THE CURRENT STATE OF BIOGAS PLANTS DEVELOPMENT IN UKRAINE AND THE POTENTIAL FOR DEVELOPMENT DURING EUROPEAN INTEGRATION

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Abstract. *This paper examines the role of anaerobic treatment in sustainable development, with a specific focus on biogas production. Anaerobic treatment is a key component of biogas plants, which efficiently convert organic waste into renewable biogas while minimizing environmental impacts. Biogas offers a sustainable solution for waste management by reducing landfill usage and methane emissions. It also provides a renewable energy source that contributes to energy diversification, greenhouse gas reduction, and enhanced energy security.*

The paper analyzes the state of biogas plants in Ukraine, which has made progress with 50 existing plants. However, there is room for further growth. By leveraging Ukraine's agricultural orientation, abundant organic waste resources, and the experiences of European countries, the country can unlock the full potential of its biogas sector. This will contribute to sustainable energy production, waste management, and broader European integration goals.

The paper concludes by emphasizing the importance of sustainable development and maximizing the potential of biogas production. By adopting sustainable practices and promoting biogas utilization, countries can achieve economic growth, environmental protection, and social well-being in line with the EU's objectives and global sustainability targets.

DOI: 10.24263/EDSD-2023-5-22

1. Introduction.

1.1 Sustainable development as a key principle of the European Union

Sustainable development has emerged as a critical concept, guiding nations and regions toward a more equitable, resilient, and environmentally responsible future. It emphasizes the interdependence between economic development, social well-being, and environmental conservation. The European Union, with its commitment to sustainable development, has played a pioneering role in setting ambitious targets and implementing comprehensive policies that align economic growth with environmental preservation (European Commission, 2019; European Council, 2010; Kovačič, 2018). Currently, Ukraine is on the way to ensuring European practice related to sustainable development (Shapovalov, et al., 2022; Yakymenko et al., 2022; Yakymenko et al., 2018)

The EU recognizes that sustainable development is essential for ensuring the long-term well-being of its citizens, protecting the planet, and maintaining a competitive advantage in the global economy. By adopting a holistic approach, the EU strives to strike a balance between economic prosperity, social cohesion, and environmental stewardship. This approach aligns with the principles enshrined in the United Nations' Sustainable Development Goals (SDGs) (Sdgs, n.d.) and the Paris Agreement on climate change (EC, n.d.; Kobayashi et al., 2019).

The EU's commitment to sustainable development is evident in its policy frameworks, such as the European Green Deal (Fetting, 2020) and the Circular Economy Action Plan (Bürgin, 2020).

The European Green Deal, launched in 2019 (Fetting, 2020), is a comprehensive roadmap that aims to transform the EU into a climate-neutral and sustainable economy by 2050. It sets ambitious targets for reducing greenhouse gas emissions, promoting renewable energy, protecting biodiversity, and ensuring a just transition for all stakeholders.

Moreover, the Circular Economy Action Plan focuses on decoupling economic growth from resource consumption and waste generation. By promoting circular practices, such as recycling, reuse, and product design for longevity, the EU aims to create a more resource-efficient and less wasteful society. These policy frameworks exemplify the EU's commitment to integrating sustainability into all aspects of its decision-making processes.

The EU's special role in promoting sustainable development extends beyond its borders. Through international partnerships, such as the Partnership Agreement with Africa, the EU supports sustainable development efforts in other regions. The EU also contributes significantly to global climate finance, assisting developing countries in their transition towards low-carbon and climate-resilient economies.

Sustainable development stands as a cornerstone of the European Union's agenda, reflecting its dedication to creating a prosperous, inclusive, and environmentally conscious society. Through comprehensive policy frameworks, initiatives, and international cooperation, the EU aims to lead the global community toward a sustainable future. By embracing sustainable practices, the EU sets an example for other nations and reinforces its position as a global leader in sustainability. The subsequent sections of this paper will delve deeper into specific aspects of sustainable development within the EU and examine the transformative initiatives driving this paradigm shift.

1.2 The role of anaerobic treatment in sustainable development

In the pursuit of sustainable development, the management of waste and wastewater plays a crucial role in minimizing environmental impacts and promoting resource efficiency. Anaerobic treatment, a biological process that occurs in the absence of oxygen, has gained recognition as an effective and sustainable method for treating various types of organic waste and wastewater. Sustainable biogas production technologies are that technologies, which can provide biogas production from waste (not from useful products), and characterized by high performance of destruction, with obtaining of high quality of biogas and biofertilizer, being maximally environment-friendly (Shapovalov, Usenko, et al., 2022; S. Zhadan et al., 2023) that means that it could be sustainable approach.

Renewable Energy Production. One of the key benefits of anaerobic treatment is its ability to generate renewable energy in the form of biogas. During the anaerobic digestion process, microorganisms break down organic matter, such as sewage sludge, agricultural waste, and organic residues, producing biogas primarily composed of methane and carbon dioxide. Methane, a potent greenhouse gas, can be captured and utilized as a valuable energy source. Biogas can be combusted to generate heat and electricity, reducing the reliance on fossil fuels and contributing to the transition towards a low-carbon economy. The utilization of biogas not only reduces greenhouse gas emissions but also provides a sustainable energy solution, thereby promoting sustainable development.

