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# ECONOMIC ASPECTS OF USING THE POTENTIAL OF BIOENERGY CROPS FOR BIOGAS PRODUCTION AND ADVANCED TECHNOLOGIES FOR DIGESTATE APPLICATION

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**Abstract.** The research examines the prospects for using the potential of the agro-industrial complex of Ukraine to study green technology innovations during economic development under martial law. Based on the study, it is proved that technological innovations in the agricultural sector contribute to economic development and improve the quality of agricultural land. The article analyses the successful implementation of the case of LLC Yuzhef-Mykolayiv Biogas Company, which has successfully restructured the production of a sugar plant and produces biogas and digestate with further processing into electricity and fertiliser. The modern capacities of the studied enterprise are highlighted, which allow to produce 2800 $m^3$ of biogas and ensure the production of 5200 kWh of electricity, while consumption does not exceed 150 kW, at a load of 80%. The volume of digestate produced per year is 100,000 tonnes. In the regional context, innovative environmental technologies aimed at improving the quality of agricultural land have been introduced. An effective mechanism of spatial synergy with adaptation of this practice at most sugar factories through restructuring of production – creation of biogas production facilities on the basis of sugar factories – is proposed. As a long-term development perspective, the paper presents further creation of alcohol production facilities to use excess heat energy from mini-thermal power plants for the production of alcohol and bioethanol. Furthermore, this study confirms the non-linear effect of economic development; a significant result shows that the impact of green technology innovations on improving the quality of agricultural land (soil humus content, amount of mineral and organic fertilisers, pesticides, area of land under organic production, etc.) contributes to the increase in the level of regional economic development of the agricultural sector. The article clarifies the intermediary role of economic development of the agro-industrial complex. The results of the study implement the tasks of sustainable development, such as improving the environment through the innovation of green technologies and achieving regional synergy in green development.

**Keywords:** economic development innovations, digestate, biogas, green technologies, potential benefits, economic efficiency.

**JEL Classification:** Q42, Q28, Q16

## 1. Introduction

In order to fulfil the tasks set by the goals and targets of the Global Agenda for Sustainable Development until 2030, adopted at the UN Sustainable Development Summit in September 2015, the world's population will have to make significant changes in the direction of spreading the model of resource-saving and ecologically oriented consumption and production. This model is aimed at ensuring resource efficiency, minimising the generation and accumulation of waste and environmental pollution, introducing productive, ecologically safe technologies and innovations and, as a result, promoting economic growth and employment of the population, ensuring access of broad sections of the world's population to the results of social development (Yang et al., 2022).

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The development of resource-efficient agriculture is now a natural development vector for a number of developed countries in the world, even those with significant natural resource endowments (Chen et al., 2022). Resource efficiency is one of the key priorities of many UN member states, and environmental technologies can serve as a means to implement new innovative solutions aimed at increasing resource efficiency, dematerialising production and consumption, and attracting additional sources of value creation (Dong et al., 2022). In response to the ongoing and growing challenges posed by Russia's aggression, resource limitations, climate change and competition on international markets, Ukraine has also begun the process of transforming its economic system. Sustainable development of Ukraine's agricultural sector is impossible without energy-efficient technologies for growing agricultural crops (Pantsyreva et al., 2023). An important role is played by the development of innovative systems for the application of organic fertilisers, which would reduce the use of expensive mineral fertilisers and increase productivity (Du et al., 2019; Hnatiuk et al., 2019; Bakhmat, et al., 2022; Petrychenko et al., 2020). The agro-industrial complex of Ukraine has implemented measures to combat climate change through sustainable production, protection of biological resources, processing of food waste, plant residues and animal manure for the production of biofuels. Prospects for the use of biogas plants in Ukraine find solutions to the problems of waste disposal, improvement of the ecological situation, increase in soil fertility, growth of energy independence and development of rural areas (Kaletnik, 2018; Pohrishchuk et al., 2023). Therefore, biogas production is based on the use of waste from agricultural enterprises, poultry farms, livestock farms, processing and food processing facilities. First of all, this applies to various types of organic waste that are subject to biological decomposition.

