CURRENT STATUS AND PROSPECTS FOR BIOGAS DEVELOPMENT IN UKRAINE

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Abstract. The article explores the potential of the agricultural sector in renewable energy and in particular in the development of biogas production. The Ukrainian biogas sector has potential both in terms of the availability of raw materials and in terms of demand for biogas. Currently, there is great interest in biomethane production from large agricultural companies that have sufficient amounts of their own raw materials. The Bioenergy Association of Ukraine estimates that Ukraine can produce 21.8 billion cubic meters of biogas annually. It is noted that the structure of agricultural enterprises is favorable for biogas production due to the sufficient number of large and medium-sized enterprises that can offer cheap raw materials for its production. The activities of biogas plants and biogas production facilities are highlighted, as well as biomethane projects planned for launch in Ukraine. An analysis of the number of companies operating in the electricity production sector and their capacity is presented. The volumes of electricity production from biogas and its ratio to the total production from renewable sources are determined. The social and environmental benefits of using biogas plants in terms of reducing greenhouse gas emissions are indicated. Attention is drawn to the Law of Ukraine on the Mandatory Use of Liquid Biofuels (Biocomponents) in the Transport Sector, adopted on 24/06/2024, which provides for the introduction of a mandatory share of liquid biofuels (biocomponents) in the volume of automobile gasoline from May 1, 2025. The need for favorable changes in legislation to stimulate investors to invest in the construction of biogas plants is argued.

Keywords: biogas, biomethane, biogas production, biomethane projects, biogas plants.

Introduction

The beginning of the development of biogas technologies was laid back in the 17th century with the observation that the decomposition of biomass is accompanied by the release of flammable gas. The first documented biogas plant was built in India, and the idea was borrowed from the technology developed for the treatment of municipal wastewater and implemented in Hague. And already in the 40s of the last century, two scientists in Algeria patented and built a plant for the production of biogas from manure. In the last quarter of the 20th century, many European countries were actively engaged in the search for effective fermentation technologies for the production of biogas from a wide range of raw materials of agricultural origin. Currently, developed countries are focusing on the development and implementation of powerful industrial, agricultural and commercial biogas plants, which are operated for further conversion of biogas into electrical and thermal energy or into biomethane. Thus, Geletukha G. G. and co-authors [1-3] noted that Ukraine has favorable conditions for the development of the biogas industry and the prospects for biomethane production. Pryshlyak N. and Bilokinna I. drew attention to the possibility of improving the fertile properties of agricultural soils by fertilizing them with high-quality organic biofertilizers formed during the biogas production process [4]. Massimo Raboni and Giordano Urbini noted that the EU deserves attention for the implementation of an effective policy to promote the use of biomethane for public and private transport [5]. Trypolska G. proves the need for state support for the development of the biomethane industry in Ukraine [6]. Tkachenko S., Stepanov D., Stepanova N. noted that modern production technologies provide the opportunity for waste and by-products of one production to act as raw materials or semi-finished products for another [7]. While the works of the mentioned authors form a solid foundation, further research is required to evaluate the actual implementation of policies, compare Ukrainian conditions with international practices, and identify effective pathways for industry growth. The scientific works of the mentioned scientists contain significant developments, but the issues of biogas production are quite broad and require further study and research.

The purpose of the scientific research is to substantiate the significance and necessity of developing biogas production in Ukraine. Compared to global leaders, Ukraine is at the early stage of biogas development, but has strong potential due to its large agricultural sector and high volumes of organic waste. However, this potential is constrained by economic, technical, and regulatory barriers.

Materials and methods

The research applied analytical, statistical, and comparative methods. It involved the analysis of legislative frameworks, statistical data on biogas production capacities and utilization in Ukraine, and the assessment of raw material potential from the agricultural sector. The efficiency of individual biogas enterprises and the prospects for the industry's development until 2050 were also evaluated. Using the ordinary least squares regression (OLS) method, forecasted production indicators for electricity production from biogas were calculated.

The authors of the article have been conducting long-term scientific research in the field of optimizing bioeconomic processes and the efficient utilization of renewable energy sources. In particular, a significant portion of the research has been carried out in the educational and scientific laboratory "DAK GPS" of the Higher Education Institution "Podillia State University" [8-10], which has established a solid foundation for further advancements in this field.

Results and discussion

In recent years, Ukraine has been following global trends and developing clean energy. An important condition for further development of the energy sector in Ukraine is the use of such types and sources of energy that would not disrupt the balance in nature and replace the exhaustible reserves of organic fuel. There are the necessary resources and sufficient potential for the production of this new type of product. An important reason for the increase in the use of renewable energy sources is the uncontrolled growth of household and industrial waste, which leads to environmental pollution and requires high costs for disposal. One of the promising areas is the production of biogas as a type of renewable energy sources, the raw materials for which are supplied by agriculture [1].

