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Assessment of the development of the biomethane market in Ukraine during and after martial law: environmental and customs approaches

Zamula Iryna[1], Nazarenko Tetiana[2], Seletska Daria[3]

[1] Doctor of Economic Sciences, Professor
Zhytomyr State Polytechnic University

[2] Candidate of Economic Sciences, Associate Professor
Zhytomyr State Polytechnic University

[3] Applicant for Higher Education Degree «PhD»
Zhytomyr State Polytechnic University

Abstract

The article examines the development of the biomethane market in Ukraine during and after martial law from environmental and customs perspectives. The relevance of the topic is driven by the need to increase state budget revenues to support the activities of the Armed Forces of Ukraine. Estimates suggest that the country's losses from military actions amount to approximately $499 billion. Leading experts consider the production and export of biomethane – a renewable gas with a high methane content (over 96 %) that significantly reduces greenhouse gas emissions – as one of the viable investment directions for developing the national economy. The use of biomethane aligns with the goals of the Paris Agreement and is in demand in EU countries aiming to reduce greenhouse gas emissions by at least 55 % by 2030 compared to 1990 levels.

In Ukraine, potential biomethane production could reach 20 billion m³ per year, attracting up to 40 billion euros in investments in this sector. From an environmental standpoint, replacing natural gas with biomethane will contribute to achieving sustainable development goals. The article also provides a SWOT analysis of the biomethane market in Ukraine, highlighting its strengths, such as a significant raw material base and successful project implementations, as well as weaknesses, including an imperfect legislative framework.

The article discusses the possibilities of implementing effective mechanisms to stimulate biomethane production, attracting international investments, developing the biomethane market as a motor fuel, and exporting to EU countries. Special attention is given to legislative initiatives aimed at improving the regulatory framework for the development of the biomethane market, including the adoption of a law on the customs clearance of biomethane. The article concludes by emphasizing the necessity of developing biomethane production to achieve Ukraine's energy independence, reduce waste volumes, create additional jobs, and attract investments, all of which will promote sustainable economic development in the country.

Keywords: sustainable development; European integration; impact investments; biofuel; biofuel market; customs clearance.

Corresponding author:

[1] ORCID: https://orcid.org/0000-0002-6075-095X
[2] ORCID: https://orcid.org/0000-0003-4602-414X
[3] ORCID: https://orcid.org/0000-0003-2812-1691

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1. Relevance of the topic

Recently, there have been increasing calls to fill Ukraine's state budget with domestic revenues, as the effectiveness of the Armed Forces of Ukraine directly depends on sufficient funding from the country [1]. According to Roksolana Pidlasa, a Ukrainian politician and economist, «additional financial costs for mobilization and rearmament in 2024 may amount to approximately 700 billion hryvnias,» as confirmed by calculations from the Ministry of Defense and the Ministry of Finance of Ukraine. This amount represents about 22.5 % of all expenditures in 2024 and 41 % of defense expenditures [2].

It is also worth noting that due to the military actions by the Russian Federation against Ukraine, as of the end of 2023, Ukraine's losses amount to approximately $499 billion, with significant impacts on the energy, transport, industry, trade, and agriculture sectors [16]. Considering these factors, how can the state budget be replenished with domestic funds?

Leading economic experts believe that one of the most appropriate investments for developing the national economy could be the production and export of biomethane – a combustible gas obtained from biomass and upgraded to the quality of natural gas [1].

The unique feature of biomethane is that it is a renewable gas containing over 96 % methane (CH4), with carbon dioxide (CO2) completely separated during biogas production [1]. The use of biomethane significantly reduces greenhouse gas emissions into the atmosphere, contributing to the achievement of the goals set by the Paris Agreement [17]. For this reason, it is in high demand in European Union (EU) countries, which aim to reduce greenhouse gas emissions by at least 55 % by 2030 compared to 1990 levels [18]. Potentially, Ukraine could occupy about 20 % of the European biomethane market by producing over 20 billion m³ of biomethane per year, thereby attracting up to 40 billion euros in investments in this sector [1].

