

Biogas Market Research in EU Countries

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Abstract—Recently, the development of renewable energy is considered one of the important criteria for energy security in the world. The article examines the potential and possibilities of biogas production in the EU countries due to the available biological waste and agricultural raw materials. The state of technology and development of the biogas market, the dynamics of production and conversion of biogas into electricity are characterized. It is determined that an important reason for the need to increase the use of renewable energy sources is the uncontrolled growth of household and industrial waste, which leads to environmental pollution and requires high costs for disposal. It is studied that modern methods of waste management through the production of biogas and biomethane can not only alleviate the global energy crisis, but also effectively protect the ecology of the environment. It is emphasized that biogas will play a key role in achieving Europe's long-term goals for energy security and mitigating the effects of climate change, as part of a promising and balanced complex of renewable energy sources. It has been proven that the production and use of biogas has a number of justified and confirmed by world practice advantages, since the availability of a wide range of necessary raw materials for the production of biogas and biomethane allows the construction of biogas plants in areas of concentration of agricultural production and technologically related industries. Special attention is paid to the role played by biogas and biomethane in the fight against climate change and the development of sustainable technologies, since sustainable development is the basis of the well-being of EU countries, it is respect for the

environment in which the population of European countries lives and their future generations will live. This ideology underlies the development of the biogas industry in Europe. Based on statistical data of past periods and regression analysis, a calculation of the forecast volumes of energy production from biogas and biomethane in EU countries was made using a trend model and Excel spreadsheet editor. Considering the development perspective, it is determined that the transition to sustainable energy remains the most important for the EU economy, where the biogas sector can already provide a competitive and sustainable alternative to imported fossil gas thanks to domestic production.

Keywords— *renewable energy, renewable energy sources, biogas, biomethane, biogas plant, energy crisis, sustainable development.*

I. INTRODUCTION

One of the priority vectors for the development of renewable energy is the production of biogas from organic residues. In achieving Europe's long-term goals for energy security and mitigating the effects of climate change, biogas will play a key role as part of a promising and balanced set of renewable energy sources. Sustainable biogas production in Europe is of strategic importance given the growing dependence on gas imports. A study of the materials of the European Biogas Association showed that biogas and biomethane are becoming increasingly

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important energy sources in the EU energy mix, and their production has been increasing over the decade. In this study, we were guided by the need to study the European experience in shaping waste management policies and biogas and biomethane production in the context of effective environmental protection and the transition to sustainable energy. That is why the production and use of biogas and biomethane in the EU must comply with a set of sustainability criteria that were proclaimed by the Renewable Energy Directive (RED II) in 2018 [1].

The purpose of the scientific research is to study the experience of developing sustainable technologies in Europe in the context of the ideology that underlies the development of the biogas industry in EU countries.

Recently, renewable energy sources have become one of the important criteria for energy security in the world. An important reason for the increase in the use of renewable energy sources is the uncontrolled growth of household and industrial waste, which leads to environmental pollution and requires high costs for disposal. If they are not treated, they lead to uncontrolled methane emissions. Therefore, the design of biogas plants and installations can contribute to their reduction. Anaerobic digestion (AD) plants are a controlled environment where these emissions are converted into renewable gas. Currently, attention to this energy source and scientific developments in the biogas field are increasing [2].

One of the promising types of raw materials for biogas that does not compete with food and feed crops is cover crops grown between two annual food crops. According to EBA, more than a quarter of the potential for biomethane production can be provided by using cover crops for this purpose. Using the harvested mass of such crops for biogas, with the subsequent return of the digestate to the same fields, allows to significantly expand the potential for attracting arable land resources to the energy sector without harming agricultural production [3]. The use of high-quality compost or digestate to replace mineral nitrogen, phosphorus and potassium fertilizers reduces the impact on the environment as a result of avoiding the production of primary mineral fertilizers [4]. The formation of effective methods of managing agricultural waste and converting it into biomass energy available to people can effectively protect the environment and at the same time make a significant contribution to reducing carbon emissions [5].

II. MATERIALS AND METHODS

The authors of the article have been conducting scientific research for a long time in the field of optimizing bioeconomic processes and the efficient use of renewable energy sources. In particular, a significant portion of the research has been carried out in the educational and scientific laboratory "DAK GPS" of the Higher Education Institution "Podillia State University" [6-9], which has provided a solid foundation for further work in this direction.

The study employed a comprehensive set of scientific methods to ensure an in-depth analysis of the problem.