Fertiliser production is energy intensive. It is estimated that up to 60% of the energy used in agriculture is used for fertiliser production. Nitrogen fertiliser production is characterised by the highest energy consumption (Cavali et al., 2022). Natural gas is a key feedstock for the production of ammonia, which is the basis for nitrogen fertilisers. As a result of Russia's war against Ukraine in early 2022 and the associated increase in natural gas prices to 280 EUR/MWh (a 10-fold increase), some mineral fertiliser companies in Europe have reduced or stopped production altogether (Ahrens et al., 2022). This has affected the market prices of mineral fertilisers, especially nitrogen fertilisers, as well as their availability (Amhamed et al., 2022). As a result, farmers have become increasingly interested in alternative methods of fertilising crops. One of these is the use of digestate from biogas plants.

Digestate is a by-product of anaerobic fermentation (Palamarchuk et al., 2021). For many biogas plants, it is a waste that is costly to deal with (Awasthi et al., 2019). In today's geopolitical and economic conditions, the production and use of digestate can be an important source of income for farms with biogas plants. Digestate is an alternative to mineral, natural (manure) and organic (compost) fertilisers as it is a source of valuable minerals for plants (Adiansyah et al., 2021). Its low dry matter content, comparable to manure, neutral, alkaline pH, relatively high organic matter content and high NPK content are just some of the few quality characteristics that demonstrate the effectiveness of using this by-product as a fertiliser (Chojnacka et al., 2022). Its properties and composition depend on the substrates used in the biogas plant and the technology of the biogas plant (Lohosha et al., 2023). The use of unprocessed digestate does not involve large additional costs (Doyeni et al., 2021). Digestate is also increasingly being used to make compost, biochar or digestate pellets – especially for more demanding crops (Dalby et al., 2021). The use of digestate as a fertiliser can also help to reduce gas emissions. The aim of the study was to assess the potential of the agro-industrial complex to replace mineral fertiliser with digestate from agricultural biogas plants using different substrates.

## 2. Literature Review

Considering the high cost of mineral fertilizers and the shortage of traditional types of organic fertilizers, it is important to study the possibility of effective use of alternative types of organic fertilizers (Razanov et al., 2018). One of the types of renewable energy sources (RES) is biogas produced in agricultural biogas plants, which allows for the production of stable energy. Therefore, the number of functioning biogas plants worldwide has been increasing for many years. In addition to the choice of substrates and the technology of anaerobic fermentation, more and more attention is being paid to the production of digestate, a by-product of the methane fermentation process (Honcharuk et al., 2022).

The studies of Zhang et al. (2023). consider the prospects for studying the importance of green technology innovations for economic development and the quality of biodiversity. Ukraine has a great potential for the development of green technology innovations, as well as for the production of biogas and digestate, due to significant reserves of agrobiomass and organic production wastes, which are used for methanogenesis during the implementation of bioenergy projects in the agricultural sector (Kaletnik et al., 2020). Digestate is a heterogeneous material (some scientists interpret it as a bioorganic fertiliser) produced in significant quantities during the anaerobic fermentation of plant residues, animal waste or bird droppings in biogas reactors.

The physico-chemical properties of the digestate are determined by the nature and composition of the feedstock and the operating parameters of the anaerobic fermentation process. Agricultural waste usually contains high levels of lignocellulose. In this rigid structure, lignin usually prevents the degradation of cellulose and hemicellulose by anaerobic bacteria (Neugebauer, 2018). The use of energy-intensive processes (with high pressure and temperature) and aggressive chemicals (NaOH and $H_2SO_4$) in the raw material pretreatment methodology helps to improve anaerobic digestion processes (Lin et al., 2017).