Biogas is a gas that is formed during the decomposition of biomass in landfills, swamps, sewage systems, and landfills for household waste. The technology for producing biogas consists in the fact that it is obtained from organic waste in biogas plants and used to produce heat or electricity. The most effective raw material base for biogas production in Ukraine is agrobiomass and cover crops, which are grown in the interval between two annual food crops (Table 1) [2].

Table 1

Main sources and types of raw materials for biogas production 1 million m^3 CH_4 per year [2]

Sources of raw materials		Types of raw materials	CH_4 yield per unit of raw materials	Amount required to produce 1 million m^3 of CH_4 per year
Industrial animal husbandry	Cattle farms	Cattle manure	1 hd → 780 L CH_4/day	3600 hd
	Pig farms	Pig manure	1 hd → 207 L CH_4/day	13500 hd
	Poultry farms	Chicken droppings	1 hd → 11 L CH_4/day	250000 hd
Industrial crop production	Energy crops	Corn silage	1 ton → 100 m^3 CH_4	250 hectares
	Crop residues	Wheat straw	1 ton → 230 m^3 CH_4	1700 hectares
		Corn stalks	1 ton → 180 m^3 CH_4	1350 hectares
	Cover crops	Rye	1 ton → 100 m^3 CH_4	400 hectares
Food, feed and beverage production	Sugar refineries	Pulp	per 1 ton of beets → 28 m^3 CH_4/day	6800 tons of sugar
	Distilleries	Bard	per 1 dal of alcohol → 3,5 m^3 CH_4	0.4 million dal. alcohol
	Breweries	Grounds	per 1 dal of beer → 0,15 m^3 CH_4	7 million dal. beer

The use of the organic fraction of industrial and household waste is a significant reserve for improving the country's energy supply through their processing into biogas. At the same time, the issue of improving the fertile properties of agricultural soils is being positively resolved by fertilizing them with high-quality organic biofertilizers formed after processing the specified waste into biogas [4]. Information on the availability and use of biogas production energy capacities by enterprises of Ukraine as of 1.01.2023 is presented in Table 2.

Table 2

Availability and use of biogas production capacity in 2023 [11]

Enterprises	Power, MW	Installed capacity utilization factor, %	Enterprises	Power, MW	Installed capacity utilization factor, %
LLC Demetra Bioenergy	0.5	81	LLC LNK	5.3	44
LLC Korsun Eco Energy	7.5	74	LLC Clear Energy-Kherson	2.7	42
LLC Agrofirma im. Chkalov	6.0	72	LLC Energo Sich	1.1	39
LLC Vinnytsia Poultry Farm	12.0	68	LLC Teofipol Energy Company	26.1	38
LLC Yuzefo Mykoliivska Biogas Company	5.2	66	LLC Gorodishche-Pustovarivskaya Agrarian Company	14.7	42
LLC Biogas Energy-Ternopil	0.7	66	LLC Zahid Agroenergoinvest	1.1	80
LLC Lankkast	2.1	64	LLC Clear Energy	3.5	50
LLC Clear Energy-Odesa	5.0	61	LLC Biogas-Ukraine	3.2	28
LLC Biogas Energy	0.7	56	LLC AEU Energo	1.0	27
PJSC Oril-Leader	5.7	55	LLC International Center for Gas	0.7	26
LLC Clear Energy-Kremenchuk	1.8	53	LLC Clear Energy-Chernihiv	1.1	24
LLC Goodwell Ukraine	1.2	48	LLC Masterenergo Invest	0.7	18
PP MPP Latex	0.6	45	SPRAT Ukraine	0.4	12

The analysis of biogas use (Table 3) showed that in 2023, the volume of electricity production from biogas will be 580 million kWh, which is 7.25 percent of its total production from renewable sources.

Table 3

Electricity production from renewable energy and biogas, 2023 [12]

Indicators	Electricity generation from renewable sources	Electricity generation from biogas	Electricity from biogas to total production, %
RES facilities/installations	1767	68	3.85
Installed capacity. MW	8773	135	1/54
Installed capacity utilization rate, %	x	49	x
Facility/installations received a “green tariff” in 2023	65	43	66.15
Total production of “green energy”	8 million MWh.	580 million kWh.	7.25
Generation facilities have a surcharge for the local component	181	12	6.63

In the EU, biogas is mainly used for electricity and heat generation, and biogas is also converted into biomethane, which is injected into the natural gas network or used as biofuel in vehicles. In this regard, the implementation of an effective policy to promote the use of biomethane for public and private transport deserves attention [5].

