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Bioeconomy potential in Poland compared to EU countries

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Abstract. The aim of the research was to assess the potential of the bioeconomy in Poland in comparison with the European Union countries. The research used an indicator of added value, the number of people employed and the value of turnover for individual sectors included in the bioeconomy. An analysis of the structure of indicators in Poland in 2020, compared to other EU countries, allowed us to determine the level of development of the country's bioeconomy. The analysis shows that Poland is a leader in terms of employment in the EU bioeconomy. However, the assessment of potential in terms of added value and value of turnover in the bioeconomy placed Poland in fifth position. The reason for this is Poland's characteristic fragmented agrarian structure and excessive employment in the agricultural sector. An opportunity to redress the imbalance is to obtain EU funding and support for research and innovation.

Keywords: bioeconomy, added value, employment, turnover

INTRODUCTION

In recent years, increasing attention has been given to the idea of a bioeconomy, which aims to meet societal demands for food, energy and industrial products by increasing the sustainable use of renewable resources and pursuing the Sustainable Development Goals (Giuntoli et al., 2020; UN SDSN, 2015). In 2012, with the adoption of the strategy 'Innovating for sustainable growth: a bioeconomy for Europe', it was recognised that the development of the bioeconomy would ensure dynamic and sustainable growth and that good management of renewable biological resources would create new opportunities for the production of bioproducts through the use of biotechnology (European Commission, 2012).

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Different interpretations of the bioeconomy concept have resulted in a diversity of definitions. Numerous interpretations have, on the one hand, focused on resources and their sustainable use (Cristóbal et al., 2016; Juerges, Hansjürgens, 2018), while on the other hand, biotechnological processes have been more appreciated (Pellis et al., 2018; Scheiterle et al., 2018). In general, it can be said that a bioeconomy that relies on the use of biomass connects primary production sectors (agriculture, forestry, fisheries and aquaculture) with other economic sectors that transform biomass into new products (food, feed, bioproducts, biochemicals, bioenergy, etc.) through technological processes.

The bioeconomy is a strategy that should lead to economic and social benefits, while preserving the environment (European Commission, 2012). The promotion of the bioeconomy results in an increased demand for bioresources and increasing pressure on land. Sources of biomass underpinning the development of the bioeconomy are primary production sectors. Of course, these resources are limited, so sustainable production is an important issue. The literature increasingly emphasises the sustainable and efficient use of natural resources with a view of not exceeding environmental thresholds (Liobikiene et al., 2019, 2020; Faber, Jarosz, 2023). Knowledge of available resources is a prerequisite for shaping a strongly sustainable bioeconomy. Our own research has shown that the ecological potential for increasing biomass production in Poland is low. In this situation, meeting biomass demand is possible by increasing productivity without increasing input consumption and by increasing the use of by-product and waste biomass (Faber, Jarosz, 2023).

According to Czernyszewicz (2016), economic growth will result from sustainable primary production, food processing, the development of industrial biotechnology and biorefineries, which will introduce new bioeconomy-based industries into the economy, transform existing industries and open new markets for higher value-added bioproducts.

The market for bioeconomy products is growing. Demand for new products is expected to reach €50 billion in 2030 (Bell et al., 2018). Also Balcerzak (2009) emphasises that innovation involving the implementation of new products, new processes and the improvement of new organisational solutions, and technological change, involving the introduction, and diffusion of new technological solutions, are key drivers of economic growth.

The primary source of energy for the European Union economy is fossil resources (coal, oil, natural gas). The current situation resulting from Russia's aggression against Ukraine is a perfect example of how important it is to become independent from the volatile fossil fuel market. Abandoning the exploitation of non-renewable resources and switching to the use of renewable resources (conservation of resources, respect for the environment) creates the opportunity for the EU to become a resource-efficient society. This direction of transformation enhances international competitiveness and brings us closer to climate neutrality.

The development of the bioeconomy has an impact on many sectors. The transition is expected to increase the demand for labour in all sectors that make up the bioeconomy. Shaping a new sustainable approach to production and consumption and improving resource efficiency, offer the opportunity for rural development and job creation and can increase farmers' incomes. According to Pink (2020), the bioeconomy has significant social potential. She believes that one million new jobs should be created by 2030, especially in rural areas.

Kasztelan et al. (2021) states that in order to maintain competitiveness and jobs in light of major societal challenges and growing markets in developing countries, European bioeconomy sectors need to innovate and diversify. According to Urban and Piwowar (2016), the development of the bioeconomy is driven by collaboration between manufacturing and service actors and research and development units.

The development of the bioeconomy varies from one EU Member State to another and depends both on the specific characteristics of the country and on the development strategies adopted and implemented. The amended bioeconomy strategy entitled "A sustainable bioeconomy for Europe: strengthening the links between the economy, society and the environment" outlines an action plan for transforming the current economy into a sustainable, innovative and circular economy (European Commission, 2018). The strategy was a response to the challenges related to the implementation of five original goals: ensuring food security, sustainable management of natural resources, reducing dependence on non-renewable resources, mitigating and adapting to climate change, and strengthening the competitiveness of the EU economy and increasing employment. The set goals were also reflected in the European Green Deal adopted by the European Commission in 2019 (European Commission, 2019).

Successful implementation of the bioeconomy depends on local environmental, social and economic opportunities and challenges. In order for each country to adapt strategies to its specific situation, it can translate EU goals into national goals and methods of action. As of the end of 2022, ten Member States had developed bioeconomy strategies. These were: Austria, Finland, France, Spain, the Netherlands, Ireland, Germany, Latvia, Portugal and Italy. Strategies are being developed in countries such as the Czech Republic, Croatia, Lithuania, Poland, Slovakia and Hungary. Seven countries have been included in macro-regional bioeconomy policies (Bulgaria, Denmark, Estonia, Romania, Slovenia, Sweden) and Belgium in sub-national policies. However, in countries such as Cyprus, Greece, Luxembourg and Malta, other strategies have been implemented that have links with the bioeconomy (Brenne, 2022; Mubareka et al., 2023). In Poland, the bioeconomy strategy is at the stage of construction, and bioeconomy issues appear in various strategic documents.

Attention was also drawn to the need to monitor progress in achieving the goals of the bioeconomy to provide a comprehensive picture of the bioeconomy and its development trends (Ronzon, M'Barek, 2018; Mubareka et al., 2023).