From an environmental perspective, according to the Paris Agreement, Ukraine has committed to reducing greenhouse gas emissions by 35 % by 2030 compared to 1990 levels—replacing natural gas with biomethane, which has a significantly lower carbon footprint, will help achieve this goal [17].

Therefore, we believe that investments in the production of biomethane in Ukraine and promoting its entry into the international market will be key factors in the country's economic development, as well as strengthen Ukraine's position as a responsible partner in achieving sustainable development goals.

2. Analysis of the latest research and publications

The studies by H.M. Kaletnik and N.V. Pryshlyak [26] are dedicated to the formation of development scenarios for the biofuel market in Ukraine and the justification of ways to implement them under sustainable development conditions. V.K. Berehovyi [27] conducted an analysis and justification of the need to develop alternative energy sources, taking into account the possibility of preventing the deterioration of the food supply system for the population. O.Yemelyanov and A.Uzhelin [28] evaluated the impact of biofuel production on the sustainable development of agricultural enterprises in Ukraine. O.O. Kravchuk [3] researched the development of the biofuel market using agricultural energy crops, proving the relevance of the application and production of liquid biofuels from plant raw materials, as well as providing a characterization of the raw material base of agricultural enterprises in Ukraine for biofuel production.

The aim of this research is to assess the development of the biomethane market in Ukraine during and after martial law, based on environmental and other sustainable development indicators, as well as the country's export potential considering the customs clearance of biomethane when crossing Ukraine's state border, as part of the European integration processes.

3. Presentation of the main material

The production of biomethane – a gas obtained by purifying biogas from impurities – is one of the most promising directions in the development of renewable energy sources. Biomethane offers several advantages over traditional natural gas, including lower greenhouse gas emissions and the potential to achieve energy independence. The primary raw materials for producing biogas/biomethane are agricultural waste (manure, silage, other plant residues), food industry waste, and sewage sludge.

It is essential to emphasize that biomethane production in Ukraine is crucial for implementing sustainable development concepts. From an environmental perspective, biomethane is a source of sustainable, renewable, and clean energy that can be produced from organic waste, such as manure, food scraps, damaged plants, other plant materials, and sewage sludge, which would otherwise pollute the environment and contribute to global warming. In other words, biomethane production is a modern waste management approach that allows part of municipal waste to be converted into a tool for combating climate change rather than exacerbating it. Increasing biomethane production in the EU will help decarbonize the economy, enhance independence from imported fossil fuels, and strengthen energy security [19].

Clearly, sustainable biomethane is a rational solution for the environment. However, it also offers significant economic benefits: it helps reduce energy costs for individuals and businesses in the EU, ensuring a continuous energy supply regardless of rising fossil fuel prices. Moreover, for industries and households, there are no additional costs associated with switching to biomethane, as it can be used in the same systems as natural gas. This also generates additional income streams for rural areas where production takes place [19].

Biomethane also boosts agriculture because the production process generates digestate, an organic fertilizer rich in macronutrients such as nitrogen, phosphorus, and potassium, making it a high-quality fertilizer for plants. From an agricultural perspective, the more livestock waste used for biomethane production, the lower the methane emissions, which is one of the most threatening greenhouse gases released into the atmosphere [19] (table 1).

