

Ewa Woźniak-Gientka

Institute of Bioorganic Chemistry, Polish Academy of Sciences

ewozniak@ibch.poznan.pl,  <https://orcid.org/0000-0001-6403-4240>

Regional bioeconomy development in Poland: evidence from the Wielkopolskie voivodeship

Abstract: This study analyses the economic and environmental conditions for bioeconomy development in Poland's Wielkopolskie voivodeship. Using a case study approach and indicator-based analysis, the study examines the structure of bioeconomy sectors, employment, and biomass potential. The findings indicate that the regional bioeconomy represents an important, though structurally traditional, segment of the regional economy, dominated by agriculture, food processing, and wood-based industries, with limited involvement of R&D and advanced biotechnology. The study contributes to the literature on regional bioeconomy development by highlighting the role of economic structures, innovation, and resources in shaping its development pathways.

Keywords: bioeconomy, Poland, regional analysis, strategy, sustainable development

Introduction

The bioeconomy encompasses a wide range of sectors, including agriculture, forestry, fisheries, food and feed production, pulp and paper industries, as well as cutting-edge biotech and bio-based industries. These areas demonstrate substantial innovation potential, drawing on insights from diverse scientific fields, such as life sciences, ecology, food science, applied biotechnology, nanotechnology, and local tacit knowledge (Bioeconomy Strategy 2012, 2018, 2025, Haarich 2017, Ronzon et al. 2020). As a driver of sustainable development and global competitiveness, the bioeconomy relies on renewable biological resources that can be transformed into value-added products and bioenergy (Lokko et al. 2018, Park, Grundmann 2023, Barra, Falcone 2024). Its development depends on effective governance, political stability, and coherent regulatory frameworks (D'Adamo et al. 2020, Barra, Falcone 2024).

The European Union's (EU) approach to bioeconomy has evolved significantly, reflecting changing policy priorities and sustainability challenges (Patermann, Aguilar 2021, Warchold et al. 2026). The bioeconomy concept, developed more than twenty years ago, has shifted from a biotechnology-centred paradigm to

a bioeconomy as a key driver of sustainable development (Patermann, Aguilar 2018). The first EU Bioeconomy Strategy, launched in 2012, primarily emphasized research and innovation as the key forces shaping a knowledge-based bioeconomy. Its main objective was to harness renewable biological resources for economic growth while addressing global challenges including resource scarcity, environmental degradation, and food security. The 2012 strategy promoted cross-sectoral policy coherence and encouraged stakeholder cooperation, positioning bioeconomy largely as a tool for scientific advancement, technological development, and economic competitiveness (Bioeconomy Strategy 2012).

The 2018 Strategy update broadened the focus to include explicit environmental and sustainability goals. While still recognizing the importance of research and innovation, this version placed greater emphasis on circularity, ecological limits, and alignment with global frameworks such as the *Sustainable Development Goals* (SDGs) and the *Paris Agreement*. It emphasized the importance of implementing bioeconomy initiatives at both regional and local scales, while ensuring that socio-economic progress is aligned with environmental sustainability. By linking bioeconomy development more closely with sustainability, the 2018 strategy marked a shift from an innovation-centered approach to one that balances technological progress with environmental and social responsibility (Bioeconomy Strategy 2018).

The 2025 latest framework represents a further evolution, placing industrial competitiveness, market scaling, and strategic resilience at the forefront. The 2025 strategy emphasizes bringing innovations from research to market, developing lead markets for bio-based products, and enhancing Europe's global role in the bioeconomy. It integrates the bioeconomy more explicitly with broader EU policies on industrial competitiveness, supply chain autonomy, and clean industry transitions (Bioeconomy Strategy 2025).

Overall, the evolution from 2012 to 2025 illustrates a clear trajectory: the EU has moved from establishing a foundation for research-driven bioeconomy, through embedding sustainability and circularity, to strengthening the link between innovation, market competitiveness, and strategic autonomy. This progression underscores the growing recognition that a successful bioeconomy requires not only scientific and technological excellence but also coherent policies, strong institutions, mechanisms to translate innovation into regional and economic impact, as well as effective stakeholder engagement and transparent communication (Bioeconomy Strategy 2012, 2018, 2025, Lokko et al. 2018, Aguilar et al. 2019, Woźniak et al. 2021a, b). Despite this progress, empirical evidence on the structural characteristics of bioeconomy development at the regional level remains limited.