There is currently no definition of digestate in current Ukrainian legislation, which creates problems for its mass use. Despite this, digestate is most often defined as the undecomposed residue formed in the process of anaerobic fermentation. After its formation, this product obtained from agricultural biogas plants is considered in Ukraine as a waste, a by-product, and less often as an organic fertiliser (Tokarchuk et al., 2021). According to EU legislation, digestate can be classified in three categories: "organic soil improver", "growing medium" and "organic non-microbial plant biostimulant", but not as "organic fertiliser" (Duan et al., 2018).

The composition of the digestate is the remains of fermented raw materials and dead cells of microorganisms. The volume of digestate produced is usually around 90-95% of the initial volume of raw material fed into the tank (biogas plant) (Zikali et al., 2022). Irrespective of the regulatory framework and its aspects, the methods of digestate management are the same. Thus, the fermentation process degrades only some of the compounds contained in the substrate. As a result, the digestate contains mainly water, undecomposed organic compounds and minerals. For this reason, the type of substrate from which the final product is formed has an important influence on the properties of the digestate and its use.

Due to the high concentration of nutrients, raw digestate is most commonly used as a fertiliser. For this reason, its pre-treatment is not regulated, so the digestate can be spread directly on the fields. On the other hand, the separation of the solid and liquid fractions opens up other possibilities for the use of the by-product. The liquid fraction is characterised by a low dry matter content and is used for fertilisation or for wetting the raw material for biogas plants, which is often in the form of a solid substrate or silage. The solid fraction, on the other hand, can be used in many other ways, for example as a fertiliser or as an energy source. Another solution may be to add solids to the sludge from small plants that do not have on-site sludge treatment for co-composting. Even the solid fraction without additives can be used for the production of compost. In addition, the discussed fraction can be used for the production of solid biofuel, as shown in numerous studies by authors such as Kaletnik et al. (Zeng et al., 2022). A new area of use of the solid fraction may be its application in thermal processes, including biogas production, for example, with preliminary biological treatment in the form of biological drying. Given that agricultural biogas plants often do not have a multi-stage fermentation, it was decided to analyse the biogas efficiency of the resulting digestate. The aim of this study was to determine the efficiency of biogas and methane utilisation of the crude digestate.

**3. Materials and Methods**

The methodological basis of the study of the prospects for using the potential of the agro-industrial complex of Ukraine under martial law is the structural-functional and systemic approaches as of 2023. A set of general scientific and special methods was used to fulfil the research objectives:

– Monographic (an analysis of the works of scientists on the research topic, which allowed us to establish a cause-and-effect relationship between the development of innovative organic fertiliser systems and the use of mineral fertilisers to increase yields);

– deductive method (was used for theoretical consideration of the problem and clarification of certain concepts; moving from the general to the specific allowed to develop a scenario for combating climate change based on sustainable production and protection of biological resources, processing of food waste, plant residues, animal manure and poultry manure for biofuel production);

– inductive (the study from the individual to the general allowed to develop recommendations for the successful implementation of the case of LLC Yuzhef-Mykolayiv Biogas Company);

– economic analysis (during the collection, systematisation and processing of information on the production restructuring of sugar factories' capacities for the production of biogas and digestate with further processing into electricity and fertilisation);

– analysis and synthesis (when combining the components of economic phenomena into a single process);

– graphical and tabular (for visual display of individual indicators of biogas and digestate production with further processing into electricity and fertilisation);

– statistical (when processing information to analyse and evaluate the production of biogas and digestate with subsequent processing into electricity and fertilisation).

The research methodology includes the following tasks: (1) analysis of the dynamics of biogas and digestate production in Ukraine; (2) research on the handling of mineral and organic fertilisers in Ukraine; (3) analysis of a successful case of LLC Yuzhef-Mykolayiv Biogas Company, Ukraine; (4) development of proposals for restructuring the production capacities of sugar factories for the production of biogas and digestate with further processing into electricity and fertiliser application; (5) formulation of proposals for using the experience of LLC Yuzhef-Mykolayiv Biogas Company, which can be used by other sugar factories as an example of a successful case.