Greenhouse Gas Mitigation. Anaerobic treatment plays a significant role in mitigating greenhouse gas emissions, particularly methane, which has a significantly higher global warming potential than carbon dioxide. By capturing methane produced during anaerobic digestion, the process prevents its release into the atmosphere, thus reducing the overall carbon footprint. Moreover, anaerobic treatment facilitates the conversion of methane into carbon dioxide, which has a lower global warming potential, further minimizing the environmental impact. The implementation of anaerobic treatment systems, particularly in sectors such as agriculture, food processing, and wastewater treatment, presents a viable strategy for greenhouse gas mitigation, supporting climate change mitigation goals and sustainable development objectives.

Resource Recovery. Anaerobic treatment also enables the recovery of valuable resources from organic waste and wastewater. The byproduct of anaerobic digestion, known as digestate, is a nutrient-rich material that can be utilized as a biofertilizer. This digestate, when properly treated and processed, can be safely applied to agricultural lands, enhancing soil fertility and reducing the need for synthetic fertilizers. By recovering nutrients from organic waste through anaerobic treatment, the reliance on non-renewable resources, such as phosphorus and nitrogen, can be reduced, contributing to resource conservation and sustainable agricultural practices. The recovery of resources from waste streams not only reduces environmental pollution but also creates economic opportunities and promotes a circular economy.

Anaerobic treatment plays a vital role in ensuring sustainable development through its contributions to renewable energy production, greenhouse gas mitigation, and resource recovery. By harnessing the potential of anaerobic digestion, organic waste and wastewater can be transformed into valuable resources, minimizing environmental impacts, and promoting resource efficiency. The adoption and expansion of anaerobic treatment systems in various sectors hold great promise for achieving sustainability goals, both at the local and global levels. Future research and technological advancements in anaerobic treatment processes will further enhance its effectiveness and contribute to the realization of a more sustainable and circular economy.

Therefore, it is important to provide development of anaerobic treatment technologies to ensure sustainable development. It is important to ensure high efficiency of anaerobic treatment. To provide this, it is important to analyze the characteristics of biogas plants to understand the state and requirements for optimization to ensure sustainability. The optimization of technologies requirement was proven before and specially for complex to treatment substrates (Shapovalov et al., 2020). **This paper aims** analyzing of the current state of anaerobic technologies in Ukraine and define the potential of its development during European integration.

2. Methods

Data set generation. We collected data related to biogas plants from open sources. It was structured in form of Google Sheets by specific criteria related to biogas plants. We analyzed the data on official web pages of companies such as MHP (Ukrainian poultry company) (MHP, n.d.) and analysis's of NGOs (Geletukha et al., 2022; Matveev, 2012; UABIO, n.d.) and government institutions (Derzhenerhoefektyvnosti, 2019) that provided data accumulation and processing. We also accompanied the data with geodata of location of such biogas plants. To ensure the same metric type, we have provided calculations.

Specific criteria. The specific criteria were «Main substrate», «Cosubstrate 1», «Cosubstrate 2», «Cosubstrate 3», «Cosubstrate 4», «Ratio of main substrate to cosubstrate, %», «Moisture, %», «Volume (total, all reactors), m^3», «Number of biogas plants», «Substrate amount, t», «Productivity, m^3 of biogas/ day», «Energy production, MW», «Methane output, m^3/m^3», «Year of implementation», «TYPE of reactors», «Biogas plant manufacturers», «Owner», «Features» and «Location».

Data analysis. We used Google Maps to visualize location of the biogas plants. To provide data analysis and define main trends, we used Pvot tables in Google sheets. We discuss the potential of biogas plants development based on the Eurostat data related to biogas plants and energetic.

3. Results

3.1. Main characteristic of biogas plants

It is important to define essential characteristics used to analyze biogas plants. We used to analyze Plant Capacity that denotes the maximum biogas production capacity, typically measured in megawatts (MW). This characteristic provides insights into the potential energy output of the plant. In addition, Plant Efficiency is important as it assesses the overall efficiency of biogas production and utilization, taking into account energy conversion and resource recovery. It helps evaluate the effectiveness of the plant in achieving sustainable energy production and waste management.

Feedstock description is important to define the type of organic material used as feedstock, which can include agricultural residues, manure, or other organic waste. Understanding the feedstock used helps evaluate the sustainability and resource availability of the biogas plant.

Biogas plants could use different digestion technologies. This category describes the specific anaerobic digestion technology employed in the plant, such as mesophilic or thermophilic digestion, or the practice of co-digestion. This characteristic influences the efficiency and operational parameters of the biogas plant. We described the biogas utilization purpose whether it is for electricity generation, heat production, or upgrading to biomethane for injection into the natural gas grid. Understanding the end use of the biogas aids in assessing its value and potential contribution to the energy mix. Currently there is a huge problem with a digestate Management. This characteristic focuses on how the byproduct of anaerobic digestion, known as digestate, is managed. This can include land application as fertilizer or composting. Effective digestate management is crucial for closing nutrient loops and minimizing environmental impacts.

"Operational Status" indicates the current status of the biogas plant, whether it is in the planning, construction, or operational phase. This characteristic provides insights into the stage of development and potential for future contributions.

Lastly, the analysis related to environmental impact may provide environmental benefits and impacts associated with the biogas plant, including greenhouse gas emissions reduction and waste management. This helps evaluate the plant's contribution to sustainability goals and environmental protection.