The aim of this article is to assess the state and structural characteristics of the bioeconomy in the Wielkopolskie voivodeship, with a particular focus on sectoral composition, employment patterns, and biomass potential in 2022. The findings are based on a pilot study and provide a foundation for more comprehensive research currently underway.

Pathways to bioeconomy development

The literature indicates that the barriers and enabling factors shaping bioeconomy development are highly diverse, with governance, investment, and public awareness identified as key dimensions (Briers et al. 2026). Kelleher et al. (2019) emphasised the importance of appropriate regulatory frameworks for successful cross-sectoral development. Heimann (2018) showed that, without complementary measures such as regulatory frameworks, policy instruments, and sustainability-oriented investments, the bioeconomy may constrain rather than support the achievement of the SDGs. Financial conditions, particularly investment in research and development (R&D) and innovation, play a critical role in either enabling or limiting progress (Briers et al. 2026). Limited access to capital and insufficient support for commercialisation remain significant barriers (Dietz et al. 2018). In addition, public perception and engagement are crucial, as societal acceptance underpins the long-term sustainability of bioeconomy transitions, including workforce development (Pender et al. 2024). Accordingly, the literature emphasises the need to strengthen public awareness and understanding of the bioeconomy (e.g. Trigkas, Karagouni 2023, Briers et al. 2024, Pink et al. 2024).

In rural contexts, the bioeconomy is increasingly conceptualised as a place-based innovation approach that builds on specific regional assets, knowledge, and capacities (De Schutter et al. 2019). This implies that development strategies should be tailored to the ecological, economic, and socio-cultural conditions of each region rather than standardised (Meyer 2017). Innovation is therefore closely linked to local resources, institutional structures, cultural practices, and stakeholder networks. Empirical studies highlight the importance of participatory approaches, and the need for inter- and cross-sectoral as well as transdisciplinary cooperation (Patermann et al. 2018, Szarka et al. 2023, Hofer et al. 2025). Spatial perspectives are particularly relevant, as they enable the alignment of innovation strategies with territorial and ecological specificities (Vivien et al. 2019, Szarka et al. 2023). This suggests that successful bioeconomy transitions are multidimensional and strongly dependent on regional embeddedness, which enhances social sustainability and resilience (Meyer 2017, Szarka et al. 2023, Laasonen 2024, Schlaile et al. 2025). In this context, the bioeconomy extends beyond traditional resource-based production models towards broader systemic transformations across value chains. This also highlights the need for clear governance framework that enable diverse stakeholders – such as farmers, businesses, policymakers and researchers – to collaboratively shape sustainable innovation pathways (FAO 2021, Hofer et al. 2025).

While previous studies have primarily examined bioeconomy development at national and EU levels (Haarich et al. 2022, Dolge et al. 2023), there is a notable gap in regional-level analyses in Poland, particularly regarding structural characteristics, innovation potential, and development barriers (Skorwider-Namiotko 2015, Kraska et al. 2024). By focusing on the Wielkopolskie voivodeship as a case study, this research provides preliminary evidence on the regional determinants

shaping bioeconomy development and contributes to a better understanding of how regional contexts influence the transition toward a sustainable bio-based economy.

Materials and methods

Defining the scope of the bioeconomy

This study is grounded in the bioeconomy definition provided in the EC communication COM (2012) mentioned in the Introduction (Bioeconomy Strategy 2018). The bioeconomy is understood here as a broad set of economic activities associated with the production and manufacturing of biomass. Based on the European statistical classification of economic activities (NACE Rev. 2), and previous studies by Ronzon et al. (2020), these activities correspond to the sectors presented in Table 1 (Eurostat 2008). Due to the limitations of publicly available regional statistical data, the identification of bioeconomy activities was conducted at the level of entire PKD/NACE divisions. The inclusion of R&D activities

