FINANCIAL AND LEGISLATIVE ASPECTS OF BIOGAS DEVELOPMENT IN POLAND AND UKRAINE*

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European Biogas Association experts predict rapid growth of the biogas sector in the near future in all EU countries. However, the development of the biogas market is impossible without legislative and financial support from governments. The financial and legal aspects of the development of the biogas market in Poland and Ukraine were analysed using statistical and graphical methods, as well as retrospective data analysis. In Poland, the initial incentive for biogas investments ('green' tariff and strict environmental policy) has been replaced by other incentives (tax benefits, energy subsidies). Despite the objective problems, Ukraine's government is actively working to activate the bio-industry in Ukraine by making changes in the legislation and reforming the energy sector. Due to the comprehensive analysis, significant parallels and common strategies were highlighted for Poland and Ukraine in terms of energy policy development, legislative changes and strategy planning in the sector, financial and investment support, measures to reduce producers' costs, preferential transport tariffs, and development of biomethane infrastructure. In the medium and long term, biogas market development will bring benefits such as macroeconomic stabilization, reduced energy consumption, and reduced dependence on energy imports for both countries.

sustainability, waste management, biogas project, energy crisis.

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INTRODUCTION

Biogas production is an essential perspective to the energy market development worldwide. It considers sustainable development goals (SDG) and helps reach environmental and economic benefits (Roubík et al., 2020). North and South America, Southeast Asia, Africa and Europe show the intensive development of the biogas market in the last 10 years (Pryshliak, 2021). Now there is about 20% of total final energy consumption comes from renewable energy sources (RES) (World Bank, 2023). In general, since 2015, the share of RES has been steadily growing. According to the European Biogas Association (EBA) experts, the renewable sector has already provided 18.4 billion m3 of renewable gas, and by 2050, it can grow almost 10 times and could cover 35-62% of total energy demand (Biogas report, 2023). As for the analysed Poland and Ukraine, the share of renewables in 2020 was 16.14% and 8.72%, respectively and have risen rapidly since 2022 (Igliński et al., 2020; Kuzior et al., 2021). Due to the RED III Directive on Renewable Energy Policy (RED III Directive (EU) 2023/2413), the EU committed

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to reducing greenhouse gas emissions by at least 55% by 2030, and it opens new opportunities for biogas development. For the world's economy, investments in renewables provide socio-economic benefits, innovations in production circles, help to reduce dependence on energy imports and make positive changes to the environment. The demand for these technologies is constantly growing, as well as the interest of investors worldwide.

Since 24 February 2022, the development of biogas market experienced rapid development due to the possible energy crisis in Europe (Kuzemko et al., 2022; Osička, Černoch, 2022). Military actions led to the destabilization of fossil gas prices and demonstrated the dependence of the European Union (EU) on external energy supplies (Araujo, de Medeiros, 2022), which is a threat to energy security and economic stability. As a result, the share of renewables increased by 2% worldwide for 2022-2024. The EU has taken a course to eliminate the consumption of Russian gas and accelerate the transition to renewable energy with the 'REPowerEU Plan' (2022) that provides price regulation, temporary tax and other measures to improve the development of the energy market and protect consumers and the economy. The focus of the legislation changes lay on decarbonizing industry by accelerating the switch to electrification and RES, renewable hydrogen and enhancing low-carbon manufacturing capabilities. In this context, biogas and biomethane play a leading role in shaping the future energy balance. The reform of the legislative support for renewable energy projects has begun to minimize the time for the deployment of renewable energy projects and the improvement of network infrastructure. For example, the Special Act on Biogas (2023) was adopted in Poland and declared readiness for specific and quick actions in the development of the biogas sector.

Legislative changes in Ukraine in terms of renewables were significant in the last 10 years. According to the Association Agreement with EU (Association Agreement, 2022) Ukraine starts the work on sustainable energy market development since 2015. 'The National Renewable Energy Action Plan for 2020 (NREAP) and the next measures until 2030' focus on diversifying the country's energy sector and strengthening local production of renewable energy, including biogas. In April 2023, the Ukrainian Government officially endorsed 'The National Energy Strategy of Ukraine' (2023, Cabinet of Ministers Order No. 373-p). Key initiatives include constructing and installing 1.4 GW of new highly flexible capacities using biogas, biomass, and alternative sources to reinforce these objectives. This is ongoing under the financial support of donors despite huge damages to the renewable sector of Ukraine - more than 17% of all biogas plants in Ukraine were destroyed during the shelling (Bergmann and Romanyshyn, 2022).

Biogas market development in different countries has its own trends, including national, regional, and European issues. Lössel J. studied the main disadvantages of the biogas market development in Poland and resumes that it includes administrative and legal procedures and financial barriers (Lössel, 2011). It means many formal requirements in implementing biogas projects (too extensive documentation to prepare an application and the lack of trust of banks for biogas projects). Besides, there are difficulties in issuing green certificates in Poland (Bößner et al., 2019). Igliński et al. (2020) showed that the current development of the biogas plants market in Poland is essentially the result of the operational support system for renewable energy sources. It could be the system of certificates of origin (GoO) and support for energy production in cogeneration in the form of yellow certificates.

European project developers and investors consider the Ukrainian market as a developing with the possibility of business expansion during the post-war reconstruction. At the same time, it is necessary to take into account the risks that arise due to the variety of local Ukrainian characteristics and their impact on the project's financing (Dergachova et al., 2020). Both in Poland and Ukraine, there is a wide range of opportunities to attract investment to implement biogas projects from grant programs, international funds, banking structures, technical assistance programs, and donor programs, and to attract private capital, both local and foreign (Gadirli et al., 2024). The possibility of combining investment support and support for green energy production has created favourable conditions for the planning and construction of biogas plants. The initial effects of this system construction were the dynamic development of the biogas sector and investors' preference for significant investments in the 0.5–1.5 MWe range, which account for approximately 55% of projects on the market (Curkowski, 2016).

Currently, financial support for biogas plants is still a problem for Ukraine and Poland despite many changes that have been throughout the last ten years. So, the purpose of this article is to review the legislative and economic changes for the development of the biogas market in Poland and Ukraine to identify trends, strengths and weaknesses of the biogas market development in both countries and make an outlook for the future.