Theoretical analysis and synthesis of literary sources made it possible to determine the main approaches to studying the issue and to establish the theoretical foundation of the research. Statistical data processing methods ensured the accuracy and reliability of the obtained results, while comparative analysis helped identify patterns and differences between the studied phenomena. Modeling and forecasting methods were used to construct possible development scenarios and assess their consequences. This integrated approach allowed for well-founded conclusions and recommendations.

III. RESULTS AND DISCUSSION

The production and use of biogas has a number of justified and confirmed by world practice advantages, since a wide range of necessary raw materials for biogas production allows building biogas plants in areas of concentration of agricultural production and technologically related industries [10]. Biogas will play a key role in achieving Europe's long-term goals of energy security and climate change mitigation [2]. It should be noted that an essential aspect of biogas production is the use of renewable energy sources, which are also waste. The state of technology and development of the biogas market for the period 2009-2022 is evidenced by the increase in the number of biogas plants in Europe by 2.5 times and amounts to 19491 units. (Fig. 1).

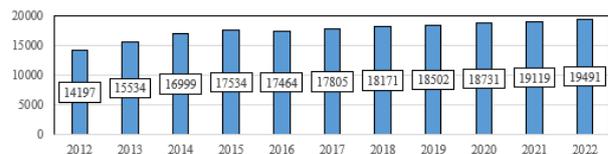


Fig. 1. Number of biogas plants in the EU, units. (Covered by the authors) [11].

Biogas production has been increasing since the 1990s. Market conditions, together with targeted policies, are stimulating the use of biogas. While combined heat and power plants run on biogas, other gas demand markets (gas utilities, industry and transport sectors) require the use of biomethane, a purified biogas with a high methane content, similar in quality to natural gas and therefore capable of replacing it [12].

That is why the production and use of biogas and biomethane in the EU must comply with a set of sustainability criteria, which were announced by the Renewable Energy Directive (RED II) in 2018 [1].

The RED II policy has had a positive impact on the quality of the raw materials used for biogas production. Data show that since the introduction of the regulations, new biomethane plants are increasingly using waste and residues for their operations [13].

The uses of biogas are mainly directed to the production of electricity and heat. There are, however, several cases of conversion of biogas into biomethane injected into the natural gas grids or used as biofuel in vehicles. In this last direction, worthy of note are a few north-central EU countries which have implemented an effective policy to

promote the use of biomethane for public and private transport.

According to the statistical report of the Biogas professional association in 2023, data on combined biogas and biomethane production in 10 European countries in 2022 are presented, among which Germany is the leader (Fig. 2).

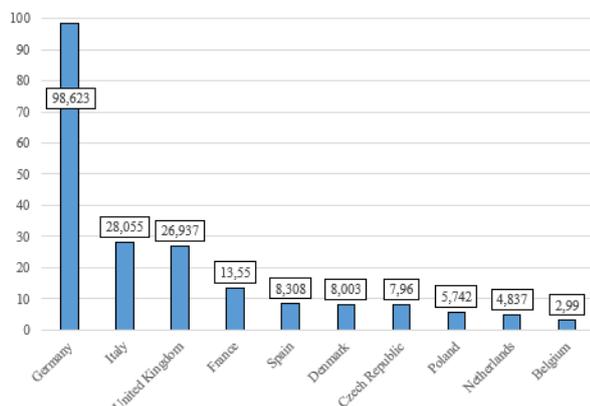


Fig. 2. Energy production in Europe, by country [11].

According to estimates, the prospects for biogas production in Europe indicate a tenfold increase in production by 2030. Currently, it is believed that biogas production is better to focus on less controversial raw materials, such as livestock manure, agricultural waste and residues, which do not compete with agricultural land used for food production. This model is advocated by Denmark, which opened its first biogas plant based on manure in 1975. After the adoption of the national “energy agreement” for 2012-2020, the country began to develop biomethane, which now accounts for about 10% of what is injected into the natural gas network. [13]. According to data from the German Biogas Association, the number of biomethane plants in Europe in 2011 was 182 units. Over an eleven-year period, their number increased to 1,323 units, or almost 7.3 times (Figure 3).

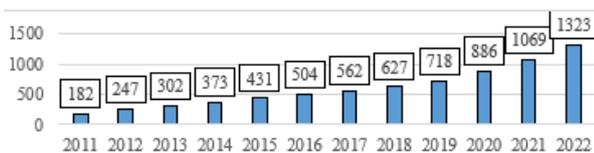


Fig. 3. Number of biomethane plants in the EU, units [7].

