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# THE SIGNIFICANCE OF BIOENERGY PRODUCTION IN EUROPEAN UNION MEMBER STATES IN THE CONTEXT OF ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

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**Purpose:** This study aims to assess the significance of bioenergy production in EU member states in the context of selected sustainable development goals achieving.
**Design/methodology/approach**: This study focuses on the socioeconomic aspects related to the achievement of SDG 7 (clean and affordable energy) and SDG 8 (economic growth and decent work), assuming that progress in these objectives also contributes to the achievement of SDG 13, which concerns climate protection. The analysis covers changes in employment levels, gross value added, and labour productivity within the bioeconomy sectors related to bioenergy production in EU members countries. This study utilised data from the Data-Modelling Platform of Resource Economics and the EU Bioeconomy Monitoring System for the years 2010-2023.
**Findings:** The results indicate that the development of bioenergy production in the EU contributes to the achievement of sustainable development goals; however, the scale and effectiveness of this contribution vary greatly between member states and depend on national structural conditions and the extent of political support for the sector.
**Practical implications:** The research results presented in the article, showing the efficiency of production of particular types of bioenergy, may provide guidance for private entrepreneurs regarding the allocation of capital in sectors related to the production of renewable energy sources.
**Social implications:** The results presented in the article can be used by public institutions in promotional and educational activities to increase the use of bioenergy in European Union countries in achieving sustainable development goals.
**Originality/value:** This study fills the research gap by assessing the importance of bioenergy production in European Union countries in the context of achieving selected sustainable development goals.
**Keywords:** bioenergy, bioeconomy, sustainable development goals, labour productivity, European Union.
**Category of the paper:** Research paper.

## 1. Introduction

The growing world population, depletion of many non-renewable resources, and increasing scale of environmental pollution and climate change are prompting the member states of the European Union to seek new development strategies in response to the socio-economic challenges faced by the modern world (Adamowicz, 2017, p. 29). The answer to the rising economic, social, and environmental challenges is the idea of sustainable development within the European Union, which aims to improve the quality of life and well-being of current and future generations (Kasztelan et al., 2021, p. 9).

Sustainable development is currently a key concept within the framework of global policy and development programs, providing a mechanism by which society interacts with the natural environment. Simultaneously, it is a concept that calls for the improvement of living standards without compromising the planet's ecosystems or creating environmental threats such as deforestation and water and air pollution, all of which now lead to climate change and species extinction (Cerin, 2006; Benaim et al., 2008). The bioeconomy development strategy created in the first decade assumed the sustainable use of natural resources and a reduction in dependence on non-renewable resources, mitigation and adaptation to climate change, and strengthening Europe's competitiveness and job creation (EC, 2012, 2018).

Over several decades, the goals of sustainable development have evolved from a single-factor approach focused on the sustainable use of natural resources, through the Millennium Development Goals, which concentrated on poverty, to the current comprehensive and universal objectives of the SDGs (Asadullah, Savoia, 2018). In 2015, based on the experience of implementing the Millennium Goals, the UN adopted the 2030 Agenda, in which the Sustainable Development Goals (SDGs) were redefined (UN, 2015). The Sustainable Development Goals now consist of 17 main goals and 169 sub-goals, intended to serve as guidelines for the operation of all countries and regions over the next 15 years (Muff, 2017).

Sustainable development constitutes the overriding paradigm of the European Union's economic policy, defined by the objectives of the UN 2030 Agenda (UN, 2015) and the European Green Deal (EC, 2019). Bioenergy production, as a key component of the bioeconomy development strategy, integrates environmental, social, and economic objectives, making it a natural area of analysis in the context of implementing Sustainable Development Goals (SDGs). Despite the growing role of bioenergy in the EU energy mix, its contribution to achieving SDGs has rarely been comprehensively and comparatively analysed at the member state level.

Bioenergy is an important component in combating climate change, securing energy supply, and providing income for producers operating in regional biomass supply chains. (Perišić et al., 2022, p. 2; IEA, 2023). Bioenergy supports the transition to a low-carbon economy in several ways and offers numerous benefits to society. It substitutes fossil fuels and thereby reduces

greenhouse gas emissions (Tiwari et al., 2024; IEA, 2023). Owing to the high prices of fossil resources, renewable energy sources are becoming a cost-effective alternative for energy acquisition, contributing to improved economic competitiveness and the creation of new jobs (IRENA, 2025). Therefore, bioeconomy sectors associated with bioenergy production require special attention from both researchers and policymakers responsible for implementing climate and energy policies. Meanwhile, there is a clear research gap in this area, especially in the context of the role these sectors play in the development of the bioeconomy, and thus the extent to which the Sustainable Development Goals (SDGs) are implemented in the country.