In 2022, the European Commission report on progress in implementing the EU bioeconomy strategy was adopted (European Commission, 2022). It provided an overview of developments in national bioeconomy policies since 2018.

The aim of the study was to assess the potential of the bioeconomy in Poland in comparison with the EU countries. On the basis of information concerning added value, employment, and the volume of turnover in individual sectors that make up the bioeconomy, an attempt was made to draw conclusions about the potential of the bioeconomy in 2020 in Poland and EU countries.

DATA AND METHODS

The issue of building appropriate indicators for use in monitoring and evaluating the bioeconomy has been of interest for many years (Jander et al., 2020; Ronzon, M'Barek, 2018). During the Global Forum on Food and Agriculture (GFFA) in 2015, FAO was given the mandate to coordinate work on a 'food first' sustainable bioeconomy. The aim of the work was to provide assistance to interested countries in developing and monitoring the development of a bioeconomy with a balance between the three dimensions of sustainability (social, economic and environmental). Often, however, the complexity of the indicators in correlation with the lack of data makes it impossible to perform analyses. It is, therefore, suggested to use a basic range of indicators (Bracco et al., 2019).

Value-added and employment indicators were used to assess the potential of the bioeconomy in Poland and individual EU countries. These are the most commonly used indicators for monitoring the bioeconomy and measuring

its size (Gołębiewski, 2020; Kuosmanen et al., 2020). The aforementioned indicators were obtained from a database developed at the JRC EC (Tamošiūnas et al., 2022). The value of turnover was also used in the analyses. This is the total market value of sales of goods and services to third parties realised in the bioeconomy (European Commission, 2020). The research was conducted for 2020 and all sectors that are a component of the bioeconomy. The bioeconomy includes: agriculture; forestry; fisheries and aquaculture; food, beverages and tobacco; biotextiles; bio-based chemicals, pharmaceuticals, plastics and rubber; paper; wood products and furniture; liquid biofuels; and bioelectricity (M'Barek et al., 2018). The potential of the Polish bioeconomy, was assessed against the background of EU countries.

FINDINGS AND DISCUSSION

According to Gołębiewski (2020), value added is applicable in formulating and giving direction to policies and parties to maximise economic growth. Value added is the monetary value of the goods and services obtained in the production process minus the value of the inputs used. Of course, the amount of value added also depends on the demand for goods and services.

In 2020, the European Union's bioeconomy generated 664.8 billion € in added value. Among EU Member States, Germany, France, Italy and Spain generated the highest added value (Figure 1). The contribution of the added value of these countries' bioeconomies to the total added value of the EU bioeconomy was, respectively: 18.9%; 15.2%, 13.5% and 10.3%. Poland ranked fifth with a bioeconomy value added of 38.3 billion € (5.8%), followed closely by the Netherlands, which generated 32.9 billion € in value added, accounting for 4.9% of the total EU bioeconomy value added. Belgium and Sweden had a slightly smaller share. Their share of the total added value of the EU bioeconomy was 3.6% and 3.4%. Countries with a 2–3% share in the EU added value of the bioeconomy included Austria, Denmark, Ireland and Romania. The remaining countries generated less than 2% of EU bioeconomy value added (Figure 1). The study by Nowak et al. (2022) showed that the share of Poland's added value in the EU bioeconomy in 2017 was 5.0%, which means that by 2020 there was an increase in this share by 0.8%. The obtained results are also consistent with the research of Lakner et al. (2021). The authors state that the bioeconomy in Poland generates greater added values compared to other Visegrad Group countries.

Knowledge of the sectoral structure of added value creation allows for a sectoral decomposition of economic growth (Nowak et al., 2019). An analysis of value added by sector as a component of each country's bioeconomy showed that Greece, Romania, Hungary, Spain and Bulgaria had the highest share of value added of the agriculture sector in the overall bioeconomy, which amounted to,

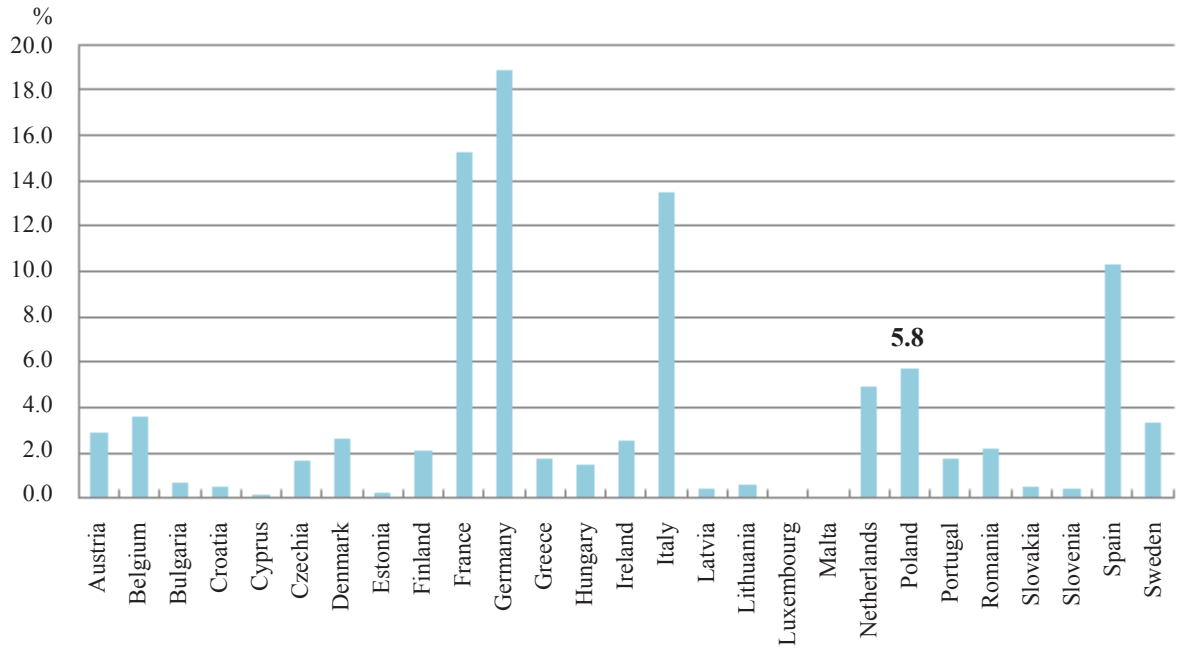

Figure 1. Share of respective member states in the total added value of bioeconomy in EU-27 in 2020.
Source: own study based on Tamošiūnas et al. (2022).