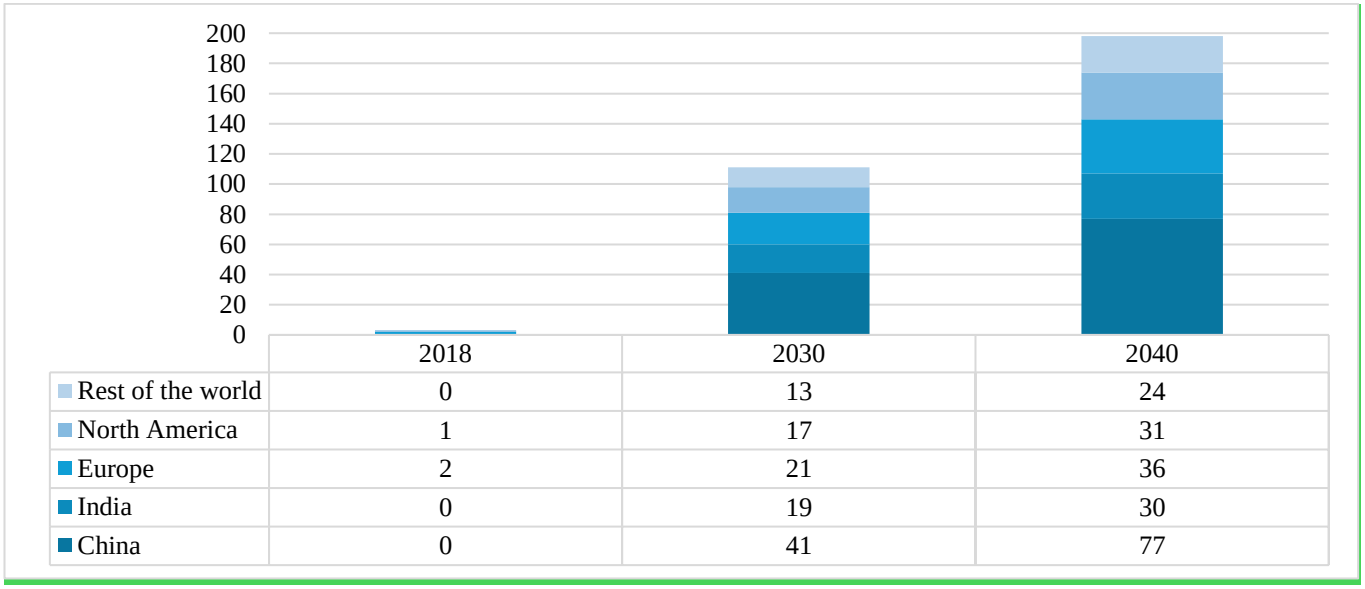
Table 1

Biomethane Production in Ukraine as a Means to Achieve Sustainable Development Goals

Sustainable Development Goal	Compliance of biomethane production with the stated goal
Goal 7 – Affordable and Clean Energy	Biomethane is a renewable energy source that can partially replace fossil natural gas
Goal 8 – Decent Work and Economic Growth	The development of biomethane production will create new jobs, especially in rural areas
Goal 12 – Responsible Consumption and Production	Using waste as a raw material for biomethane production is an example of a circular economy
Goal 13 – Climate Action	Biomethane has lower greenhouse gas emissions compared to fossil natural gas

Source: developed by the authors

Biomethane is an almost pure source of methane, produced by «upgrading» biogas or through the gasification of solid biomass. Since it is indistinguishable from the regular flow of natural gas, it can be transported and used wherever gas is consumed, but without increasing emissions. Biomethane production is rapidly growing according to scenarios by the International Energy Agency. This allows countries to reduce emissions in sectors that are difficult to mitigate, such as heavy industry and freight transport. It also helps make certain existing gas infrastructure more compatible with lower emission levels, thereby enhancing the economic efficiency and security of energy transitions in many parts of the world [15] (Fig. 1).



Source: depicted based on [15]

Fig. 1. Forecast of Global Biomethane Consumption by Region in the Sustainable Development Scenario for the period 2018-2040, million tonnes

Biomethane in the International Energy Agency's Sustainable Development Scenario is expected to prevent approximately 1 billion tonnes of greenhouse gas emissions by 2040. This includes carbon dioxide (CO_2) emissions that would have occurred if natural gas had been used instead, as well as methane (CH_4) emissions that would otherwise result from the decomposition of raw materials [15].

