POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2026 ✦ Volume 29 ✦ Issue 3 ✦ 81–102

DOI: 10.33223/epj/216807

Svitlana Lutkovska[1], Tetiana Kolomiiets[2], Nataliia Zelenchuk[3], Oleg Dmytryk[4]

Assessment of the potential of Ukrainian agrobiomass for biogas production in the context of ensuring food and energy security

Abstract: In the context of global challenges, in particular the martial law in Ukraine and the turbulence in the global energy market, the issues of ensuring food and energy security are becoming paramount. This article is devoted to a comprehensive analysis and assessment of the potential for using Ukrainian agrobiomass for biogas production, which is considered a key direction for achieving sustainable development and strengthening national independence.

The conducted research demonstrates the significant untapped potential of Ukraine in biogas production from various agrobiomass, including crop residues, manure, and food industry waste. The realization of this potential promises significant economic benefits, such as reducing greenhouse gas emissions, increasing the profitability of the agricultural sector, obtaining valuable organic fertilizers, as well as reducing critical dependence on energy imports. The national potential for biomethane production in Ukraine is estimated at over 8.4 billion m^3 per year.

✉ Corresponding Author: Tetiana Kolomiiets; e-mail: Kolomiets.tanichka@gmail.com

[1] Vinnytsia National Agrarian University, Ukraine; ORCID iD: 0000-0002-8350-5519; e-mail: svetvsau@gmail.com

[2] Vinnytsia National Agrarian University, Ukraine; ORCID iD: 0000-0001-5241-4107; e-mail: Kolomiets.tanichka@gmail.com

[3] Vinnytsia National Agrarian University, Ukraine; ORCID iD: 0000-0001-7140-1571; e-mail: natalia.vnau@ukr.net

[4] Vinnytsia National Agrarian University, Ukraine; ORCID iD: 0000-0002-7642-1640; e-mail: olegvdmytryk@ukr.net

However, despite the clear benefits, the development of Ukraine's biogas industry faces major obstacles. These include the high initial cost of biogas plants, which restricts their use in both large companies and households. Additionally, a lack of adequate state incentives and sufficient investment also hinders development. To overcome these barriers and fully realize the biogas potential, the article justifies the need to develop and implement a comprehensive state support program. These measures are vital to promoting energy autonomy, improving the environmental situation, stimulating economic growth, and effectively rebuilding Ukraine in the post-war period.

Keywords: agrobiomass, biogas, biomethane, energy security, waste

Introduction

With regard to modern challenges, in particular martial law in Ukraine and the constant increase in energy prices on the world market, the issues of food and energy security are becoming particularly relevant. In this context, biogas production at enterprises and in households is considered one of the key areas for ensuring sustainable development and independence of Ukraine and the EU. Ukraine has significant potential for biogas production, since the main types of biomass that can be used are plant residues, manure, and food industry waste.

In general, the volume of organic waste (Kaletnik 2020) suitable for biogas production includes animal waste, mixed food waste, plant waste, animal excrement, urine and manure, as well as household and similar waste (4,817.4 thousand tons). Studies show that the implementation of biogas production projects will reduce greenhouse gas emissions and increase profits from the sale of electricity. In addition, Ukraine has the potential to use about 11–12 million hectares of arable land for growing energy crops.

By using digestates as a high-quality organic fertilizer, biogas production contributes to the reduction of greenhouse gas emissions, the efficient utilization of organic waste, and the improvement of soil quality. From an economic point of view, it is a source of stable income from the sale of electricity, heat, and organic fertilizers, reducing waste disposal costs, and creating new jobs. In terms of energy, biogas is a renewable energy source that contributes to the decentralization of energy supply and increases the country's energy security, reducing dependence on fossil fuel imports.

To realize this potential, effective mechanisms of state support are needed, reducing the cost of equipment and raising public awareness of the benefits of biogas.

This study is aimed at a comprehensive assessment of the potential of agrobiomass in the Ukrainian agro-industrial complex for the production of biofuels, taking into account current trends and forecast indicators of the industry's development. To achieve this goal, the following research questions were posed:

To summarize the key economic, environmental, and energy benefits of biogas production in Ukraine.

To identify the main types of organic waste that are raw materials for biogas and their volumes mentioned in the study.

To characterize the overall potential for biomethane production in the regions of Ukraine and name the most promising ones.

To formulate the key constraining factors for the development of the biogas industry in Ukraine and propose ways to overcome them, in accordance with the recommendations of the study.

To present an action plan for creating a state incentive program for the development of biogas production, taking into account international experience and the possibility of ensuring energy and food security.

1. Literature review

Global challenges, such as energy independence, food security, and environmental sustainability, require Ukraine and the world community to find innovative solutions. Hence, biogas production is emerging as a strategic direction that not only allows diversification of energy sources, but also reduces greenhouse gas emissions and increases soil fertility. Taking into account Ukraine's significant resource capabilities and geopolitical context, this literature review analyzes current research on the potential, advantages, and challenges of developing the biogas industry there. Reviewing the scientific works covers a wide range of subjects, from assessing the raw material base and technological solutions to economic efficiency and strategic planning, emphasizing biogas's role in energy autonomy and sustainable development.

The study (Koval et al. 2025) revealed that plant residues (71.4%), manure (26.6%), and food industry waste (2.0%) are the three main types of biomass used in Ukraine to produce biogas. The implementation of biogas production projects will reduce greenhouse gas emissions by 3.98 billion tons of CO_2 and increase profits from the sale of electricity.

At the same time, studies (Hontaruk et al. 2024) substantiate the need to develop biogas and digestate production at Ukrainian sugar factories, focused on the further sale of biomethane on the energy market and for their own needs, which will partially ensure the energy security of the state under martial law.

Studies (Lohosha et al. 2023) have proven that the use of mineral fertilizers and their combination with high rates of bioorganic fertilizer (digestate) when growing crops contributes to increased productivity.

At the same time, research (Kaletnik et al. 2025) substantiates the relevance and potential of implementing waste-free technology, which has significant benefits of energy autonomy for both the enterprise and the country. Besides, effective economic evaluation ensures long-term benefits from ecosystem preservation and sustainable resource use.

Research (Pryshliak et al. 2022) has formed a model of a territorial bioenergy cluster for the production of biofuels from agricultural crops and waste, and has analyzed the benefits of

creating bioenergy clusters. In addition, a PEST analysis matrix for the formation of bioenergy clusters in Ukraine has been formed.

According to calculations (Tokarchuk et al. 2022), Ukraine can use about 11–12 million hectares of arable land for growing energy crops with their subsequent processing into biofuels.