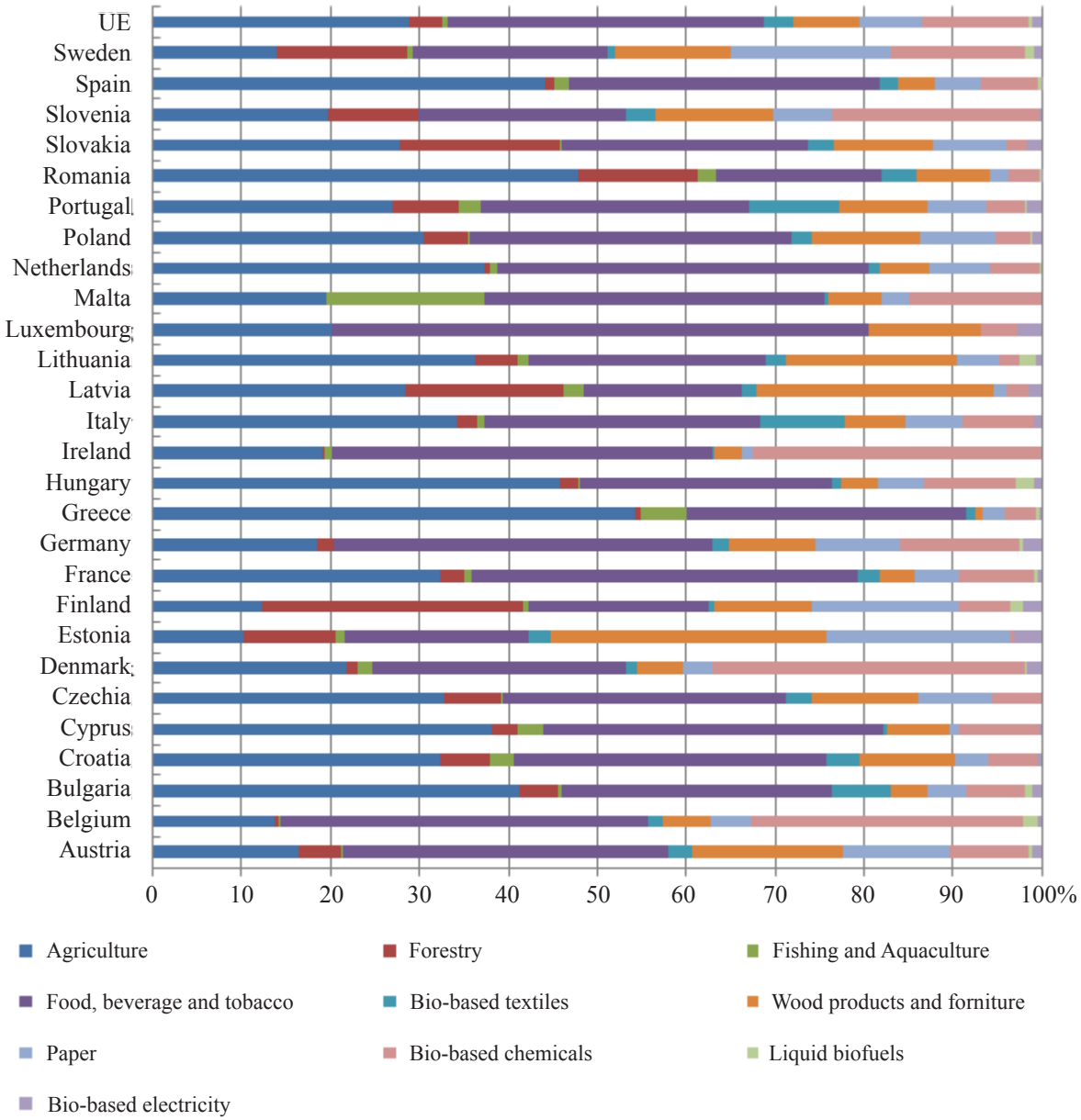

Figure 2. Share of sectors to the added value of the bioeconomy of individual countries in 2020.
Source: own study based on Tamošiūnas et al. (2022).

respectively: 54.3%; 47.9%; 45.8%; 44.1% and 41.3%. (Figure 2). The group of countries with 30–40% share of agriculture in the total value added of the bioeconomy included: Cyprus (38.2%), Netherland (37.2%), Lithuania (36.3%), Italy (34.1%), Czechia (32.8%), France (32.4%), Croatia (32.4%) and Poland (30.5%). Germany deserves a special mention. Although it generated 23.1 billion € of added value in the agricultural sector (4th position among the countries analysed), the sector's share in the added value of the entire bioeconomy was 18.4%. In the remaining countries, the share of agricultural sector value added in the value added of the whole bioeconomy was less than 30%. In the EU, this share was 28.8%.

A sector that contributes significantly to the value added of each country's bioeconomy is the food industry (Figure 2). The largest share of the food, beverage and tobacco sector in the value added of the whole bioeconomy was observed in Luxembourg (60.3%); France (43.3%); Ireland (42.7%), Germany (42.5%), the Netherlands (41.8%) and Belgium (41.3%). At the same time, it was noted that in the aforementioned countries, the share of the food, beverage and tobacco sector in the value added of the entire

