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SOCIO-ECONOMIC IMPORTANCE OF BIOENERGY PRODUCTION IN EU MEMBER STATES

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Purpose: This study aimed to assess the socio-economic importance of bioenergy production for the economy of the European Union and its individual members in relation to its competitiveness and situation on the labour market.
Design/methodology/approach: This study analyzes the socioeconomic importance of bioenergy production in EU countries in the context of the turnover generated, volume of employment, and labour productivity in the various sections that produce energy from biomass (bioelectricity, bioethanol and biodiesel). This study uses figures extracted from the EU Bioeconomy Monitoring System (Data-Modeling platform, 2025) for 27 EU countries.
Findings: The study showed that bioenergy production in the European Union member countries has a significant importance for its labour market, because the scale of employment in the three analyzed bioenergy sectors doubled between 2010 and 2021 to nearly 50 million employees. During this period revenue from bioenergy production increased more than threefold. In terms of labour productivity, which determines the competitiveness of bioenergy production, the situation in the three examined sectors varies greatly across European Union member states.
Practical implications: The findings presented in this article, illustrating the efficiency of individual types of bioenergy production, may provide guidance for private investors regarding capital allocation in the renewable energy sector and for public authorities to support the development of renewable energy sources in EU countries.
Social implications: The research results presented in this article can be used in promotional and educational activities to achieve a greater degree of acceptance of the EU climate and energy strategies through the large-scale use of renewable energy by the inhabitants of the European Union, and thus improve the condition of the natural environment and their quality of life.
Originality/value: This study fills the research gap by assessing the importance of bioenergy production for the labour market in the European Union.
Keywords: bioenergy, bioeconomy, European Union, labour market, labour productivity.
Category of the paper: Research paper.

1. Introduction

One of the main socio-economic challenges of the world, due to the growing population, increased scale of human economic activity, and associated exploitation of natural resources, is the need to protect the environment, combat climate change, and sustainably use of natural resources (Adamowicz, 2017, p. 29). To address this challenge, the European Commission (2012) adopted the Bioeconomy Strategy in 2012, which was updated in 2018. The updated strategy confirmed its five original objectives: ensuring food and nutrition security, managing the sustainable development of natural resources, reducing dependence on non-renewable resources, mitigating and adapting to climate change, strengthening Europe's competitiveness, and creating jobs (European Commission, 2018). These goals, in line with the latest European Green Deal strategy adopted in 2019 (European Commission, 2019), are now more relevant than ever in the context of the Russian invasion of Ukraine and the need to accelerate the achievement of climate and energy independence (European Commission, 2022b). The EU Bioeconomy Strategy enables a green and just transition and covers all three dimensions of sustainability: environment, society, and economy. To achieve these goals, the updated Bioeconomy Strategy is accompanied by a targeted action plan with three main areas of action: strengthening and scaling up bio-based sectors, unlocking investments and markets, rapidly implementing local bioeconomies across Europe, and understanding the ecological boundaries of the bioeconomy (European Commission, 2022a).

The bioeconomy encompasses all sectors and systems that rely on biological resources (animals, plants, microorganisms and their biomass, and organic wastes). The EU Bioeconomy Strategy should help identify, assess, and resolve trade-offs between policy objectives and competing uses of land, sea, and biomass. By optimizing the use of biological resources from land and sea, the bioeconomy maximizes co-benefits such as biomass production, climate change mitigation, and enhanced biodiversity, while protecting and benefiting from other ecosystem services (Faber, Jarosz, 2023, p. 5).

Bioenergy is a key element in combating climate change, securing energy supplies, and providing income for producers in regional biomass supply chains. Bioenergy is the conversion of biomass - such as agricultural and forestry by-product residues and wastes, organic municipal waste, low-risk indirect land use energy crops, algae, biological CO2 - into useful energy carriers, including heat, electricity and transportation fuels (Perišić et al., 2022, p. 2; IEA, 2023, p. 4). Bioenergy supports the transition to a low-carbon economy in several ways and offers numerous benefits to society. It replaces fossil fuels, thereby reducing greenhouse gas emissions. Bioenergy and biofuel facilities can act as sources of biogenic CO2 for carbon capture, storage, or use, in certain cases, and even offer the possibility of achieving negative net CO2 emissions (Tiwari et al., 2024; IEA, 2023, p. 5). Therefore, bioeconomy sections related to bioenergy production require special attention. However, there is a clear

research gap in this area, especially in the context of the role of these sections in the development of the bioeconomy. The present study blends into the current of bioeconomy research, with the main goal of assessing the importance of bioenergy production in European Union member states from a socio-economic perspective.