The main features of biogas plants are shown int the table. This table provides a comprehensive summary of the characteristics used to analyze the amount and features of biogas plants. By considering these characteristics, stakeholders can assess the performance, efficiency, and environmental impact of biogas plants, facilitating informed decision-making and promoting sustainable energy production and waste management practices. Description of main characteristics of biogas plants is shown in Table 1.

Table 1.

Description of main characteristics of biogas plants

Characteristic	*Description*
Plant Capacity	The maximum biogas production capacity of the plant, typically measured in kilowatts (kW)
Feedstock	The type of organic material used as feedstock, such as agricultural residues or manure
Digestion Technology	The specific anaerobic digestion technology employed in the plant, e.g., mesophilic, thermophilic, or co-digestion
Biogas Utilization	The purpose and utilization of the biogas produced, e.g., electricity generation, heat production, or upgrading to biomethane for injection into the natural gas grid
Digestate Management	The management approach for the digestate byproduct, such as land application or composting
Plant Efficiency	The overall efficiency of biogas production and utilization in terms of energy conversion and resource recovery
Operational Status	The current operational status of the biogas plant, whether it is in planning, construction, or operational phase
Location	The geographical location of the biogas plant, which can provide insights into regional distribution and potential
Funding Sources	The sources of financial support for the biogas plant, including public funding, private investments, or international cooperation
Environmental Impact	The environmental benefits and impacts associated with the biogas plant, such as greenhouse gas emissions reduction and waste management

3.2. Current state of the biogas development in Ukraine

Today, the data in a systematical view related to the amount and characteristics of biogas plants do not exist. Some analysis is provided by the NGO “Bioenergy Association of Ukraine" (UABIO, n.d.), a member of the Board of the European Bioenergy Association. However, it does not cover the importance of technologists’ aspects.

According to our data, as of 2018, more than 50 facilities producing biogas were operating in Ukraine (figure), of which 33 operated on organic waste. Taking to account the method used to collect data that provides the possibility to collect such data, but it does not provide the exact data for all biogas plants as each source provides data in individual structure and fullness. Therefore, the number of values will be additionally noted to provide the possibility to justify the relevance of the data. Generally, there is data related declared 27[9] biogas plants that operate on industrial waste and we will provide additional data on the number of each value that it was able to consider. In data is in line with data of NGO “Bioenergy Association of Ukraine" (UABIO, n.d.) and Government Energy Efficiency Agency where number of biogas plants that processing industrial waste was similar. According to it, 28 stations are designed for the production of biogas from agricultural raw materials and at 9 stations, biogas is produced as a result of anaerobic treatment of industrial wastewater (UABIO, n.d.). According to Government Energy Efficiency Agency (Derzhenerhoefektyvnosti, 2019).

[9] We took additional information about biogas plants form informational sources like https://zaxid.net/vichna_energiya_z_vidhodiv_n1507364 , https://mhp.com.ua/uk/prat-oril-lider, https://uabio.org/wp-content/uploads/2012/11/matveev.pdf, https://ecolog-ua.com/news/na-vinnychchyni-zapustyly-naybilshiy-v-sviti-biogazovyy-kompleks

Substrate. Ukrainian biogas plants utilize diverse feedstocks, including agricultural residues, such as crop residues and manure from livestock farming, as well as organic waste from food processing and municipal sources. The choice of feedstock is influenced by the local agricultural and industrial sectors, as well as regional waste management practices. There is data related to the substrate that biogas plants use.

The analysis of the dataset comprising 27 samples revealed variations in substrate utilization for biogas production. The distribution across biogas plants was as follows: beet pulp (2 occurrences), cattle manure (3 occurrences), chicken manure or litter (5 occurrences), dairy farm effluents (1 occurrence), effluents of yeast production (1 occurrence), manure drains (1 occurrence), pig manure (4 occurrences), and wastewater (1 occurrence). The distribution of substrates across different biogas plants provides insights into their prevalence and suitability for biogas production. Chicken manure or litter emerges as the most frequently utilized substrate, indicating its abundance and favorable biogas production potential. Cattle manure and pig manure also demonstrate notable utilization, reflecting their availability and efficiency in biogas generation. Beet pulp, dairy farm effluents, effluents of yeast production, manure drains, and wastewater are employed to a lesser extent but showcase their potential as alternative substrates for biogas production. The pie diagram of the substrates used in Ukraine to produces biogas is shown in Figure 1.