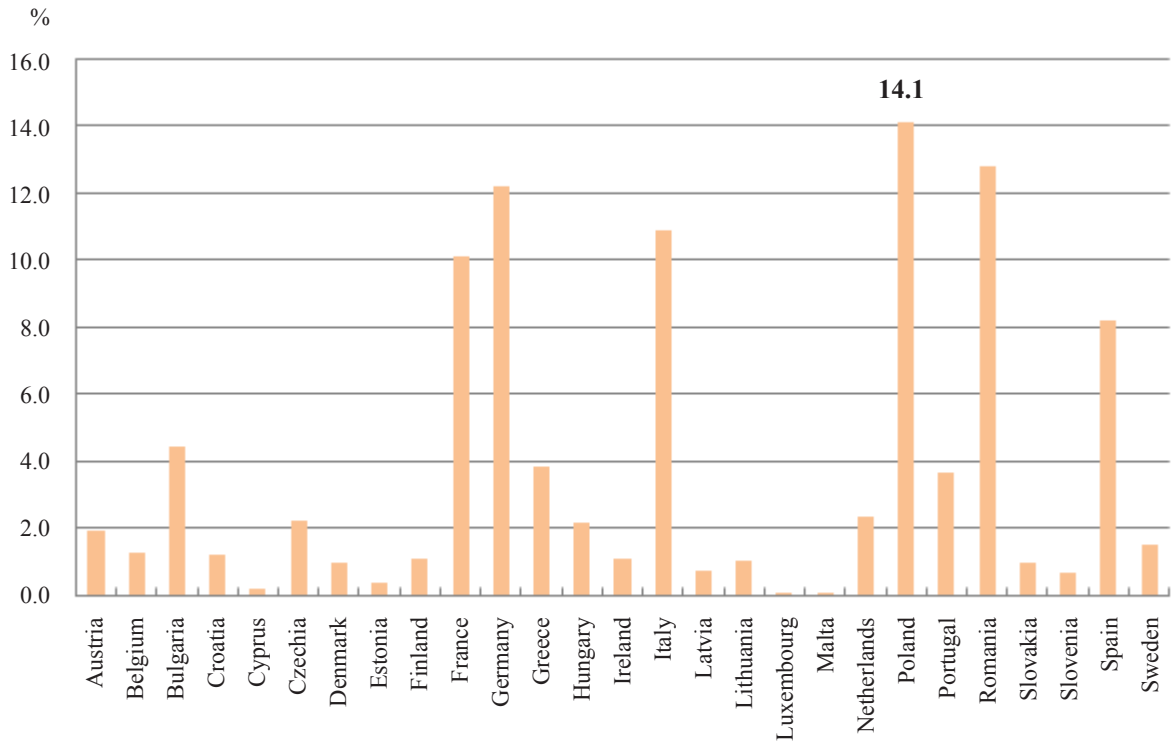

Figure 3. Share of individual member states in bioeconomy employment in the EU-27 in 2020.
Source: own study based on Tamošiūnas et al. (2022).

bioeconomy of each country was higher than that of the agricultural sector. It can therefore be concluded that this sector is becoming more important in the development of the bioeconomy. In Poland, the share of the food, beverage and tobacco sector in the value added of the bioeconomy was 36% and was also higher than the share of agriculture. Also, research by Bas et al. (2019) confirms that the structure of the share of added value of individual sectors in the Polish bioeconomy is dominated by the food industry. A similar trend was found across the EU.

The leaders in the forestry sector were Finland, Slovakia, Latvia and Sweden (Figure 2). The shares of these countries in the added value of the bioeconomy were 29.2%; 18.1%; 17.9% and 14.8%, respectively. In the wood products and furniture sector, Estonia (30.9%) and Latvia (26.8%) had the highest shares in the value added of the bioeconomy, while in the paper industry, Estonia was the leader (20.6%). In Poland, the share of the wood products and furniture sector in value added was 12.3% and in the EU 7.6%. In the bio-chemicals sector, Denmark (35.1%), Ireland (32.6%) and Belgium (30.6%) had the highest shares in value added. Liquid biofuels and bioelectricity did not have a major impact on the added values of the overall bioeconomy of the individual countries.

An important objective of bioeconomy development is the creation of new jobs (European Commission, 2018). The implementation of technological innovations is expected to contribute to a faster development of the bioeconomy and thus to an increase in employment. Particular importance is attributed to the primary production sectors (agriculture, forestry, fisheries and aquaculture) having the largest bioresources and being the first link in the chain of production of higher value added bio-products.

In 2020, the EU bioeconomy employed around 17,170 thousand people. Kasztelan et al. (2021), analysing employment changes in the EU bioeconomy between 2008 and 2017, found a steady decline in employment levels. In the years analysed, the labour force decreased by 12% reaching around 17.5 million people in 2017. Thus, employment levels were reduced by an additional 2% over the following three years.

An analysis of the employment share of individual countries in the EU bioeconomy showed that Poland, Romania, Germany, Italy and France were the leaders (Figure 3). Their employment shares were, respectively: 14.1%; 12.8%; 12.2%; 10.9% and 10.1%. Spain ranked sixth with an 8.2% share of employment in the EU bioeconomy, followed by Bulgaria with a 4.5% share. In the remaining countries, the share of employment in the EU bioeconomy was below 4%.

The development of the bioeconomy is naturally accompanied by changes in the employment structure. The employment structure, on the one hand, is an expression of changes taking place in the bioeconomy under the in-

