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Analysis and assessment of risk in the implementation of a cogeneration installation at a livestock farm

Abstract: The introduction of increasingly strict rules related to the processing and storage of animal waste, the growing demand for energy and the creation of sustainable animal husbandry have led to an increased interest in the production of clean energy from animal waste. The production of biogas and its subsequent burning on the farm is among the most promising technologies. One of the possibilities for the utilization of biogas is through the use of small aggregates for the combined production of electricity and heat energy based on an internal combustion engine. Analysis of such facilities that have been put into operation show that alternative technologies using biogas as fuel are better than conventional options, both from an economic and an environmental point of view. In this sense, however, the introduction of such a technology into operation is always associated with a number of risks, since investments in new technologies are influenced by technical and economic uncertainty. When planning and preparing the plan for the construction of such a biogas facility, the investment costs, technical support and profitability of the project are essential. Introducing critical economic and technical parameters to inform the farmer of all possible investments, operational and unforeseen risks will allow him to accept the challenges and choose the best solution for his farm. In this publication, an analysis and assessment of the risk has been carried out based on the characteristics of the technology – the possible consequences of the risk are also presented.

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A risk matrix related to the specifics of the object and the technology is proposed, with the help of which, the type of risk is identified. Based on an analysis of the obtained results, a motivated proposal for reducing the risk is made.

Keywords: biogas, animal waste, risk assessment, risk identification, risk analysis

Introduction

The rising prices of energy carriers force more and more farmers to look for alternative sources of energy. This has led to an increased interest in biogas plants for the joint production of heat and electricity. Numerous studies have been conducted that prove the advantages of this technology (Kaur et al. 2021; Bai et al. 2022; Wang et al. 2021; Caetano et al. 2022; Rouhollahi et al. 2020). In the construction of cogeneration plants using biogas for livestock farms, decisions related to the choice of a specific technology and the availability of raw material (animal waste) on a significant scale are of crucial importance (Ardebili 2020; Kozłowski et al. 2019; Barozzi et al. 2021; Pryshliak et al. 2022; Doseva and Chakyrova 2019). This is done in order to ensure the smooth operation of the facility.

In the livestock sector of the Republic of Bulgaria, there remain different ways to deal with the problem of manure obtained from livestock farms. The direct dumping of organic waste into the environment by farmers is highly unacceptable, but it still happens in places in the country. Since animal manure contains high concentrations of nitrogen (N) and phosphorus (P), residues of some harmful substances, such as growth hormone, antibiotics and heavy metals, its disposal causes soil-nutrient imbalance and environmental pollution. From this, it can be concluded that the indiscriminate disposal of animal manure pollutes the air, the soil and water sources.

Since a large part of the large livestock producers are located outside populated areas, the installation of a biogas plant that utilizes the sludge will undoubtedly be of great benefit to them. The main disadvantage of cogeneration – the utilization of heat energy – here finds its natural solution, with proper design and operation of the facility. Produced heat can be used for technological needs and the heating of building stock. The availability of the possibility to absorb the thermal and electrical energy obtained from a cogeneration module will undoubtedly increase the financial indicators of such a project.

Although the technology related to the utilization of biogas is well studied and well known, the individual facilities and modules hide a number of different risks regarding the functioning of the system as a whole. Preparing an accurate risk assessment in the process of implementing such an installation is of great importance for the implementation of the project itself. As with any different technology, the risks here are strictly specific. A number of authors (Terziev et al. 2021; Zaina et al. 2011; Nyenno et al. 2020; Terziev et al. 2021; Bartela et al. 2015) have made a risk assessment of various facilities, but there are none regarding the implementation of a biogas utilization plant from a livestock farm.

In order to assess the risk associated with an investment in the energy facility by a non-specialist, it is essential that the farmer has complete clarity about the value of the investment, its uncertainty and the inputs that provoke it. During the design and risk analysis, the farmer should be provided with data on the full life of the cogeneration plant, taking into account fixed costs and production patterns. Risk identification will allow the farmer to recognize critical factors, thus reducing uncertainty and enabling the choice of the best investment prospects. This is why the research done clearly defines that risk analysis and assessment are extremely important for the realization of an efficient and useful project. Based on this, the publication presents a methodology for risk analysis and assessment when implementing a biogas cogeneration plant at a livestock farm. In addition to the indicated significant factors that are the result of the analysis, the possible consequences from an economic and ecological point of view are also indicated.