A report by the European Biogas Association showed that biogas and biomethane are becoming increasingly important energy sources in the EU energy mix, and their production has been increasing over the decade. In 2022, there were 1,222 biomethane plants in Europe, a 6.7-fold increase compared to 2011 (Table 1). [14].

According to the new edition of the statistical report of the European Biogas Association (EBA), biomethane production in Europe in 2022 increased by almost 20% compared to the previous year, and the combined energy

production from biogas and biomethane amounted to 21 billion cubic meters (table 2).

TABLE 1. NUMBER OF BIOMETHANE PLANTS IN THE EU [14]

| Years | Existing plants | New plants | Total |
|-------|-----------------|------------|-------|
| 2011 | 182 | 0 | 182 |
| 2012 | 182 | 61 | 243 |
| 2013 | 243 | 59 | 302 |
| 2014 | 302 | 71 | 373 |
| 2015 | 373 | 58 | 431 |
| 2016 | 431 | 73 | 504 |
| 2017 | 504 | 58 | 562 |
| 2018 | 562 | 65 | 627 |
| 2019 | 627 | 90 | 717 |
| 2020 | 717 | 166 | 883 |
| 2021 | 883 | 184 | 1067 |
| 2022 | 1067 | 155 | 1222 |

The deployment of 35 bcm of sustainable biomethane a year by 2030 proposed by the European Commission in the REPowerEU action plan, will contribute to energy security and climate change mitigation. To reach the 35 bcm target, biomethane must sustain a substantial growth until 2030. The development of the sector will additionally contribute to an integrated net-zero energy system, encompassing the energy and agroecological transitions and helping Europe embrace circular economy [16].

TABLE 2. DYNAMICS OF ENERGY PRODUCTION FROM BIOGAS AND BIOMETHANE IN THE EU BILLION M³/YEAR [15].

| Years | Energy from biogas | Energy from biomethane | Total |
|-------|--------------------|------------------------|-------|
| 2011 | 6.8 | 0.5 | 7.3 |
| 2012 | 11.0 | 0.7 | 11.7 |
| 2013 | 12.5 | 0.9 | 13.4 |
| 2014 | 13.7 | 1.0 | 14.7 |
| 2015 | 14.9 | 1.3 | 16.2 |
| 2016 | 15.3 | 1.7 | 17.0 |
| 2017 | 15.4 | 1.9 | 17.3 |
| 2018 | 15.5 | 2.1 | 17.6 |
| 2019 | 16.5 | 2.4 | 18.9 |
| 2020 | 16.6 | 3.1 | 19.6 |
| 2021 | 16.7 | 3.5 | 20.2 |
| 2022 | 16.8 | 4.2 | 21.0 |

The Head of the Renewable Energy Division of the International Energy Agency (IEA) highlighted the expected global expansion of biogas in the coming years. The realistic target of producing 35 billion cubic meters of biomethane by 2030 was also confirmed, which will be aimed at building a greener and more energy-efficient EU [17].

According to the European Biomethane Map [18], published in July 2024, Europe has reached an installed capacity of 6.4 billion cubic meters of biomethane per year, of which 81% of the capacity corresponds to plants located in the European Union and amounts to 5.2 billion cubic meters per year.

Of the 1,548 registered biomethane plants, over 80% are connected to the gas grid, with almost half of them (49%) connected to the distribution network and 14% to the transport network. This means that the biomethane sector

is making a major contribution to Europe's long-term energy security and climate mitigation goals, in line with the REPowerEU Plan.

According to a recent analysis by the European Biogas Association (EBA), €25 billion of private investment will be attracted by 2030, leading to the installation of 950 new biomethane plants [18].

The forecast for the development of the biogas industry in European countries was calculated based on statistical data from past periods using regression analysis and the Excel spreadsheet editor. Regression analysis allows you to determine the degree of relationship between variables and predict the value of a certain variable based on known values. The trend line is a geometric representation of the average values of the analyzed indicators. The resulting linear trend graphs illustrate the relationship between periods and volumes of production and the coefficient of determination (R^2). It makes it possible to assess the density of the relationship between the studied phenomena, which is determined by the quantitative value. The closer R^2 is to 1, the more precisely the relationship is determined, which reflects the relationship between the values and the tendency to positive or negative changes (Figure 4).