In 2022, following the full-scale invasion of Ukraine by the Russian Federation, energy security once again became a primary argument for expanding biofuel policies. The International Energy Agency's 2023 forecast predicted an 11 % increase in biofuel demand (18 billion liters) by 2024, driven by policies aimed at ensuring energy security. However, as in 2022, only a few markets actively sought to accelerate deployment by 2024 [14].

For Ukraine, biomethane production during martial law is critically necessary. The destruction of energy infrastructure due to military actions and the cessation of natural gas supplies from the Russian Federation have exacerbated Ukraine's energy security issues. Developing decentralized biomethane production can partially compensate for the natural gas deficit and ensure stable energy supply, particularly in regions far from central gas networks. Additionally, the uninterrupted operation of critical infrastructure, such as hospitals, water supply, and wastewater facilities, is of utmost importance. Biomethane production at these facilities (e.g., from sewage sludge) can provide them with an autonomous energy source in case of disruptions to centralized supply.

From an economic perspective, developing biomethane production based on agricultural waste can become an additional source of income for farmers and increase their resilience during crises. Moreover, the development of «green» technologies can be a significant argument for attracting international financial and technical assistance for Ukraine's reconstruction, as donor countries and organizations are interested in supporting projects that positively impact the environment and promote sustainable development. Additionally, after the active phase of the war, Ukraine will face the need to restore destroyed territories, and

implementing biomethane production technologies in this process will lay the foundation for sustainable development in renewed regions and reduce their dependence on fossil fuels.

In conditions of war and economic crisis, replacing imported natural gas with locally produced biomethane will reduce foreign currency expenditures on imports and enhance the economy's resilience. To assess the prospects for developing the biomethane market in Ukraine, a SWOT analysis was conducted (tab. 2).

Table 2

SWOT Analysis of the Biomethane Market in Ukraine

Strengths	**Weaknesses**
1. Significant potential of raw material base for biomethane production (agricultural waste, food industry waste, municipal waste). 2. Successful examples of biomethane production projects in Ukraine. 3. Growing demand for renewable energy sources in domestic and international markets. 4. Ability to use existing gas infrastructure for biomethane transportation and distribution. 5. Availability of qualified specialists in bioenergy	1. Imperfections in the legislative framework and lack of effective mechanisms to stimulate biomethane production. 2. High capital costs for the construction of biogas/biomethane plants. 3. Complex certification procedures and market access for biomethane producers
Opportunities	**Threats**
1. Implementation of effective mechanisms to stimulate biomethane production. 2. Attraction of international investments and grant financing for the development of the biomethane sector. 3. Development of the biomethane market as a motor fuel for transportation. 4. Export of biomethane to EU countries to help achieve their decarbonization goals. 5. Creation of new jobs and development of rural areas through biomethane project implementation	1. Political and economic instability in Ukraine, deterring investments in the sector. 2. Competition from other renewable energy sources (solar, wind) for investments and state support. 3. Reduction in fossil natural gas prices, decreasing biomethane competitiveness. 4. Technological risks associated with the reliability and efficiency of biogas / biomethane plants

Source: developed by the authors

One of the strengths of the development of the biomethane market is the significant raw material base. The assessment of the raw material potential for biomethane production is provided in Table 3.

Table 3

Biomethane Production Potential in Ukraine

Types of biomethane	**Production Volume, billion m³/year**
Biomethane produced from:	
Agricultural waste (livestock waste)	0,9
Agricultural crop residues	5,2
Food industry by-products	0,7
Solid municipal waste	0,5
Sewage sludge (municipal treatment facilities)	0,1
Energy crops: corn silage (from 1 million hectares)	3,8
Cover crops (from 20 % of arable land)	9,8
Wood fuel through thermal gasification (from 10 % of wood fuel)	1,0
Total	**21,8**

Source: developed based on [1].