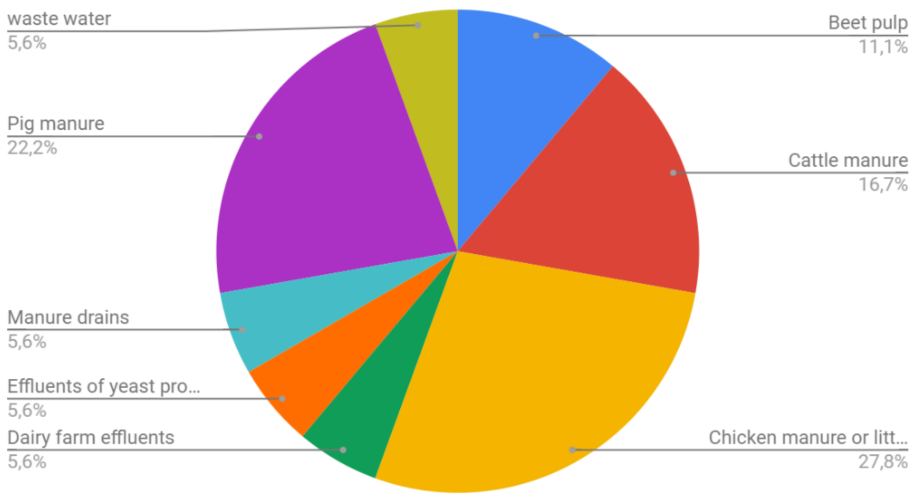

Fig. 1. The pie diagram of the substrates used in Ukraine to produces biogas

Co-substrates usage. Analysis of the dataset consisting of 15 recorded instances of cosubstrate usage revealed that generally, 10 different biogas plants utilized cosubstrates (there was no data for the other 17 biogas plants). Some of these biogas plants employed multiple cosubstrates. The data is given in relation to usage of cosubstrate (not in related to biogas plants). The distribution of cosubstrates across the different biogas plants was as follows: beet pulp (1 occurrence), CIP waste (1 occurrence), corn silage (3 occurrences), fat waste from animal slaughter (1 occurrence), flotation sludge from treatment plants (1 occurrence), green biomass (1 occurrence), pig manure (1 occurrence), silage (3 occurrences), sorghum (1 occurrence), wastewater (1 occurrence), and wastewater from washing poultry houses (1 occurrence). Therefore, the most common cosubstrates are silage (and its different types). The distribution of cosubstrates provides insights into their prevalence and effectiveness in biogas production. Cosubstrates such as corn silage, silage, and sorghum demonstrate their suitability for enhancing biogas production due to their high organic content. Other cosubstrates, including beet pulp, CIP waste, fat waste from animal slaughter, flotation sludge from treatment plants, green biomass, pig manure, wastewater, and waste water from washing poultry houses, show potential for further exploration and optimization in biogas production. The pie diagram of the cosubstrates used in Ukraine to produces biogas is shown in Figure 2.

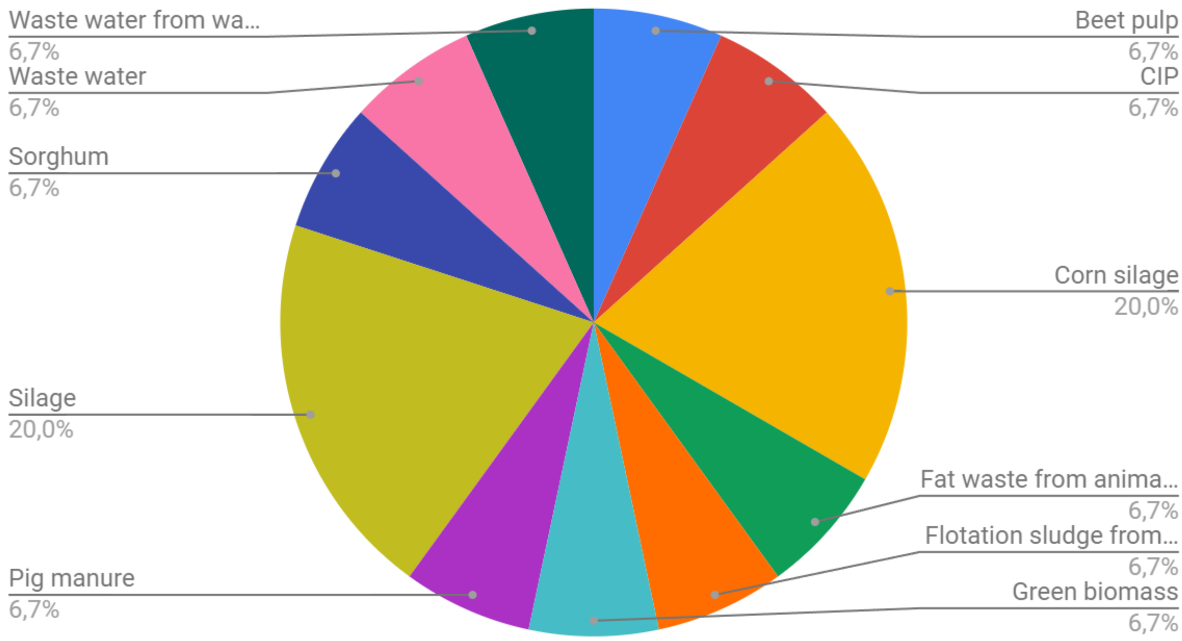

Fig. 2. The pie diagram of the substrates used in Ukraine to produces biogas

Plant Capacity. Biogas plants in Ukraine exhibit a wide range of capacities, varying from small-scale installations with capacities as low as a few kilowatts to large-scale facilities capable of generating several megawatts of biogas. The capacity of these plants is influenced by factors such as the availability of organic waste feedstock, financial resources, and the intended energy utilization.

The table provides valuable insights into the performance and capacities of the analyzed biogas plants. The range of the amount of treated substrate varies widely, from 20 tons per day to 6000 tons per day, indicating significant differences in feedstock availability and processing capabilities among the plants.

Biogas production ranges from 650 to 150,000 m^3/day, with an average of 42,483 m^3/day. This indicates diverse biogas production capacities among the studied plants, influenced by factors such as feedstock composition and plant design.

Methane production, although represented by only two data points, shows a narrow range, indicating relatively consistent methane production levels within these specific plants.