The basis of the research is the case study method – qualitative research in social sciences, which is based on the study of individual social objects (such as situations, events, cases, persons or social groups) or several representative objects with the aim of understanding a wide range of similar cases (class events). The basis is a successful case – the practice of LLC Yuzhef-Mykolayiv Biogas Company, Ukraine, which is recommended for implementation by other territorial communities of Ukraine. The design method was used in the development of proposals to combat climate change based on sustainable production and protection of biological resources, processing of food waste, plant residues, animal manure and bird droppings for the production of biofuels.

The study involved the processing of statistical material and documentation of LLC Yuzhef-Mykolayiv Biogas Company, which carried out the restructuring of the sugar factory for the production of biogas and digestate for further processing into electricity and fertiliser.

The results include a set of measures aimed at addressing the underlying climate change situation based on sustainable production and protection of biological resources, processing of food waste, crop residues, animal manure and poultry manure for biofuel production.

Fulfilment of the tasks of the article will involve the development of bioorganic technologies for growing crops for biofuel production and implementation of their results in production during 2024–2025 in order to ensure energy independence of the agricultural sector.

## 4. Results and Discussion

Today in Ukraine the case of LLC Yuzhef-Mykolayiv Biogas Company is successfully implemented, which successfully restructured the production of a sugar factory and produces biogas and digestate with further processing into electricity and fertiliser application. The technical and economic indicators of the construction of the Yuzefo-Mykolaiv biogas plant of MW capacity are presented in the data of Table 1.

Thus, the modern capacities of the company under study allow the production of 2,800 $m^3$ of biogas and ensure the production of 5,200 kW/h of electricity with a consumption of no more than 150 kW at 80% load. The amount of digestate produced per year is 100,000 tonnes.

The agrochemical analysis of the digestate (fermentation residue) produced by LLC Yuzhef-Mykolayiv Biogas Company on the basis of a biogas plant is the closest in composition and properties to the humic substances of the soil humus, therefore the use of fertiliser for preservation and restoration of natural soil fertility, greening of agricultural production. Fertilisers are applied to the soil with the aim of enriching it with macro- and microelements, promoting agro-physical-chemical processes, enriching it with biologically active humic substances, increasing the soil microbiota, thus restoring and increasing the natural fertility of the soil (Table 2).

The use of digestate on the company's own crops increased yields by an average of 60%. The largest increase in yield was recorded when sowing sugar beet (by 150 t/ha), which makes it possible to increase the volume of one of the main resources for biogas and digestate production. And also to increase the level of own supply of raw materials for sugar production (Table 3).

Table 1
**Study of technical and economic indicators for the construction of the Yuzefo-Mykolaiv biogas plant**

| Indicator | Value |
|---|---|
| Use of raw materials, t/d | 380 |
| Biogas performance, $m^3$/h | 2800 |
| Electricity generation, kW/h | 5200 |
| Consumption capacity (installed), kW/h | 150 |
| Average annual load, % | 80 |
| Liquid digestate yield, annual | 100000 |
| Total volume of reactors, $m^3$ | 22500 |
| Capital investments, million EUR | 12,0 |
| Revenue from electricity sales, EUR/year | 4613130 |
| Simple payback (before taxes and depreciation), (DPP), years | 5 |
| Specific investment in KGS, EUR/MW | 2307392 |

*Source: LLC Yuzhef-Mykolayiv Biogas Company*

Table 2
**Results of the agrochemical analysis of organic fertiliser (digestate) produced at LLC Yuzhef-Mykolayiv Biogas Company**

| Indicator | Units of measurement | Data from experimental test results |
|---|---|---|
| KCI | % | 8,42 |
| Mass fraction of moisture | % | 94,51 |
| Dry matter | % | 5,51 |
| Ash content in nature | % | 1,42 |
| Organic matter content in nature | % | 4,11 |
| Nitrate nitrogen content | kg/t | 3,22 |
| Ammonium nitrogen content | % | 0,01 |
| Total nitrogen content | kg/t | 3,84 |
| Mass fraction of total phosphorus (P) | kg/t | 0,93 |
| Mass fraction of total potassium ($K_2O$) | kg/t | 3,59 |
| Copper | mg/kg | 16,30 |
| Zinc | mg/kg | 31,91 |
| Manganese | mg/kg | 21,11 |
| Iron | mg/kg | 63,02 |
| Magnesium (MgO) | kg/t | 0,45 |
| Calcium (CaO) | kg/t | 1,28 |