2. Data and methods

This study uses figures extracted from the EU Bioeconomy Monitoring System, including the database Data-Modeling platform of resource economics created by the European Commission's Joint Research Center (Data-Modeling platform, 2025). The purpose of this system is to provide a consistent approach to monitoring progress toward bioeconomy goals across EU member states, reflecting the five goals of the Bioeconomy Strategy (European Commission, 2022a). The analysis considers the official classification of economic activities in Europe called NACE 3, which includes 10 sections of the bioeconomy (Ronzon, M'Barek, 2018, p. 2): Agriculture; Forestry; Fishing and aquaculture; Food, beverages and tobacco; Biotextiles; Wood products and furniture; Paper; Biochemicals, pharmaceuticals, plastics and rubber (excluding biofuels); Liquid biofuels (bioethanol and biodiesel); and Bioelectricity (electricity generation from biomass). The analysis conducted in this study focuses on employment and labour productivity issues in the divisions that comprise bioenergy production, that is, biofuel production and bioelectricity. Its timeframe covers the period from 2010 to 2021 and is based on the availability of statistical data. This study analyzes the socioeconomic importance of bioenergy production in EU countries in the context of the turnover generated, volume of employment, and labour productivity in the various sections that produce energy from biomass. The productivity index was calculated as the ratio of the gross value added of each bioeconomy section to the number of people employed. The study covered 27 EU countries, excluding the UK, which formally left the EU in early 2020.

3. Results and discussion

The analysis of the potential and effectiveness of its use in selected sections of the bioeconomy related to bioenergy production included indicators illustrating the level of employment in individual sections, the amount of generated revenues (turnover), and labour productivity indicators measured by value added per employee.

First, the potential of the studied bioeconomic sections and their socioeconomic importance are presented through the prism of the volume of employment in the three sections related to bioenergy production (Figure 1). In 2021, the three analyzed bioeconomy sections related to bioenergy production employed 49,962.6 thousand people. Compared with 2010, this number doubled (209%). Of the three analyzed sections, the production of electricity from harvested biomass had the highest employment. In 2021, it employed 36.4 million people, and the average annual increase in the number of employees between 2010 and 2021 was more than 2 million. The growth rate of employment in this section was 231% over the years under review. On the other hand, the section related to bioethanol production employed 10,277.9 thousand people in 2021, while biodiesel production employed 3334.0 thousand people. The dynamics of growth in the number of employees compared with 2010 were 143.3% and 376.7%, respectively.

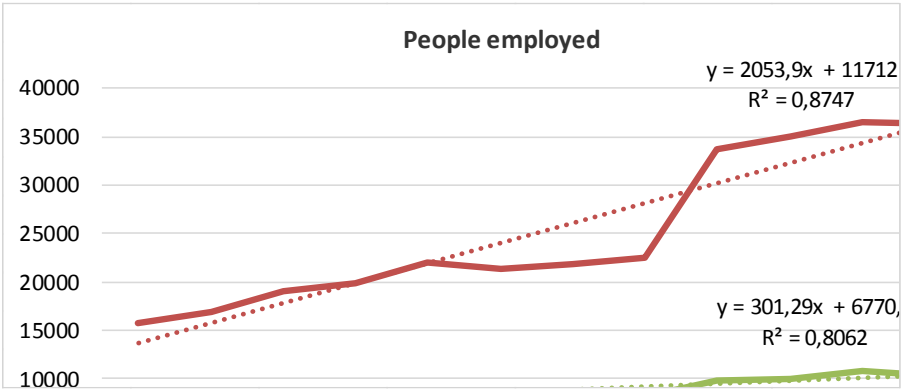

Figure 1. Changes in employment in selected sections of bioenergy production in the EU from 2010 to 2021.

Source: own elaboration based on the database Data-Modelling platform of resource economics.