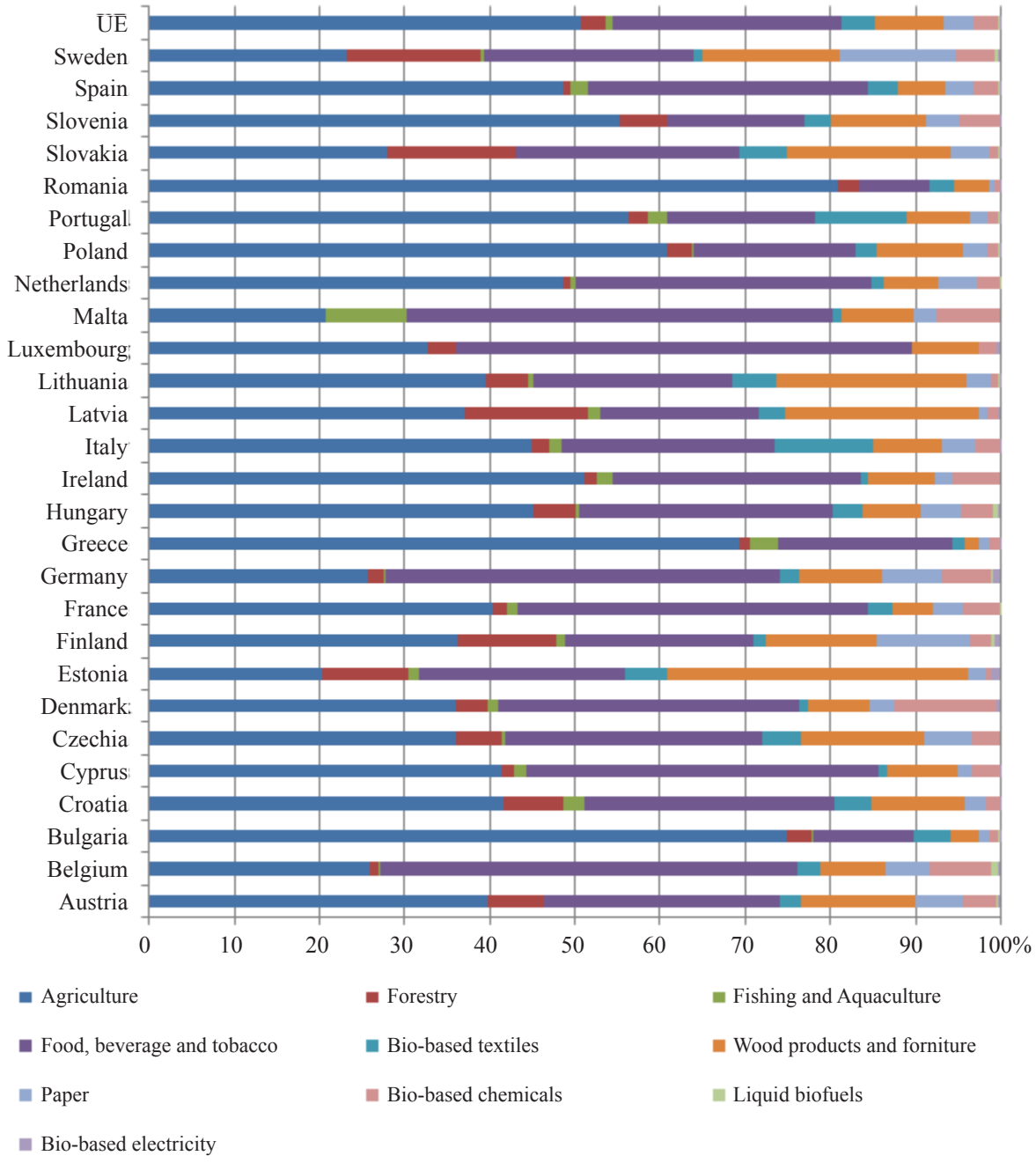

Figure 4. Share of sectors in employment in the bioeconomy of individual countries in 2020.
Source: own study based on Tamošiūnas et al. (2022).

fluence of technology or changes in the demand structure, and on the other hand, it is a resource determining the economies' ability to change (Węgrzyn, 2015). When analysing the potential of individual bioeconomy sectors in EU Member States from an employment perspective, it can be seen that the highest shares are found in the agriculture and food, beverages and tobacco sectors (Figure 4). In the agriculture sector, the leaders in terms of employment share in the bioeconomy were Romania (81.0%); Bulgaria (74.8%); Greece (69.2%) and Poland (60.8%). Our own research has shown that employment in the agricultural sector in the Polish bioeconomy is steadily declining (Faber, Jarosz, 2023a). In the period 2008–2019, the reduction in employment in agriculture was 33.3%, which was due to structural transformations in this sector (acceleration of the land concentration process) and an increase in invest-

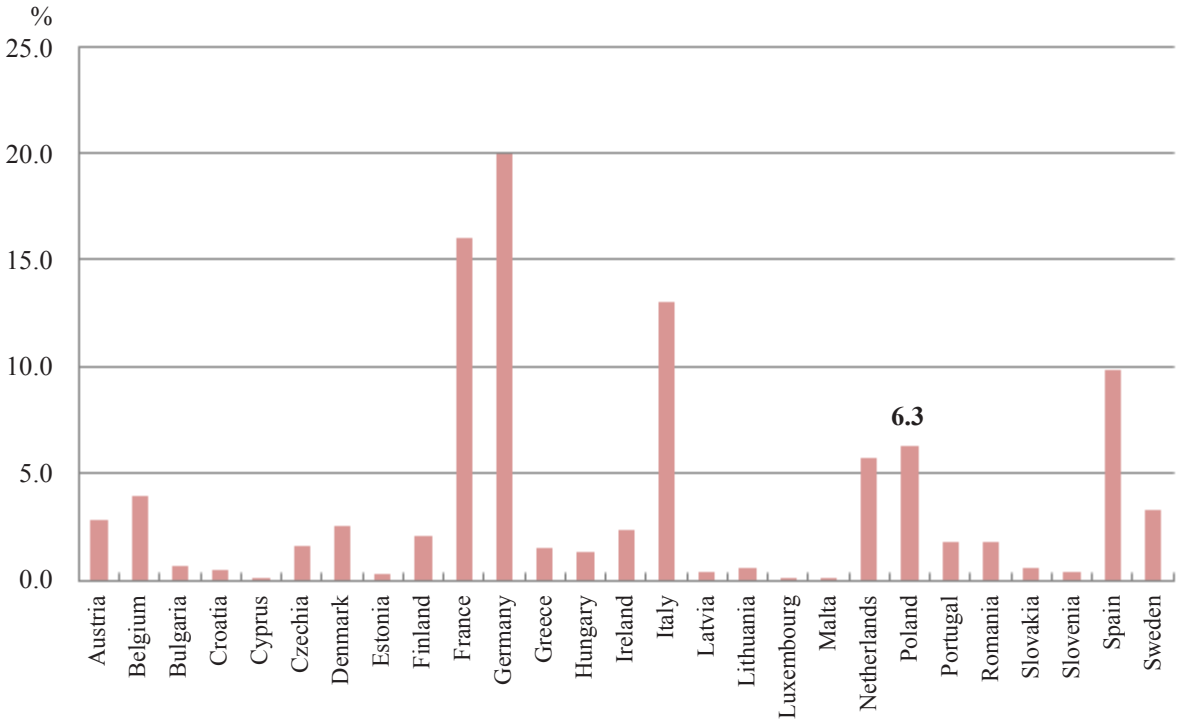

Figure 5. Share of individual member states in the bioeconomy turnover in the EU-27 in 2020.
Source: own study based on Tamošiūnas et al. (2022).

ment expenditures in this sector. However, employment in the agricultural sector is still high. A characteristic feature of Polish agriculture is excessive agrarian fragmentation. The consequence of agrarian fragmentation is a low scale of production and high employment, which results in low profitability. The sector is characterised by low labour productivity (Gołębiewski, 2020; Faber, Jarosz, 2023a). Thus, correcting over-employment in agriculture can improve farmers' profitability. Higher shares of the agricultural sector in bioeconomy employment than the EU average (50.7%) were recorded for Portugal (56.2%); Slovenia (55.4%) and Ireland (51.2%). In the remaining countries, the share of the agricultural sector in the employment in the bioeconomy was lower than in the EU.