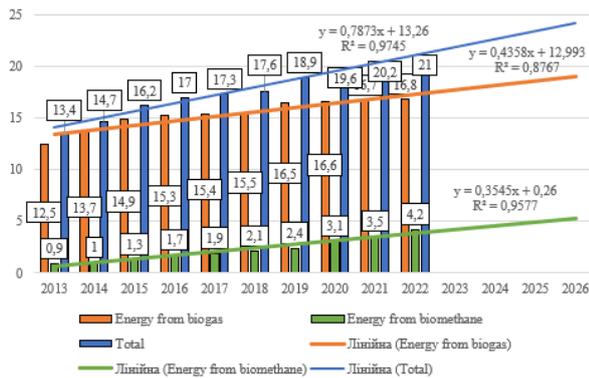


Fig. 4. Trend model for forecasting energy production from biogas and biomethane in Europe, billion m³/year

The calculations showed that for the trend line of energy production from biogas $R^2 = 0.8767$ and determines a high level of density of the relationship between the values. For the trend line of energy production from biomethane $R^2 = 0.9577$, which characterizes a significantly high degree of reliability of the relationship between the values, i.e. the linear regression equations are in good agreement with the sample data. Also, the high density of the relationship between the studied phenomena is illustrated by the trend line of the total energy production from biogas and biomethane, which confirms the obtained coefficient of determination $R^2 = 0.9745$ and predicts an increase in these indicators in the prospective period (Figure 4).

According to the regression analysis indicators, the trend line on the graph was extended beyond the available data in order to predict future values. Statistical data on energy production from biogas and biomethane for the period 2013-2022. made it possible to obtain graphs

showing the predicted values of biogas production development for 2023-2026. (Table 3).

TABLE 3. FORECAST OF DEVELOPMENT OF ENERGY PRODUCTION FROM BIOGAS AND BIOMETHANE, BILLION M³/YEAR

| Year | Energy from biogas | Energy from biomethane | Total | Linear (Energy from biogas) | Linear (Energy from biomethane) | Linear (Total) |
|------|--------------------|------------------------|-------|-----------------------------|---------------------------------|----------------|
| 2013 | 13 | 1 | 13 | 13 | 1 | 14 |
| 2014 | 14 | 1 | 15 | 14 | 1 | 15 |
| 2015 | 15 | 1 | 16 | 14 | 1 | 16 |
| 2016 | 15 | 2 | 17 | 15 | 2 | 16 |
| 2017 | 15 | 2 | 17 | 15 | 2 | 17 |
| 2018 | 16 | 2 | 18 | 16 | 2 | 18 |
| 2019 | 17 | 2 | 19 | 16 | 3 | 19 |
| 2020 | 17 | 3 | 20 | 17 | 3 | 20 |
| 2021 | 17 | 4 | 20 | 17 | 4 | 20 |
| 2022 | 17 | 4 | 21 | 17 | 4 | 21 |
| 2023 | x | x | x | 18 | 4 | 22 |
| 2024 | x | x | x | 18 | 5 | 23 |
| 2025 | x | x | x | 19 | 5 | 24 |
| 2026 | x | x | x | 19 | 5 | 24 |

Analyzing the results of the trend model of energy production from biogas and biomethane in the EU countries for 2013-2022, it should be noted that its production during this period is characterized by constant growth. The trend line showed a further growth trend until 2026. In particular, energy production from biogas will increase to 19.1 billion m³/year, energy from bioethanol will increase to 5.2 billion m³/year, which in total will be 24.3 billion m³/year. The results of the research indicate that European countries pay due attention to the development of this industry.

IV. CONCLUSIONS

Summarizing the results of the study, the following key positions in the development of biogas production in the EU countries can be identified:

- analysis of the development of the biogas industry showed that biogas plays a key role in achieving Europe's long-term goals for energy security and climate change mitigation
- highlighted a new trend to focus on biomethane production, since biomethane is a universal energy carrier and is suitable for a number of sectors of the economy, including transport, industry, energy and heat supply
- conducted studies have shown that biogas and biomethane are becoming increasingly important energy sources in the EU energy mix, and their production has been increasing over the decade.
- during the study period, a steady positive trend in the increase in biogas and biomethane production capacities was noted
- the production and use of biogas and biomethane in the EU must meet a set of sustainability criteria that were proclaimed by the Renewable Energy Directive (RED II) in 2018.

Based on the research conducted, it can be stated that the development of renewable energy and sustainable technologies is one of the priority vectors that will contribute to energy security, reduce the burden on the environment, and achieve the main goals of a resource-efficient economy.

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