1. Materials and methods

The focus of this publication is on risk analysis and assessment when implementing a biogas plant to a livestock farm. The method of operation and the main elements of such type of installations have been well studied (Mühl and Oliveira 2022; Tsapekos et al. 2021; Marchetti et al. 2022; Chodkowska-Miszczuk and Szymańska 2013; Igliński et al. 2012; Brudermann et al. 2015; Aoki et al. 2006; Chevalier and Meunier 2005). The proposed installation works on the principle of wet fermentation create a good opportunity for the exchange of nutrients and energy between anaerobic bacteria and sludge from animal manure. A block diagram of the installation is shown in Figure 1. Depending on the way of organizing the cleaning of the premises for

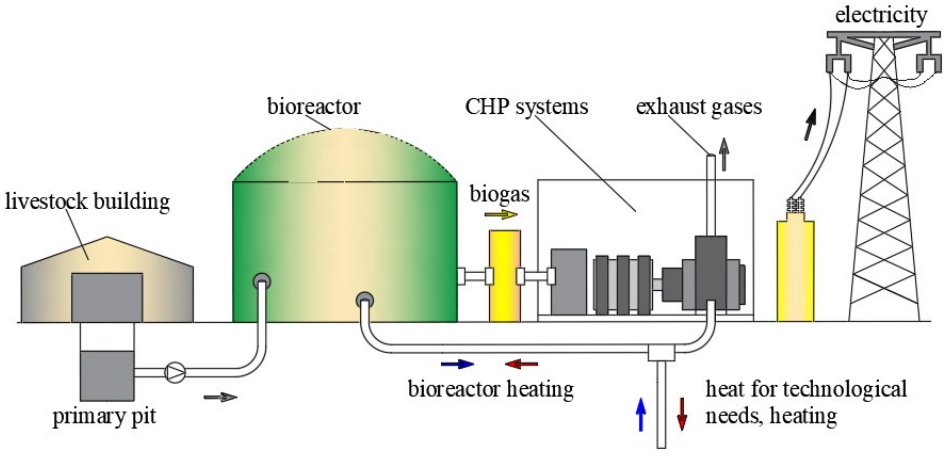

Fig. 1. Block diagram of the biogas plant

Rys. 1. Schemat blokowy biogazowni

keeping the animals, animal manure is fed to a receiving tank. In it, the sediments are mixed and homogenized, after which, they are sent to the anaerobic bioreactor with the help of a pump. In the bioreactor, mesophilic bacteria convert the animal waste into biogas. To carry out the process, heat is needed, which comes from the cogenerator. The produced gas passes through a scrubber to remove hydrogen sulphide, it is then dehumidified, compressed and fed to be burned by the internal combustion engine. In this way, electrical and thermal energy is obtained.

The technical parameters of such an installation depend entirely on the number of animals that are kept on the farm. The economic benefits will undoubtedly be there but only with proper sizing and design of the installation. It is important to note that in addition to economic benefits, there will also be environmental benefits from such a project. The introduction into operation of such facilities is a prerequisite for the development of rural areas, as well as the possibility of restoring land with spent fertilizer.

Risk assessment is a decision-making process through identification, analysis and benchmarking. Several risk assessment methods and techniques are known in the literature. Root cause analysis (Ito et al. 2022; Wen et al. 2022; Lucke et al. 2022) analyses the root cause of the discrepancy. A cause-and-effect diagram is another method described by authors (Decker et al. 2010; Gould 1992). Failure mode and effect analysis (FMEA), occupational health and safety assurance system (OHSAS), hazard and operability study (HAZOP), hazard analysis and critical control points, (HACCP) and other methods have found their application (Shi et al. 2022; Zhan et al. 2022; Noriyati et al. 2015; Oyarzabal and Rowe 2017).

Given the objectives of the study, the risk assessment method was used to assess the degree of risk through the probability of the occurrence and the severity of the effect. In this method of risk analysis, it is necessary to determine their priority based on the probability of their occurrence. The risk probability characterizes the assumed frequency of occurrence of the event, which can be estimated by introducing predefined scales. This is presented in Table 1, where a five-point probability scale is proposed with an assigned number and letter and a linguistic description of each row of the scale.