MATERIALS AND METHODS

This study delves into the financial and legislative facets of biogas market development in Poland and Ukraine. It employs an analytical approach, encompassing statistical and graphical methods, coupled with retrospective data analysis spanning the period

from 2009 to 2020. The choice of this timeframe is driven by the availability of comprehensive analytical data during this period. Notably, data beyond 2020 is unavailable due to the imposition of martial law in Ukraine, resulting in a lack of official analytics on biogas project investments.

Financial Analysis and Methods

Financial analysis and methods are focused on several key aspects:

- Investment Evaluation: this analysis assesses the investment inflows into the biogas sector between 2009 and 2022 and forecasting values till 2030. It examines the trends and patterns in financial commitments to biogas projects during this period.
- Subsidies and Financial Support: the financial support extended to the biogas sector is scrutinized, encompassing a comprehensive evaluation of bioenergy subsidies and other financial allocations directed towards supporting biogas projects.

Legislative Framework Assessment

Legislative analysis focuses on the following key aspects:

- European Union Alignment. In examining the legislative framework, we utilize European Union directives as benchmarks following Framework Directive 2008/98/EC 'On Waste'; Directive 2010/75/EC 'On Industrial Emissions'; EU Renewable Energy Directive (RED II 2018, RED III 2023); European Green Deal (2020); REPowerEU Plan (2022). This approach facilitates the evaluation of Poland's and Ukraine's alignment with European bioenergy and environmental policies.
- National Strategic Documents. The study incorporates a detailed analysis of key Polish and Ukrainian national strategic documents. This includes an examination of Special on facilitating the preparation and implementation of investments in agricultural biogas plants and their operation (2023), Energy Policy of Poland, National Renewable Energy Action Plan for 2020 (NREAP) and the next measures until 2030' (2014); 'The State Strategy for the Regional Development of Ukraine for 2021–2027' (2020); 'Association Agreement' (2022); 'The National Waste Management Strategy of Ukraine until 2030' (2017); The Energy Strategy of Ukraine till 2050' (2023); Law of Ukraine 'On Alternative Energy Sources' (2003); Law of Ukraine 'On Alternative Fuels' (2009); Law of Ukraine 'On the Natural Gas Market' (2015); the Law of Ukraine on 'Electric Power Engineering' (2019); the Law of Ukraine 'On Amendments to Certain Laws of Ukraine on the Development of Biomethane Production' (2021). These documents provide insights into the long-term commitment of Ukraine to sustainable energy practices.
- Analytical Resources. The study is enriched by the utilization of analytical materials sourced from the Bioenergy Association of Ukraine and the European Biogas Association. These materials contribute to a comprehensive understanding of the dynamic landscape of the biogas sector in Ukraine.

Comparative Analysis

A central component of our methodology involves a comparative analysis between Poland and Ukraine. This approach enables us to discern nuanced disparities and commonalities in the financial and legislative landscapes, considering the distinct challenges and opportunities each country faces.

RESULTS AND DISCUSSION

1. Legislative aspects of biogas market development

Ukraine

State Agency on Energy Efficiency and Energy Saving of Ukraine said that 'today 49 biogas facilities in Ukraine that generate energy from biogas are supported by the 'green tariff'. Ukraine adopted the green tariff in 2008. The 'green' tariff for electricity from biogas in Ukraine is regulated by the Law of Ukraine 'On Alternative Energy Sources' (2003). The government has pledged to buy all renewable electricity at a high fixed rate until 2030. The 'green tariff should become a stimulus for the development of electricity production from renewable sources.

This policy has provided positive results in the period 2012-2020. However, the rapid development of renewable energy sources and the high green tariff, in addition to positive consequences, also create specific problems. According to K. Startseva, this is due to the technical issues of integrating the bioenergy sector into the unified energy system of Ukraine (Startseva, 2020). In addition, there is a burden on the state budget and risks of a significant increase in prices for electricity consumers.

In 2014–2017, Ukraine made initial important steps to change the situation through a commitment to comply with the EU Directives as part of the Association Agreement with the EU and adoption of the 'National Waste Management Strategy until 2030'. In addition to the national policy framework, according to the Association Agreement with the European Union and European Green Deal, Ukraine's national environmental legislation should be aligned with certain EU directives and Regulations (Rees, 2020). The biogas market development is also connected with 'The National Waste Management Strategy of Ukraine until 2030' (2017).

The National Strategy is developed with the support of international donors and is considered one of the main drivers of waste management market develop-

ment, compliant with the EU requirements and close to the innovative integrated concept. The goal of the 'National Waste Management Strategy 2030' is to create conditions for raising living standards by introducing a systematic approach to waste management at the state and regional levels, reducing waste generation and increasing the volume of its recycling and reuse, including the production of biogas.

New opportunities for the development of biogas projects appeared after the adoption of the Law of Ukraine 'On Amendments to Certain Laws of Ukraine on the Development of Biomethane Production' (№ 1820-IX of 21.10.2021, so-called 'Law on Biomethane'). It provides for amendments to the Law of Ukraine 'On Alternative Fuels' (2009) and the Law of Ukraine 'On the Natural Gas Market' (2015) and defines biomethane as biogas, which in its physical and chemical characteristics meets the requirements of regulations on natural gas for supply to the gas transmission or gas distribution system or for use as motor fuel. This allows the introduction of the biogas market in Ukraine and the export of biomethane abroad, primarily to the EU market.

The Council of Ministers of Ukraine adopted the 'National Renewable Energy Action Plan until 2020' in the form of an executive order on 1st October 2014. NREAP provides goals for 2020 and projections until 2030. It provides for incentives until 2030, and end-user renewable energy consumption is planned to have a share of 11% in 2020.

In addition to the aforementioned incentives, the Law of Ukraine on 'Electric Power Engineering' (2019) provides for very attractive feed-in tariffs in Ukraine since 2010. In April 2019, the Verkhovna Rada of Ukraine passed a Law 'On Amendments to Certain Laws of Ukraine to Ensure Competitive Conditions for Electricity Production from Alternative Energy Sources'. In particular, it introduced a system of auctions for the distribution of support quotas or 'green auctions'.