Table 1. Bioeconomy sectors in Poland

Section	NACE classification	Bioeconomy sectors
A – Agriculture, Forestry and Fishing	A01	Agricultural crops, animal breeding and husbandry, hunting, including service activities
	A02	Forestry and timber harvesting
	A03	Fishing
C – Manufacturing	C10	Food production
	C11	Beverage production
	C12	Production of tobacco products
	C13	Textile production
	C14	Clothing production
	C15	Production of leather and leather products
	C16	Manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	C17	Production of paper and paper products
	C20	Production of chemicals and chemical products
	C21	Production of basic pharmaceutical substances and medicines and other pharmaceutical products
	C22	Production of rubber and plastic products
D – Electricity, gas, steam and air conditioning supply	C31	Furniture production
	D35.1	Generation, transmission, distribution and trade of electricity
M – professional, scientific and technical activities	M72.1	Scientific R&D work in the field of natural and technical sciences

Source: NACE classification, Polish Classification of Activities.

reflects the growing importance of biotechnology and innovation systems as enabling components of the knowledge-based bioeconomy.

Data sources and methods

The analysis is based on publicly available data from the Central Statistical Officeⁱ and the Local Data Bankⁱⁱ supplemented with purchased data on the number of registered entities (REGON)¹ and the average employment in bioeconomy as of December 2022. Data on renewable energy sources (installed capacity and number of installations) were obtained from the Polish Energy Regulatory Office.ⁱⁱⁱ The selection of indicators was guided by two main criteria: (i) the availability and consistency of data at the regional level, and (ii) their relevance to key dimensions of the bioeconomy as identified in the international literature. The adopted indicators capture essential socio-economic and environmental aspects of bioeconomy development, in line with methodological approaches used in comparable studies across European regions.

The following methods were used:

- **Case study.** Analysing the bioeconomy development in the Wielkopolskie voivodeship. This method involves a detailed, comprehensive description of a single case, and its analysis allows for the presentation of conclusions regarding the causes and effects of its functioning (Stake 1995).
- **Indicator methods.** In this study, socio-economic and environmental indicators were analysed to measure bioeconomy in the region. Moreover, the analysis of available biomass sources from agriculture and forestry in the region was examined.

Results

This section presents the main findings of the analysis, structured around the few dimensions of the research question: *What is the size of bioeconomy and bio-based industries in the Wielkopolskie voivodeship, and what areas of bioeconomy represent the region's development potential?* The state of the bioeconomy in the region was examined based on relevant indicators and statistical data to provide a comprehensive assessment of its development.

The state of the bioeconomy in the Wielkopolskie voivodeship

In 2022, a total of 28 910 entities in the region were active in bioeconomy sectors. Approximately 34% operated in Section A (agriculture, forestry, and fishing; Table 2). Among the main industrial sectors, furniture manufacturing accounted for 16% of all entities, followed by wood and cork (12%) and food production (11%).

¹ REGON register is a continuously actualised set of information on subjects of national economy run as an IT system in the way of central database.

Table 2. National economy entities from the REGON register reporting engagement in economic activities in the Wielkopolskie voivodeship in 2022

Division	Activity	National economy entities from the REGON register reporting engagement in economic activities	Share [%]
01	Agricultural crops, animal breeding and husbandry, hunting, including service activities*	8 479	29.3
02	Forestry and timber harvesting	1 201	4.1
03	Fishing	72	0.2
10	Food production	3 291	11.3
11	Beverage production	141	0.5
12	Production of tobacco products	8	0.03
13	Textile production	968	3.4
14	Clothing production	2 335	8.0
15	Production of leather and leather products	232	0.8
16	Manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	3 512	12.1
17	Production of paper and paper products	624	2.2
20	Production of chemicals and chemical products	493	1.7
21	Production of basic pharmaceutical substances and medicines and other pharmaceutical products	39	0.1
22	Production of rubber and plastic products	1 426	4.9
31	Furniture production	4 570	15.8
35.1	Generation, transmission, distribution and trade of electricity	1 095	3.8
72.1	Scientific R&D development work in the field of natural and technical sciences	424	1.5
All		28 910	100.0

* excluding individual farms.

Source: own study based on data from the CSO in Poznan (2022).