The following analysis presents the economic importance of the sections in terms of generated revenue value (turnover). They correspond to the market sales of goods or services provided by these sections and are therefore higher than the gross value added in most cases (Ronzon, M'Barek, 2018, p. 3). The total value of turnover of the three sections under study was 64,697.9 million euros and 19,700.1 million euros in 2021 and 2010, respectively (Fig. 2). This represents a more than three-fold increase in their value. The growth dynamics of the analyzed sections varied. Turnover in the bioenergy sector grew at an average annual rate of €2273 million and its dynamics from 2010 to 2021 reached 401%. In the case of biodiesel, turnover increased sharply in the last year of the study, amounted to 14,082.8 million euros. In contrast, the turnover of bioethanol increased by 74% in the years under study, amounted to 8978.6 million euros.

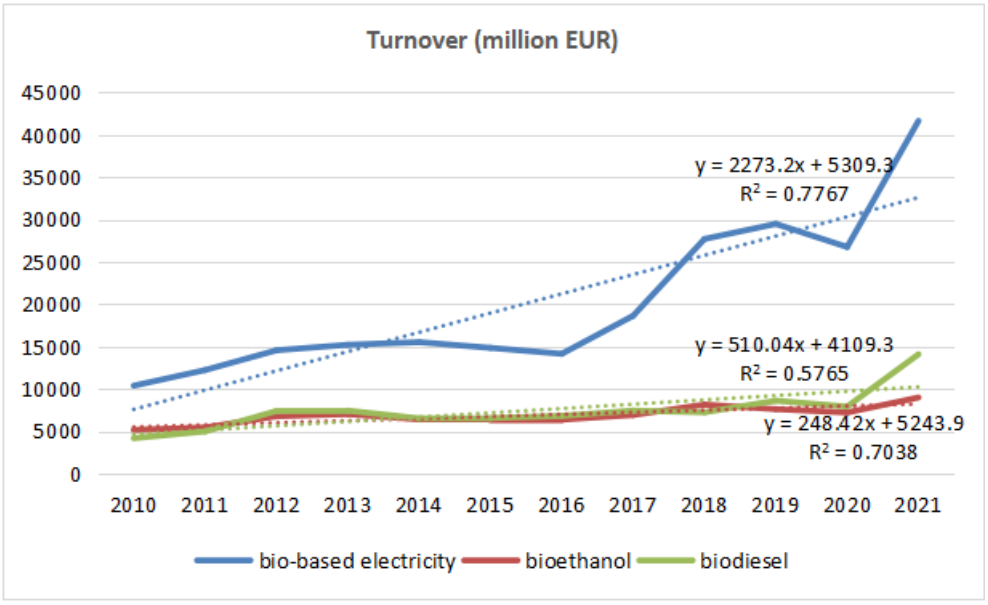

Figure 2. Changes in the value of turnover in selected sections of bioenergy production in the EU from 2010 to 2021.

Source: own elaboration based on the database Data-Modelling platform of resource economics.

In addition to the level of employment and volume of turnover, gross value added (GVA) is among the most commonly used indicators for monitoring the bioeconomy and measuring its size (Kuosmanen et al., 2020). It reflects both the production possibilities inherent in the accumulated and utilized stock of production factors and their market realization made possible by the existence of effective demand (Cyrek, 2014). In 2021, the total GVA of the three surveyed sections was €13,233.9 million, an increase of 270% from 2010. The largest GVA was generated by the bioenergy production section, with an average annual increase of 343.8 million euros (Figure 3).