The changes in legislation shift the focus to biomethane projects due to encouraging the consumption of biomethane and new generation biofuels in transport for the period 2020-2030 (based on the EU RED II Directive). Here are the main of them:

- Commitment to increase the share of renewable gases/biomethane in the structure of use in transport (5-10% in 2030).

- Changes to the Tax Code - exemption from payment of excise tax on biomethane/renewable gases. Active use of excise tax, CO2 tax, and special taxes for all types of fossil fuels.

- Changes to the National Energy Strategy – setting targets for the use of biomethane/renewable gases (for example, the volume of gas produced, the number of stations for refueling compressed or liquefied biomethane in 2035). Definition of short-term (2035) and long-term (2050) goals.

- Implementation of measures and programs to support vehicles using biomethane in municipalities and agriculture.

- programs for municipalities and agricultural enterprises.

- Measures to promote biomethane as a motor fuel (award for a 'green' car, support for gas stations with biomethane sales, investment grants).

- Implementation of investment programs and subsidies for the development of infrastructure of supply and consumption of biomethane.

Poland

Each EU member state has adopted its own approach to the promotion of renewable energy sources according to its own objectives (Márquez-Sobrino et al., 2023). Preferential tariffs and increasing the demand for renewable energy through changes in legislation were identified as important tools (Bersalli et al., 2020; Fleck, Annatolitis, 2023).

The development of the biogas market in Poland was ensured by the 'Energy Policy of Poland until 2030' (2009) and obligations to implement Directive 2009/28/EU of the European Parliament and the Council (2009) on the promotion of the use of energy from renewable sources. Further legislative changes in the Polish biogas market took place in direct accordance with European directives and other regulatory and legal documents. The amendment to the Polish Law on Renewable Energy Sources (2017) has opened great opportunities for the biogas market development in Poland (Marks et al., 2020). The European Green Deal, Fit for 55, and the war in Ukraine led to fluctuating prices on the natural gas, oil and coal markets and accelerated the transition of the energy market toward RES. There has been a huge increase in investment in biogas plants in Poland over the past 2 years. In particular, the sector of small agricultural installations (50-499 kW) has developed due to a faster legislative route (Iglinski et al., 2023).

In general, the war in Ukraine strengthened the European and Ukrainian energy policy to get rid of fossil fuels and irreversibly turned towards a phased transition to alternative energy, in particular biogas and biomethane, as was mentioned by numerical studies (Steffen, Patt, 2022; Plotkin et al., 2023).

2 Financial aspects of biogas market development

Trends in Biogas Market Development

The Ukrainian government has been actively working to attract foreign investment in biogas production, highlighting the sector's substantial potential. Since 2020, investments in biogas in Ukraine have progressed significantly. In 2020, Ukraine launched 68 biogas plants, with 50 operating under a green tariff. By the end of that year, the total electrical capacity of cogeneration biogas plants was approxi-

mately 105 MW, and the total biogas usage exceeded 230 million cubic meters.

Data from the State Agency on Energy Efficiency and Energy Saving indicates that approximately 112 million euros were invested in biogas stations in Ukraine from 2012 to 2019. As of the end of 2019, biogas power stations operating on agricultural waste generated 47 MW of electricity, while those on landfill sites produced 23 MW (GetMarket, 2019). The total investment in this sector from 2009 to 2020 was more than 150 million euros (Fig. 1).

The development of the biogas market in Ukraine, considering its high investment cost, is primarily driven by large corporations (Prokopenko et al., 2021). The cost of capital in Ukraine significantly influences the construction costs and return on investment for biomethane plants. Currently, these costs are elevated due to the war and associated investment risks, which greatly limit the availability of foreign financing. In contrast, in European countries, more than 50% of farms possess biogas units of varying capacities, supported by state programs (Geletukha, Zheliezna, 2021).

Ukraine holds substantial potential for the biogas market due to low market saturation and high agricultural development, which provides the main volume of bioenergy raw materials. According to the Bioenergy Association, Ukraine has the capacity to produce 9.7 billion cubic meters of biomethane annually. However, the ongoing conflict poses a major obstacle, as investors are hesitant to establish new biomethane facilities during times of martial law (Sustainable Agribusiness Forum, 2023).

Ukraine aims to produce at least 11 TWh of biomethane annually by 2030 (Golz et al., 2021). Retrofitting a biogas plant to produce biomethane costs approximately 1.5 million euros, or EUR 55 per MWh production capacity. Greenfield construction of a new biomethane plant is estimated at EUR 200 per MWh of annual capacity. To reach the 11 TWh target, Ukraine would need 420 biomethane plants, each with a 26.4 GWh annual capacity. This requires an estimated total investment of 2.2 billion euros, necessitating the construction of 60 plants annually from 2024 to 2030, about 300 million euros per year (Golz et al., 2021). According to recent projections, 12.4 billion euros will be invested in biogas production across the European Union from 2026 to 2030. Of this total, 3.3 billion euros will be allocated to projects in the UK and Ukraine (1st EBA Biomethane Investment Outlook, 2024). This substantial investment highlights the significant potential and commitment to advancing biogas production in Ukraine.

In 2020, Ukraine took eighth place among 100 developing countries in terms of the attractiveness of investments in renewable energy, which is 55 places higher than in 2018. It is worth noting that according to the research agency 'Bloomberg New Energy Finance' (2023), a comprehensive assessment of the attractiveness of investment in renewable energy sources was calculated on three indicators: Fundamentals', 'Opportunities', and 'Experience'. A group of reputable experts evaluated each indicator. For Ukraine, the 'Fundamentals' indicator was 2.96; 'Opportunities' – 0.71 and 'Experience' – 2.17; for Poland – 2.74; 2.04 and 1.28, respectively.

On the one hand, Ukraine lags in the development of the biogas market compared to Poland. Besides that, Ukraine has enormous potential for the biogas market due to the low market saturation and the high rates of agriculture development, which produces the main volume of bioenergy raw materials.