*Source: LLC Yuzhef-Mykolayiv Biogas Company*

Table 3
**Study of the data on yield changes when applying digestate using a hose system in the fields of LLC Yuzhef-Mykolayiv Biogas Company**

| Culture | Amount of digestate applied $m^3$/ha | Application cost UAH/ha | Yield without digestate addition, t/ha | Yield from digestate application t/ha | Yield increase, t/ha |
|---|---|---|---|---|---|
| Wheat | 50 | 2000 | 3,63 | 5,79 | 2,16 |
| Sugar beet | 110 | 4400 | 25,02 | 40,22 | 15, |
| Corn | 80 | 3200 | 5,31 | 8,52 | 3,21 |
| Turnip | 50 | 2000 | 1,71 | 2,74 | 1,03 |
| Sunflower | 80 | 3200 | 2,31 | 3,45 | 1,14 |

*Source: LLC Yuzhef-Mykolayiv Biogas Company*

Based on the data of the studied enterprise, it should be noted that the introduction of cereal straw into the substrate for biogas production is more appropriate than corn straw, as it allows to obtain a significantly higher biogas yield per 1 ha of crops due to the higher content of dry organic material (Table 4).

Based on the average yield increase, it is necessary to note the economic feasibility of using these fertilisers. However, it is advisable to reduce the cost of applying these fertilisers by using domestic equipment through liquid application by pumping digestate from settling tanks. For example, the A.TOM PUMP 290 diesel pumping station is designed for pumping liquid sewage from reservoirs and liquid manure for further application on fields as organic fertiliser, and it can deliver from 77 $m^3$ to 454 $m^3$ of liquid digestate at a distance of up to 5 km. And in the case of 4 such stations, up to 20 km, which is confirmed by studies carried out by the manufacturer of this equipment (Figure 1).

The use of this or similar equipment will reduce the cost of transporting digestate and remove the washing process from the production cycle. This will have a positive effect on the cost of this fertiliser. In order to improve assimilation in the soil, it is advisable to use injection application systems, which allow the use of hose systems in combination with the use of the above-mentioned station to apply liquid fertiliser to a depth of up to 15 cm. For example, the A.TOM 7DS INJECTOR injection cultivator is designed for the application of liquid organic fertiliser. It is used at the final stage of processing the liquid fraction of manure or filtrate from biogas plants. This equipment works on the technology of hose systems, where the material to be injected is pumped from the storage place with the help of pump-diesel stations that provide the injection (Figure 2).

The possibility of processing rapeseed in the export volume of this agricultural crop in 2023 will ensure the production of more than 1.31 million tonnes of biodiesel at a total cost of more than 39.61 billion

Table 4
**Study of biogas yield from different raw materials in the conditions of LLC Yuzhef-Mykolayiv Biogas Company in 2023**