The power generated by the plants varies significantly, with a minimum of 0.13 MWt and a maximum of 32.5 MWt. The average power production is 12,94 MWt, suggesting the substantial energy generation potential of biogas plants. This data is line with data of Government Agency of

Energy Efficiency where general power generated by biogas plants is 70 MWt (Derzhenerhoefektyvnosti, 2019)

Electric power and heat production follow similar patterns, exhibiting a wide range of values. The year of construction data indicates that biogas plants have been constructed over a span of several years, from 2000 to 2016, demonstrating the continuous development and implementation of biogas technology.

It is important to note that the counts of the available data points vary for each parameter. The "Amount of treated substrate," "Biogas production," "Power," and "Year of construction" have a count of 16, 8, 13, and 5 respectively, indicating the number of values that were available in the dataset. The limited count in some parameters reflects the need for comprehensive and standardized data collection practices within the biogas industry.

The results provide valuable insights into the capacities, energy production, and temporal aspects of the studied biogas plants. Further analysis and research on these parameters, along with an increased count of available data points, will contribute to optimizing biogas plant design, operation, and overall efficiency. The main characteristics of productivity of biogas plants in Ukraine is shown in Table 2.

Table 2.

The main characteristics of productivity of biogas plants in Ukraine

Value name	*Amount of treated substrate ,t per day*	*Biogas production, m3/day*	*Methane production, m3/day*	*Power, Mt*	*Electric power, Mt*	*Heat production, Mt*	*Year of construction*
Min	20	650	30	0,13	0,16	0,32	2000
Max	6000	150000	35	32,5	16,00	320,00	2016
Avarage	592	42483	32	12,935	3,51	67,63	2010
Count	16	8	2	14	4	4	5

The analysis of the dataset revealed the following distribution based on the manufacturer: "Ecotank" (1 biogas plant), Bigadan Ltd (Denmark) (1 biogas plant), BTG (Holland) in collaboration with "NTC Biomass" (Ukraine) (1 biogas plant), Byteko Biogas (2 biogas plants), Holland (1 biogas plant), Integro (1 biogas plant), NVT (Holland) in collaboration with "ukrletfarmin" (1 biogas plant), Poldanor S.A (1 biogas plant), Wawatech (Poland) (1 biogas plant), and ZORG (4 biogas plants). Additionally, 16 biogas plants had no specific manufacturer data. The distribution of biogas plants based on the manufacturer provides insights into the industry landscape. While some manufacturers, such as "Ecotank," Bigadan Ltd (Denmark), BTG (Holland) in collaboration with "NTC Biomass" (Ukraine), Byteko Biogas, and ZORG, are associated with multiple biogas plants, others have a single representation. The presence of various manufacturers indicates the diversity in biogas plant manufacturing and suggests that different manufacturers may employ different technologies and approaches in their biogas plant designs. The data also highlight a significant number of biogas plants (16) with no specific manufacturer data, emphasizing the need for improved documentation and reporting practices within the biogas industry. The pie diagram of the manufactures of biogas plants used in Ukraine is shown in Figure 3.

There were no data (24 biogas plants), 2000 (1 biogas plant), 2012 (1 biogas plant), 2013 (2 biogas plants), and 2016 (1 biogas plant) by years of construction. The distribution of biogas plants based on the year of construction provides insights into the temporal landscape of biogas plant development. The majority of the analyzed biogas plants (24) lacked specific data regarding their year of construction, highlighting a significant gap in information. This emphasizes the need for improved data collection and documentation practices within the biogas industry. However, the available data suggests that biogas plant construction has occurred across various time periods, with one plant constructed in 2000, one in 2012, two in 2013, and one in 2016.

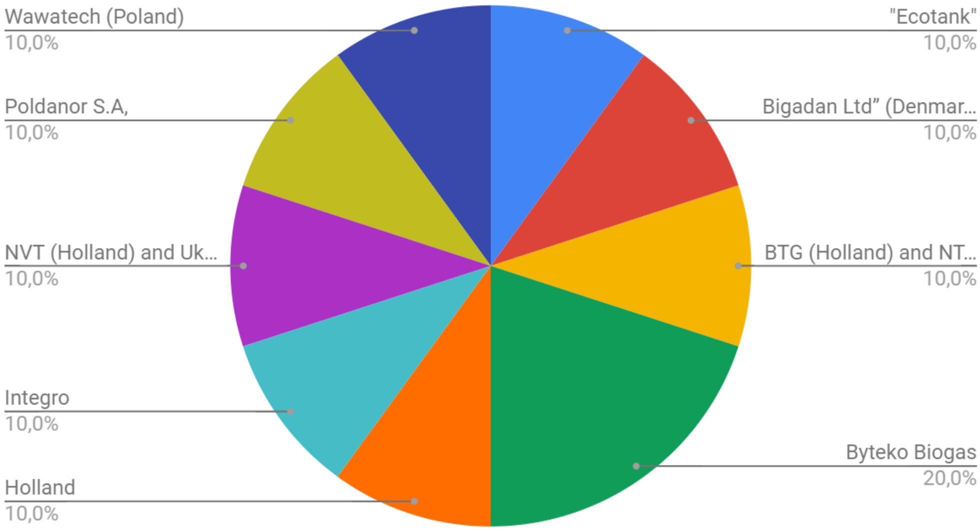

Fig 3. The pie diagram of the manufactures of biogas plants used in Ukraine

The presence of biogas plants constructed in different years indicates a range of development stages within the industry. It suggests that biogas plant construction has been ongoing over the years, with sporadic progress observed in certain time periods. The limited number of recorded biogas plants with known construction years indicates the necessity for comprehensive and standardized data collection methods to track the progress and evolution of biogas plant construction. The diagram of the years of construction of biogas plants in Ukraine is shown in Fig. 4.