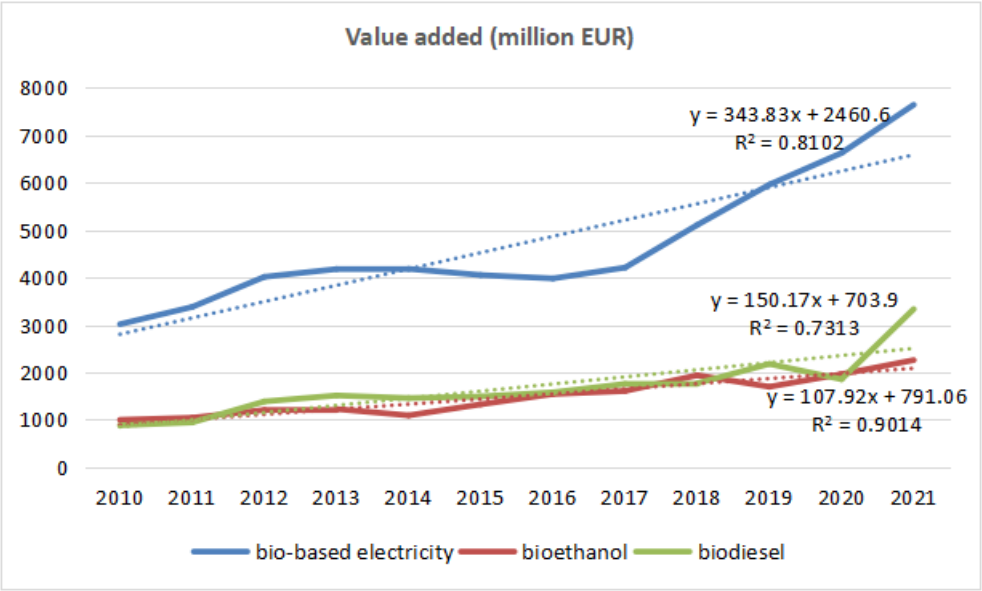

Figure 3. Changes in gross value added in selected sections of bioenergy production in the EU from 2010 to 2021

Source: own elaboration based on the database Data-Modelling platform of resource economics.

Labour productivity is a measure of a sector's competitiveness in the economy. It is the ratio of gross value added to the number of employees (Faber, Jarosz 2023, p. 8). Labour productivity, which is fundamental to economic competitiveness, depends on technical progress and structural transformations. The increase in labour productivity is seen as an important source of economic growth, progress, and improvement in society's standard of living (Hearne, Lewis 2024, p. 447). As can be seen from the data presented in Table 1, the highest average labour productivity in 2010-2021 was characterized by the section on bioenergy production, but its growth rate was relatively low (109.6%). The other two sections were characterized by higher growth dynamics of the studied productivity index and a higher coefficient of variation, with the bioethanol production section having an absolute value of labour productivity that averaged 149.6% of the level achieved in the biodiesel production section in the years under study.

Table 1.
Labour productivity in selected sections of bioenergy production in the EU from 2010 to 2021

Years	Gross value added per employee (€1000/person)		
	Bioelectricity	**Bioethanol**	**Biodiesel**
2010	191.7	139.4	90.9
2011	200.6	143.9	92.2
2012	211.5	148.2	93.8
2013	210.7	141.6	103.2
2014	190.4	138.3	105.1
2015	189.7	167.1	109.0
2016	181.6	179.5	115.4
2017	186.6	197.3	129.3
2018	151.5	197.5	127.2
2019	170.5	170.4	130.2
2020	181.4	181.2	117.9
2021	210.2	219.8	139.0
Dynamics (2010 = 100)	109.6	157.7	152.9
Mean	189.7	168.7	112.8
Coefficient of variation	9.3	16.1	14.5

Source: own elaboration based on the database Data-Modelling platform of resource economics.

There are significant differences between EU member states in the level of labour productivity in the analyzed sections of the bioeconomy. Due to the minor importance of the selected sections for the development of the bioeconomy of some EU countries and the availability of data, all EU members were not included in the analysis. In the case of bioethanol production, labour productivity for all EU countries in the years under study increased by 57.7%, from €139,424.3 to €219,818.0 per employee (Fig. 4). The highest level of this indicator in 2021 was characterized by countries such as Romania 404,267.1 euros, the Netherlands 387,520.7 euros and Belgium 285,307.2 euros per employee. In contrast, Croatia, Bulgaria, and Slovakia had the lowest levels. The greatest progress in this regard in the years under review was made by former Eastern Bloc countries such as Romania, where the dynamics amounted to an impressive 2328.0 percent, followed by Bulgaria (595.2%) and Hungary (436.7%). Large changes were recorded in Italy 373.2% and Poland (261.3 %). In contrast, a decrease in

the value of this indicator was recorded only in the case of Slovakia (down 19.2 p.p.) and a slight dynamic in countries such as Finland (108.0%), France (111.6%), and Germany (116.8%). The figures presented here determine the importance of the production of liquid fuel biocomponents in the form of bioethanol for a country's economy, both for its situation in the internal labour market (employment levels and labour efficiency) and its export position in international markets (Nowak, Jarosz-Angowska 2024, p. 87).