The highest number of bioeconomy entities was recorded in Poznan County (3804) and the city of Poznan (3715). In Poznan County, activity was concentrated primarily in the furniture manufacturing (933 entities), followed by crop and animal farming (556) and food product manufacturing (425).^{i,ii} The majority of R&D entities in natural and technical sciences were located in the city of Poznan (271) and Poznan County (71), together accounting for around 80% of such entities in the region. This concentration reflects the presence of key scientific and research institutions. According to CSOⁱ, 80 entities from the REGON register were engaged in biotechnology R&D, including 58 in Poznan and 11 in Poznan County.

In 2022, a total of 202 079 people were employed in the bioeconomy in the Wielkopolskie voivodeship, accounting for 13% of total regional employment. The largest shares were recorded in food product manufacturing (25%), furniture manufacturing (23%), and the rubber and plastic products manufacturing (12%;

Table 3). In contrast, employment in sectors such as leather production (0.5%), pharmaceuticals (1.3%), and R&D in the natural and technical sciences (1.5%) remained relatively low.^{i,ii}

Table 3. Average employment in the bioeconomy*

Activity	Average employment	Share [%]
Agricultural crops, animal breeding and husbandry, hunting, including service activities	9208	4.6
Forestry and timber harvesting	3054	1.5
Food production	50 333	24.9
Beverage production	5 683	2.8
Textile production	9 357	4.6
Clothing production	3 980	2.0
Production of leather and leather products	968	0.5
Manufacture of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	16 574	8.2
Production of paper and paper products	11 773	5.8
Production of chemicals and chemical products	7 510	3.7
Production of basic pharmaceutical substances and medicines and other pharmaceutical products	2 544	1.3
Production of rubber and plastic products	24 683	12.2
Furniture production	47 346	23.4
Generation, transmission, distribution and trade of electricity	6 108	3.0
Scientific R&D work in the field of natural and technical sciences	2 958	1.5
All	202 079	100.0

* for entities with more than 9 employees; data for the fisheries sector and tobacco product manufacturing are not available due to statistical confidentiality.

Source: CSO Poznań, based on form Z-06 (2022).

An important indicator of bioeconomy development is the number of organic producers and the area of organic farmland. Since 2019, the region has recorded an increase in organic farms alongside a decline in certified farms, likely reflecting stricter EU quality requirements. In 2022, there were 1 075 organic producers in the region (approximately 5% of the national total). At the same time, 585 certified organic farms operated on 22 026 ha, accounting for about 64% of the total organic agricultural area.^{iv}

Biotechnology

According to CSOⁱ, in 2022 there were 23 biotechnology enterprises operating in the region, accounting for 12% of all such enterprises in Poland. Most employed 49 or fewer persons (16 firms), while seven employed 50 or more.^{i,ii} Biotechnology enterprises in the Wielkopolskie voivodeship employed a total of 314 persons, 56% of whom were women, representing 7% of national employment in the sector^{i,iii} (Table 4).

Table 4. Persons employed in biotechnology enterprises

	Total	Woman	In R&D	Share of persons employed [%]
Wielkopolskie voivodeship	314	175	195	7.3
Poland	4317	1967	2144	100.0

Source: based on CSO (2022).

Scientific units conducting R&D in biotechnology can be classified into government, higher education, and private non-profit sectors. The government sector includes public administration units and state-controlled non-commercial institutions not classified as higher education. The higher education sector comprises universities and technical higher education institutions providing post-secondary education. The private non-profit sector includes non-market institutions operating for public benefit. ⁱ

In 2022, a total of 10 scientific units conducting biotechnology R&D operated in the Wielkopolskie voivodeship, compared to 110 nationwide. ^{i,ii} Biotechnology R&D activities are commonly classified into three categories: basic research, applied research, and development work. Basic research is undertaken to generate new knowledge without immediate practical application, while applied research is oriented towards specific practical uses. Development work focuses on generating knowledge and skills for the development or improvement of products, processes, and services. ^{i,ii}

In 2022, the Wielkopolskie voivodeship hosted 10 scientific units conducting biotechnology R&D, all of which performed basic research. Development work was carried out by three units, while applied research activities were conducted by eight units. Altogether, 681 individuals were employed in biotechnology-related R&D, with women accounting for 67% of the workforce (Table 5). Most employees held a doctoral degree (34%) or tertiary education qualifications (38%), while 8,5% has a professorial title. ^{i,ii}

Table 5. Persons employed in R&D in biotechnology in scientific units

	Total	Woman	Share of persons employed [%]
Wielkopolskie voivodeship	681	459	10.8
Poland	6275	4085	100.0

Source: based on CSO and Local Data Bank (2022).