Comparing the results of Climatescope (2023), we can adjust that both countries' clean energy sectors are desirable to investors. Still, the disclosed share of foreign investment in the clean energy sector in Ukraine is 77.19%. In Poland – 89.95% (Fig. 2). Based on the investment data provided for Poland and Ukraine, a comparative analysis reveals significant differences in the trends and levels of clean energy investments between the two countries.

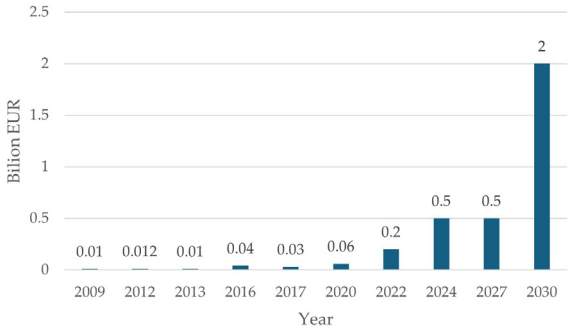

Fig. 1. Investments to the Biogas Sector in Ukraine (2009-2030). *2024-2030 – optimistic scenario of Ukrainian biomethane market
Source: formed by authors using Prospects of biomethane in Ukraine (2023); Vision of the development of the Ukrainian biogas/biomethane sector (2021); Investments in alternative energy (2019).

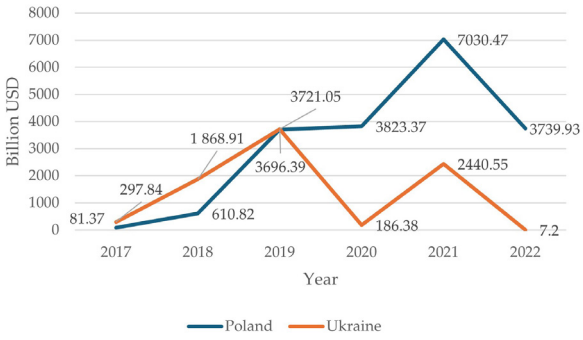

Fig. 2. Clean Energy Investment in Poland and Ukraine
Source: prepared by authors using 'Climatescope' (2023)

Table 1. The Investment cost of some biogas plants in Ukraine and Poland

Project	Energy, MW	Investment, mln euros*	Substrates
Ukraine			
Ladyzhyn Poultry Farm	12	18	Chickens manure
Theophipolian biogas complex	10.5	14	Corn silage
Biogas station of 'Yuzefo-Nikolaev sugar plant'	5.2	11	Beet pulp, silage
Rokytnia Biogas Plant	2.25	8	Beet pulp, corn silage, sorghum
Biogas station in the village of Okny, Odessa region	1.2	3.5	Corn silage
Poland			
Biogas plant in Pawłówko	7.5	1.76	Slurry from the farms
Biogas plant in Koczała	16.7	3.6	Slurry and corn silage
Biogas plant in Nacław	4.9	2.1	Liquid manure, Corn silage, Glycerine
Biogas plant in Mełno	12.8	3.1	Distillery slop
Biogas plant in Liszkowo	14.4	-	Corn silage, Plant wastes, Distillery slop
Microbiogas plant in Studzionka	4	0.088	Corn silage, Plant wastes, Distillery slop

*Investment costs are given for the year of construction of the installation

Source: prepared by the authors based on data of Bioenergy Associations of Poland and Ukraine

In recent years, Poland and Ukraine have demonstrated distinct investment patterns in the clean energy sector. Despite experiencing a notable decline in clean energy investments, Poland remained substantially more invested than Ukraine. In 2022, Poland's investment in clean energy amounted to approximately $3.74 billion, representing a 46.8% decrease from the $7.03 billion recorded in 2021. This decline follows a peak in investment in 2021, indicating a volatile but significant commitment to clean energy. Conversely, Ukraine's clean energy investments plummeted dramatically in 2022, falling to a mere $7.2 million, a staggering 99.7% decrease from the $2.44 billion invested in 2021 (Fig. 2). This drastic reduction highlights a severe contraction in investment flow and suggests a sharp decline in financial support and interest in the sector.

When comparing the two countries, Poland's investment figures reveal a higher and more stable investment trajectory, even with recent declines. While reduced, Poland's clean energy investments are still significantly higher than Ukraine's. While substantial, the decrease in Poland's investment represents a typical cyclical adjustment rather than a complete retreat from the sector. In contrast, Ukraine's extreme drop in investment signifies a more profound crisis within its clean energy sector.

Overall, Poland's relatively higher investment levels and its ability to maintain substantial financial commitments, despite recent decreases, contrast sharply with Ukraine's severe decline in clean energy investments. This disparity underscores the challenges Ukraine faces in sustaining investor confidence and funding in its clean energy sector. At the same time, Poland, despite setbacks, continues to demonstrate a stronger overall investment capacity in clean energy.

The estimated cost of investment in a biogas plant varies, depending mainly on the scale of the investment. B. Iglinski believes that installations with more than 1 MW capacity are profitable in Poland (Igliński et al., 2012). The average cost of building a 1 MW biogas plant is approximately PLN 15 million. The biogas plant, with a capacity of 1.1 MW, generates demand for about 40,000 tons of liquid manure and 20,000 tons of corn silage as feedstock for biogas production. In this case, the theoretical return on investment occurs on average in about three years. In the case of a smaller biogas plant with a capacity of 230 kW, the cost of 1 MW of electricity generated is PLN 21 million, or approximately PLN 4,830,000, and this investment will only be profitable in 5 years (Igliński et al., 2012; Igliński et al., 2020). Poland has a wide range of measures supporting renewable electricity generation, including a green certificate scheme, an auction system, a dedicated program for offshore wind, a feed-in tariff and feed-in premium for medium-scale hydropower and bioenergy, and several loan and grant programs to finance small- and medium-scale renewable energy projects. The cost of subsidies awarded through the renewable energy auction and other renewable support measures are covered by a fee charged to all electricity consumers (Poland, 2022). In Ukraine, experts note that the larger the biogas plant, the less investment per 1 kW of generated electric power, which is associated with the peculiarities of the technologies of biogas plants (Chasnyk et al., 2015). The investment cost of some biogas plants in Poland and Ukraine is presented in Table 1 (data presented for the year of construction of the installation). Recently, the average cost of biogas installations varies depending on

Table 2. Comparison of investment indicators of a biogas power plant with a capacity of 2 MW

Indicator	'green' tariff	'auction price'
Tariff, euro per kWh	0.1239 (before 2030) 0.06 (after 2030)	11.15* (for 20 years)
CAPEX, mln euros	5.74	5.74
NPV, mln euros	1.833	3.364
IRR	14.2%	15.3%
Payback period, years	5.5	6.5

*estimated tariff for electricity after the auction (10% less than the 'green' tariff).

the technology used at 3-5 million euros per MW of installed energy capacity.