Ukraine has one of the best potentials for biomethane production due to having the largest agricultural land area in Europe. Considering biomass from cover crops (plants sown in between main agricultural crops) that can be grown on 20% of arable land, the potential for biomethane production in Ukraine could reach 21.8 billion m³ per year [1]. The UABIO forecast for the production and consumption of Ukrainian biomethane is presented in Table 4

Table 4

UABIO Forecast for Production and Consumption of Ukrainian Biomethane until 2050

Criteria	2027	2030	2035	2040	2045	2050
Biomethane Production, billion m³	0,25	1,0	2,1	4,5	9,5	20
Biomethane Export, billion m³	0,13	0,5	1,05	2,25	4,8	10
Domestic Consumption, billion m³	0,13	0,5	1,05	2,25	4,8	10
Number of Biomethane Plants	50	200	420	900	1900	4000
Required Investments, billion €	0,5	2,0	4,2	9,0	19,0	40
Reduction in GHG Emissions, million t CO_2-eq.	0,6	2,5	5,3	11,3	23,8	50
Jobs Created, thousand	3,1	12,5	26,2	56,2	118	250

Source: developed based on [5].

To produce 20 billion m³ of biomethane annually, approximately 4,000 biomethane plants with an average capacity of 5 million m³/year each need to be commissioned, with each plant costing around 10 million euros. It is noteworthy that during the construction of such a plant, at least 50 % of the investments will go towards Ukrainian equipment, services, and works [1].

As of 2024, Ukraine has 77 biogas plants that theoretically can produce about 150 million m³ of biomethane per year [4]. Additionally, in April 2023, Gals Agro LLC in the Chernihiv region commissioned a biomethane module at a biogas plant with a capacity of up to 3 million m³/year. The primary raw materials used include sugar beet pulp, beet molasses, plant residues, cattle manure, silage from energy crops, and waste from food and combined production [5].

In addition to this, there are several biomethane production projects underway in Ukraine:

1. Yuzhef-Mykolayiv Biogas Company LLC is implementing a biogas complex project, one stage of which includes biogas upgrading to biomethane;
2. Ukraine 2001 LLC is developing the «Green Park» project in Khmelnytskyi region, which involves connecting a plant producing 24 tons/day of liquefied biomethane to the gas transportation system;
3. Group of companies VITAGRO LCC has developed an investment plan of 44.1 million euros to build four biomethane projects, three in Khmelnytskyi region and one in Rivne region, with a total capacity of 20 million m³/year [7];

Besides these projects, the development of the biomethane sector in Ukraine includes the commissioning of 10 new plants during 2024–2025, each with a production capacity of at least 1.5 million m³/year. At this pace, Ukraine will be able to reach a biomethane production level of 1 billion m³/year by 2030, accounting for 10 % to 20 % of the total EU biomethane market [4]. By establishing a strong position in the EU, Ukraine can not only meet its own clean fuel needs but also become a significant player in the European energy market, contributing to decarbonization and climate change mitigation goals.

Regarding biomethane transportation, Deputy Minister of Energy S. Hrynchuk stated that Ukraine's gas transportation system is «fully suitable for transporting such gases» [8]. Furthermore, Oleksiy Lukashuk, Director of External Economic Relations and Partnership Development at Naftogaz Group, mentioned that the potential for connecting to the gas transportation system is estimated at 7.2 billion m³, with the potential for connection through gas distribution networks up to 2.4 billion m³ [9].

During the First Ukrainian Biomethane Forum, it was revealed that for the needs of biomethane producers, «there is an option to connect plants through the network of gas refueling stations, with a potential of 1 billion m³.» Additionally, some regions have the potential for connection through the infrastructure of UkrGasVydobuvannya JSC with a capacity of up to 1.2 billion m³ [9].

Moreover, Serhiy Minin, a member of the board of Gas Distribution Networks of Ukraine LLC, stated that as of 2024, there are already 22 customers from different parts of Ukraine interested in connecting biomethane plants to gas distribution networks. As a result, the company has already issued two technical conditions in Kyiv and Dnipropetrovsk regions for such connections, with two more plants in Khmelnytskyi and Chernihiv regions «in the acceptance stage» [10].