Internal R&D expenditure is an important indicator in the analysis of the biotechnology sector and refers to all R&D spending carried out by a given statistical unit, regardless of funding source. In 2022, internal R&D expenditure on biotechnology in enterprises located in Wielkopolskie voivodeship amounted to approximately PLN 39.5 million, compared to PLN 604 million at the national level. ^{i,ii} This represented 22% of total internal R&D expenditure in biotechnology enterprises in the region (PLN 177 million). In scientific units, internal R&D expenditure on biotechnology in the region totalled approximately PLN 75 million, representing around 9% of national expenditure. ^{i,ii}

The main areas of activity in biotechnology indicated by scientific units were health care (6 units), non-genetically modified agricultural biotechnology (6 units), health care without using rDNA technology (5 units), environment (5 units) and bioinformatics (4 units). ⁱⁱ

Bioenergy

The generation of electricity from renewable sources is important for environmental protection and energy security. Key policy priorities include increasing renewable energy production, supporting technological innovation, and strengthening energy supply security (Bachanek et al. 2025). In 2022, total installed RES capacity in Poland amounted to 14,180.043 MW, dominated by wind energy (58%), followed by solar (22%), biomass (10%), hydropower (7%), and biogas (2%). ^v In the Wielkopolskie voivodeship, total installed RES capacity reached approximately 1,818.804 MW, with wind energy accounting for 56%, solar for 27%, and biomass for 13%. ^v

In 2022, a total of 792 RES installations operated in Wielkopolskie voivodeship, representing a 36% increase compared to the previous year (Table 6). The dominant technologies were solar installations (57%) and wind installations (35%). About 20% of all wind installations and 14% of solar installations in Poland were located in the region. ^v

Table 6. The number of RES installations in the Wielkopolskie voivodeship

Type of installations	2021	2022
using biogas	33	35
using biomass	4	5
waste thermal treatment plant	2	2
using solar energy	250	452
using wind energy	252	273
using hydropower	39	25
using the technology of co-firing biomass, biogas or bioliquids with other fuels (fossil fuels and biomass/biogas/bioliquids)	no data	no data
All	580	792

Source: Energy Regulatory Office (2021–2022).

Considering the spatial distribution, the highest numbers of installations was recorded in Gniezno County and Konin County (53 each; Fig. 1). The highest installed capacity was observed in the city of Konin (177.892 MW) and in Chodzież (138.302 MW), Wągrowiec (132.951 MW), Turek (122.901 MW), and Konin counties (110.042 MW). Notably, 87% of capacity in Chodzież County was generated by a single wind installation in Margonin, while in Poznań biomass and thermal waste treatment installations accounted for 74% of installed capacity. ^v

In 2022, there were 35 biogas and 5 biomass installations operating in Wielkopolskie voivodeship, accounting for 9% and 11% of all such installations in Poland, respectively. The region has substantial biomass potential, due to its