This study aims to fill this research gap by analysing the significance of selected bioeconomy sectors responsible for the production and supply of bioenergy (biofuels, i.e. bioethanol and biodiesel, as well as bio-electricity) for the development of the bioeconomy and by analysing socio-economic indicators that determine the degree of attainment of selected Sustainable Development Goals (SDGs) directly linked to the development of the bioeconomy. The assumption was made of a relationship between bioenergy production and Goal 7, which ensures access to stable, sustainable, and modern energy sources at an affordable price for all, and Goal 8, which concerns promoting stable, sustainable, and inclusive economic growth, full and productive employment, and decent work for everyone. Furthermore, it was assumed that the development of bioeconomy sectors responsible for bioenergy production directly contributes to achieving Goal 13, which pertains to taking urgent actions to combat climate change and its impacts, that is, substituting fossil fuels, the potential for greenhouse gas emission reduction, and climate neutrality. This study focuses on analysing socioeconomic indicators without determining environmental indicators that verify the level of Goal 13 achievement.

## 2. Data and Methods

This study uses numerical data obtained from the EU Bioeconomy Monitoring System, including the Data-Modelling platform of resource economics (Data-Modelling platform, 2026) and Eurostat data covering the share of renewable energy sources (RES) in energy consumption from 2008 to 2023 for all 27 European Union countries (Eurostat, 2025). The analysis includes the official European classification of economic activities known as NACE 3, which encompasses ten sections of the bioeconomy (Ronzon, M'Barek, 2018).

The first part of the study presents the significance of renewable energy production in total energy acquisition and the share of bioenergy production in RES generation in individual EU countries. The analysis then focuses on economic indicators related to employment, gross value added, and labour productivity within sectors covering bioenergy production, that is, the production of biofuels (biodiesel and bioethanol) and bioelectricity. The time frame of the

analysis covers the period from 2008 to 2023 and is determined by the availability of the statistical data. This study presents the significance of bioenergy production in individual EU countries and analyzes socio-economic indicators, including added value, employment level, and labour productivity, understood as the ratio of gross value added to the number of people employed in the analysed bioeconomy sections. This indicator allows for a comparison of labour efficiency between EU member states and between different types of bioenergy produced, that is, biodiesel, bioethanol, and bio-based electricity. The analysis covers the years 2008 and 2023, enabling the capture of long-term changes under conditions of intensive energy transformation and the implementation of the EU's climate and energy policy.

## 3. Results and Discussion

As part of the implementation of the EU's climate and energy policy, the revised Directive of the European Parliament and of the Council (EU) 2023/2413, known as RED III, came into force in November 2023, focusing on the promotion of energy from renewable sources. The main goal of the new regulations was to increase the share of "green" energy in the European energy mix to 42.5% by 2030, with the intention of raising it to 45%. Another objective was to encourage investment in the production of energy from renewable sources while allowing member states to maintain energy sovereignty in the face of Russian policy (EC, 2022).

The degree of goal achievement varies highly across European Union countries. As shown in Figure 1, the highest share of renewable energy consumption was recorded in Scandinavian countries, such as Sweden (66.4%), Finland (50.8%), and Denmark (43.7%). These countries also experienced the highest growth rates in renewable energy consumption, exceeding 20% in the years surveyed. On the other hand, the lowest values of this indicator were found in countries from both the "old" and "new" European Union that joined the Community in 2004, such as Luxembourg (14.3%), Belgium (14.7%), Ireland (15.2%), Malta (16.7%), and Poland (15.4%). The low share of renewables in these countries was mainly observed in the transport sector, which, alongside the sectors of electricity production, heating, and cooling, includes the possibility of producing energy from renewable sources.