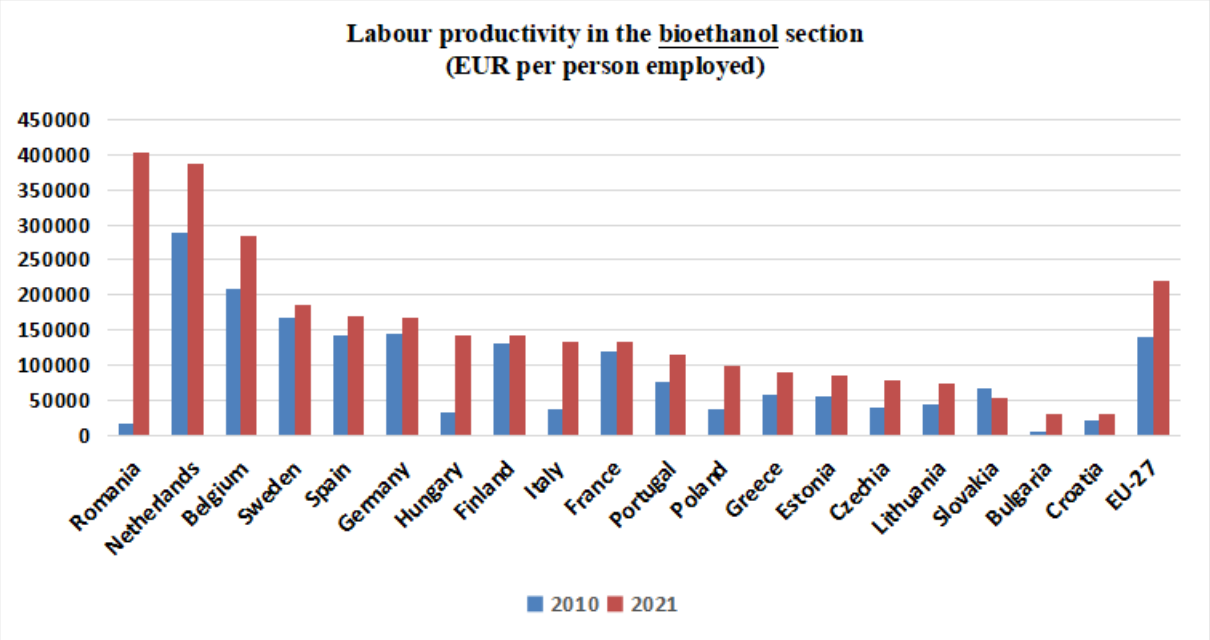

Figure 4. Labour productivity in the bioethanol production section in selected EU countries, 2010-2021. Source: own elaboration based on the database Data-Modelling platform of resource economics.

A similarly diverse situation across the European Union was observed in biodiesel production (Figure 5), where labour productivity more than doubled (i.e., by 208.2%) from 90,897 thousand euros to 189,249 euros per employee. In this case, the undisputed leader in the level of labour productivity in 2021 was Lithuania, with an indicator of 436 451.6 euros per employee. In the case of this country, the dynamics of change of this indicator were also impressive, increasing more than nine times (935.4%) in the years under review. This was followed by Finland (189 248.8 euros), Belgium (174574.0 euros), and Austria (167609.1 euros). The lowest labour productivity in the biodiesel production section was recorded in Croatia (37204.4 euros), Romania (34887 euros) and Bulgaria (27106.7 euros). The analyses presented show the varying importance of biodiesel production in EU countries and determine the labour market situation related to the development of the bioeconomy in terms of biofuel production, as well as the efficiency of the sections studied. The changes that have been observed in the socioeconomic importance of bioenergy sections are a consequence of the availability of the raw material base as well as the extent of private and public investment that has been made in connection with the implementation of EU climate and energy policies in individual countries.