At the same time (Mazur et al. 2020), it was found that in Ukraine, the use of corn silage to increase the efficiency of biogas production at existing biogas plants has not yet been used. The problems of increasing the yield of corn plants have been proven not only by breeding and genetic methods, but also by cultivation technology.

At the same time, as indicated in studies (Pisarenko et al. 2024), in the post-war recovery strategy, important areas of research are the adaptation of production to the requirements of the bioeconomy, the introduction of environmental technologies, and the development of sales channels that would ensure efficiency and cost minimization.

According to the National Renewable Energy Action Plan for the period up to 2030 and the action plan for its implementation, at the beginning of 2024, the total electrical capacity of facilities using biomass and biogas in Ukraine (excluding temporarily occupied territories) was 319 MW. This indicates that the development of electricity production from biomass and biogas is still lagging behind the growth rates of other renewable energy sources.

As noted in the studies (Bondarenko et al. 2023), the primary importance for the formation of a "green" economy in Ukraine is the justification of measures to solve economic, ideological, educational and legal problems and the introduction of organizational factors of state support for the transformation of the economy at the national, sectoral and regional levels.

Thus, a number of scientific works emphasize the relevance of the development of biogas technologies in the context of ensuring energy security under martial law (Hontaruk et al. 2024) and the post-war recovery strategy (Pisarenko et al. 2024). The concept of waste-free production, integrating biogas plants, is considered a path to energy autonomy for both individual enterprises and the country as a whole (Kaletnik et al. 2020). The formation of territorial bioenergy clusters and optimization of land use for growing energy crops (Pryshliak et al. 2022; Tokarchuk et al. 2022) are important elements for scaling the industry. Despite the obvious advantages, the development of biogas energy in Ukraine still lags behind the growth rates of other renewable energy sources, as evidenced by the relatively low total electrical capacity of facilities (National Action Plan 2024). There are also untapped opportunities, such as the use of corn silage to increase the efficiency of biogas production (Mazur et al. 2020). Therefore, to fully unlock the potential of the biogas industry in Ukraine, further improvements in public policy, investment incentives, technology development, and research aimed at overcoming existing challenges and ensuring sustainable development are necessary. The literature review convincingly demonstrates that biogas production is a promising area for Ukraine, capable of significantly enhancing its energy and food security, as well as contributing to environmental sustainability. Studies confirm the significant potential of biomass in Ukraine, where the main raw materials are crop residues, manure, and food industry waste (Koval et al. 2025). The implementation of biogas projects not only contributes to the reduction of greenhouse gas emissions and the increase of profits from the sale of electricity,

but also provides a valuable bioorganic fertilizer – digestate, which increases the productivity of agricultural crops (Lohosha et al. 2023).

2. Materials and methods

Several key methodologies are used to determine the efficiency of biogas production, both in large enterprises and in households. They allow for a comprehensive assessment of the project, taking into account its economic, environmental, and social aspects (Lutkovska 2020; Romanchuk 2015; Tokarchuk 2018).

The internal rate of return (IRR) method involves calculating the internal rate of return of a project by analyzing all cash flows associated with biogas production over a certain period. It allows you to assess the attractiveness of the project from an investment perspective and compare it with other potential investments.

At the same time, the internal cost of ownership (LCUE) method focuses on the cost of internal resources (such as land, labor, capital) required for biogas production, as well as all related economic and environmental costs. This allows you to obtain a comprehensive assessment of the total cost of the project and its effectiveness.

The life cycle economic analysis (LCA) method is based on a methodology that allows you to assess the economic and environmental impact of biogas production at all stages of the project's life cycle – from initial production to operation and subsequent disposal. It helps to take into account all aspects of environmental impact and potential socio-economic benefits.

At the same time, the comparative analysis method consists of comparing the costs and efficiency of a biogas production project with alternative ways of using resources or other energy sources. This helps to choose the most profitable and rational solution.

The socio-economic analysis method: this method takes into account the social and economic benefits that biogas production can bring. These include, for example, the creation of new jobs, improving the environment and raising the standard of living of the local population.

The use of these methods allows for a deep and comprehensive analysis of the efficiency of biogas projects, assessing their feasibility from an economic, environmental, and social point of view. However, in our opinion, the method for assessing the potential of biogas production should be based on the calculation of the total volume of raw materials and their specific biogas productivity.

The total potential for biogas (or biomethane) production can be expressed by the following formula:

$$P_{biogas} = \sum_{i=1}^{n} (V_{raw,i} \cdot K_{biogas,i})$$

where:

- P_{biogas} – total biogas (or biomethane) production potential over a certain period (e.g., year) [m^3].
- n – total number of categories of organic raw materials (e.g., cattle, pig, poultry waste, plant residues, etc.).
- $V_{raw,i}$ – volume of the i-th type of organic raw material available for processing during the period (e.g., tons/year or heads/year for livestock),
- $K_{biogas,i}$ – specific yield coefficient of biogas (or biomethane) from the i-th type of raw material (for example, m^3/ton of raw material, or m^3/capita/day with subsequent conversion to the period).

This approach allows not only to assess the actual effectiveness of existing projects, but also to predict the potential of new initiatives, ensuring the sustainable development of bioenergy.

3. Results

Biogas production from organic waste has significant potential for Ukraine and can become a tool for ensuring energy and food security, including in the EU, but clear actions are needed for its full implementation. It is necessary to introduce effective state support mechanisms, reduce the cost of equipment, and raise public awareness of the benefits of using biogas. These steps are key to stimulating the development of this important industry.

According to Table 1, the main types of waste that can be raw materials for biogas are: 240.4 thousand tons of animal waste and mixed food waste; 4,526.0 thousand tons of plant waste; 2,959.4 thousand tons of animal excrement, urine, and manure; as well as 4,817.4 thousand tons of household and similar waste.

Based on the declared average cost of landfilling 1 ton of organic waste at the level of 255 UAH/t, savings of UAH 3.198 billion can be achieved through biogas production at the landfill. Studies show that the market price of digestate is on average UAH 590/t, and the potential volume of waste of animal origin alone, according to Table 2.3, can be 7.7 million tons. With a digestate yield of 80%, the potential cost will be UAH 3.63 billion.

Due to the significant increase in the cost of mineral fertilizers, biogas production will provide agricultural producers with cheap organic fertilizers such as digestate, which will positively affect the cost of production and yield.

According to research (Lohosha 2023), the application of bioorganic fertilizer “Effluent” based on digestate contributed to an increase in conditional net profit by 12,993.0–17,215.0 UAH/ha at an application rate of 55.0 t/ha.