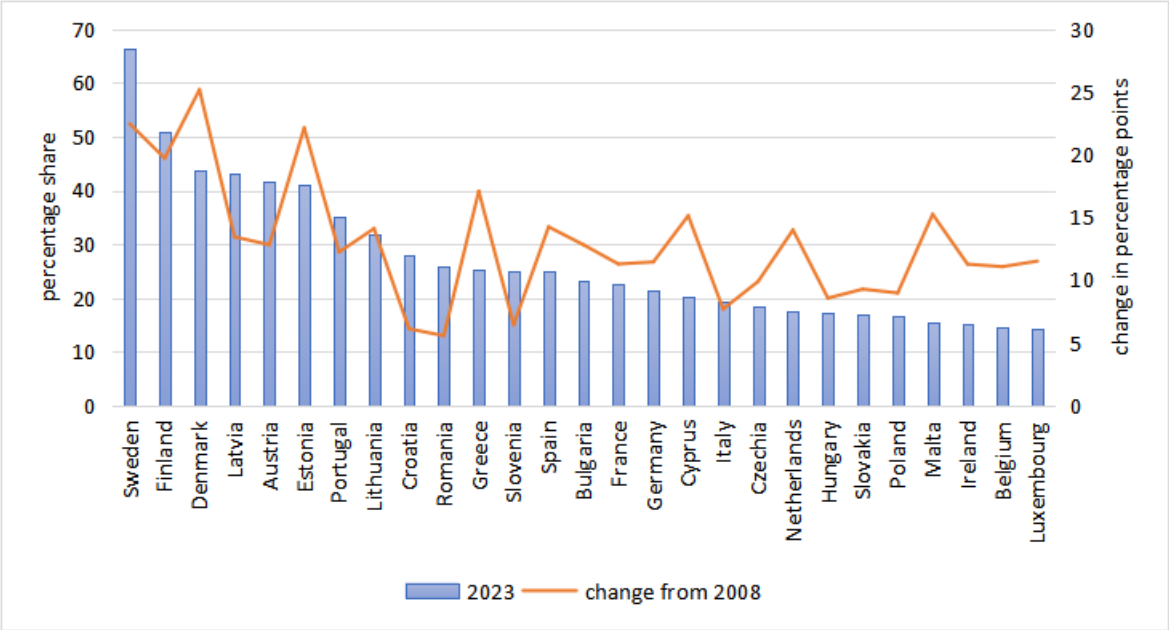



**Figure 1.** Share of renewable energy in total final energy consumption in 2023 and change compared to 2008 (percentage points) in EU member states.

Source: Own elaboration.

The renewable energy used in EU countries can come from diverse sources, depending on the natural and climatic conditions, biomass production potential, and types of technologies employed. Renewable energy sources in EU countries include solar radiation, wind energy, rivers and waterfalls, marine energy, geothermal energy, waste, and biomass. Bioenergy is primarily produced from biomass and biological waste, and its share in energy production varies among different EU countries. In 2023, the highest levels of bioenergy production and consumption were observed in the largest EU economies, such as Germany, France, Italy, Sweden, Poland, and Finland. In contrast, the greatest significance in renewable energy (RES) production, measured by its share, was found in Latvia (84%), Lithuania (77%), Luxembourg (77%), the Czech Republic (79%), and Estonia (78%). Conversely, the smallest share and least significant bioenergy production were observed in Malta (19%), Ireland (32%), Spain (33%), the Netherlands (37%), and Greece (37%) (Figure 2).