The possibilities of increasing labor productivity in Polish agriculture are limited. Too large labor resources in agriculture discourage action to modernize production, because investment is uncompetitive against the cheap labor force of family members. Funding from the CAP may be an incentive. On the one hand, the positive impact of the CAP on structural changes is visible, yet subsidies unrelated to the volume of agricultural production may reduce the motivation to look for a job, and thus have an adverse effect on the change in employment in agriculture (Kołodziejczak, 2018). However, educational support and incentives for farmers' professional development and increased investment in innovation can stimulate development in rural areas.

In August 2022, the European Commission accepted the CAP Strategic Plan for 2023–2027 developed in Poland, which indicates support for enterprises creating additional value from products and by-products of agriculture and forestry. Supported actions should contribute to the following objectives: improving the position of farmers in the value chain and promoting employment, growth, gender equality, including women's participation in agriculture, social inclusion and local development in rural areas, including a circular and sustainable bioeconomy forestry.

However, in the food, beverage and tobacco sector, the leader in bioeconomy employment was Luxembourg (53.5%). The group of countries with a 40–50% share of the food industry in bioeconomy employment included: Malta (49.9%); Belgium (49.0%); Germany (46.3%); and France (41.3%) and Cyprus (41.3%) (Figure 4). In Poland, the sector accounted for 19.0% of employment and 26.8% in the EU. In the wood products and furniture sector, Estonia (35.3%), Latvia (22.6%) and Lithuania (22.2%) had the highest employment shares, and in the paper sector Sweden (13.7%) and Finland (11.0%). The liquid biofuels and electricity bioenergy sectors accounted for small shares of employment in each country's bioeconomy. However, these sectors are becoming increasingly important.

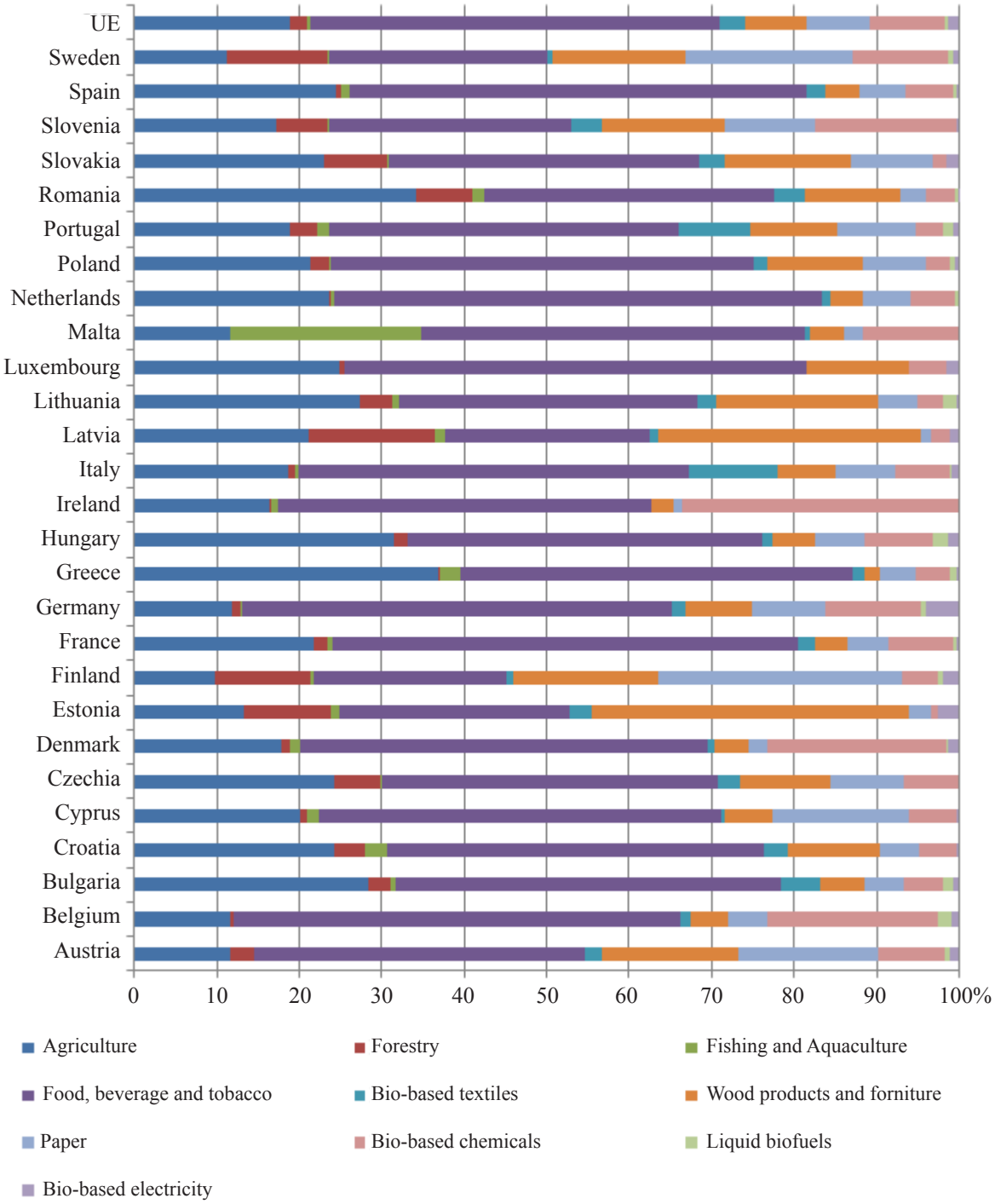

Figure 6. Share of sectors in turnover in the bioeconomy of individual countries in 2020.
Source: own study based on Tamošiūnas et al. (2022).

The potential of each country's bioeconomy was also examined through the value of turnover. In 2020, the EU-wide turnover value was 2,333.5 billion €. The leaders in terms of turnover value were Germany, France, Italy, Spain and Poland. Their share of the total turnover of the EU bioeconomy was, respectively: 19.9%, 16.0%; 13.0% 9.9% and 6.3% (Figure 5). A very low share of turnover of less than 1% in the EU bioeconomy was characterised by Bulgaria, Croatia, Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, Slovakia and Slovenia (Figure 5).

An analysis of the breakdown of turnover in each country's bioeconomy by sector showed that the food, beverage and tobacco sectors had the largest shares (Figure 6). In countries such as Netherland, France, Luxembourg, Spain, Belgium, Germany and Poland, this sector accounted for more than 50% of sales. The average share of turnover of the food, drink and tobacco sector in the EU bioeconomy was 49.6%.