Biogas production from organic waste from agribusiness and households has a multi-purpose positive impact. It allows for efficient use of waste, minimizing methane emissions and

Table 1. Generation and processing of waste of hazard classes I–IV by waste categories by material in 2024 [thousand tons]

Tabela 1. Wytwarzanie i przetwarzanie odpadów klas zagrożenia I–IV w podziale na kategorie odpadów według rodzaju materiału w 2024 r. [tys. ton]

	Mass of waste			
	generated	recovered	incinerated	disposed of in landfills
Total	176,276.6	39,266.5	902.8	104,924.8
Used solvents	2.1	0.0	0.0	5.3
Waste acids, alkalis, etc.	117.0	13.4	–	102.1
Waste oils	14.9	5.6	1.2	0.0
Chemical waste	319.2	0.9	1.6	305.9
Industrial sewage sludge	758.4	245.0	98.7	83.4
Ferrous metal waste	482.4	256.5	0.0	5.7
Non-ferrous metal waste	18.3	2.2	0.0	0.0
Mixed ferrous and non-ferrous metal waste	12.8	7.3	0.0	0.2
Glass waste	55.7	0.3	0.0	0.3
Paper and cardboard waste	165.9	74.6	1.6	4.3
Rubber waste	17.6	0.5	0.0	0.9
Plastic waste	37.1	11.3	0.2	0.8
Wood waste	509.9	41.9	242.7	7.9
Textile waste	7.7	0.3	0.9	0.9
Animal waste and mixed food waste	240.4	24.2	3.0	0.9
Plant waste	4,526.0	1242.0	362.6	17.4
Animal excrement. urine and manure	2,959.4	1816.9	5.0	154.1
Household and similar waste	4,817.4	14.9	157.5	5,939.2
Mixed and undifferentiated materials	1,461.5	451.4	0.7	858.6
Sorting residues	12.6	1.4	0.0	4.3
Regular sludge	355.5	61.7	–	66.3
Mineral waste from construction and demolition of facilities	530.4	1.5	0.0	1,040.1
Combustion waste	3,661.9	332.4	0.4	1,307.2
Other mineral waste	148,183.7	28,753.7	23.0	93,902.5
Soil waste	631.9	0.1	0.0	623.6
Dredged rock from dredging operations	6,056.0	5788.4	–	304.5
Hardened, stabilized or vitrified waste	18.1	105.5	–	0.3

Source: compiled based on data from the State Statistics Service of Ukraine.

environmental pollution. In addition, it creates additional sources of income for enterprises and farms, ensures the stability of energy supply, especially in remote regions, and increases energy independence. For households, biogas production provides the opportunity to be self-sufficient in hot water supply and organic fertilizers (digestate).

Despite the significant potential, there are restraining factors, in particular the high cost of biogas plants for households (from 15 to 80 thousand UAH) and the need for additional costs for biogas storage. The lack of state incentives and the necessary amount of investment is the main restraining factor for the development of biogas production at agribusiness enterprises. However, state support in the amount of 15–20 thousand UAH per household can significantly facilitate the acquisition of such plants.

Active implementation of biogas production technologies is strategically important for the post-war reconstruction of Ukraine, contributing to the energy autonomy of villages, reducing dependence on gas imports, improving the environmental situation, and creating new jobs.

The data presented indicate that the biogas industry has enormous potential for development in Ukraine, especially with adequate state support and investment.

A study of the potential for biomethane production in the regions of Ukraine, based on data on the availability of six types of organic raw materials (sewage sludge, organic MSW, food industry waste, manure, corn silage, crop residues), revealed a significant nationwide volume exceeding 8.4 billion m^3/year. This potential demonstrates significant regional differentiation and dependence on the specifics of available biomass resources (Fig. 1).

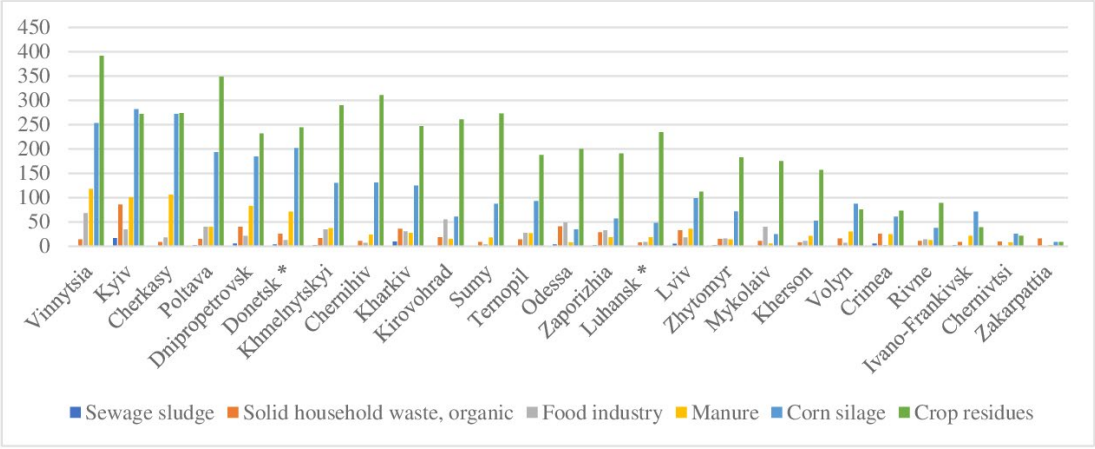

Fig. 1. Structure of raw material potential for biogas production
* without taking into account the temporarily occupied territories
Source: author's own research based on (Ecodia website data, Environmental tax return 2025; World experience in greenhouse gas emission trading under the Kyoto Protocol)

Rys. 1. Struktura potencjału surowcowego do produkcji biogazu
* bez uwzględnienia terytoriów tymczasowo okupowanych

Agricultural biomass (crop residues, corn silage, manure) is the dominant source of potential, forming the largest part of the total volume. In particular, corn silage and crop residues are the most significant categories.

Waste from urbanized and industrial areas (organic MSW, food industry waste, sewage sludge) is also important, but their contribution is smaller in absolute terms compared to agricultural biomass.

The most promising regions for biomethane production:

1. Vinnytsia region (846 million m^3) – this region is the undisputed leader, which indicates a high concentration and diversity of agricultural raw materials.

2. Kyiv region (793 million m^3), which demonstrates the second largest potential due to the synergy of agricultural resources and a significant volume of organic waste of the metropolitan agglomeration.

3. Cherkasy region (681 million m^3) has significant potential, mainly due to agricultural biomass.

4. Poltava region (640 million m^3) is also among the leaders, emphasizing the role of the agricultural sector in central Ukraine.