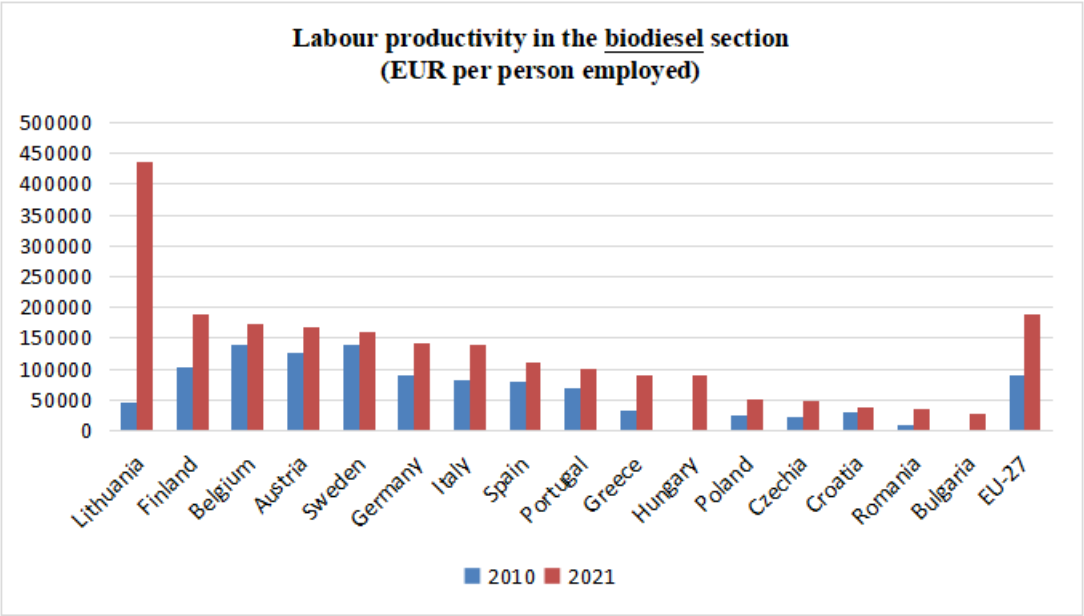

Figure 5. Labour productivity in the biodiesel production section in selected EU countries in 2010 and 2021.

Source: own elaboration based on the database Data-Modelling platform of resource economics.

The last section analyzed in the study related to bioenergy production is bioelectricity (Figure 6). Here, labour productivity varies considerably between EU countries. At the level of the European Union as a whole, the change that took place in the years under review does not appear to have been too great, as labour productivity increased by less than 10%, from €191 730.7 in 2010 to €210 191.9 per employee. In this case, the leader in the size of the labour productivity index in 2021 was Spain (€737,362.9), followed by the Netherlands (€455,107.0) and Belgium (€431,455.6). Countries with the lowest level of this indicator included Romania (€87,085.0), Latvia (€86,179.1) and Slovenia (€80,006.9). In terms of the growth rate of this indicator in the years under review, Lithuania (345.2%), Spain (327.2%), and Bulgaria (257.6%) stood out positively. In contrast, a decrease in the growth rate of the labour productivity indicator was recorded in Portugal (by 53 p.p.), Sweden (by 52.5 p.p.), and Latvia (by 20.6 p.p.). It can be assumed that the changes recorded were due to the amount of investment and restructuring activities undertaken by the country in the bioenergy production sector and the scale of innovation implemented in the technologies used, resulting in an increase in labour productivity and value added. In turn, an increase in the efficiency of bioenergy suppliers results in improved competitiveness in other industrial sectors using cheaper energy compared to traditional suppliers using fossil resources.