Each investment project of a biogas plant is highly individual due to various factors. These include:

- types of raw materials and the level of methane content in it.
- production technology.
- whether the raw material is owned or needs to be bought.

It is also necessary to evaluate the project from the point of view of the final product after obtaining biogas (electricity, heat, fertilizer, car fuel, solving waste disposal). An essential factor influencing the cost of the project when calculating the investment project of the biogas plant is the raw material logistics. According to experts of the European Biogas Association, an economically viable distance for the delivery of raw materials is a distance of up to 20 km for liquid raw materials and up to 50 km for dry raw materials.

According to the entrepreneurs' opinion in Poland, several sources of financing were used in the construction of biogas plants, namely: own resources of the enterprise, bank loans and other loans, EU funds, resources of the European Regional Development Fund, co-financing from the National Fund for Environmental Protection, Fund for Protection and Water Management, co-financing from the Regional Environmental Fund. Polish entrepreneurs identified the main problems associated with investing in the biogas sector: high investment costs, resistance from the local community, no support for specialized companies in the market, lengthy and complex administrative procedures, legal instability, lack of specialists, dishonest performers, and legal problems with connecting to electrical networks for the marketing of biogas plant products.

It should be noted that in some European countries, investing in the plant construction phase through subsidies is generally accepted. In Poland, a substantial reduction amounting to approximately 57 million euros occurred, primarily attributable to a decline in the valuation of green certificates. In the year 2018, the aggregate sum of subsidies, for which data is ascertainable, exhibited a modest decrease as compared to the levels recorded in 2017 (Financial Support for Electricity Generation & CHP from Solid Biomass Final Report, 2019). However, the most popular support method guarantees fixed purchase prices for electricity, the so-called 'feed-in tariff'. Such an instrument is particularly beneficial for small biogas plants, which, due to lower profitability and higher overall social benefits, are compensated in the form of operational support in subsidies for the production and sale of green electricity (Biogas Report 2020).

The example of calculating the investment model of a biogas power plant in Ukraine given below assumed that the model of government support in the form of a 20-year auction price has advantages over the model under the 'green' tariff, which expires in 2030. Below is the calculation of a 2 MW biogas power plant operating on silage and pig manure (GetMarket, 2021). Table 2 shows that the project at the auction price tariff is 1.8 times more profitable than the project at the 'green' tariff, even though the 'green' tariff is higher.

The internal rate of return of the project is high and allows the investor to attract foreign currency credit financing. The European Bank for Reconstruction and Development (EBRD), together with the Global Energy Fund, launched a 4-year financial program in Ukraine worth more than 50 million euros to finance bioenergy projects (Prospects of biomethane in Ukraine, 2023). The program will start in 2019. The program aims to lend to private bioenergy projects where technologies and systems for the collection, storage, and processing of agro-biomass will be applied. In the EBRD opinion, this will allow mobilizing investments in this sector (Vision of the development of the Ukrainian biogas/biomethane sector, 2021).

Financial instruments for biogas market development

National support schemes are different depending on the country. For example, feed-in tariffs were applied in Germany, France, Austria, and Great Britain; fiscal incentives were applied in Sweden, Poland, and Switzerland; and quota systems were applied in the Netherlands, Italy, and Malta. Finland provides mostly investment support.

In September 2021, Ukraine utilized several financial instruments to support the biogas market. These financial instruments were designed to encourage investments in the biogas sector and promote renewable energy production. Some of the key financial instruments included:

Feed-in Tariffs (FiTs): Feed-in tariffs were established to guarantee fixed, attractive prices for biogas electricity over a specified period. Producers were offered a stable and favourable rate for the electricity they generated, providing financial security for biogas projects. For instance, a specific tariff might guarantee a certain amount per kWh of biogas-generated electricity over a 20-year contract period.

Green Certificates: Green certificates were tradable certificates issued to biogas producers for each megawatt-hour of electricity generated from renewable sources. These certificates could be sold to other market participants, including obligatory buyers, such as electricity suppliers, who were required to acquire a certain number of green certificates. Biogas producers in Ukraine received green certificates for each megawatt-hour of electricity generated from renewable sources. These certificates could be traded on the green certificate market.

Investment Grants and Subsidies: The Ukrainian government, in collaboration with international organizations, provided grants and subsidies to support the development of biogas plants. These grants often covered a portion of the project's construction costs.

Tax Incentives: Tax incentives, such as reduced or waived taxes on imported equipment or exemptions from certain taxes, were sometimes offered to biogas project developers to make their investments more financially attractive. Some regions in Ukraine offered tax incentives to biogas project developers, such as exemptions from import duties on equipment or reduced property taxes on biogas facilities.

Loan Programs: Financial institutions, including the European Bank for Reconstruction and Development (EBRD), provided loans to biogas developers at favourable terms. These loans often featured lower interest rates (6%) and longer repayment periods. The EBRD provides loans to private and municipal enterprises' projects. According to agreements, a specific feature of cooperation with the EBRD is providing guarantees in the form of pledges of company assets, shares, or other formats. The loan size can be 10-25 million euros.

The financing program of the European Investment Bank provides an interest rate of 2.4-4% per annum for a crediting period of up to 22 years with a grace period of 5 years for loans to municipalities and private entrepreneurs from 10 million euros.

The German-Ukrainian Fund works through domestic partner banks, providing loans of up to 300,000 euros for subsequent lending to enterprises implementing renewable energy projects. The loan term is usually up to 5 years at an interest rate of 7% in euros.