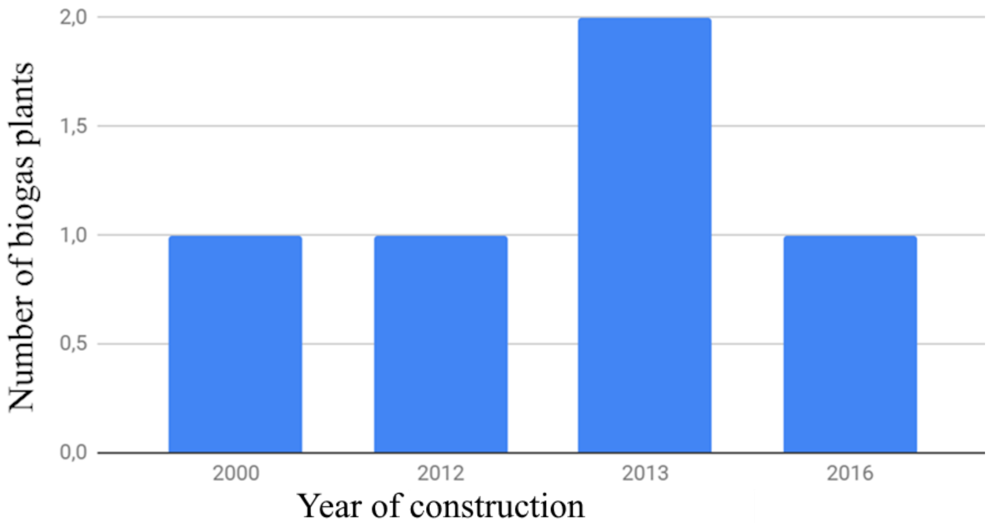

Fig. 4. The diagram of the years of construction of biogas plants in Ukraine

Digestion Technology. Various anaerobic digestion technologies are employed in Ukrainian biogas plants, including both mesophilic and thermophilic digestion processes. Additionally, co-digestion is increasingly being adopted, allowing the co-processing of multiple feedstocks to optimize biogas production. These technologies contribute to efficient biogas production and resource recovery.

Biogas Utilization. Biogas produced in Ukrainian plants is primarily utilized for electricity generation and heat production. Combined Heat and Power (CHP) systems are commonly employed to maximize energy efficiency by utilizing the heat generated during electricity production. Some plants also upgrade biogas to biomethane for injection into the natural gas grid, enabling wider use and distribution.

Digestate Management. Digestate management practices in Ukraine vary, with some biogas plants utilizing the digestate as a valuable biofertilizer through land application. Others may opt for composting or further treatment to produce high-quality organic fertilizers. The choice of digestate management approach depends on the specific requirements of the agricultural sector and environmental regulations.

Plant Efficiency. The efficiency of biogas plants in Ukraine is a key focus to maximize energy output and resource recovery. Technological advancements, including improved digester designs and process optimization, enhance plant efficiency and economic viability. Ongoing research and development efforts aim to improve further the overall efficiency of biogas production in the country.

Operational Status. Ukraine has many operational biogas plants, with many already contributing to the country's renewable energy generation. However, there are also biogas projects in various stages of planning and construction, indicating a positive outlook for future growth and development in the sector.

Location. Biogas plants in Ukraine are distributed across the country, with concentrations in regions where agricultural and industrial activities generate significant organic waste streams. Proximity to feedstock sources and potential energy consumers is crucial in determining plant locations. The distribution of biogas plants in Ukraine is shown in Fig. 5.

Funding Sources. The funding of biogas projects in Ukraine relies on a mix of sources, including public grants, private investments, and international cooperation. Government support programs and incentives, as well as financial institutions and project partnerships, play a vital role in providing the necessary funding for biogas plant development and operation.

Environmental Impact. Biogas plants in Ukraine make significant contributions to environmental sustainability. By utilizing organic waste, they help reduce methane emissions, mitigate greenhouse gas emissions, and promote circular economy principles. Moreover, the use of digestate as a biofertilizer supports sustainable agriculture practices and reduces dependence on synthetic fertilizers.