Risk impact can also be represented by predefined scales and shows what the consequences are. Table 2 provides a qualitative description of the levels of the power of influence rating scale.

Table 1. The probability of the risk and the estimated frequency of the event

Tabela 1. Prawdopodobieństwo ryzyka i szacunkowa częstotliwość wystąpienia zdarzenia

Probability	Assigned value	Description
Negligible	A	implausible, minimal
Limited	B	unlikely, small
Significant	C	probable, rare
High	D	very likely
Very high	E	honor, very honor

Table 2. Qualitative description of the levels of the scale of impact strength assessment

Tabela 2. Jakościowy opis poziomów skali oceny siły wpływu

Influence	Description	Assigned value
Very strong	Minor consequences that can be ignored	1
Strong	Minor consequences that can be easily overcome	2
Moderate	Moderately severe consequences that do not endanger the project too much	3
Weak	Severe consequences that endanger too many projects	4
Negligible	Very serious consequences that threaten the completion of the project and have a negative impact	5

The probability and impact of the risk can be represented by a matrix (Fig. 2) containing a combination of probability and impact. The matrix usually has three risk zones – high, medium and low, and it is used to rank the risks (Terziev et al. 2021; Roman et al. 2022; Ibrahim et al. 2022).

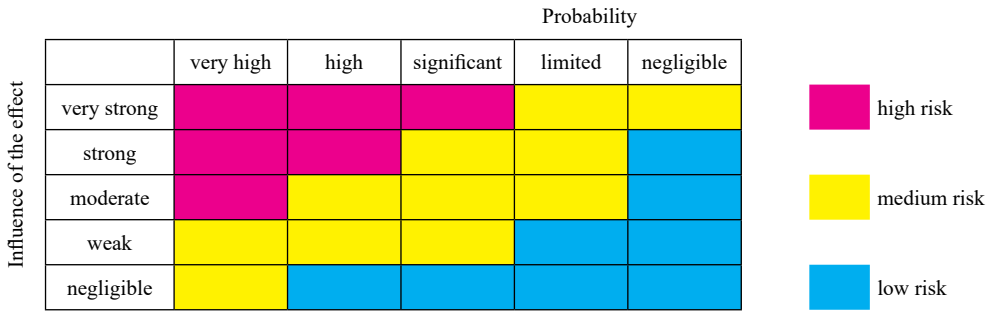

Fig. 2. Risk matrix

Rys. 2. Macierz ryzyka

All risk events related to the project are plotted on the matrix, with those with the highest priority placed in the red zone and the lowest in the green zone. The data is analyzed and the threshold above which the risks will be managed is determined. During the implementation of the project, it is necessary to carry out a regular revision, as it is possible that over time, some risks may disappear, new risks may appear or their assessments may change.

2. Discussion

The investment and implementation of a biogas installation on a livestock farm can be identified with the following risks:

- risk related to the specific object and its specific features,
- risk related to the equipment,
- risk related to financing the project,
- risk related to the design and implementation of the installation,
- risk associated with the possibility of selling electricity,
- risk related to the selected biogas extraction technology.

The risk associated with the site can be classified as high risk. Analyzing this risk, it is necessary to take into account the type of animals kept, their feeding method and their number. Since the installation is expected to be fed with manure mass only from farmed animals, its optimal dimensioning is necessary. A sudden and large change in the number of animals (due to illness or other unforeseen circumstances) will lead to a shortage of raw material for biogas production. Depending on the purpose of the animals (for meat, for milk), they are fed with different food, which ultimately affects the chemical composition of the biogas. Here, unforeseen circumstances may occur, necessitating the installation of additional equipment, which in turn leads to a risk assessment of the chosen technology.

Equipment risk analysis is high. It is related to the company supplying the installation. Before purchasing the installation, it is necessary to conduct research about the leading companies and their completed projects.

The assessment of the risk related to the financing of such a project is the low financial power of the Bulgarian farmers. For an investment in such a facility, it is necessary to prepare an investment project either under a European program or using a bank loan. Both conditions are difficult and come with guarantees.

The design and implementation of the installation is related to the preparation of the project, the delivery of the equipment, the construction of the installation and introduction and into operation. The evaluation and analysis of each of the stages listed above carries a risk in itself. Therefore, it is necessary, when concluding the contracts, to clearly and categorically fix clauses guaranteeing the farmer both the implementation of the installation according to the current standards and low operating costs.