The second most traded sector in the bioeconomy was agriculture. The leaders were Greece (36.8%), Romania (34.3%) and Hungary (31.5%). In Poland, the share of turnover from the agriculture sector in total bioeconomy turnover was 21.3% and in the EU 18.8%. Adamowicz (2017) points out that part of the value of turnover from agriculture, together with manufactured products, moves to other sectors.

The wood products and furniture sector are becoming increasingly important in bioeconomy turnover. Estonia (38.5%) and Latvia (31.8%) had the highest share of this sector's turnover value in the bioeconomy. In Poland, the share was 11.6% and was significantly higher than in the EU – 7.5%. The bio-chemicals sector was characterised by a large variation in turnover values between countries (Figure 6). The leaders were Ireland (33.6%), Denmark (21.8%) and Belgium (20.7%). In the bioelectricity sector, Germany had the highest turnover with a bioeconomy share of 4.0%. Poland was among a large group of countries with a share of less than 1% in this sector (Figure 6).

SUMMARY

The analysis presented here shows that the potential of the bioeconomy varies strongly between countries. It depends on the specific characteristics of the country, the available resources, but most importantly, on the bioeconomy development strategy adopted and implemented. An important issue is the ability to exploit the conditions for development.

The potential of the bioeconomy in individual EU countries was determined on the basis of added value, employment and turnover. The highest position in terms of added value generated was held by Germany, France, Italy and Spain. Poland took fifth place, generating 5.8% of the total added value of the EU bioeconomy. The share of sectors in the total added value of the bioeconomy in individual countries varied. In most countries, food, beverages and tobacco, as well as agriculture, were the main contributors. In Poland, the share of the food industry and agriculture in the added value of the bioeconomy was 36.0% and 30.5%, respectively. This proves that the role of agriculture in creating added value in relation to the food, beverage and tobacco sectors is decreasing.

An analysis of the potential of the bioeconomy in individual EU countries from the employment perspective showed that the largest labor resources were in Poland, Romania, Germany, Italy and France. Diversity in the structure of people working in the bioeconomy was also observed. The sectors with the greatest impact in terms of jobs included agriculture and the food, beverage and tobacco sectors. In Poland, the share of agriculture in the total employment of the bioeconomy was 60.8%, being much higher than the EU average. Own research has shown that the share of agriculture in bioeconomy employment in Poland is systematically decreasing, but is still high, which translates into low labor productivity in this sector (Faber, Jarosz, 2023a).

The bioeconomy potential of individual countries was also examined based on the volume of turnover. The leaders in terms of turnover value were Germany, France, Italy, Spain and Poland. Poland's share in the total turnover of the EU bioeconomy was 6.3%. In terms of turnover structure, three sectors dominated: food, beverages and tobacco, agriculture and wood products and furniture.

To sum up, it can be said that Poland is characterized by significant bioeconomy potential, especially in terms of labor resources. It should be noted that not always high resource potential is reflected in high added value and turnover. An example is Poland, which is characterised by the highest labour resources (1st position) and, at the same time, is not a leader in generating added value and achieved turnover. This is the effect of overemployment in the agricultural sector. However, this sector is still important for the labor market.

The main idea of the bioeconomy is to replace non-renewable resources with renewable raw materials. The agricultural sector plays an important role here, as it is a significant source of biomass. Pajewski (2014) emphasizes that agriculture and forestry are key sectors producing biomass, which is used as a raw material in the food, feed, textile industries, etc. and transformed into bioproducts. The development of the bioeconomy based on innovation contributes to the increase in added value, employment and turnover. Gołębiewski (2020) also noted that progress in natural sciences causes the bioeconomy to develop very dynamically. Increased investment in skills, knowledge and innovation can stimulate regional development, including in rural areas. An opportunity to even out the disproportions may lie in the use of EU funds.

REFERENCES

Adamowicz M., 2017. Bioeconomy – concept, application and perspectives. Problems of Agricultural Economics, 1(350): 29-49, doi: 10.5604/00441600.1232987.

Balcerzak A.P., 2009. Znaczenie wiedzy i innowacyjności w warunkach nowej globalnej gospodarki. In: Przedsiębiorstwo w warunkach globalnej konkurencji; red. nauk. A.P. Balcerzak, E. Rogalska, Wydawnictwo Adam Marszałek, Toruń. (in Polish)

Bas D., Janakowska A., Kryszak Ł., 2019. Potencjał ekonomiczny biogospodarki w wybranych krajach Unii Europejskiej. pp. 17-28. In: Rozwój biogospodarki w Unii Europejskiej

– uwarunkowania, dylematy, perspektywy: seminarium studencko-asystenckie; red.: A. Grzelak, J. Staniwszewski, Parlament Europejski, Bruksela, grudzień 2018. Bydgoszcz: Wydawnictwo Kujawsko-Pomorskiej Szkoły Wyższej w Bydgoszczy. (in Polish)

Bell J., Paula L., Dodd T., Németh S., Nanou Ch., Mega V., Campos P., 2018. EU ambition to build the world's leading bioeconomy. Uncertain times demand innovative and sustainable solutions. New Biotechnology, 40: 25-30, doi: 10.1016/j.nbt.2017.06.010.

Bracco S., Tani A., Çalıcıoğlu Ö., Gomez San Juan M., Bogdanski A., 2019. Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward. Rome, FAO.

Brenne R., 2022. European Bioeconomy Strategy: Stocktaking and future developments. Digitisation of biology for circular bioeconomy applications. 31 May 2022. Bioeconomy and Food System Unit, European Commission.

Cristóbal J., Matos C.T., Aurambout J.-P., Manfredi S., Kavalov B., 2016. Environmental sustainability assessment of bioeconomy value chains. Biomass and Bioenergy, 89: 159-171, https://doi.org/10.1016/j.biombioe.2016.02.002.

Czernyszewicz E., 2016. Conditions and prospects of the development of the bio-economy in the European Union. Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego, T16(31), 3: 49-56. (in Polish + summary in English)

European Commission, 2022. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Progress report on the implementation of the EU bioeconomy strategy. European bioeconomy policy: summary and future developments. Brussels, COM(2022) 283 final.

European Commission, 2020. Europe 2020 - A strategy for smart, sustainable and inclusive Growth. Brussels, COM(2010) 2020 final.