Ukraine's existing gas transportation infrastructure has significant potential for biomethane transportation, and the interest of producers in connecting to it is real, indicating a positive development outlook for this type of biofuel in the country.

Regarding qualified specialists in the field of bioenergy, Ukraine has considerable potential in training professionals in this area. Institutions such as the National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute» (Faculty of Biotechnology and Bioengineering), the National University of Life and Environmental Sciences of Ukraine (Educational and Scientific Institute of Energy, Automation and Energy Efficiency), the Lviv Polytechnic National University (Institute of Power Engineering and Control Systems), Kharkiv Petro Vasilenko National Technical University of Agriculture (Educational and Scientific Institute of Energy and Computer Technologies), and Podillia State University (Faculty of Energy and Information Technologies), among others, offer educational programs related to biomass, biofuels, bioenergy plants, energy efficiency, and renewable energy sources.

Biomethane production in Ukraine faces numerous challenges that significantly impact the stability and development of the sector. One key issue is the National Commission for State Regulation of Energy and Public Utilities (NCREPU) Resolution № 178, which introduced significant changes to the procedure for purchasing electricity produced from alternative sources, including biogas and biomass. These changes have caused considerable concern among producers, as they effectively block the receipt of funds for supplied electricity.

Resolution № 178 imposed the obligation for electricity producers from biogas and biomass to sign contracts for participation in the guaranteed buyer balancing group and contracts with the National Energy Company «Ukrenergo» (NEC Ukrenergo) for providing load reduction services. Additionally, producers must install telemetry equipment for remote data transmission, requiring additional financial and technical costs [20].

In practice, implementing these new requirements has proven extremely difficult for many producers. For example, most plants commissioned before 2022 are not equipped with the necessary telemetry, as it was not previously required. Installing

new equipment costs approximately 300,000 UAH and takes time, with long queues for contractors who can perform such work [11].

Furthermore, according to energy sector experts, capital expenditures for biomethane production by 2030 could reach 83 billion euros. «Specifically, 4,000 medium-sized enterprises (average unit capacity of 4 million m^3 CH_4 per year, capital costs per enterprise of 12 million euros, average biomethane production cost of 80 euros/MWh) and 1,000 large enterprises (average unit capacity of 16 million m^3/year, capital costs of 35 million euros, average biomethane production cost of 55 euros/MWh) will be built» [12, 13].

Resolution № 178 also requires contracts with NEC «Ukrenergo» for providing load reduction services, which is technically impossible for most biogas and biomass plants [20]. These plants cannot suddenly stop or reduce power without emergency consequences, such as steam discharges or boiler shutdowns. This complicates their participation in balancing the energy system. Due to these changes, electricity producers from biomethane and biomass lose approximately 31 million UAH daily. Between January 27 and February 13, 2024, the sector lost almost 530 million UAH in revenue [11]. This could lead to the bankruptcy of enterprises that cannot operate for long without payment for their products.

Industry representatives are urging the President of Ukraine, relevant committees of the Verkhovna Rada, NCREPU, and NEC «Ukrenergo» to suspend the effect of Resolution №. 178 for biomass and biogas power plants. This would prevent enterprises from going bankrupt and provide time for them to adapt to the new requirements [11].

Therefore, it can be asserted that NCREPU Resolution No. 178, despite its good intentions to improve energy market regulation, has caused significant problems for biomethane producers in Ukraine. The introduced requirements proved to be overly complex for implementation in a short period, resulting in financial losses and the threat of bankruptcy for the industry. Urgent measures are needed to revise the resolution and develop more flexible and realistic conditions for alternative energy producers.

It is also worth considering the possibilities of using biomethane as a versatile gaseous fuel that can be applied in various industries, given its undeniable advantages of renewability and sustainability, provided that sustainable types of raw materials are used (table 5).