5. Dnipropetrovsk region (567 million m^3) has high potential, due to both agricultural and industrial sources.

Ukraine has an extremely high potential for biomethane production, mainly due to the effective use of agricultural biomass. The regions of central and eastern Ukraine, characterized by intensive agriculture, are key for the development of large-scale biomethane projects. The realization of this potential is critically important for strengthening energy independence, decarbonization of the gas sector, and sustainable development of the country.

It should be noted that in the structure of biogas production potential, the main raw materials are post-harvest residues and corn silage, which in the future will amount to over 9.6 billion m^3 (Fig. 2).

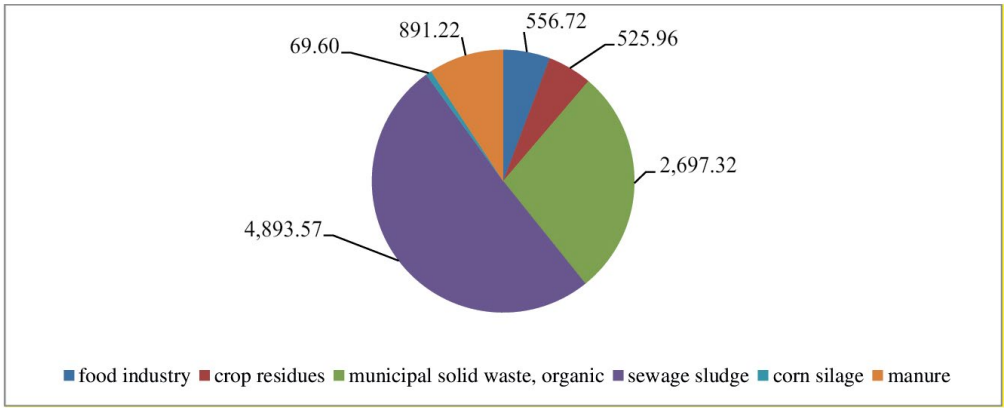

Fig. 2. Potential volume of biomethane production in Ukraine [million m^3]
Source: author's own research based on (Ecodia website data, Environmental tax return 2025; World experience in greenhouse gas emission trading under the Kyoto Protocol)

Rys. 2. Potencjalna wielkość produkcji biometanu na Ukrainie [mln m^3]

Our research allows us to propose improved approaches to assessing the significance of biogas production both at enterprises and in households. The main goal is to ensure the environmental, food, and energy security of Ukraine and the EU. This is possible by determining the economic effect of each impact factor, including the cost expression of environmental and economic benefits (Fig. 3).

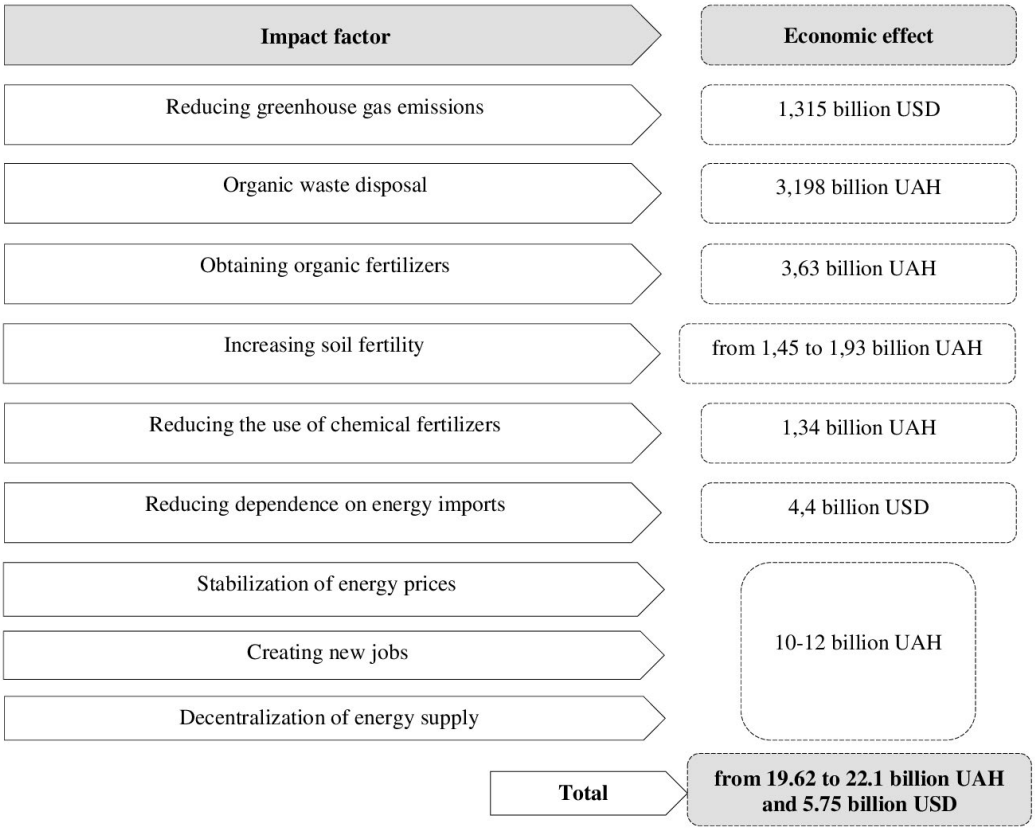

Fig. 3. Environmental and economic efficiency of biogas production at enterprises and households
Source: own research

Rys. 3. Efektywność środowiskowa i ekonomiczna produkcji biogazu w przedsiębiorstwach i gospodarstwach domowych

Analysis of the data presented in the figure reveals significant economic benefits from the implementation of these initiatives. In particular, the reduction of greenhouse gas emissions is estimated at 1.315 billion USD. Utilization of organic waste generates 3.198 billion UAH, and the production of organic fertilizers – 3.63 billion UAH. The positive impact on soil fertility leads to an economic effect in the range from 1.45 to 1.93 billion UAH.

Reducing the use of chemical fertilizers provides savings of 1.34 billion UAH. In addition, reducing dependence on energy imports is estimated at 4.4 billion USD, and stabilizing energy prices at 10−12 billion UAH. It is important to note that impact factors such as the creation of new jobs and decentralization of energy supply, although they do not have a separate quantitative assessment of the economic effect in the table, their contribution is implicitly taken into account in the overall indicators. The total economic effect of all considered initiatives is estimated in the range from 19.62 to 22.1 billion UAH, supplemented by 5.75 billion USD. Thus, the presented data clearly demonstrate the complex and multiplicative positive impact of the implementation of these initiatives on the national economy, which is expressed both in reducing costs and in creating new sources of income.