Bank lending is offered by several domestic banks: Ukrgasbank, Oschadbank, Raiffeisen Bank Aval, ProCredit Bank, Ukreximbank, and Piraeus Bank. All banks have approximately the same conditions:

- the share of the loan in the total project budget – up to 70–80 %.
- loan rate – 5–7.5 % in euros.
- the loan repayment period – up to 7 years, but not more than the payback period.

Public-Private Partnerships (PPPs): Some biogas projects in Ukraine were developed through PPPs, where the government partnered with private investors to share the financial burden and risks associated with project development. In some cases, the Ukrainian government collaborated with private investors in a public-private partnership to develop biogas projects. The government may have provided infrastructure or land, while private investors contributed funding and expertise.

In Poland, there is a multi-level and differentiated system of financing innovative investment projects in the field of energy efficiency and renewable energy sources. This system encompasses both non-repayable financing (grants) and repayable financing (loans and credits). Many potential sources of funding utilize funds from the European Union budget, enabling investors to obtain highly favourable financing conditions. The financing process operators include government institutions and their separate organizational units (at the national and regional levels) as well as commercial entities offering products dedicated to investment projects related to renewable energy and energy efficiency.

Support at the state level is available within the framework of the Operational Program 'Infrastructure and Environment'. This program provides backing for investment projects in the construction of facilities that generate electricity or heat from renewable sources. Minimum thresholds have been established for projects eligible for funding under the program:

- For investment projects in the production of electricity from biomass or biogas, as well as in the construction or expansion of small hydroelectric power stations, the minimum amount is set at 10 million PLN.
- For other types of projects, the minimum value is 20 million PLN.

The selection of a specific Regional Operational Program is determined primarily by the location of the investment project. All regions employ a competitive selection procedure for enterprises seeking co-financing of their projects.

Poland is one of the few EU countries where, in spring 2024, there is still not a single working biomethane plant. The situation is only slightly better in the case of the biogas market – the municipal biogas sector is generally experiencing stagnation (despite the very great interest of local governments).

Table 3. Main risks associated with biogas projects in Poland and Ukraine

Risk	Explanation
Regulatory instability	Frequent changes in legislation and regulatory frameworks create uncertainty for investors, complicating long-term project planning and execution
Financial Barriers	High initial investment costs and difficulties in securing financing pose significant challenges, even with available subsidies and incentives, which may not always sufficiently mitigate these risks
Infrastructure barriers	Existing grid infrastructure may be inadequate to support the integration of new renewable energy sources, leading to inefficiencies and increased costs
Market risks	Fluctuations in energy prices and competitive market dynamics affect the profitability and feasibility of renewable energy projects

Source: prepared by authors

According to the Polish National Support Centre for Agriculture, the number of agricultural biogas plants will increase in the coming years. The basis for these estimates is the entry into force of the provisions of the so-called special law on biogas, which introduced a number of benefits for investors. At the same time, the National Fund for Environmental Protection and Water Management implements the 'Energy for the Village' program, under which you can get a loan of up to 100 % of eligible costs and/or a subsidy of up to 65 % of eligible costs for the construction of an agricultural biogas plant.

Legislative changes came into force in 2020, according to which 'green' auctions for the guaranteed purchase of electricity by the state of renewable energy sources for 20 years, including biogas power plants, will start in Ukraine. With a payback period of 5–8 years of biogas projects, such government support is significant and allows recouping investments. Also, until 2030, the 'green' tariff for biomass and biogas power plants remains unchanged, which from 2020 will be higher than for wind and terrestrial solar power plants – 12.39 euros per kWh (S a k u n et al., 2020).

Auctions are a way to identify green generation projects that will receive government support for electricity generation. Auctions must be held at least twice a year at the end of 2029. The auction system works in a way where the investor who offers the lowest electricity price wins. The starting price is the statutory amount of the green tariff, from which participants reduce their rates. The winner gets the opportunity to build new capacities and sell electricity at a price determined at an auction within 20 years from the date of commissioning of the station Law of Ukraine 'About the suppression of competitive minds, the stimulation of electrical energy production from alternative energy sources'. According to it, investors in biogas power plants can participate in auctions voluntarily or receive a green tariff until 2030 under a preliminary procedure.

In Ukraine and Poland, the biogas sector's stimulation is a developing system, and these countries are like each other in terms of development. Currently, Poland is switching from a system of certificates and guaranteed prices to an auction system. The auction system in Poland assumes that the support provided for green energy producers is divided into several auction baskets. However, according to Igliński et al. (I g l i ń s k i et al., 2020), the auction system, in comparison with the color certificate system, does not seem attractive to the owners of currently operating plants in terms of income. At the same time, Ukraine has chosen to stimulate electricity production through a 'green' tariff, and Poland has immediately chosen to use auctions and other incentive mechanisms. The start of auctions in Ukraine is constantly postponed for various reasons, so the prospects and exact dates of the start of the auctions are unclear.

The example of Poland shows that the auctions that are planned in Ukraine are less effective. Poland does not use this type of incentive as a 'green' tariff but uses auctions more like 'European-style' auctions when the state does not pay all the generated electricity, but only for a 'premium'. This significantly reduces the burden on the state and helps green energy producers move from absolute state support to partial support when bioenergy producers are gradually looking for sales markets on their own. The key to the successful development of green energy should be market conditions for green energy producers on the same principles as other electricity producers.

A more convenient support format for bioenergy producers is a 'green' tariff. However, the price of electricity for consumers is growing. Introducing auctions and contracts for differences should reduce the financial burden to offset the investment for bioenergy producers (E p s t e i n Y., 2019).