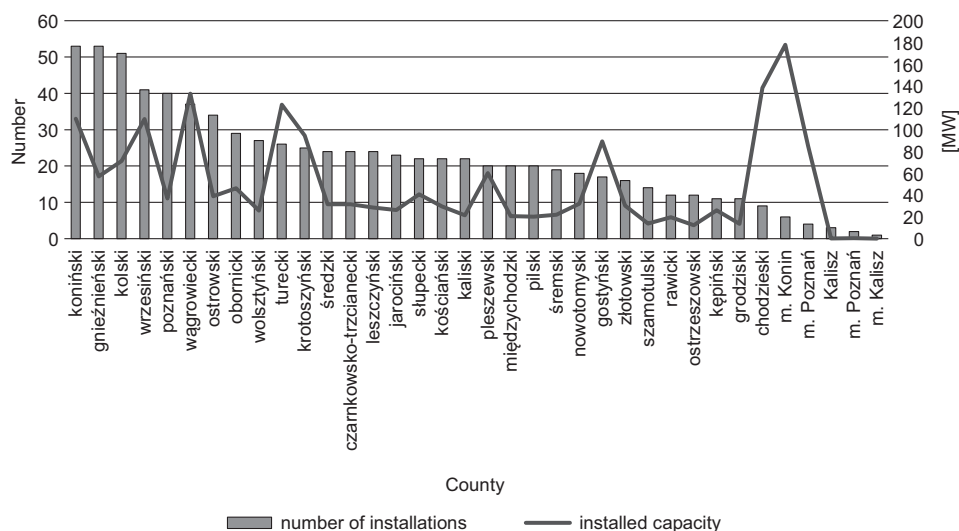


Fig. 1. Number of RESs installations and their installed capacity by Counties in the Wielkopolskie voivodeship in 2022

Source: Energy Regulatory Office (2022).

geographical conditions, particularly the large share of forested and agricultural land. Biogas and biomass therefore play a significant role in the development of the regional bioeconomy. According to data from the National Support Centre for Agriculture, 25 agricultural biogas plants operated in the region in 2022. The highest installed capacities were recorded for Group AWW sp. z o.o. (3.500 MW) and Cychry Biogas Power Plant (2.134 MW).^v

The region, with a high share of weather-dependent renewable energy sources, has significant potential for hydrogen production from surplus electricity generated by photovoltaic and wind installations. In 2023, the Marshal's Office developed a regional strategy outlining objectives for hydrogen infrastructure development. The region has also joined Hydrogen Europe, a key European network in the field of hydrogen and fuel cell technologies, and strengthened international cooperation, including the designation of Wielkopolskie voivodeship as a hydrogen valley (Strategy 2023).

Biomass potential

The level and structure of biomass production in Poland are determined by natural, organizational, and economic conditions. Crop production is a key sector of Polish agriculture, accounting for 34.3% of market-oriented agricultural output in 2022.^{i,ii} According to the 2020 Agricultural Census, total agricultural land in Wielkopolskie voivodeship amounted to 1.776 million ha, representing 12% of Poland's total agricultural area.ⁱⁱ Agricultural land is predominantly held by individual farms, which accounted for approximately 91% of this production factor in Poland and 86% in Wielkopolskie voivodeship.

Of particular importance for biomass utilization potential is the share of fallow and idle land in the land-use structure. At the national level, such land accounted for 1.2% of total agricultural area, compared to 0.6% in the Wielkopolskie voivodeship (Table 7; Statistical Yearbook of the Regions 2022). Agriculture is the main source of both primary and secondary raw materials used in the bioeconomy (Chyłek et al. 2017). Biomass production in agriculture is characterized by temporal and spatial variability in cropping patterns and yields.

Table 7. Agricultural land area by type of land in 2020

	Total	Agricultural land in good agricultural condition								Remaining
		All	Sowing	Fallow land	Permanent crops		Kitchen garden	Meadows	Permanent pastures	
					All	Orchards				
in thousand ha										
Poland	14952.9	14754.9	10961.8	187.8	380.1	355.7	22.3	2788.1	414.7	198.0
Wielkopolskie voivodeship	1776.9	1764.5	1495.8	11.2	17.8	15.7	1	220.3	18.4	12.4
in %										
Poland			74.3	1.2	2.6		0.2	18.9	2.8	
Wielkopolskie voivodeship			84.7	0.6	1.0		0.05	12.5	1.0	

Source: own study based on data from the Agricultural Census (2020).

In 2021, the cropping structure in Wielkopolskie voivodeship was dominated by cereals (52%), maize (13%), and oilseed rape and turnip rape (7%). Within cereals, wheat accounted for 32% of the sown area, followed by triticale (28%) and rye (18%) (Statistical Yearbook of the Regions 2022). The region also recorded the largest national sown area of cereals, grain maize, potatoes, and sugar beet (Statistical Yearbook of the Regions 2022).