Table 2 systematizes the significant potential of Ukraine in the production of biogas from various organic wastes of the agro-industrial complex (AIC) and households, as well as the use of the developed author's methodology. Data analysis indicates the high prospects of bioenergy for ensuring the energy and environmental security of the state.

Table 2. Biogas production potential from different types of raw materials in Ukraine

Tabela 2. Potencjał produkcji biogazu z różnych rodzajów surowców w Ukrainie

Type of raw material	Total biogas production potential [billion m^3]	Total potential in terms of biomethane [billion m^3]
Livestock waste OSG (cattle, pigs, poultry)	4.2	4.2 (biomethane)
Livestock waste (all categories of farms: cattle, pigs, poultry)	9.59	7.97 (biomethane)
Molasses	0.224	0.146
Beet pulp	0.745	0.484
Bard	0.031	0.02
Crop residues and corn silage	12.1	12.1 (biomethane)
General raw material potential of agriculture	> 7.97 (basics – poultry farming)	9.59 (biomethane)
General raw material potential of livestock farming of households	–	4.2 (biomethane)
General potential of the processing industry of the agro-industrial complex	1	0.65

Source: own research based on (Lutkovska 2023; Gromm 2020; Fedunyak 2014).

Investments in biogas production are a multifaceted solution that integrates economic, environmental, and energy benefits. It is a strategic direction for sustainable development, contributing to the country's energy and food security, improving the environmental situation and economic growth, especially relevant in the current geopolitical situation and rising energy prices (Table 3).

Table 3. Comparison of advantages and disadvantages of investing in biogas production

Tabela 3. Porównanie zalet i wad inwestowania w produkcję biogazu

Advantages of investing in biogas production	Disadvantages of investing in biogas production
Economic advantages:	Economic disadvantages:
✦ stable income from the sale of electricity, heat and organic fertilizers	✦ high initial investments in equipment and construction
✦ possibility of receiving state support (green tariff, tax breaks)	✦ long payback period
✦ reduction of waste disposal costs	✦ dependence on raw material and energy prices
✦ creation of new jobs	✦ risks associated with market fluctuations
Environmental advantages:	Environmental disadvantages:
✦ reduction of greenhouse gas emissions	✦ possible negative consequences for the environment in case of improper operation
✦ disposal of organic waste	✦ use of land resources for growing energy crops
✦ improvement of soil quality	✦ production of a large amount of digestate that requires disposal
Energy advantages:	Energy disadvantages:
✦ renewable energy source	✦ low energy density of biomass compared to fossil fuels
✦ decentralization of energy supply	✦ seasonality of biogas production
✦ increase in the level of energy security	✦ dependence on climatic conditions

Source: authors' own research.

The economic benefits of investing in biogas are realized through several key channels:

Revenue generation, as biogas can serve as fuel for cogeneration plants that produce electricity and heat. Selling the generated electricity at "green" tariffs and other incentives can become a profitable business.

Sale of organic fertilizers – digestate, which is a biological residue after biogas production, is a high-quality organic fertilizer that can be sold to agricultural enterprises. Reducing waste disposal costs through the use of organic waste as raw material for biogas production allows for a significant reduction in the costs of their disposal.

The financial aspects of such investments require consideration:

Initial capital investment – the construction of a biogas plant requires significant investments in equipment, construction, and connection to engineering networks.

Existing risks, because investments in biogas projects are associated with certain risks, such as fluctuations in prices for raw materials and energy carriers, changes in government policy, technological risks, etc.

Production factors that affect economic feasibility include:

The scale of the plant itself, because large biogas plants are usually more cost-effective due to the effect of scale. However, small biogas plants in households are also an economically viable solution to ensure their energy autonomy.

At the same time, the biogas yield and the choice of the optimal technology depend on the type of raw material used.

The location of the plant relative to consumers of biogas and organic fertilizers affects transportation costs.

The presence and size of "green" tariffs, tax breaks, and other support measures significantly increase the economic feasibility of projects.

The environmental benefits of biogas production are significant:

Reducing greenhouse gas emissions through biogas production helps to reduce greenhouse gas emissions, in particular methane, which is formed during the natural decomposition of organic materials.

Biogas plants effectively solve the problem of organic waste disposal, reducing the burden on the environment.

Digestate, which is a by-product of biogas production, is a high-quality organic fertilizer that helps increase soil fertility.

The use of biogas as a fuel reduces dependence on imported fossil fuels and increases the country's energy security.

At the same time, biogas is a renewable energy source that can replace part of traditional fossil fuels.

Modern biogas plants provide high energy efficiency, allowing to convert a significant part of the energy contained in biomass into heat and electricity.

Biogas production at the local level contributes to the decentralization of energy supply, increasing the energy security of regions and reducing the costs of developing energy infrastructure.

Therefore, investing in biogas production is a promising direction for the development of energy and agriculture. It contributes to solving a number of urgent problems, such as climate change, environmental pollution, energy security, and the development of rural areas. However, for the successful implementation of such projects, it is necessary to carefully analyze all economic, environmental, and technological factors of each specific project.

It can be argued that the successful development of the biogas industry in Ukraine depends on a complex of interacting factors, both internal and external. For the effective implementation of projects in this area, coordinated cooperation of the state is necessary, aimed at attracting investments and developing business support programs, as well as active participation of civil society. Such a synergistic approach will allow for maximum use of the potential of biogas and its derivatives.

Thus, the importance of biogas production at enterprises and in households for ensuring the environmental, food and energy security of the state should be assessed through the value expression of the following interrelated factors: reduction of greenhouse gas emissions; possibility

of recycling organic waste; cost of obtained organic fertilizers; economic effect of increasing soil fertility; amount of reduction in the use of chemical fertilizers; reduction of dependence on energy imports and possibility of stabilizing prices for them; budget revenues from the creation of new jobs; possibility of decentralization of energy supply; as well as the availability of state investment programs and state support measures. At the same time, the presence of a large number of types of raw materials for biogas production requires the development of technologies for the production and operation of biogas reactors of small and medium capacity, which, in our opinion, can be implemented through the creation of student farms on the basis of higher education institutions.

For example, today, within the framework of the educational and scientific activities of student farms of VNAU, specializing in livestock breeding on the basis of the experimental plot of VNAU and the Scientific and Research Group "Agronomic" of VNAU, where 50 heads of cattle, 100 heads of goats, 100 heads of sheep, 80 heads of pigs and 500 heads of poultry are kept, it is advisable to create conditions for the development of scientific research in the field of biogas production. Based on calculated data, the theoretical volume of biogas formation per 1 head/day ranges from 0.06 m^3 to 1.1 m^3, which allows producing up to 83.95 thousand m^3 of biogas (Table 4).