| Indicator | Unit of measurement | Corn for silage | | | Cereal crop straw | | |
|---|---|---|---|---|---|---|---|
| | | min. | max. | fact. | min. | max. | fact. |
| Yield level | t/ha | 58 | 92 | 80 | 2 | 5 | 4,5 |
| Dry matter content | % | 25 | 32 | 27 | 76 | 92 | 80 |
| Dry matter yield | t/ha | 2 | 2,56 | 2,16 | 1,52 | 4,6 | 3,6 |
| Organic dry matter content | % | 23-28% | | | 74-90% | | |
| Biogas output | $m^3$ from 1 t of organic dry matter | 700-800 | | | 600-650 | | |
| Methane content | % | 58-65 | | | 45-62 | | |
| Estimated biogas yield | $m^3$ from 1 t of organic dry matter | 1400 | 2048 | 1620 | 912 | 2990 | 2200 |
| Estimated electricity output per 1 ha | kW | 2520 | 3686,4 | 2916 | 1641,6 | 5382 | 3960 |
| Green tariff rate | UAH / kW | 0,16 | | | 0,16 | | |
| Current exchange rate | UAH /euro | 39,8 | | | 39,8 | | |
| Estimated gross profit | UAH/ha (including VAT)* | 16077,6 | 23519,23 | 18604,08 | 10473,4 | 34337,16 | 25264,8 |

