on the operation of an agricultural biogas plant.

Due to the nature of the company's business, as well as the legal conditions related to renewable energy sources, a key aspect is the source of the substrate used. The owner of the agricultural biogas plant pointed to the occasional occurrence of opportunistic behaviour among new contractors. In the past, there were problems with the substrate supplied, which did not meet the conditions necessary under Polish law for it to be recognised as organic raw material. Thus, the company was in danger of being struck off the list of agricultural biogas and green energy producers. In addition, there was a risk of stopping the fermentation processes and thus the biogas production process. There were also situations where suppliers concealed contamination of the supplied substrate, e.g. in the form of metal components. This could result in the need to stop the operation of the biogas plant for an extended period and to service the plant. It was indicated that cooperation with such entities was not continued.

DISCUSSION OF RESULTS

A number of factors influence the transactions conducted in an agricultural biogas plant. From the perspective of the transactions carried out involving the supply of the substrate necessary for electricity production, one of the key elements is the availability and quality of the raw material. A study by Stelios Rozakis and team [2021] presented a case study for biogas production from dedicated crops and animal waste in the Lublin Province.

It was pointed out that one of the key aspects is the availability of cheap substrate. The results obtained by Stelios Rozakis et al. [2021] coincide in this aspect with the study of Adrea Bartoli et al. [2020]. The agricultural biogas plant studied is located in the Lublin Province and has access to obtaining cheap and good quality substrate. This influences the profitability of agricultural biogas production and the cogeneration of electricity and heat. The cited studies also considered the regulatory – legal aspects of the operation of an agricultural biogas plant, shaping the institutional environment specific to it. As Akhilesh Kumar Singh and his team [2023] point out, substrate availability, operating costs, regulatory framework, and environmental impacts are important challenges facing agricultural biogas plants, and they also shape the opportunities for deal-making and execution. The results obtained indicate an important aspect of transaction costs in the operation of agricultural biogas plants. The nature of the transactions entered into is consistent with the results of other studies. Stefan Gold [2012] indicates that collaborations based on mutual trust and loyalty are effective in establishing long-term stable feedstock supplies. As indicated by [Theuerl et al. 2019], transactions based on long-term and reliable relationships allow for lower transaction costs. The lack of contractual penalties in the transactions used poses a significant threat to the operation of agricultural biogas plants. At the same time, the less formal nature of the relationship between business partners allows for a reduction in uncertainty and also reduces the threat to the agricultural biogas plant in terms of substrate delivery default by counterparties. According to Benjamin Klein [2002], incomplete and not fully explicit terms and conditions save actors on initial (ex-ante) transaction costs related to information and negotiation costs. As Laura Onofri and his team [2023] point out, the presence of non-price provisions such as break clauses and notice periods extends the duration of the contract and provides the necessary flexibility. Godfrey Moses Owot et al. [2023], on the other hand, emphasise the importance of information in the area of transaction costs in the agribusiness industry. He points out that it is information that mediates between trust and the efficiency of transactions. These results are in line with the findings of Alcido E. Wander [2014], who also emphasises the key role of information at all stages of transactions.

CONCLUSIONS

Agricultural biogas plants convert organic waste into a valuable energy source in the form of biogas. They also have the potential to simultaneously address the problem of waste management and produce the renewable energy needed for the energy transition. The institutional environment of agricultural biogas plants, in the form of legislation and transactions made in the supply of substrates and the sale of electricity, influences transaction costs. The focus of the study was to obtain information on market transaction

costs resulting from contracts. Transaction costs influence the choices made within an agricultural biogas plant and translate into the efficiency of its operation. The technological solutions used in the biogas plant under study allow it to achieve a highly efficient agricultural biogas process. The technology also allows for a high degree of versatility in terms of the substrates used without the need to maintain a specific feedstock of food and agricultural waste. The relevance of information and the level of trust between the various participants in the transaction is also pointed out. This avoids in most cases an increase in the level of transaction costs as well as negative consequences for the operation of the agricultural biogas plant. The concluded transactions indicate that agricultural biogas plants primarily operate within a region and a local community. The study is a contribution to further research into the area of transaction costs occurring in agricultural biogas plants.

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FUNKCJONOWANIE BIOGAZOWNI ROLNICZYCH Z PERSPEKTYWY KOSZTÓW TRANSAKCYJNYCH – STUDIUM PRZYPADKU

Słowa kluczowe: koszty transakcyjne, nowa ekonomia instytucjonalna, biogazownia rolnicza, bioenergia, biogospodarka

ABSTRAKT. Biogazownie rolnicze przekształcają organiczne odpady w cenne źródło odnawialnej energii, koniecznej w transformacji energetycznej. Otoczenie instytucjonalne biogazowni rolniczych wpływa na wiele aspektów działalności, począwszy od zapewnienia jakości surowców użytych do produkcji energii, jak i sprzedaży wytworzonej energii. Głównym celem artykułu jest przedstawienie ponoszonych kosztów transakcyjnych przez przykładową biogazownię rolniczą i wskazanie ich wpływu na działalność przedsiębiorstwa. W celu zebrania danych pierwotnych w lipcu 2023 roku przeprowadzono ustrukturyzowany wywiad z właścicielem biogazowni rolniczej znajdującej się w województwie lubelskim. Badany podmiot wytwarza energię elektryczną i cieplną z biogazu rolniczego w układzie kogeneracyjnym. Stwierdzono, że koszty transakcyjne wpływają na podejmowane wybory w ramach biogazowni rolniczej i przekładają się na jej funkcjonowanie. Wskazuje się na istotność przekazywanych informacji i poziomu zaufania pomiędzy poszczególnymi uczestnikami transakcji. Pozwala to w większości przypadków uniknąć wzrostu poziomu kosztów transakcyjnych, a także negatywnych konsekwencji dla działalności biogazowni rolniczej. Zawierane transakcje wskazują, że biogazownie rolnicze funkcjonują przede wszystkim w ramach danego regionu i lokalnej społeczności. Opracowanie stanowi przyczynek do dalszych badań nad obszarem kosztów transakcyjnych występujących w biogazowniach rolniczych.

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