Table 4. Biogas production indicators on the basis of the educational student farm of the VNAU based on the implemented experience of the The Weihenstephan-Triesdorf University of Applied Science

Tabela 4. Wskaźniki produkcji biogazu na terenie studenckiego gospodarstwa edukacyjnego VNAU w oparciu o doświadczenia zgromadzone przez Uniwersytet Nauk Stosowanych w Weihenstephan-Triesdorf

Animal type	Number [units]	Average biogas yield per capita [m^3/day]	Potential volume of biogas generation [m^3/year]	In terms of biomethane [m^3/year]
Cattle	50	0.8	14,600	8,760
Goats	100	0.06	2,190	1,314
Sheep	100	0.06	2,190	1,314
Pigs	80	1.1	32,120	19,272
Poultry	500	0.18	32,850	19,710
Total	830	2.2	83,950	50,370

Source: own research

Today, scientists at VNAU have created and patented a biogas reactor (Honcharuk et al. 2021), the use of which on the basis of this farm will allow conducting research into the possibility of mixing various types of waste, including those of plant origin.

At the same time, the systematization of the experience of leading EU countries and China in the field of biogas production made it possible to partially implement their experience in modern realities and develop an action plan for creating a program of state incentives for the development of biogas production in personal farms, as presented in Table 5.

Table 5. Action plan for creating a program of state incentives for the development of biogas production in personal farms, taking into account the experience of China and EU countries

Tabela 5. Plan działania dotyczący stworzenia programu państwowych zachęt na rzecz rozwoju produkcji biogazu w gospodarstwach prywatnych, z uwzględnieniem doświadczeń Chin i krajów UE

Category	Measures	Expected results	Years of implementation
Financial support	Direct subsidies for households, tax breaks and credit programs for enterprises	Increase in investments in the industry, decrease in the cost of equipment and services	2024–2030
Information support	Development of methodological manuals, organization of training events, creation of an information portal for households	Dissemination of knowledge about biogas production technologies, increase in public awareness	2024–2030
Research activities	Funding of scientific projects, cooperation with scientific institutions and creation of bioenergy laboratories based on universities, student training farms	Improvement of biogas production technologies, increase in its efficiency	2024–2030
Favourable legislative environment	Simplification of the procedure for obtaining permits, setting quality standards, market regulation	Reduction of administrative burden, ensuring product quality, creation of a competitive market	2024–2025
International cooperation	Attracting investments, exchange of experience	Acceleration of industry development, introduction of new technologies	2024–2030
Overall program results	Increasing biogas production, reducing greenhouse gas emissions, creating new jobs, developing rural areas, increasing biofuel exports	Energy security of the country, environmental protection, development of agriculture	2030

Source: own research.

According to this plan, it is necessary to:

- direct the income from the sale of CO_2 emission quotas under the Kyoto Protocol to subsidize the purchase of equipment for households planning to produce biogas for their own needs (compensation of the cost of domestically produced equipment in the amount of 40%);

- create information portals to popularize biogas production (websites of research institutions, local administrations) and attract investors (inclusion of potential investment proposals of enterprises in the investment passports of regions);
- finance the creation of a network of educational student farms following the example of VNAU to popularize biogas production, support scientific research in this area;
- improve the regulatory framework to minimize the tax burden on biogas projects in industry (tax holidays for biogas plants until commissioning);
- establish quotas for the export of biomethane by industrial enterprises in order to ensure the energy independence of the state;
- development of exchange of experience in the field of biogas production with EU countries and China, conducting joint research within the framework of international research projects.

Development and implementation of a program of state incentives for the development of biogas production in private farms and enterprises is a necessary step to ensure the energy and environmental security of the country, environmental protection, and development of agriculture, including through the implementation of the practice of intermunicipal investment cooperation. Conducting joint research between scientific institutions of the EU countries and Ukraine. The source of funding for the program should be revenues from the sale of "carbon" quotas provided for by the Kyoto Protocol.

For the effective development of the biogas industry in Ukraine, it is necessary to implement a number of measures, including:

Financial support for households by directing funds received from the sale of CO_2 emission quotas under the Kyoto Protocol to subsidize the purchase of biogas production equipment by households that plan to use it for their own needs. It is proposed to compensate 40% of the cost of domestically produced equipment.

Information support and investment attraction through the creation of specialized information portals (based on research institutions and local administrations) to popularize biogas production. It is also necessary to actively attract investors, including potential investment proposals of enterprises in the investment passports of the regions.

Stimulation of scientific and educational activities, namely the creation of a network of educational student farms similar to VNAU, in order to popularize biogas production and support relevant scientific research.

Optimization of tax legislation through improving the regulatory framework to minimize the tax burden on industrial biogas projects, in particular, by providing tax holidays for biogas plants until their commissioning.

Establishment of a quota for biomethane exports by industrial enterprises in order to prioritize the country's domestic energy needs and increase its energy independence.

Actively develop the exchange of experience in the field of biogas production with the countries of the European Union and China, as well as conduct joint international research projects.

The development and implementation of a comprehensive state program to stimulate the development of biogas production in private farms and enterprises is a critically important step

in ensuring the energy and environmental security of the country and the EU. This can also be achieved through the introduction of the practice of intermunicipal investment cooperation and joint research between scientific institutions of the EU and Ukraine. The main source of financing for such a program should be revenues from the sale of "carbon" quotas provided for by the Kyoto Protocol.

Thus, investing in biogas production is a promising direction for the development of the energy and agricultural sectors. This contributes to solving a number of urgent problems, such as climate change, environmental pollution, energy security, and the development of rural areas. However, for the successful implementation of such projects, it is necessary to take into account a number of economic, environmental, and technological factors. It is important to understand that the economic feasibility of investing in biogas plants is individual for each specific project and depends on many factors. Therefore, biogas production is an important element of sustainable development, contributing to the energy and food security of the state, ensuring environmental safety and economic growth, which is especially relevant in conditions of martial law, refusal of energy sources by the aggressor country, and the constant increase in the price of energy sources on the world market.

Conclusions

The study demonstrates that the potential of Ukraine's agrobiomass is a strategic asset, critically important for achieving the goals of energy autonomy, food security, and environmental sustainability of the state. The volume of biomethane production (over 8.4 billion m^3/year) confirms the possibility of significant substitution of natural gas, which correlates with national interests.