*Source: LLC Yuzhef-Mykolayiv Biogas Company*

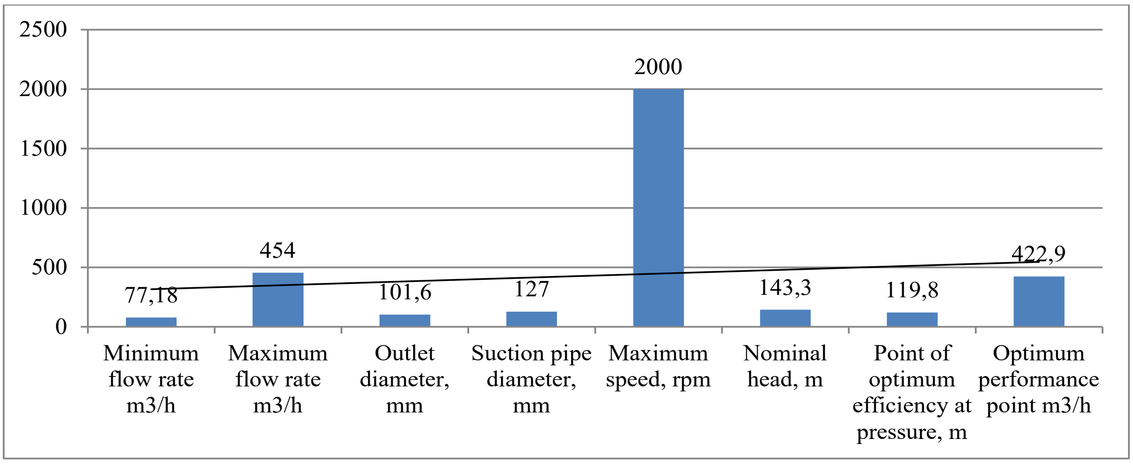


**Figure 1. Technical characteristics of the Cornell 4NHTB pump**

*Source: developed by the authors based on their own research*

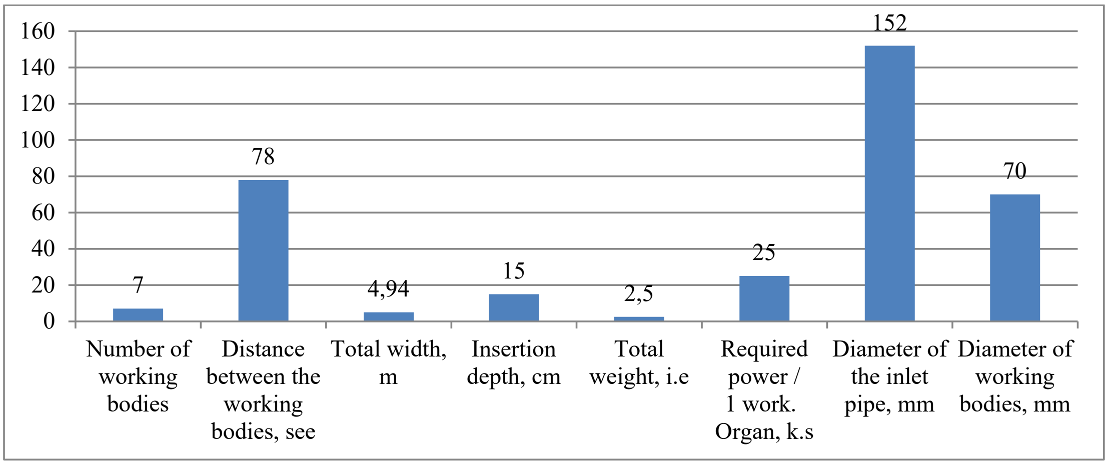


**Figure 2. Technical parameters of the injection cultivator for manure application A.TOM 7DS INJECTOR**

*Source: developed by the authors based on their own research*

UAH. In addition, by-products will be produced, including rapeseed meal in the amount of 1.47 million tonnes at a cost of more than 8.81 billion UAH, and technical glycerine in the amount of 120 thousand tonnes at a cost of 9.61 billion UAH. In total, the cost of the manufactured products will be over 58.12 billion UAH, which exceeds the selling price of rapeseed at 2023 prices by 20.28 billion UAH (Table 5).

Table 5
**Potential of rapeseed processing for biodiesel and by-products in Ukraine in 2023**

| Indexes | Unit of measurement | Value |
|---|---|---|
| Calculating the volume of rapeseed grown | t | 2670783,0 |
| Export value at the price as of 12/31/2023 | billion USD | 1,71 |
| Value in domestic prices as of 12/31/2023 | billion USD | 37720,9 |
| Calculation of biodiesel yield (45%) | t | 1201709,4 |
| Calculation of the cost of biodiesel production | million UAH | 39760,0 |
| Calculation of rapeseed cake yield, (55%) | million UAH | 1468779,3 |
| Value of the selling price | million UAH | 8809,9 |
| Glycerin yield (10% from biodiesel) | t | 120179,0 |
| Value of realisation price | million UAH | 9620,7 |

*Source: (Honcharuk et al., 2022)*

The use of advanced technologies for transporting and injecting liquid digestate will make it possible to reduce application costs and increase assimilation in the soil through fertiliser injection technology. The use of a flexible active harrow with the teeth of a loosener, which has shown the advantages of loosening and compacting the soil compared to conventional harrows, will provide an opportunity to improve cultivation after feeding (Bulgakov et al., 2019).

Using the proposed technology of soil application and cultivation in combination will reduce the production costs of biogas plants by reducing the cost of drying the digestate, increase the assimilation of fertilisers through the use of injection systems, and the use of biodiesel will significantly reduce the cost of fuel and lubricants.

After the raw materials are processed at BP, the end product is methane gas and the by-product is liquid fertiliser. In order to efficiently pump the gas into cylinders, it is necessary to buy a powerful compressor – to cope with the task of pumping the gas, it is necessary to buy a compressor with a capacity of 25 $m^3$/h, the cost of which is 4.9 thousand UAH. To store liquid fertiliser, it is necessary to build a bunker with a capacity of 360 $m^3$, which will cost 200,000 UAH. It is also necessary to purchase a vehicle for selling biofertilisers and delivering raw materials to consumers. The cost of such a vehicle is about 200,000 UAH, of which 120,000 UAH is for a used truck and 80,000 UAH is for a vacuum tank with a volume of 5,000 litres.

The funds will be invested in four stages:

– To start the first production period, the company needs a cash injection of 1,372.6 thousand UAH to set up the production process, primarily for the purchase of equipment, a bucket loader, a delivery vehicle, production facilities and a storage facility for organic fertilisers;

– at the beginning of the second one – 912.6 thousand UAH, with the aim of doubling production and increasing the storage area of biofertilisers, which will allow for additional profit;

– at the beginning of the 3rd and 4th periods, cash investments are required to extend the lease agreement for the biogas plant – 693.36 thousand UAH and 849.4 thousand UAH, respectively. These last two investment tranches can be realised at the expense of the company's own profits from the operation of the BP (biogas plant) in previous years.