The joint production of heat and electricity allows part of the electricity produced to be sold. Analysis of this risk is extremely important. Livestock farms are located in rural areas, outside populated areas. From here, the risk arises of whether there is a possibility to connect to the electricity transmission network and whether the capacity allows it. In addition, this risk is related to the legislation in the country. The purchase of electricity at preferential rates depends on the concluded contracts and their term. When the political situation changes, contracts may be terminated or tariffs may change, which may lead to the bankruptcy of the farmer.

For the proposed baseline biogas plant, the summarized risks are presented in Table 3.

Table 3. Summary of threats to biogas plants

Tabela 3. Podsumowanie zagrożeń dla biogazowni

Identified risk	Influence	Probability
Construction permit	low	average
Undefined conflicts with the route of the electricity distribution company	very high	high
Delay in the supply of biogas plant equipment	average	average
Delay of installation activities on the biogas plant	medium high	high
Delay of installation activities on the biogas plant	medium high	high
Defects in the individual facilities of the biogas plant	high	low
Low yield of electricity and heat energy based on incorrect design	very high	average
Reduced yield of electricity and heat based on improper management and maintenance	very high	average
A sudden change in the number of farmed animals	very high	low
Damage from natural disasters and accidents	low	low

Conclusion

There are various challenges facing farmers who decide to invest in biogas plants. Risks arise from many uncertain factors, such as investment size, price, revenue from electricity extraction, and government subsidy. The presented considerations emphasize the importance of performing a risk analysis when implementing a biogas plant on a livestock farm. The results prove that the farmer will take a significant risk if he chooses an inappropriate installation and his investment largely depends on the purchase price of electricity. In addition, the construction of such an installation without financial support from the state is economically unjustified and very risky. However, the results of the analyses prove that the investment risk associated with the construction of a biogas plant has benefits related to environmental and social factors. The possibility of additional income and the reduction of energy costs by using available resources is another good prospect for any farmer.

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Analiza i ocena ryzyka realizacji instalacji kogeneracyjnej w hodowli żywca

Steszczenie

Wprowadzenie coraz ostrzejszych zasad związanych z przetwarzaniem i składowaniem odchodów zwierzęcych, rosnące zapotrzebowanie na energię oraz tworzenie zrównoważonej hodowli zwierząt spowodowały wzrost zainteresowania produkcją czystej energii z odchodów zwierzęcych. Produkcja biogazu i jego późniejsze spalanie w gospodarstwie należy do najbardziej obiecujących technologii. Jedną z możliwości wykorzystania biogazu jest wykorzystanie małych agregatów do skojarzonej produkcji energii elektrycznej i cieplnej w oparciu o silnik spalinowy. Analiza takich obiektów oddanych do użytku pokazuje, że alternatywne technologie wykorzystujące biogaz jako paliwo są lepsze od konwencjonalnych, zarówno z ekonomicznego, jak i środowiskowego punktu widzenia. Jednakże wprowadzenie takich technologii do eksploatacji zawsze wiąże się z szeregiem zagrożeń, ponieważ na inwestycje w nowe technologie wpływa niepewność techniczna i ekonomiczna. Przy planowaniu i przygotowaniu planu budowy takich biogazowni istotne są koszty inwestycji, wsparcie techniczne i opłacalność projektu. Przedstawienie rolnikowi krytycznych parametrów ekonomicznych i technicznych informujących go o wszelkich możliwych zagrożeniach inwestycyjnych, operacyjnych i nieprzewidywalnym ryzyku pozwoli mu podjąć wyzwania i wybrać najlepsze rozwiązanie dla swojego gospodarstwa.

W publikacji dokonano analizy i oceny ryzyka w oparciu o charakterystykę technologii oraz przedstawiono możliwe konsekwencje tego ryzyka. Proponowana jest macierz ryzyka związana ze specyfiką obiektu i technologią, za pomocą której identyfikowany jest rodzaj ryzyka. Na podstawie analizy uzyskanych wyników formułowana jest umotywowana propozycja ograniczenia ryzyka.

Słowa kulczowe: biogaz, odpady zwierzęce, ocena ryzyka, identyfikacja ryzyka, analiza ryzyka