As a result, the study identified a significant potential of agricultural waste and by-products (plant residues, manure and excrement) that provides a reliable raw material base. The regional concentration of potential in leading agricultural regions (Vinnytsia, Kyiv, Cherkasy, Poltava and Dnipropetrovsk) allows focusing investments on large-scale industrial biomethane projects.

The study confirms the multifaceted economic effect, which includes a reduction in energy imports (at the level of 4.4 billion USD), stabilization of energy prices (10–12 billion UAH), as well as a synergistic agricultural effect from obtaining digestate (valued at 3.63 billion UAH) as a highly effective organic fertilizer.

Realization of the potential will contribute to the reduction of greenhouse gas emissions, estimated at 1.315 billion USD, which is a direct contribution to the fulfillment of international environmental obligations.

At the same time, the development of the industry is constrained by institutional and financial and economic barriers that require immediate adjustment of state policy:

It has been determined that it is necessary to develop mechanisms to subsidize initial capital expenditures and ensure access to long-term preferential financing (compared to the EU, where targeted investment programs operate). This is critical for stimulating the introduction of biogas plants in the small and medium-sized enterprise (SME) sector, as well as households.

It is advisable to optimize and simplify the permitting documentation (compared to the EU regulatory environment) and provide tax incentives (e.g., tax holidays before commissioning) to reduce the investment risks of industrial projects.

A comprehensive program of state incentives is needed, drawing on international experience (China, EU countries) and financing through the proceeds from the sale of carbon quotas (Kyoto Protocol). This should include guarantees for the sales market, in particular, the establishment of quotas for biomethane exports to ensure a stable return on investment.

For the accelerated growth of the industry, it is critically important to harmonize Ukraine's policy with the best practices of the EU:

- unlike Ukraine, EU countries (in particular, Germany, Denmark) actively use "green" tariffs, investment bonuses, and direct subsidies as key tools to ensure profitability and rapid deployment of biogas infrastructure. Recommendation: Ukraine should move from point incentives to a systematic and predictable policy of guaranteeing income for biogas projects;
- it is necessary to strengthen the exchange of experience and conduct joint research projects with EU institutions. This will contribute to the transfer of technologies, improving the skills of personnel and integrating the Ukrainian biomethane network into the pan-European energy space;
- the creation of a network of educational and student farms and the stimulation of scientific activity are key to the formation of a qualified personnel reserve, which is a guarantee of the sustainable development of the industry, as is the case in the leading agricultural EU member states.

This publication was prepared under a scholarship from the Verkhovna Rada of Ukraine for young scientists holding the degree of Doctor of Sciences.

Development of an organizational-economic model for the functioning of innovation-oriented clusters to stimulate the implementation of bioenergy technologies in Ukraine's agricultural sector.

The Authors have no conflicts of interest to declare.

References

Bondarenko et al. 2023 – Bondarenko, V., Pokynchereda, V., Pidvalna, O., Kolesnyk, T. and Sokoliuk, S. 2023. Green Economy as a Prerequisite for Sustainable Development: Analysis of International and Ukrainian Experience. *European Journal of Sustainable Development* 12(1), https://doi.org/10.14207/ejsd.2023.v12n1p221.

Carbon price in Ukraine and practices of using revenues from the CO_2 tax (*Tsina vuhletsiu v Ukraini ta praktyky vykorystannia dokhodiv vid podatku na CO_2*). [Online:] https://ecoaction.org.ua/wp-content/uploads/2021/12/cina-vyhleciu-v-ukrainiv-2.pdf [Accessed: 2025-06-01] (*in Ukrainian*).

Fedunyak, I.O. 2014. Efficiency of biogas production in Ukraine (*Efektyvnist vyrobnytstva biohazu v Ukraini*). *Scientific Notes of the National University "Ostroh Academy". Series "Economy"* 26, pp. 45–49 (*in Ukrainian*).

Gromm, K. 2020. 6 environmental effects of the implementation of biogas projects (*6 ekolohichnykh efektiv realizatsii biohazovykh proektiv*). [Online:] https://ecolog-ua.com/news/6-ekologichnyh-efektiv-realizaciyi-biogazovyh-proyektiv [Accessed: 2024-02-21] (*in Ukrainian*).

Honcharuk et al. 2021 – Honcharuk, I.V., Tokarchuk, O.A., Tokarchuk, D.M. and Pryshlyak, N.V. 2021. Biogas reactor with air heating (*Biohazovyi reaktor z pidohrivom povitria*). Pat. No. 146896 Ua, MPK 146895 C02F 11/04 u 2020 06001; appl. 21.09.2021, publ. 31.03.2021, Bull. No. 13. 5 p. (*in Ukrainian*).

Hontaruk et al. 2024 – Hontaruk, Y., Furman, I., Bondarenko, V., Riabchyk, A. and Nepochatenko, O. 2024. Production of biogas and digestate at sugar factories as a way of ensuring the energy and food security of Ukraine. *Polityka Energetyczna – Energy Policy Journal* 27(2), pp. 195–210, https://doi.org/10.33223/epj/185210.

Kaletnik, G. and Honcharuk, I. 2020. Economic calculations of the potential of renewable bioenergy production in formation of energy independence of the agro-industrial complex. *Ekonomika APK* 27(9), pp. 6–16, https://doi.org/10.32317/2221-1055.202009006 (*in Ukrainian*).

Kaletnik et al. 2020 – Kaletnik, G., Honcharuk, I. and Okhota, Yu. 2020. The Waste-Free Production Development for the Energy Autonomy Formation of Ukrainian Agricultural Enterprises. *Journal of Environmental Management and Tourism* 11(3), pp. 513–522, https://doi.org/10.14505/jemt.v11.3(43).02.

Kaletnik et al. 2025 – Kaletnik, G., Sakhno, A., Pryshliak, N., Lutkovska, S., and Kolomiiets, T. 2025. Economic evaluation of environmental protection activities in the context of sustainable development: the experience of Ukraine. *Polityka Energetyczna – Energy Policy Journal.* 28(3), pp. 217–236, https://doi.org/10.33223/epj/207022.

Koval et al. 2025 – Koval, V., Atstāja, D., Filipishyna, L., Udovychenko, V., Kryshtal, H. and Gontaruk, Y. 2025. Sustainability assessment and resource utilization of agro-processing waste in biogas energy production. *Climate* 13(5), https://doi.org/10.3390/cli13050099.

Lohosha et al. 2023 – Lohosha, R., Palamarchuk, V. and Krychkovskyi, V. 2023. Economic efficiency of using digestate from biogas plants in Ukraine when growing agricultural crops as a way of achieving the goals of the European Green Deal. *Polityka Energetyczna – Energy Policy Journal* 26(2), pp. 161–182, https://doi.org/10.33223/epj/163434.