European Commission, 2019. Communication from the Commission to the European Parliament, the European Council, the Council, the Economic and Social Committee and the Committee of the Regions. The European Green Deal / Komunikat Komisji Do Parlamentu Europejskiego, Rady Europejskiej, Rady, Komitetu Ekonomiczno-Społecznego i Komitetu Regionów. Europejski Zielony Ład. COM(2019) 640 final. (in Polish)

European Commission, 2018. A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment. Publications Office of the European Union, COM(2018), 673 final.

European Commission, 2012. Innovating for Sustainable Growth: A Bioeconomy for Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, COM(2012) 60 final.

Faber A., Jarosz Z., 2023. Characteristics of sustainable development of bioeconomy in Poland - ecological dimension. Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego, 23(1): 4-18, doi: 10.22630/PRS.2023.23.1.1. (in Polish + summary in English)

Faber A., Jarosz Z., 2023a. Changes and opportunities for the development of bioeconomy in Poland against the background of the European Union. Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego, 23(3): 4-19, doi: 10.22630/PRS.2023.23.3.9. (in Polish + summary in English)

Giuntoli J., Robert N., Ronzon T., Sanchez Lopez J., Follador M. et al., 2020. Building a monitoring system for the EU bioeconomy. EUR 30064 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-15385-6, doi: 10.2760/717782, JRC119056.

Gołębiewski J., 2020. Employment and added value in European Union bioeconomy – a sustainable development perspective. Annals PAAAE, XXII(4): 74-83, doi: 10.5604/01.3001.0014.6139.

Jander W., Wydra S., Wackerbauer J., Grundmann P., Piotrowski S., 2020. Monitoring bioeconomy transitions with economic – environmental and innovation indicators: Addressing data gaps in the short term. Sustainability, 12(11): 4683, https://doi.org/10.3390/su12114683.

Juerges N., Hansjürgens B., 2018. Soil governance in the transition towards a sustainable bioeconomy – A review. Journal of Cleaner Production, 170: 1628-1639, https://doi.org/10.1016/j.jclepro.2016.10.143.

Kasztelan A., Jarosz-Angowska A., Nowak A., Krukowski A., 2021. Konkurencyjna biogospodarka szansą dla zrównoważonego rozwoju krajów Unii Europejskiej. Radom, ISBN 978-83-67033-00-8. (in Polish)

Kołodziejczak W., 2018. Employment and Gross Value Added in the Sectors of the European Union Economy in 2002 and 2016. Zeszyty Naukowe SGGW w Warszawie - Problemy Rolnictwa Światowego, 18(40): 270-283, doi: 10.22630/PRS.2018.18.4.117. (in Polish + summary in English)

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. Publications Office of the European Union, Luxembourg.

Lakner, Z., Oláh, J., Popp, J., Balázs, E., 2021. The structural change of the economy in the context of the bioeconomy. EFB Bioeconomy Journal, 1, 100018, https://doi.org/10.1016/j.bioeco.2021.100018.

Liobikiene G., Balezenti T., Streimikiene D., Chen X., 2019. Evaluation of bioeconomy in the context of strong sustainability. Sustainable Development, 27(5): 955-964, https://doi.org/10.1002/sd.1984.

Liobikiene G., Chen X., Streimikiene D., Balezentis T., 2020. The trends in bioeconomy development in the European Union: exploiting capacity and productivity measures based on the land footprint approach. Land Use Policy, 91:104375, https://doi.org/10.1016/j.landusepol.2019.104375.

M'Barek R., Parisi C., Ronzon T., 2018. Getting (some) numbers right – derived economic indicators for the bioeconomy, EUR 29353 EN, Publications Office of the European Union, Luxembourg.

Mubareka S., Giuntoli J., Sánchez López, J., Lasarte-López J., M'Barek R., Ronzon T., Renner A, Avraamides M., 2023. Trends in the EU bioeconomy. EUR 31434 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-68-00295-7, doi:10.2760/835046, JRC132639.

Nowak A., Jarosz-Angowska A., Krukowski A., 2022. The potential of Polish bioeconomy compared to the European Union countries. Przegląd Prawno-Ekonomiczny, 4: 97-115, https://doi.org/10.31743/ppe.13792 .

Nowak A., Kijek T., Krukowski A., 2019. Polskie rolnictwo wobec wyzwań współczesności. Wymiar ekonomiczno-strukturalny. T. 1. Wyd. UP w Lublinie, Lublin, ISBN 978-83-7259-306-1.

Pajewski T. 2014. Bioeconomy as a strategic component of sustainable agriculture. Roczniki Naukowe SERIA, XVI(5): 179-184. (in Polish + summary in English)

Pellis P., Cantone S., Ebert C., Gardossi L., 2018. Evolving biocatalysis to meet bioeconomy challenges and opportunities. New Biotechnology, 40: 154-169, https://doi.org/10.1016/j.nbt.2017.07.005.

Pink M., 2020. Biogospodarka w strategiach Unii Europejskiej i Polski. pp. 55-80. In: Biogospodarka. Aspekty społeczne, instytucjonalne i produkcyjne; ed.: D. Bedla, J. Szarek; Kraków, Tyniec Wydawnictwo Benedyktynów, ISBN 978-83-8205-055-4. (in Polish)

Ronzon T., M'Barek R., 2018. Socioeconomic indicators to monitor the EU's bioeconomy in transition. Sustainability, 10(6): 1745, https://doi.org/10.3390/su10061745.

Scheiterle L., Ulmer A., Birner R., Pyka A., 2018. From commodity-based value chains to biomass-based value webs: The case of sugarcane in Brazil's bioeconomy. Journal of Cleaner Production, 172: 3851-3863, https://doi.org/10.1016/j.jclepro.2017.05.150.

Tamošiūnas S., Ronzon T., Piotrowski S., M'Barek R., Carus M., 2022. Jobs and wealth in the EU bioeconomy / JRC - Bioeconomics. European Commission, Joint Research Centre (JRC), [Dataset] PID. http://data.europa.eu/89h/7d7d5481-2d02-4b36-8e79-697b04fa4278 (accessed 25.09.2023).

United Nations SDSN, 2015. Indicators and a Monitoring Framework for the Sustainable Development Goals. Launching a data revolution for the SDGs. A report to the Secretary-General of the United Nations by the Leadership Council of the Sustainable Development Solutions Network. https://sustainabledevelopment.un.org/content/documents/2013150612-FINAL-SDSN-Indicator-Report1.pdf (accessed 25.09.2023).

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