Table 5

Main Possible Applications of Biomethane and Corresponding Potential Markets

Application	**Extended Characteristics**
Replacement of natural gas with biomethane	Biomethane can be used in any application where natural gas is used. This helps replace imported natural gas and liquid petroleum products and meet Ukraine's commitments to reduce greenhouse gas emissions under the Paris Agreement
Use as a motor fuel for automotive, agriculture, aviation, and marine transport	This option allows replacing fossil motor fuels (gasoline, diesel, aviation fuels, CNG, LNG, LPG). It provides an excellent opportunity for farmers to obtain fuel from their own waste and secondary products. Using biomethane as fuel for public transport can significantly reduce air pollution in large cities. Biomethane use in private vehicles is also possible and popular in some developed countries (like in Italy)
Export to the EU using the national biomethane production and consumption registry	Utilizing Ukraine's gas transportation system, which is connected to the European gas system through a virtual export mechanism, can enhance the economic attractiveness of biomethane production in Ukraine
Electricity and heat production from biomethane using the gas network	This option allows producing electricity and heat close to the consumer, thereby increasing fuel use efficiency, especially in urban district heating systems. Currently, biogas in Ukraine is used with efficiency not exceeding 50 %
Storing biomethane in the natural gas network for electricity production during peak loads	This option allows using biomethane during periods of maximum load on the energy system, reducing the need for power regulation currently provided mainly by coal-fired power plants in Ukraine. Using biomethane for this purpose can compensate for the limited regulation capabilities of rapidly developing renewable energy sources like solar and wind
Biomethane as a renewable feedstock for the chemical industry and other industries	Natural gas consumption in the chemical industry is linked to the production of derivative products such as nitrogen fertilizers, methanol, and ammonia. Potential export restrictions on products using fossil fuels, including carbon taxation mechanisms, could incentivize domestic producers to switch to renewable feedstocks like biomethane

Source: compiled based on [13]

Table 6

Prospects for the Development of the Biomethane Market in Ukraine (Based on SWOT Analysis)

Strengths	**Considering the opportunities**	**Considering the threats**
Significant potential of raw material base	The possibility of implementing effective mechanisms to stimulate biomethane production and attracting international investments will allow more efficient use of agricultural waste, food industry waste, and municipal waste.	Political and economic instability may deter investments necessary for the effective utilization of the raw material base.
Successful examples of project implementation	Grant financing and the development of the biomethane market can be supported by the experience of launching such plants in Ukraine.	Competition from other renewable energy sources may limit access to investments and state support for new projects.
Growing demand for renewable energy sources	Exporting biomethane to EU countries will contribute to achieving decarbonization goals and create new opportunities for Ukrainian producers in international markets.	Decreasing prices of fossil natural gas may reduce the competitiveness of biomethane despite the growing demand.
Existing gas infrastructure	The possibility of using existing gas networks for biomethane transportation will facilitate the integration of biomethane into the country's energy system.	Technological risks (equipment compatibility, corrosion, and material degradation, the necessity for modernization, etc.) may affect the reliability and efficiency of using the existing infrastructure for biomethane transportation.
Qualified specialists in the field of bioenergy	The development of the sector and the creation of new jobs will attract and develop personnel, strengthening Ukraine's position in this field.	Political and economic instability may lead to brain drain, complicating the implementation of new projects.
Weaknesses	**Considering the opportunities**	**Considering the threats**
Imperfections in the legislative framework	Implementing effective stimulation mechanisms and attracting international investments can contribute to improving legislation and easing market access for biomethane producers.	Political and economic instability may hinder the implementation of necessary legislative changes and stimulation mechanisms.
High capital costs	Attracting international investments can help offset the high initial costs of constructing biogas plants.	Competition from other renewable energy sources and decreasing prices of fossil natural gas may reduce the investment attractiveness of biomethane production projects.
Complexity of certification procedures	Developing the biomethane market as motor fuel and exporting to EU countries can encourage the simplification of certification procedures and market access.	Technological risks and instability may complicate the certification process and market entry, restraining the industry's development.