Lutkovska, S.M. 2020. Methodological approaches to assessing the processes of modernization of the environmentally safe sustainable development system. *Scientific Horizons* (2), pp. 111–118, https://doi.org/10.33249/2663-2144-2020-87-02-111-118.

Lutkovska, S.M. and Zelenchuk, N.V. 2023. Assessment of the potential of biogas production by individual peasant farms (*Otsinka potentsialu vyrobnytstva biohazu indyvidualnymy selianskymy hospodarstvamy*). *Economic Bulletin of the National Technical University of Ukraine "Kyiv Polytechnic Institute"* 25, pp. 15–20, https://doi.org/10.20535/2307-5651.25.2023.278409 (*in Ukrainian*).

Mazur et al. 2020 – Mazur, V., Pantsyreva, H., Mazur, K., Myalkovsky, R. and Alekseev, O. 2020. Agroecological prospects of using corn hybrids for biogas production. *Agronomy Research* 18(1), pp. 177–182, https://doi.org/10.15159/ar.20.016.

Order No. 761-p of August 13, 2024 "On approval of the National Renewable Energy Action Plan for the period until 2030 and the action plan for its implementation" (*Pro zatverdzhennia Natsionalnoho planu dii z vidnovliuvanoi enerhetyky na period do 2030 roku ta planu zakhodiv shchodo yoho realizatsii*). [Online:] https://www.kmu.gov.ua/npas/pro-zatverdzhennia-natsionalnoho-planu-dii-z-vidnovliuvanoi-enerhetyky-na-p-a761 [Accessed: 2026-02-05] (*in Ukrainian*).

Pisarenko et al. 2024 – Pisarenko, V., Pronko, L., Pidvalna, O., Lozhachevska, O., Fastovets, N. and Ribeiro Ramos, O. 2024. Marketing management of the bioeconomic potential of enterprises and the quality of their innovative products in the post-war recovery strategy. *Financial and Credit Activity Problems of Theory and Practice* 6(59), pp. 648–664, https://doi.org/10.55643/fcaptp.6.59.2024.4637.

Pryshliak et al. 2022 – Pryshliak, N., Bondarenko, V., Sokoliuk, S. and Brovarets, O. 2022. The formation of a bioenergy cluster for the production of biofuels from agricultural crops and waste: the experience of Ukraine. *Polityka Energetyczna – Energy Policy Journal* 25(4), pp. 149–164, https://doi.org/10.33223/epj/156210.

Romanchuk, S.V. 2015. Methodological approaches to assessing the environmental and economic efficiency of waste processing (*Metodolohichni pidkhody do otsinky ekoloho-ekonomichnoi efektyvnosti pererobky vidkhodiv*). *Economics of Environmental Management and Environmental Protection* 5(167), pp. 321–327 (*in Ukrainian*).

State Statistics Service of Ukraine. State Statistics Service of Ukraine. [Online:] http://ukrstat.gov.ua [Accessed: 2026-02-05].

Tokarchuk, D.M. 2018. Economic and ecological benefits of using biogas plants in households (*Ekonomichni ta ekolohichni perevahy vykorystannia biohazovykh ustanovok u domashnikh hospodarstvakh*). *Economics, Finance, Management: Current Issues of Science and Practice* (6), pp. 39–49 (*in Ukrainian*).

Tokarchuk et al. 2022 – Tokarchuk, D., Pryshliak, N., Berezyuk, S. and Shynkovych, A. 2022. Food security and biofuel production: solving the dilemma on the example of Ukraine. *Polityka Energetyczna – Energy Policy Journal* 25(2), pp. 179–196, https://doi.org/10.33223/epj/150496.

World experience in trading greenhouse gas emission quotas within the framework of the Kyoto Protocol (*Svitovyi dosvid torhivli kvotamy na vykyd parnykovykh haziv v ramkakh Kiotskoho protokolu*). [Online:] https://ecolog-ua.com/news/svitovyy-dosvid-torgivli-kvotamy-na-vykyd-parnykovyh-gaziv-v-ramkah-kiotskogo-protokolu [Accessed: 2025-06-01] (*in Ukrainian*).

Svitlana Lutkovska, Tetiana Kolomiiets, Nataliia Zelenchuk, Oleg Dmytryk

Ocena potencjału ukraińskiej agrobiomasy w zakresie produkcji biogazu w kontekście zapewnienia bezpieczeństwa żywnościowego i energetycznego

Streszczenie

W kontekście globalnych wyzwań, w szczególności stanu wojennego w Ukrainie oraz zawirowań na światowym rynku energetycznym, kwestie zapewnienia bezpieczeństwa żywnościowego i energetycznego nabierają nadrzędnego znaczenia. Niniejszy artykuł poświęcony jest kompleksowej analizie i ocenie potencjału wykorzystania ukraińskiej agrobiomasy do produkcji biogazu, co uznaje się za kluczowy kierunek działań na rzecz osiągnięcia zrównoważonego rozwoju i wzmocnienia niezależności narodowej.

Przeprowadzone badania wskazują na znaczny, niewykorzystany potencjał Ukrainy w zakresie produkcji biogazu z różnych rodzajów agrobiomasy, w tym z resztek pożniwnych, obornika i odpadów przemysłu spożywczego. Wykorzystanie tego potencjału obiecuje znaczące korzyści gospodarcze, takie jak ograniczenie emisji gazów cieplarnianych, zwiększenie rentowności sektora rolnego, uzyskanie cennych nawozów organicznych, a także zmniejszenie krytycznej zależności od importu energii. Krajowy potencjał produkcji biometanu w Ukrainie szacuje się na ponad 8,4 mld m^3 rocznie.

Jednak pomimo oczywistych korzyści rozwój ukraińskiego przemysłu biogazowego napotyka poważne przeszkody. Należą do nich wysokie koszty początkowe instalacji biogazowych, co ogranicza ich wykorzystanie zarówno w dużych przedsiębiorstwach, jak i w gospodarstwach domowych. Ponadto rozwój hamowany jest przez brak odpowiednich zachęt państwowych i wystarczających inwestycji. Aby pokonać te przeszkody i w pełni wykorzystać potencjał biogazu, w artykule uzasadniono potrzebę opracowania i wdrożenia kompleksowego programu wsparcia państwowego. Środki te mają kluczowe znaczenie dla promowania niezależności energetycznej, poprawy stanu środowiska, stymulowania wzrostu gospodarczego oraz skutecznej odbudowy Ukrainy w okresie powojennym.

Słowa kluczowe: agrobiomasa, biogaz, biometan, bezpieczeństwo energetyczne, odpady