To strengthen the development of biomethane production in Ukraine, in October 2021 the Verkhovna Rada adopted the Law “On Amendments to Certain Laws of Ukraine Regarding the Development of Biomethane Production”. The law is aimed at ensuring the possibility of verifying purified biogas (biomethane), the physical and chemical characteristics of which should be similar to those of natural gas. It is also envisaged to introduce a mechanism for the development of the biomethane market, which is aimed at using the capabilities of the Ukrainian GTS, which is connected to the GTS of European countries [13].

The Chairman of the Board of the Bioenergy Association of Ukraine, Georgy Geletukha, noted that Ukraine has favorable conditions for biomethane production. Several agricultural enterprises have already built biomethane plants that will operate on their own raw materials. Given the available opportunities and prospects, in 2021, the Gals Agro company in Chernihiv region made a decision to produce biomethane at the plant. The first biomethane module in Ukraine was installed and connected

to the distribution networks of JSC Chernihivgaz in January 2023. The plant's capacity was up to 3 million cubic meters of biomethane per year. Biomethane can be injected into the Ukrainian GTS and used as natural gas. The basic raw materials for the plant in Chernihiv region are sugar beet pulp after sugar production, beet molasses, plant residues, energy plant silage, waste from food and feed production, and cattle manure [14; 15].

LLC "Gals Agro" plans to further expand production, having already built capacities to produce up to 30 million cubic meters of biomethane per year. The company has already built six biogas plants at four locations in Chernihiv and Kyiv regions [16]. In Khmelnytskyi region, a biomethane plant of Vitagro was put into operation in 2023 with a capacity of 3 million cubic meters/year of biomethane. Five more enterprises are also planned to open in Ukraine by the end of the year. In the event of a successful experience in exporting bioethanol in 2025, we can expect a doubling of capacities [15,16]. According to the Bioenergy Association, in Ukraine, the Myronivskyi Khliboproduct (MHP) plant in Dnipropetrovsk region has been added to the already existing Vitagro and Gals Agro plants. If the annual capacity of the first two is 3 million cubic meters of biomethane, then the MHP plant has 11 million cubic meters. Therefore, it will already be possible to have about 2 million cubic meters of biomethane in underground storage facilities [17]. An important direction for the development of the biogas sector in Ukraine is to study and take into account the experience of other countries. In the European Union, particularly in Germany, France, and Poland, effective government support programs are in place: feed-in tariffs, long-term contracts, financial incentives for investors, as well as systems for biomethane certification and accounting. In Ukraine, many of these tools are still lacking, and the legal framework is only beginning to take shape. To ensure successful industry growth, it is necessary to improve legislation, provide stable support for producers, simplify access to gas networks, and create a unified registration system for biogas projects. The use of proven European approaches can accelerate the development of an efficient and competitive biogas market in Ukraine.

The Bioenergy Association of Ukraine estimates the potential for biogas production in Ukraine at 21.8 billion cubic meters per year by 2050 (Table 4). Ukraine has a developed system of gas networks (GTS and GDS), and the structure of agricultural enterprises is favorable for biomethane production. Priority areas for connecting biomethane plants are where the concentration of raw materials is near main gas pipelines, branches from them and loops, near some hydraulic fracturing, gas distribution zones with the possibility of "redesign", as well as the presence of large industrial consumers [18].

Table 4

Biogas production potential in Ukraine [18]

Source	**Biogas, billion m^3 per year**
Biogas from livestock waste	0.9
Biogas from crop residues	5.2
Biogas from food processing industry by-products	0.7
Biogas from municipal solid waste	0.5
Biogas from sewage sludge (municipal treatment plants)	0.1
Energy crops: biogas from corn silage (from 1 million hectares)	3.8
Biogas from cover crops (20% of arable land)	9.8
Biogas from BM obtained by thermal gasification (10%)	1.0
Biogas, total	21.8

To regulate the procedure for customs clearance of biomethane exports from Ukraine, the Law of Ukraine No. 3613-IX of March 20, 2024 (draft law No. 9456) was adopted, which should contribute to the development of the production of this type of fuel and expand export opportunities [6]. In Ukraine, there is a technical possibility of connecting biomethane producers to medium and low pressure gas distribution networks for local supply of biomethane as a substitute for natural gas, since biomethane is its analogue in terms of chemical properties [19].