The main sources of biomass from crop production include cereal grain and straw, rapeseed and turnip rape seeds and straw, maize and sorghum (green biomass), sugar beet, potato, dedicated energy crops, hay from permanent meadows and pastures, by-products of crop production (e.g. sugar beet leaves), and wood waste from pruning and the removal of permanent plantations (orchards and berry shrubs) (Chyłek et al. 2017, Statistical Yearbook of the Regions 2022). In the Wielkopolskie voivodeship, cereal yields reached 50.6 dt/ha and were among the highest in Poland. Maize grain yields were below the national average at 73.4 dt/ha, while high yields were recorded for meadow hay (65.5 dt/ha). Biomass and biogas potential are presented in Figures 2 and 3.

In 2020, straw accounted for the largest share of solid biomass potential in the Wielkopolskie voivodeship (approximately 80%), followed by wood derived from pre-commercial thinning and silvicultural operations – pruning (about

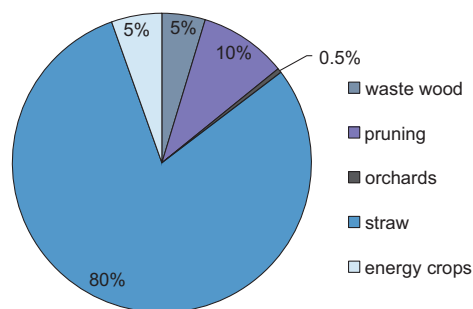


Fig. 2. Structure of the solid biomass potential (at 0% moisture content)

Source: own study based on CSO (2020).

10%). According to the *Biomass in Poland report* (2023), national straw potential exceeded 34 million tonnes, of which only around 30% was used for livestock purposes, while the remainder was available for soil fertilisation and energy production. The largest biomass resources were concentrated in western and northern Poland, including the Wielkopolskie, Lubuskie, Zachodniopomorskie and Dolnośląskie voivodeships. The second most important source of agricultural biomass in the region was

waste wood, with an estimated energy potential of 7.7 PJ per year (Biomass in Poland Report 2023). The third key source comprises perennial energy crops, particularly short-rotation coppice plantations of willow and poplar, which covered 526.6 ha in the region.¹

In 2020, biogas potential in the Wielkopolskie voivodeship was primarily derived from natural fertilizers and biodegradable waste. Natural fertilizers accounted for 65–68% of the potential, depending on yield assumptions. Bovine animal manure constituted the dominant part of the biogas potential, contributing over 37% under higher yield estimated and more than 44% under lower estimates (Fig. 3).¹

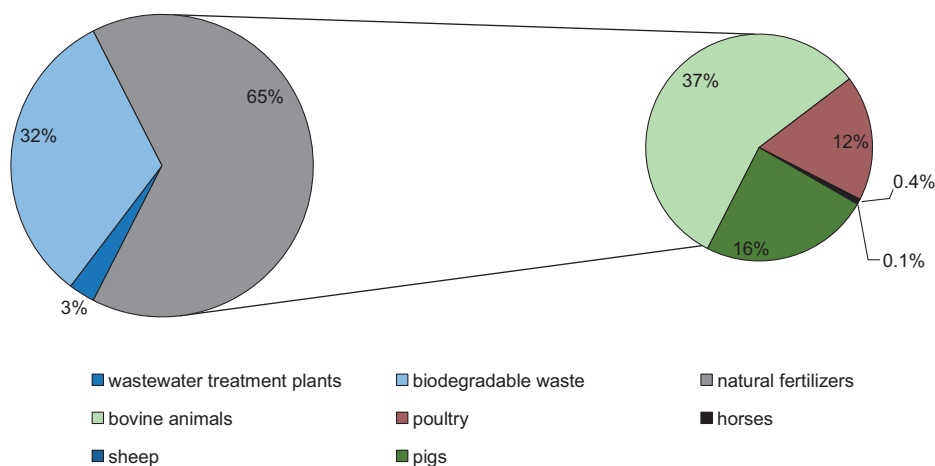


Fig. 3. Structure of the biogas potential (upper biogas yield)

Source: own study based on CSO (2020).

Discussion and conclusions

The development of the bioeconomy in the Wielkopolskie voivodeship reflects structural characteristics that are common to Poland and other Central and Eastern European (CEE) countries, where bioeconomy activities remain strongly rooted in traditional sectors such as agriculture, forestry, and food processing. In region, the bioeconomy accounted for approximately 7% of all economic entities and was dominated by agriculture, forestry, fisheries, and industrial processing, mainly in the wood-furniture and food sectors. This indicates strong reliance on natural resources and regionally-based production systems. The sector also employed around 13% of the regional workforce, with employment concentrated in food production, furniture manufacturing, and rubber and plastics products. However, R&D activities and advanced biotechnology production remain limited, suggesting that the regional bioeconomy is still largely in a traditional, resource-based development phase.