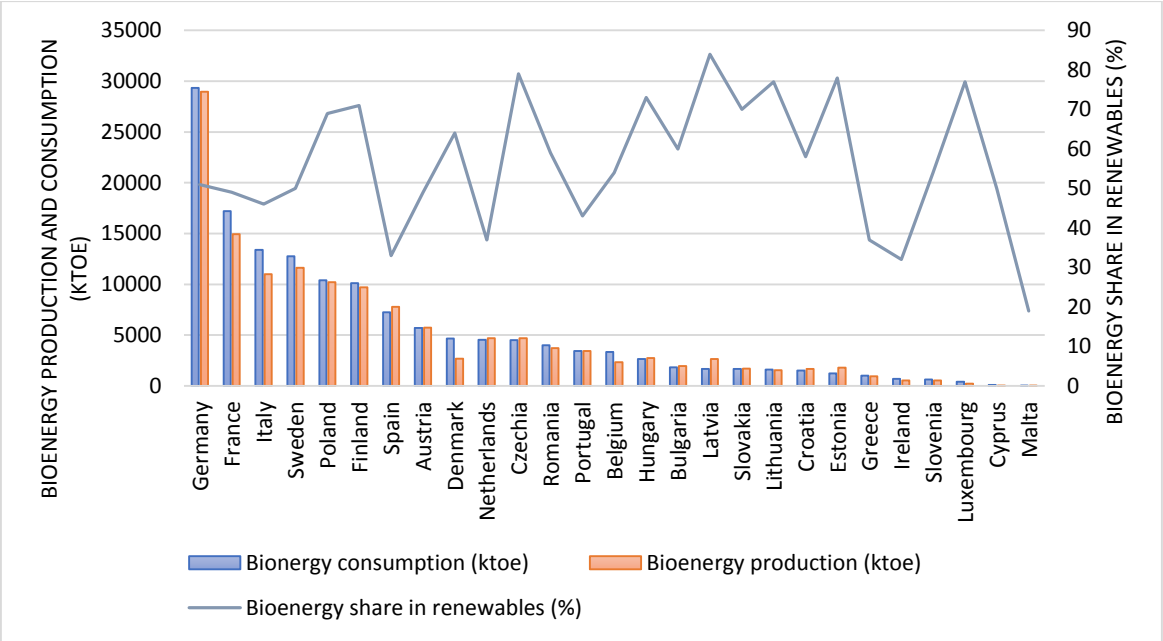



**Figure 2**. Volume of bioenergy production and consumption and its share in RES (Renewable Energy Sources) production in EU countries in 2023.

Source: Own elaboration.

The analysis conducted to assess the potential and efficiency of selected bioeconomy sectors related to bioenergy production included indicators illustrating employment levels in individual sectors, as well as labour productivity indicators measured by value added per employee. First, the potential of the examined bioeconomy sectors and their socio-economic significance are presented through the lens of employment size in the three sectors related to bioenergy production (Table 1). In 2023, these sectors employed 71,158.9 thousand people, which means that compared to 2008, this number almost tripled (278.3%). Among the three sectors studied, the highest employment was recorded in electricity production based on sourced biomass. In 2023, this sector employed 37.3 million people, and the employment growth rate during the study period was 315.4%. Meanwhile, in the sector related to bioethanol production, employment grew from just under 3.3 million to 11.1 million, which constituted an increase of 337.8% compared with 2008. The biodiesel production sector exhibited the lowest growth dynamics, where employment increased by 217.8% from 10.4 million to 22.8 million employees.

**Table 1.**
*Employment in bioenergy production sections in the EU in 2008 and 2023*

| Sections | People employed (thou.) | Share of employment in the bioeconomy (%) | People employed (thou.) | Share of employment in the bioeconomy (%) | Employment dynamics (%) |
|---|---|---|---|---|---|
| | 2008 | 2008 | 2023 | 2023 | 2008 = 100 |
| Bio-based electricity | 11808.3 | 0.06 | 37248.4 | 0.22 | 315.44 |
| Liquid biofuels, including: | 13757.3 | 0.07 | 33910.5 | 0.20 | 246.49 |
| bioethanol | 3286.2 | 0.02 | 11100.1 | 0.06 | 337.8 |
| biodiesel | 10471.2 | 0.05 | 22810.4 | 0.13 | 217.8 |

Source: Own elaboration based on the Data-Modelling platform of resource economics (2026).

The subsequent analysis presents the economic significance of the examined sections in the context of the generated value added. Gross Value Added (GVA) is a key macroeconomic indicator that represents the value of goods and services produced minus the cost of consumed intermediate goods. Alongside employment levels and generated turnover, it is one of the most commonly used indicators for monitoring the bioeconomy and measuring its size (Kuosmanen et al., 2020). It reflects both the production capacity inherent in the accumulated and utilised input resources and their market realisation made possible by the existence of effective demand (Cyrek, 2014).

Based on the data presented in Table 2, it can be stated that the total GVA of the three examined sections responsible for bioenergy production amounted to EUR 3,537.2 million and EUR 15,550.8 million in 2008 and 2023, respectively. This represents more than a fourfold increase in its value over the analysed period, resulting from investments in their development and a significant increase in the competitiveness of these sectors. The growth dynamics of this indicator varied among the analysed sections. The GVA in the section for the production of electricity from biological sources increased by 391.5%, from EUR 2,245.7 million in 2008 to EUR 11,036.6 million in 2023. In the case of biodiesel production, GVA increased by 228.9% between 2008 and 2023, whereas for bioethanol, it was 291.2%.

**Table 2.**
*Gross value added in bioenergy production sections compared to other bioeconomy sectors in the EU in 2008-2023*

| Sections | Value added (mln EUR) | Share in the added value of the bioeconomy | Value added (mln EUR) | Share in the added value of the bioeconomy | Value added dynamics (%) |
|---|---|---|---|---|---|
| | 2008 | % | 2023 | % | 2008 = 100 |
| Bio-based electricity | 2245.7 | 0.44 | 11036.6 | 1.28 | 491.5 |
| Liquid biofuels, including: | 1291.5 | 0.25 | 4514.2 | 0.52 | 349.5 |
| bioethanol | 427.9 | 0.08 | 1674.3 | 0.19 | 391.25 |
| biodiesel | 863.6 | 0.17 | 2840.0 | 0.33 | 328.85 |

Source: Own elaboration based on the Data-Modelling platform of resource economics (2026).