Analysis of financial risks

Besides, European experts identify the need for increased risk management as a critical obstacle to the successful implementation of biogas projects in developing countries. For example, in industrialized countries, private sector instruments are usually used

to increase the financial viability of green projects: insurance or a well-regulated electricity purchase agreement, which an agreement between the technology solution provider and the energy supply company can additionally regulate. However, in the current conditions of Ukraine, there are possible consequences of political and financial risks. It should be noted that attracting foreign investment in renewable energy projects, particularly biogas plants and capital investment insurance, is impossible or too expensive in such conditions. Of course, obtaining and using the advantages of foreign investment requires the project owner to confirm the degree of readiness to enter the project based on long-term cooperation in compliance with many requirements. The engagement of foreign investors involves substantial risk premiums, impacting the competitiveness and feasibility of renewable energy projects (Poland, 2022). These risks (see Tab. 3) highlight the need for stable policy environments in both countries, appropriate financial instruments, and infrastructure enhancements to promote the sustainable growth of biogas sectors in both countries.

Careful selection and combination of a set of financial instruments can provide access for foreign investors to developing regions and help implement a renewable energy project. The risks involved are borne by the capital costs of biogas plant projects. Typically, the project's competitiveness suffers from high initial investment, thereby reducing acceptability for the local economy and population.

One of the most effective mechanisms for developing the biogas market is the transition from supporting producers according to the 'green' tariff model to the so-called 'Feed-in-premium system' or contract for difference. Experts believe that it is necessary to make a gradual transition from the 'green' tariff to more market-based mechanisms to support the development of the biogas sector. But the problem in Ukraine is that a competitive electricity market has not yet been formed.

According to (Geletukha, Zheliezna, 2021), the time for stimulating the biogas market in Ukraine with the help of tariffs has been lost. A green biomethane tariff of €0.1239 per kWh cannot be an effective incentive. This means 496 EUR per 1000 cubic meters of biomethane at its cost of 350–700 EUR per 1000 m^3, and the cost of an equivalent volume of natural gas is about 150 EUR. The development and formation of the biomethane market in today's realities will lead the biogas industry to stagnation, but not too rapid and confident growth.

Challenges of biogas market development and outlook for the future

The economic stimulation of the biogas sector is complex without subsidies. Current trends in biogas production in Poland and Ukraine indicate some obstacles to the successful operation of biogas projects. This is because many entrepreneurs are not yet fully provided with adequate technology and, most importantly, face serious funding difficulties.

When looking at the subsidy levels in relation to gross domestic product (GDP) we see that the case study countries we selected spend between <0.01% and 0.08% of their GDP on support to solid biomass use (Fig. 3). Poland spends the least, the share of the overall support levels in relation to the GDP of this country is rather low. A large decrease took place in Poland, relating to a reduction in the prices of green certificates (Financial support for electricity generation & CHP from Solid Biomass Final Report, 2019).

The biogas market development was slowdown in 2015-2017 (Banja et al., 2019). Germany consist-

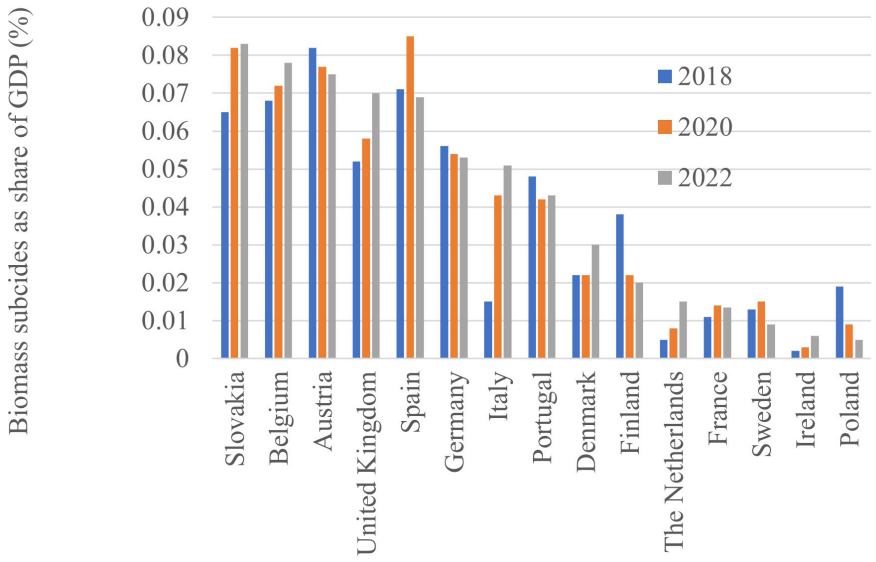

Fig. 3. Clean Energy Investment in Poland and Ukraine

Source: prepared by authors using Climatescope (2023)

ently provides the largest subsidies for bioenergy projects – approx.. 1.7 billion EUR per year. Other EU countries are gradually increasing these indicators – Italy (251%), the Netherlands (309%), and France (26%). In Poland, a decrease of 73% was observed in 2015-2017, but in the following years - an increase of up to 40%. In 2022, this growth was According to the European Commission, the EU spent €13 bln in bioenergy subsidies in 2020, down from €17bn the previous year (Financial support for electricity generation & CHP from solid Biomass, 2019). NGOs say most of those subsidies go to wood-burning power plants but could be better targeted on support for clean technology, such as heat pumps.

The problems of subsidizing biogas projects are also associated with the fact that the effects of biogas energy in terms of preventing climate change and preserving the environment are significantly underestimated in Ukraine. So, according to Epstein 2019, this is expressed in the following:

1. The existing tariff for electricity from biogas is insufficient for the investment attractiveness of biogas projects for the overwhelming number of agricultural enterprises.

2. There is no financial incentive for the efficient use of heat produced from biogas.

3. There is no financial incentive for the processing of digestate into high-quality organic fertilizers.

4. There is no financial incentive to produce biomethane to use heavy vehicles as transport fuel.

5. There are significant institutional and financial barriers to the disposal of organic waste, agricultural by-products, and food processing enterprises.

Ukraine is well positioned to successfully reform bioenergy subsidies if the government fulfils its commitments to reform the energy sector. If certain risk measures are envisaged and reforms are supported. In the medium to long term, the reform of energy subsidies will bring several benefits, such as macroeconomic stabilization, as well as a reduction in energy consumption and, consequently, dependence on energy imports. In addition, the improvement in environmental quality and associated health benefits can also be significant.