According to the regression analysis indicators, the trend line on the graph was extended beyond the available data in order to predict future values. Statistical data on energy production from biogas for the period 2017-2022 made it possible to obtain graphs showing the predicted values of biogas production development for 2023-2026 (Fig. 1).

Considering the feasibility of using biofuels in transport, the Verkhovna Rada of Ukraine adopted the Law "On Amendments to Certain Laws of Ukraine Regarding the Mandatory Use of Liquid Biofuels (Biocomponents) in the Transport Sector". According to the document, from May 1, 2025, the mandatory biofuel component in gasoline must be at least 5%. This includes the use of biobutanol, bimethane, biodiesel, bioethanol, biohydrogen, etc. [20].

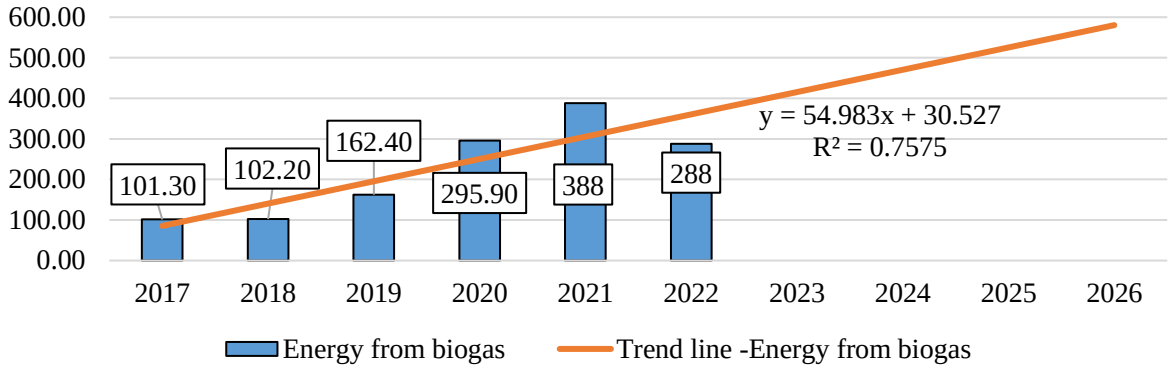

Fig. 1. **Trend model for generation of electricity from bioenergy in Ukraine (in gigawatt-hours)**

The Government of Ukraine and the European Commission, following joint consultations with the College of the European Commission, signed two important documents in the field of renewable gases.

1. Memorandum between Ukraine and the EU on a strategic partnership in the field of renewable gases, biomethane, hydrogen and other synthetic gases. The aim of the partnership is to deepen cooperation in the development of renewable energy, in particular, environmentally friendly, sustainable gases and their derivatives. This is another step in promoting the production, transportation, storage and use of renewable gases.
2. An Agreement on Ukraine's participation in the EU Single Market Programme was signed [21]. To promote the development of biogas production, the Cabinet of Ministers of Ukraine approved the National Waste Management Strategy until 2030.

The strategy envisages increasing the volume of waste directed for recycling to 50%. A plan of measures has been developed to reduce the volume of municipal waste landfilling, put waste sorting lines into operation; introduce projects for biological processing of mixed municipal waste [3]. Biogas technologies fit well into the UN doctrine of sustainable development of society. Modern production technologies, if possible, should be interconnected in such a way that the final cycle of one of them becomes the beginning of the second cycle [22].

Conclusions

Analyzing the development of biogas production, the conducted research and raw material assessments showed that the most effective raw material base for biogas production in Ukraine is agrobiomass and livestock waste, as well as industrial and household waste. The conducted analysis of electricity production showed that 68 plants with a capacity of 135 MW produce electricity from biogas, which is 1.54 percent of the total. The utilization rate of biogas plants is 49 percent. The volume of electricity production from biogas is 580 million kWh, which is 7.25 percent of "green energy" from total production.

Summarizing the results of the study, the following key positions in the development of biogas production can be noted.

- The utilization rate of the installed capacity of 26 enterprises ranges from 80-12%.
- Biogas plants operating for the production of heat and electricity have great prospects for switching to biomethane production.
- The potential for biogas production in Ukraine is 21.8 billion cubic meters per year by 2050.
- Ukraine has the technical ability to connect biomethane producers to medium and low pressure gas distribution networks for local supply of biomethane as a substitute for natural gas.

Based on the research conducted, it can be stated that the production and use of biogas in Ukraine has quite a lot of potential, thanks to favorable natural and climatic conditions and great potential for the development of biogas technologies.

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Author contributions

All authors have contributed equally to the study and preparation of this publication. The authors have read and agreed to the published version of the manuscript.

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