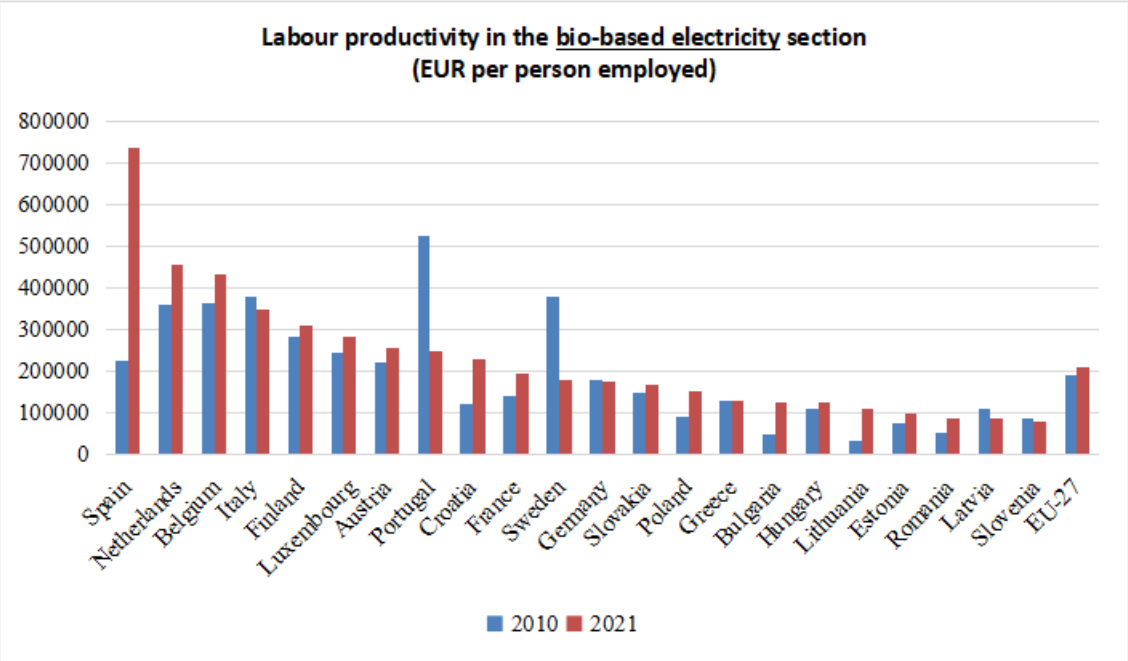

Figure 6. Labor productivity in the bio-based electricity production section in selected EU countries in 2010 and 2021.

Source: own elaboration based on the database Data-Modelling platform of resource economics.

The issue of renewable energy sources has been one of the more frequently discussed issues in recent years, related to both environmental and economic issues. Renewable energy production is considered to provide a sustainable strategy for replacing fossil fuels and mitigating climate change by meeting the growing global energy demand (Adeh et al., 2018, p. 13). This issue can also be addressed from the perspective of the bioeconomy sections analyzed in this study, which have rarely been studied by other authors. As part of the green economy, the bioeconomy plays a key role in replacing fossil fuels on a large scale, not only in energy applications but also in chemical and material applications (Scarlat et al., 2015, p. 31). Tiwari et al. (2024, p. 53) emphasized that the energy sector should make an important contribution to the EU CO2 reduction targets. As shown by the results of this study, both the size and efficiency of the sections related to bioenergy production in the EU are increasing. This is also confirmed by Nowak and Jarosz-Angowska (2024, p. 77), who analyzed the importance of all sections of the bioeconomy from a labour market perspective. The analysis of Cîrstea et al. (2019), on the other hand, show that bioenergy correlates positively with the degree of innovation in a particular field or with natural gas energy and negatively with the economic efficiency of a country. These authors confirmed that bioenergy production can make a significant contribution to climate change mitigation while ensuring the diversification of energy resources in the long term.

4. Conclusions

Research shows that the EU's climate and energy policy has a positive impact on the development of bioenergy sectors, leading to an increase in their efficiency in countries where renewable energy plays an important role and has implemented measures to financially support public and private investment and the necessary restructuring processes. An important element in the development of these sectors is the implementation of efficient technologies for the production and supply of renewable energy, as well as in the biomass supply sectors such as agriculture and forestry. The development of renewable energy in the European Union has a positive impact on the labour market and offers new employment opportunities, particularly in rural and post-industrial regions. Renewable energy, especially that produced locally, supports local communities, reduces dependence on external energy supplies, and creates new opportunities. However, the transition process needs to be properly managed to mitigate the effects of climate and energy policies on traditional energy sectors and to support workers in adapting to new labour market demands. With the bioenergy production sector being export-oriented, higher productivity allows domestic companies to compete better in international markets, which helps to increase a country's trade balance. Given the internal diversity of the European Union, further research should focus on the specific circumstances of individual countries, their potential for renewable energy production, and their environmental and climate protection economic policies.

References

1. Adamowicz, M. (2017). Biogospodarka – koncepcja, zastosowanie i perspektywy. *Zagadnienia Ekonomiki Rolnej, Vol. 1, Iss. 350*, pp. 29-49.
2. Cîrstea, S.D., Cîrstea, A., Popa, I.E., Radu, G. (2019). The role of bioenergy in transition to a sustainable bioeconomy: Study on EU countries. *Amfiteatru Economic Journal, Vol. 21, Iss. 50*, pp. 75-89. DOI: 10.24818/EA/2019/50/75.
3. Cyrek, M. (2014). Międzywojewódzkie dysproporcje wytwarzania wartości dodanej w branżach usługowych. *Nierówności społeczne a wzrost gospodarczy, Vol. 39.* Wydawnictwo Uniwersytetu Rzeszowskiego, pp. 383-393.
4. *Data-Modelling platform of resource economics* (2025). Retrieved from: https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html, 07.01.2025.
5. European Commision (2022b). *REPower EU: Joint European action for more affordable, secure and sustainable energy*. Press release, Strasbourg.