One of the key indicators for assessing the competitiveness and effectiveness of economic sectors is labour productivity, which is understood as the ability to generate added value using labour resources. In this analysis, labour productivity in the bioenergy production sector was calculated as the ratio of added value to the number of employees in a given sector. In the context of achieving sustainable development goals, this indicator gains particular significance, as it allows for the simultaneous assessment of the sector's economic efficiency, growth potential, and capacity to create stable jobs. High labour productivity promotes both improved competitiveness of the economy and the stability of workers' incomes, which aligns with the pursuit of SDG 7, that is, ensuring access to reliable, sustainable, and modern energy at an affordable price for all residents, and SDG 8, which concerns promoting sustained, sustainable, and inclusive economic growth, full and productive employment, and decent work for all people (Raman et al., 2025).

The data presented in Table 3 show both a significant increase in average labour productivity across the European Union and considerable variation in this indicator between individual countries and bioenergy production sectors. These differences reflect varying structural conditions, levels of technological advancement, scale of investments, and availability of domestic raw material bases. Consequently, labour productivity becomes not only a measure of the economic efficiency of the bioenergy sector but also an indicator of the ability of individual member states to use bioenergy as a tool for achieving sustainable development goals.

**Table 3.**
*Labour productivity in bioenergy production sectors in EU member states in 2008 and 2023 (thousand EUR)*

| Country | Labour productivity (thou. EUR) | | | | | |
|---|---|---|---|---|---|---|
| | Biodiesel | | Bioethanol | | Bio-based electricity | |
| | 2008 | 2023 | 2008 | 2023 | 2008 | 2023 |
| European Union | 82.5 | 124.5 | 130.2 | 150.8 | 190.2 | 296.3 |
| Austria | 106.0 | 126.0 | ND | ND | 254.1 | 466.7 |
| Belgium | 105.1 | 155.9 | 174.8 | 274.1 | 389.5 | 528.8 |
| Bulgaria | ND | 25.4 | 3.8 | 18.5 | 33.3 | 97.2 |
| Croatia | 27.5 | 45.3 | 36.5 | 31.1 | 72.7 | 181.7 |
| Cyprus | ND | ND | ND | ND | 102.6 | 149.5 |
| Czechia | 24.7 | 47.2 | 30.2 | 57.1 | ND | ND |
| Estonia | ND | ND | 55.1 | 49.3 | 37.3 | 146.6 |
| Denmark | 132.8 | 182.7 | ND | ND | 202.0 | 254.5 |
| Finland | 73.5 | 118.2 | 131.3 | 137.0 | 254.6 | 402.2 |
| France | ND | ND | 101.5 | 122.2 | 129.4 | 294.6 |
| Germany | 87.9 | 126.8 | 138.0 | 138.3 | 180.8 | 225.8 |
| Greece | 36.3 | 66.6 | 42.6 | 72.5 | 69.7 | 140.5 |
| Hungary | ND | 83.3 | 32.4 | 62.8 | 97.5 | 254.5 |
| Ireland | ND | ND | ND | ND | 293.2 | 395.6 |
| Italy | 75.0 | 140.6 | -3.4 | 37.9 | 368.3 | 440.9 |
| Latvia | ND | ND | ND | ND | 115.1 | 47.8 |
| Lithuania | 62.1 | 268.7 | 26.3 | 59.3 | 24.6 | 143.0 |
| Luxembourg | ND | ND | ND | ND | 245.5 | 331.7 |
| Malta | ND | ND | ND | ND | ND | 141.1 |
| Netherlands | ND | ND | 246.6 | 164.1 | 416.1 | 1171.1 |
| Poland | 27.5 | 46.0 | 40.9 | 63.6 | 89.0 | 315.7 |
| Portugal | 31.4 | 65.7 | 57.3 | 97.8 | 449.9 | 232.1 |
| Romania | 9.3 | 40.5 | 12.7 | 8.3 | 43.1 | 142.8 |
| Slovakia | ND | ND | 20.4 | 54.0 | 140.6 | 439.6 |
| Slovenia | ND | ND | ND | ND | 108.6 | 156.2 |
| Spain | 80.2 | 102.1 | 182.6 | 131.1 | 367.2 | 753.8 |
| Sweden | 116.0 | 207.7 | 111.5 | 175.4 | 287.1 | 620.5 |

Note: ND – no data.