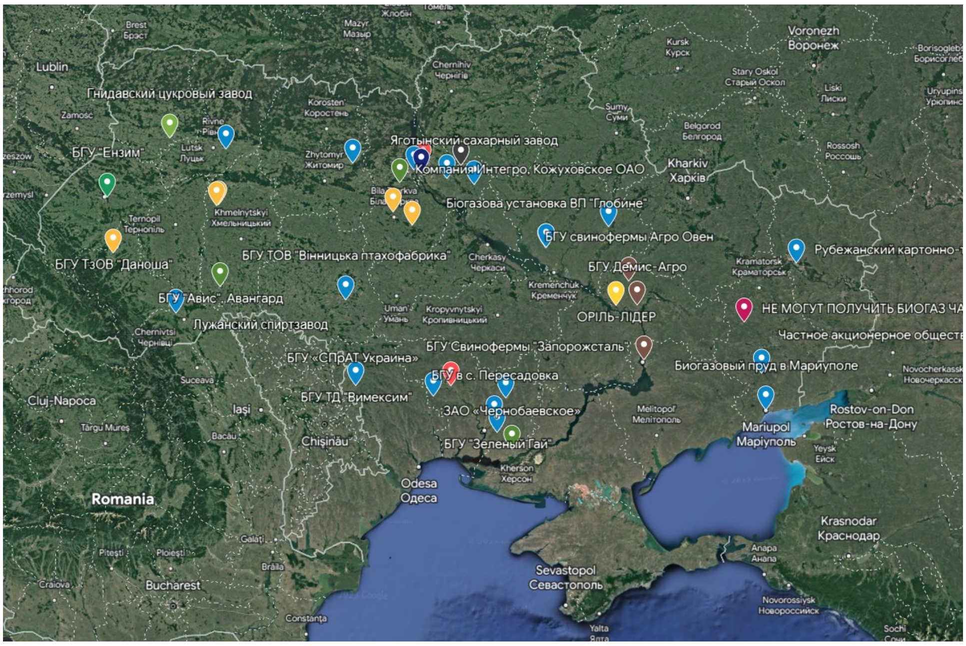

Fig. 5. The distribution of biogas plants in Ukraine

In summary, the current state of biogas plants in Ukraine reflects a diverse landscape with varying capacities, feedstocks, digestion technologies, and utilization methods. The sector shows promising growth potential, with operational plants significantly contributing to renewable energy generation and waste management. Continued efforts in improving plant efficiency, expanding operational capacities, and advancing sustainable practices will further strengthen the biogas sector in Ukraine.

3.3. The Potential Development of Biogas Plants in Ukraine during European Integration

As Ukraine pursues European integration, the development of biogas plants holds significant potential for contributing to sustainable energy production and waste management. With 50 existing biogas plants, including 33 located on factories that treat their waste, Ukraine has already taken steps towards harnessing the benefits of biogas. In this context, the country's vast territory, agricultural orientation, and the tendencies observed in European countries provide a solid foundation for the future growth and expansion of biogas production.

Agricultural Orientation and Organic Waste Resources. Ukraine's agricultural sector, with its vast arable land and diverse livestock farming, provides ample organic waste resources suitable for biogas production. The abundance of agricultural residues, such as crop residues and livestock manure, can be effectively utilized as feedstock for biogas plants. This agricultural orientation aligns with the core requirements for successful biogas development, as organic waste is readily available and can be efficiently converted into renewable energy.

European Integration and Transfer of Best Practices. The process of European integration offers an opportunity for Ukraine to adopt best practices from European countries with well-established biogas sectors. Countries like Germany, Denmark, and Austria have made significant strides in biogas development, demonstrating successful models of policy frameworks, technological advancements, and business models. By leveraging these experiences and knowledge-sharing, Ukraine can accelerate the development of its biogas sector, benefiting from the lessons learned in European countries.

Supportive Policy Framework. The integration process provides an impetus for Ukraine to align its policies and regulations with European standards and directives. The European Union (EU) has set ambitious renewable energy targets and implemented support mechanisms, such as feed-in tariffs and renewable energy subsidies, to encourage the growth of biogas and other renewable energy sources. Ukraine can draw inspiration from these policies to establish its own supportive framework, including incentives for biogas plant construction, feed-in tariffs, and favorable regulations to attract investments.

Regional Collaboration and Funding Opportunities. European integration also facilitates regional collaboration and access to funding opportunities. Ukraine can tap into EU-funded programs, such as the European Structural and Investment Funds, to support the development of biogas projects. Additionally, partnerships with European institutions, research organizations, and industry associations can promote knowledge exchange, technology transfer, and capacity building in the biogas sector.

Environmental and Energy Security Benefits. The development of biogas plants aligns with Ukraine's goals for environmental sustainability and energy security. Biogas production from organic waste helps reduce greenhouse gas emissions, mitigates climate change, and contributes to a circular economy by turning waste into a valuable resource. Furthermore, biogas can provide a stable and decentralized energy source, reducing dependence on imported fossil fuels and enhancing energy security within the country.

The integration process and the presence of 50 biogas plants in Ukraine, particularly those treating waste from factories, demonstrate the existing potential for biogas development. Ukraine's agricultural orientation, abundant organic waste resources, and the tendencies observed in European countries provide a favorable environment for the expansion of biogas production. By adopting supportive policies, leveraging European best practices, and fostering regional collaboration, Ukraine can unlock the full potential of its biogas sector, contributing to sustainable energy production, waste management, and the country's broader European integration goals.

It worth note that we European integration will positively effect on the providing innovation as it promotes the policy of using science results and best available practice. As, it was noted before, anaerobic treatment could be not suitable depending on technology and it is required to be optimized (Shapovalov et al., 2021; Shapovalov, Usenko, et al., 2022). Therefore, innovations like production of ammonia from animal waste (S. O. Zhadan et al., 2021).

3.4. The Impact of European Integration on Electricity Prices and the Potential Increase in Biogas Plants in Ukraine

The process of European integration has the potential to bring about significant changes in various sectors, including the energy market. This section focuses on the potential impact of European integration on electricity prices in Ukraine and explores the subsequent increase in the number of biogas plants. The analysis aims to shed light on the factors contributing to the price disparity between the European Union (EU) and Ukraine in terms of electricity and energy sources. Furthermore, it seeks to understand how this disparity may drive the expansion of biogas plants in Ukraine.