6. European Commission (2012). *Innovating for Sustainable Growth. A Bioeconomy for Europe*. Luxembourg: Publications Office of the European Union.
7. European Commission (2018). *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment* (COM(2018) 673 Final). Communication from the Commission to the European Parliament, Brussels, Belgium.
8. European Commission (2022a). *EU Bioeconomy Strategy Progress Report, Bioeconomy Policy: Stocktaking and future developments*, Luxemburg.
9. Faber, A., Jarosz, Z. (2023). Zmiany i możliwości rozwoju biogospodarki w Polsce na tle Unii Europejskiej. *Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego, Vol. 23, Iss. 3*, pp. 4-19. DOI: 10.22630/PRS.2023.23.3.9
10. Gardossi, L., Philp, J., Fava, F., Winickoff, D., D'Aprile, L., Dell'Anno, B., Jørgen Marvik, O., Lenzi, A. (2023). Bioeconomy national strategies in the G20 and OECD countries: Sharing experiences and comparing existing policies. *EFB Bioeconomy Journal, Vol. 3*, p. 100053. DOI: 10.1016/j.bioeco.2023.100053.
11. Hearne, D., Lewis, P. (2024). Challenging (mis)understandings of labour productivity for levelling-up: a broader research agenda for regional development. *Contemporary Social Science*, pp. 1-22. DOI: 10.1080/21582041.2024.2439466.
12. IEA Bioenergy Report (2023). *How bioenergy contributes to a sustainable future*. The IEA Bioenergy Technology Collaboration Programme.
13. Kuosmanen, T., Kuosmanen, N., El-Meligi, A., Ronzon, T., Gurria, P., Iost, S., M'Barek, R. (2020). *How big is the bioeconomy? Reflections from an economic perspective*. Luxembourg: Publications Office of the European Union.
14. Leavy, S., Allegretti, G., Presotto, E., Montoya, M.A., Talamini, E. (2024). Measuring the bioeconomy economically: Exploring the connections between concepts, methods, data, indicators and their limitations. *Sustainability, Vol. 16*, p. 8727. DOI: 10.3390/su16208727.
15. M'barek, R., Wesseler, J. (2023). The rapid development of bioeconomy policies in the EU and other regions of the world. *EuroChoices, Vol. 22, Iss. 3*, pp. 5-12. DOI: 10.1111/1746-692X.12415.
16. Nowak, A., Jarosz-Angowska, A. (2024). Employment and labour productivity in the bioeconomy - an overview of the member states of the European Union. *Scientific Papers of Silesian University of Technology Organization and Managemant Series, Vol. 199*, pp. 457-469. DOI: 10.22630/EIOL.2023.8.1.5 .
17. Perišić, M., Barceló, E., Dimic-Misic, K., Imani, M., Spasojević Brkić, V. (2022). The role of bioeconomy in the future energy scenario: A state-of-the-art review. *Sustainability, Vol. 14*, 560. DOI: 10.3390/su14010560.
18. Ronzon, T., M'Barek, R. (2018). Socioeconomic indicators to monitor the EU's bioeconomy in transition. *Sustainability, Vol. 10*, p. 1745. DOI: 10.3390/su10061745.

19. Scarlat, N., Dallemand, J.F., Monforti-Ferrario, F., Nita, V. (2015). The role of biomass and bioenergy in a future bioeconomy: *Policies and facts. Environmental Development, Vol. 15*, pp. 3-34. DOI: 10.1016/j.envdev.2015.03.006.
20. Tiwari, T., Kaur, G.A., Singh, P.K., Balayan, S., Mishra, A., Tiwari, A., (2024). Emerging bio-capture strategies for greenhouse gas reduction: Navigating challenges towards carbon neutrality. *Science of the Total Environment, Vol. 929*, p. 172433. DOI: 10.1016/j.scitotenv.2024.172433.
21. Tsiropoulos, I., Nijs, W., Tarvydas, D., Ruiz, P. (2020). *Towards net-zero emissions in the EU energy system by 2050. Insights from scenarios in line with the 2030 and 2050 ambitions of the European Green Deal*. Luxemburg: JRC Technical Report.