Source: developed by the author

Biomethane has a wide range of applications that can significantly contribute to Ukraine's energy independence, reduction of greenhouse gas emissions, and development of renewable energy. However, to realize this potential, it is necessary to address several challenges related to legislative regulation, investment attractiveness, and technological aspects of biomethane production and usage, as mentioned above.

The results of the biomethane market assessment in Ukraine using a SWOT analysis are presented in Table 6.

It is important to note that legislation in the field of biomethane production is constantly evolving, particularly within the framework of the European Green Deal and REPowerEU, which envisage additional measures to accelerate the development of the biomethane sector in the European Union. In Ukraine, legislative initiatives aimed at improving the regulatory framework for the development of the biomethane market are also ongoing.

The first «step towards» the biomethane market in Ukraine was the regulation of customs clearance for biomethane export. Until recently, there were significant legislative barriers that hindered effective export clearance of biomethane. To address this issue, the Verkhovna Rada of Ukraine developed Draft Law on Amendments to the Customs Code of Ukraine regarding the Customs Clearance of Biomethane № 9456 dated July 3, 2023, which was adopted in the second reading on March 20,2024 [22].

The legislation now requires that biomethane intended for export undergoes sustainability certification. Two main documents are required for this:

– Production Sustainability Certificate: Biomethane must have a sustainability certificate issued by one of the voluntary certification schemes approved by the European Commission, such as ISCC (International Sustainability and Carbon Certification);

– Proof of Sustainability (PoS): Each batch of biomethane must have a document confirming sustainability, which will be required by both customs and foreign buyers [21];

Legally, it is established that biomethane exported from Ukraine must be integrated into the national gas transportation or gas distribution system. Therefore, producers must use automatic flow meters (automatic chromatographs) and gas metering units. Additionally, during the period of the ban on the export of natural gas of Ukrainian origin, the export of biomethane «can be carried out exclusively regarding the volumes of biomethane accumulated in Ukraine's gas storage facilities at the end of the month preceding the export month» [23].

We can assert that the adoption of Draft Law No. 9456 creates a legal basis for effective customs clearance of biomethane, promoting its export and market development in Ukraine. The implementation of sustainability certification and the integration of biomethane into the gas transportation system are important steps to increase the competitiveness of Ukrainian biomethane in international markets.

Additionally, support for the development of the biomethane market in Ukraine is expressed through the implementation of projects by the Bioenergy Association of Ukraine. Specifically, two projects won the «Innovate Ukraine – Support for Ukraine's Energy Recovery» competition:

– Development of a Business Model for Biomethane Production in Ukraine: This project will be implemented over two years by a consortium of companies from Ukraine and the UK: Marriott Davies Yapp LLP (UK), Rika Biofuel Developments LTD (UK), Regenerative Agriculture (Ukraine), STC «Biomass» (Ukraine), and the Bioenergy Association of Ukraine [25];

– Production of Advanced Biomethane from Microalgae Grown on Digestate of Biogas Plants: This project will be implemented over two years by a consortium from Ukraine and the UK: University of Manchester (UK, administrative manager, technological leader), ALGAECYTES LIMITED (UK, commercial partner), MHP Eco Energy (Ukraine, commercial partner), and the Bioenergy Association of Ukraine (scientific partner) [24].

4. Conclusions from this study and prospects for further research

Thus, biomethane production is necessary as Ukraine is a significant importer of natural gas, which poses risks to the country's energy security. Increased biomethane production will allow partial replacement of imported gas and enhance Ukraine's energy independence.

Biomethane production from agricultural waste is an example of a circular economy, where waste from one production process becomes raw material for another, reducing waste volumes going to landfills and lessening environmental impact. Such production will create additional opportunities for farmers, diversify their income sources, and can drive rural development through investments from biomethane producers, consequently improving the quality of life for local populations. Moreover, developing biomethane production will require the construction of new facilities, creating additional jobs, especially in rural areas.

It is also worth noting that biomethane production is often combined with electricity and heat production in cogeneration plants, increasing overall energy efficiency and reducing energy losses.

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