European Integration and Electricity Prices. The European Union has been working towards creating a unified and integrated electricity market across member states. This integration aims to promote competition, enhance energy security, and achieve a more sustainable energy system. As a result of this process, the EU has implemented various policies and regulations to harmonize electricity markets and facilitate cross-border energy trade. However, the integration process has also led to higher costs in the EU compared to Ukraine in terms of electricity and energy sources.

Price Disparity in Electricity Costs. The difference in electricity costs between the EU and Ukraine can be attributed to several factors. Firstly, the EU has made significant investments in renewable energy sources, such as wind and solar power, which has driven up electricity prices. These investments have been supported by various subsidies and incentives aimed at promoting green energy production. In contrast, Ukraine relies heavily on conventional energy sources, which tend to have lower production costs. Secondly, the EU's stringent environmental regulations and emission reduction targets have necessitated costly upgrades and improvements in energy infrastructure. These additional expenses are ultimately passed on to consumers in the form of higher electricity prices. In contrast, Ukraine's energy infrastructure may not be subject to the same level of regulatory requirements, resulting in relatively lower production costs.

Potential Effects of European Integration on Ukrainian Electricity Prices. The process of European integration is likely to have a direct impact on electricity prices in Ukraine. As Ukraine seeks closer economic and energy ties with the EU, it may be compelled to align its energy policies and standards with those of the Union. This alignment could result in the adoption of stricter environmental regulations and increased investments in renewable energy sources. Consequently, Ukrainian electricity prices may experience an upward trend to match the EU's higher costs.

Increase in Biogas Plants as a Response to Higher Electricity Prices. The anticipated increase in electricity prices due to European integration may create incentives for Ukraine to explore alternative energy sources. One such potential source is biogas, which is produced through the anaerobic digestion of organic materials. Biogas plants can utilize various feedstocks, including agricultural waste, organic waste from municipalities, and dedicated energy crops. These plants can contribute to a more sustainable energy mix and reduce reliance on conventional energy sources.

Given the higher electricity prices in the EU, Ukrainian entrepreneurs and investors may find it economically viable to establish biogas plants to capitalize on the price disparity. The production of biogas not only provides an alternative energy source but also offers opportunities for waste management and agricultural sector development. Therefore, an increase in biogas plants in Ukraine could be a potential response to the rising electricity prices resulting from European integration.

Conclusion. The analysis highlights the importance of sustainable development and its special role in the European Union (EU). The EU has recognized the significance of sustainable development in achieving long-term social, economic, and environmental goals. By integrating sustainable development principles into its policies and practices, the EU aims to create a harmonious balance between economic growth, social well-being, and environmental protection.

The discussion then delves into the role of anaerobic treatment in ensuring sustainable development, particularly in the context of biogas production. Anaerobic treatment, a key component of biogas plants, enables the efficient conversion of organic waste into renewable biogas while minimizing environmental impacts. It provides a sustainable solution for waste management, reducing landfill usage and methane emissions. Moreover, biogas generated from anaerobic treatment offers a renewable energy source that can contribute to energy diversification, reduce greenhouse gas emissions, and enhance energy security.

Furthermore, the text emphasizes the need to consider the characteristics used to analyze the amount and features of biogas plants. These characteristics encompass plant capacity, feedstock type, digestion technology, biogas utilization, digestate management, plant efficiency, operational status, location, funding sources, and environmental impact. By understanding and evaluating these characteristics, stakeholders can make informed decisions regarding biogas plant development, operation, and their overall contribution to sustainable development goals.

Regarding the current state of biogas plants in Ukraine, the provided criteria shed light on the diversity and potential of the sector. With 50 existing biogas plants, including those located on factories treating their waste, Ukraine demonstrates progress in harnessing biogas benefits. However, there is room for further growth and development. Ukraine's agricultural orientation, abundant organic waste resources, and the tendencies observed in European countries provide a solid foundation for expanding biogas production. By aligning policies with European standards, collaborating with regional partners, accessing funding opportunities, and learning from European best practices, Ukraine can unlock the full potential of its biogas sector, contributing to sustainable energy production, waste management, and its broader European integration goals.

Overall, sustainable development and the development of biogas plants are integral components of a greener and more sustainable future. By embracing sustainable practices and maximizing the potential of biogas production, countries can foster economic growth, environmental protection, and social well-being in line with the objectives of the EU and global sustainability goals

The potential impact of European integration on electricity prices in Ukraine necessitates a comprehensive analysis of the factors driving price disparities and the subsequent response regarding alternative energy sources. Exploring biogas plants as a potential solution highlights the importance of promoting sustainable energy development and reducing dependence on conventional energy sources. By understanding the implications of European integration on electricity prices, policymakers and stakeholders can make informed decisions to shape the energy landscape in Ukraine.

Acknowledgment

Supported by the Erasmus+ Projects Jean Monnet EU Centre for the Circular and Green Economy (620627-EPP-1-2020-1-UA-EPPJMO-CoE) and Jean Monnet Support to Associations (611278-EPP-1-2019-1-UA-EPPJMO-SUPPA).

The authors are grateful to the Armed Forces of Ukraine for the opportunity to perform this work.

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