Source: Own elaboration based on the Data-Modelling platform of resource economics (2026).

According to the analysis, a clear increase in labour productivity was observed between 2008 and 2023 in the sectors responsible for bioenergy production in EU countries. Across the entire European Union, the average value added per employee increased in all three analysed sectors, indicating improved efficiency in the use of labour resources amid the ongoing energy transition. The highest level of labour productivity in both 2008 and 2023 was recorded in the

electricity production sector from biological sources. The value of this indicator at the EU level rose from EUR 190,200 to EUR 296,300 per employee, representing an increase of over 55%.

A significant increase in labour productivity was also observed in the biodiesel production sector, where the average EU indicator rose from EUR 82,500 in 2008 to EUR 124,500 by 2023. Although biodiesel remains the least productive of the analysed sectors, the rate of change indicates a gradual improvement in the efficiency of this segment, especially in Central and Eastern European countries (CEECs). For example, in Lithuania, labour productivity in 2023 significantly exceeded the EU average. Simultaneously, low values of this indicator in countries such as Bulgaria and Romania point to persistent technological and organizational barriers in the development of this sector.

Bioethanol production was characterised by moderate but varied labour productivity growth. Across the EU, this indicator increased from EUR 130,200 to EUR 150,800, per employee. In 2023, high labour productivity was observed in countries with a well-developed industrial base and a strong technological background, such as Belgium, Sweden, and the Netherlands. Simultaneously, some countries, including Italy and Romania, recorded very low values for the indicator, which may suggest an early development stage of the sector.

The analysis also revealed significant differences in labour productivity between the "old" and "new" EU member states. Countries such as the Netherlands, Sweden, Belgium, and Finland achieved the highest indicator values in all analysed sectors owing to advanced technological capabilities, production scale, and stable energy policy frameworks. Meanwhile, Central and Eastern European countries have demonstrated dynamic growth in labour productivity, although the absolute levels remain lower. The variation in results between countries suggests that the effective achievement of development goals requires not only increased bioenergy production but also investment in modern technologies and human capital.

The results confirm that bioenergy plays a significant role in the implementation of the EU's energy transition and key Sustainable Development Goals, particularly SDG 7 and SDG 8. The increased share of renewable energy sources and the significant rise in employment and value added in the bioenergy sectors align with the objectives of Directive 2023/2413 of 18 October 2023 aimed at accelerating decarbonisation while strengthening the EU's energy security (Directive (EU) 2023/2413 of the European Parliament and of the Council). The varying levels of bioenergy use among member states confirm that its development is highly dependent on national resource conditions and energy sector structure. Countries with a high share of bioenergy in the renewable energy mix use it as a stable source of renewable energy, which strengthens the resilience of energy systems and supports the achievement of SDG 7, in line with previous literature (Motola et al., 2023). At the same time, the observed increase in employment and gross value added in bioenergy production sectors confirms their growing socio-economic importance within the EU bioeconomy, as demonstrated, among others, by research by Krukowski and Nowak (2025). These results support the thesis that bioenergy can serve as an important pillar in achieving SDG 8, especially through job creation

and increased labour productivity, provided that investments in modern technologies and human capital are sustained (Ronzon, M'Barek, 2018; Wysocka, 2023; Hanna et al., 2024). Simultaneously, persistent differences between member states indicate that the effective achievement of sustainable development goals requires complementary actions supporting innovation and technology diffusion throughout the Community.

## 4. Conclusions

This study assessed the significance of selected sections of the bioeconomy responsible for the production and supply of bioenergy for the development of the bioeconomy and analysed socioeconomic indicators determining the degree of achievement of selected Sustainable Development Goals (SDGs). The analysis indicates that the development of renewable energy sources is a key element in achieving the European Union's climate goals and the assumptions of the European Green Deal. Despite progress in increasing the share of renewable energy, there are still significant differences among member states in the level of use. The research results confirm the growing importance of bioenergy within the structure of renewable energy sources and its significant socioeconomic role, manifested in the growth of employment and labour productivity in its production sectors. At the same time, the variation in results between countries indicates the need for further investment in technological development, innovation, and human capital to increase the efficiency of the sector and support the achievement of sustainable development goals, including SDGs 7 and 8. It is also important to support the transfer of knowledge and diffusion of technology between member states, which can contribute to reducing disparities in the development of bioenergy in the European Union.

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