In addition to the objective problems of the biogas market development, government agencies are currently working on initiatives to intensify bioindustry in Ukraine and Poland. Due to the legislative obligations to integrate the Ukrainian energy market into the European Union market and adopt 'Energy Strategy of Ukraine until 2035', it is necessary to focus efforts in Ukraine on such incentives for the stimulation of the bioenergy sector:

1. Establishing an electronic trading system for solid biofuels, which could significantly expand the domestic market. Forecasts suggest that the turnover of this system could reach about UAH 30 billion by 2035, with over UAH 1 billion expected at its inception.

2. Allowing private investors access to heat supplies for district heating systems and eliminating the CO2 emissions tax for thermal power plants using biomass and biogas.

3. Facilitating private investors' access to biomethane supply for the gas transportation system and encouraging the use of biomethane at filling stations for public transport.

The development of biomethane production in Ukraine and Poland highlights significant parallels and common strategies inspired by European experiences. Ukraine and Poland are ready to adopt bio-methane production strategies inspired by European countries, where subsidies have been essential in developing the sector. It can be implemented measures to reduce producers' costs, such as connection cost coverage (similar to Germany, where producers pay a portion of the connection costs, or Denmark, where operators cover network enhancements); preferential transport tariffs: Ireland's model, where bio-methane producers pay reduced transport tariffs; investment support (Belgium's Flanders offers grants covering up to 65% of investment costs for small enterprises, decreasing for larger companies) (Dixi Group, 2024; Rees, 2020).

Both countries are focusing on integrating biogas production into their energy transitions, leveraging subsidies, infrastructure investments, and long-term strategic planning. To conclude, it can be stated that there are some key parallels in the following issues.

Subsidies and support: Both Ukraine and Poland recognize the importance of subsidies in the initial stages of developing their biomethane markets. Financial incentives and support for connecting biomethane plants to the gas grid are critical for fostering industry growth. This approach mirrors strategies employed by other European countries, highlighting the necessity of early financial support to overcome initial market barriers.

Infrastructure and network integration: Both countries face similar challenges regarding the infrastructure needed for biomethane. Investment in gas network connections and preferential tariffs for transporting biomethane are essential steps.

Investment support: Investment support schemes in both Ukraine and Poland can significantly reduce capital and operational costs for biomethane producers. Poland, like Ukraine, could benefit from adopting grant systems similar to those in Belgium's Flanders region, where grants cover up to 65% of investment costs for small enterprises, decreasing for larger companies.

Long-term strategy and internal market development: Developing a long-term strategy for domestic biomethane use, rather than solely focusing on export, is vital for both countries. This approach not only attracts investment and creates jobs but also contributes to broader decarbonization goals and energy independence. Ukraine and Poland must design effective

support systems that align with national priorities, such as reducing CO_2 emissions in the transport and heating sectors.

Adapting policies to national priorities: Aligning biomethane support systems with national priorities is crucial. For example, Italy's support for biomethane in transport and Denmark's focus on cogeneration reflect their national decarbonization goals. Ukraine and Poland should implement differentiated support based on the sustainability of the feedstock used, ensuring that the policies are tailored to their specific sectoral needs and existing conditions.

Clear timeframes and competitive mechanisms: As seen in the Netherlands, establishing clear timeframes for support and transitioning to competitive tender processes for allocating support can ensure efficient resource allocation and provide predictability for investors.

Thus, the development of biogas holds substantial promise for both Ukraine and Poland, offering benefits such as macroeconomic stabilization, reduced energy consumption, and lower reliance on energy imports. However, persistent challenges hinder progress, such as inadequate incentive measures and low green tariffs. Addressing these issues and aligning with European standards is crucial for transitioning to market-driven biogas sector growth and sustainability mechanisms.

CONCLUSIONS

In the medium to long term, the development of the biogas sector holds considerable promise for both Ukraine and Poland, offering benefits such as macroeconomic stabilization, reduced energy consumption, and decreased reliance on energy imports. However, despite significant advancements over the past decade, both countries continue to face challenges related to financial support for biogas initiatives. A persistent issue has been the inadequacy of incentive measures, which has been exacerbated by relatively low green tariffs for electricity generated from biogas. These tariffs have failed to attract a broad range of potential investors. As a result, over the past ten years, investment has predominantly focused on highly profitable projects.

Additionally, the biogas industry in both countries has been hindered by regulatory and administrative complexities. The absence of a streamlined and transparent permitting process and uncertain regulatory frameworks have deterred potential investors from entering the biogas market. Consequently, this restricted the development of a high diversity of biogas projects. In contrast to several European nations, where initial robust green tariffs and a variety of supplementary incentives facilitated the widespread establishment of biogas facilities, the biogas sector in Ukraine has been constrained by the interests of individual innovative agricultural holdings. These holdings often prioritize traditional agricultural practices over investments in renewable energy. In European Union countries, the initial appeal for investors in biogas projects was driven by high green tariffs and stringent environmental policies. Over time, the focus shifted to premium tariffs, differentials between fixed electricity prices and average market prices, and tax exemptions as the return on capital investment was realized.

The current conditions in Ukraine and Poland are impeding the growth of the biogas market, leading to substantial missed opportunities. Addressing these challenges and aligning the market with European standards is essential for transitioning towards market-driven mechanisms for biogas sector development. The sector's development will likely go in two directions: small cogeneration installations and larger biomethane plants with access to the network or a boiling condensing unit. One of the main factors inhibiting the development of biogas in Poland is the lack of transparent administrative procedures. Resolving these issues and stabilizing the market in accordance with European legislative norms can stimulate the biogas sector to fully exploit market mechanisms for growth and sustainability and thus contribute to its development in both countries. This, in turn, will ensure the flexibility of the energy network and contribute to strengthening the energy security of Poland and Ukraine.

AUTHOR CONTRIBUTIONS

Conceptualization, Iryna Vaskina; methodology, economical analysis, Olena Shkarupa, Roman Vaskin; formal analysis, Olena Shkarupa; data collection, Serhii Sydorenko; writing original draft and editing, Iryna Vaskina; visualization, Dmytro Hopkalo; supervision, Jacek Dach; project administration, Iryna Vaskina; funding acquisition, Iryna Vaskina. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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