Given the average market price for gas, it would be more expedient to sell biofertilisers and consume the resulting biogas for space heating, electricity generation, and vehicle fuelling, which would reduce production costs for raising animals on agricultural enterprises to some extent (Table 6).

Table 6
**Potential benefits of the project on the use of BP in medium-sized agricultural enterprises**

| Biomethane production | |
|---|---|
| Average market price, UAH/$m^3$ | 13,49 |
| Biomethane produced, thousand $m^3$ | 40,5 |
| Sales price, UAH/$m^3$ | 6,45 |
| Gross revenue, thousand UAH | 261,23 |
| Net income, thousand UAH | 235,76 |
| Biofertiliser production | |
| Average market price, UAH/t | 5300 |
| Biofertilisers produced, tonnes | 1017 |
| Sales price, thousand UAH | 1500 |
| Gross revenue, thousand UAH | 1525,5 |
| Net profit, thousand UAH | 1376,76 |
| Total gross income, thousand UAH | 1786,73 |
| Total net income, thousand UAH | 1612,52 |

*Source: developed by the authors based on their own research*

Thus, the implementation of biogas projects can be aimed at creating the following production options:

Option 1 – use of biogas for the production of steam/hot water for own needs.

Option 2 – use of biogas for combined heat and power (steam/hot water) production at CHP for own needs and sale to other consumers.

Option 3 – use of biogas for combined heat and power (steam/hot water) production at KSU for the sale of electricity to Ukrenergo's grid at a "green" tariff, heat to the municipal heating network, as well as for own needs and sale to other consumers.

Option 4 – use of biogas for sale as a fuel (biomethane) after enrichment.

## 5. Conclusions

Sustainable development of the agricultural sector is impossible without energy-efficient crop production technologies. An important role is played by the development of innovative organic fertiliser s ystems that would reduce the use of expensive mineral fertilisers and increase yields. The following can be summarised as a result of the research:

(1) The analysis of fertiliser application tended to increase, but organic fertiliser application in Ukraine is insufficient and accounts for only 5.70% of the total land area. At the same time, in neighbouring Poland, organic fertiliser application is more than 30% of the total area, due to the lower development of livestock farming. The development of biogas and digestate production will help to increase the level of fertilisation of agricultural land.

(2) Waste generation in the agricultural sector, which can become a feedstock for biogas production, is mainly represented by post-harvest residues and manure. In total, the potential biogas yield from the respective raw materials will be 9.6 billion $m^3$, which will provide 50% of natural gas consumption in Ukraine.

(3) Biogas is a renewable energy source that does not pollute the environment. It can be used to produce electricity, heat and other useful products.

These are some of the benefits of building a biogas plant and producing electricity from sugar beet pulp, grain straw and corn silage:

– This project is environmentally friendly as it does not pollute the environment;
– the project is economically viable as it can provide a cheap source of energy;
– the project is social, as it can create new jobs.

However, there are also certain risks associated with the construction of a biogas plant:

– The project requires significant investment;
– the project may have a negative impact on the environment if it is not properly planned and implemented.

In general, the feasibility of building a biogas plant and producing electricity from sugar beet pulp, grain straw and corn silage is quite high. This project can bring significant economic, social and environmental benefits.

Here are some additional factors to consider when assessing the feasibility of this project:

– Availability of raw materials;
– price of raw materials;
– technical feasibility of processing the feedstock into biogas;
– cost of construction and operation of the biogas plant;
– electricity market.

(4) Surface application of the digestate is not feasible due to the high cost of transportation and the need to use large containers. The use of injection systems in combination with hose transport using diesel pumping stations with their adaptation to the use of biodiesel as a fuel will reduce the cost of transporting the fertiliser. In addition, the use of an injection system will ensure more efficient distribution of the liquid fraction in the soil, and the use of flexible active harrows with loosening teeth will improve the absorption of organic matter. Excluding the digestate drying process from the technological cycle will reduce the cost of biogas production.

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