While these results provide a snapshot of the scale and structure of the regional bioeconomy, they also highlight the need for more refined tools and frameworks to systematically assess its development. Employment and value added indicators alone are insufficient to capture the complexity of bioeconomy growth, particularly given the diversity of regional and national approaches. Previous studies emphasized the need for improved methodologies, indicator systems, and monitoring frameworks that reflect the heterogeneous nature of bioeconomy (O'Brien et al. 2017, Ferreira et al. 2022). Similar concerns have been raised regarding the lack of systematic analytical approaches and insufficient monitoring and evaluation of bioeconomy development pathways (D'Adamo et al. 2020, Wei et al. 2022).

According to Woźniak-Gientka (2025), in the Wielkopolskie voivodeship, there are currently no plans to develop a separate bioeconomy development strategy. However, this may change following the adoption of relevant legal acts or policy guidelines at the European or national level. Figure 4 presents key elements of a successful regional bioeconomy pathway. Assessing bioeconomy potential is a crucial starting point for strategy development. The introduction of a bioeconomy strategy can enhance regional competitiveness and improve access to financing, while the adoption of good practices from other regions supports policy learning and reduces implementation risks. Bioeconomy in the region is still largely based on primary biomass production and conventional processing activities. While this reflects the strong agricultural profile of the region, it also highlights the need for structural transformation toward more knowledge-intensive and higher value-added activities. In this context, the role of R&D, biotechnology and human capital becomes particularly important. Both institutional and economic barriers may hinder the development of a more advanced bioeconomy in the Wielkopolska region. Institutional challenges include, for instance, the lack of a comprehensive regional monitoring system for the bioeconomy, insufficient public and business awareness of emerging bio-based technologies, shortages of highly qualified personnel capable of supporting the development and

deployment of innovative bioeconomy solutions, etc. Furthermore, weak cooperation among stakeholders and significant development gaps between the Poznan metropolitan area and other parts of the region may limit knowledge transfer and innovation diffusion. Economic barriers include, for instance, relatively low expenditure on R&D activities, a low share of innovative enterprises, the limited commercialization of new technologies, etc. These factors may hinder investment in high-value-added bio-based industries and slow the transition from a resource-based bioeconomy towards a more knowledge-intensive and innovation-driven model.

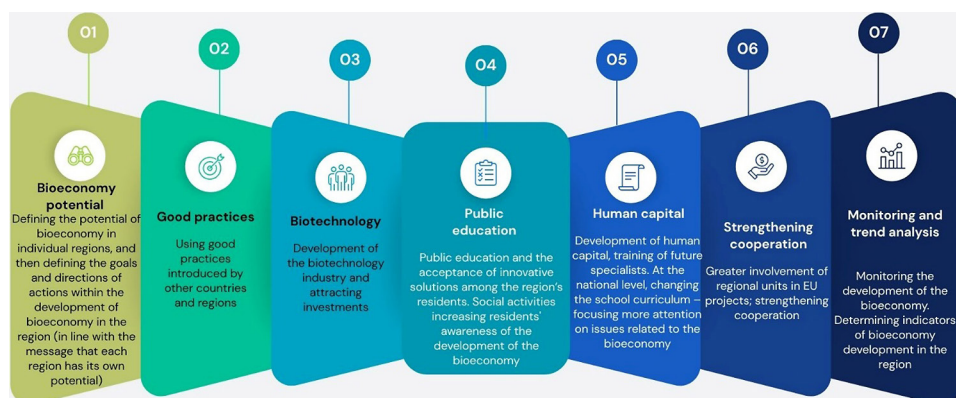


Fig. 4. Elements of successful bioeconomy pathways in regions

Source: own study based on Woźniak-Gientka (2025) and Briers et al. (2026).

The development of the bioeconomy is closely linked to the institutional and policy environment. Strategic planning, coordinated policy support, and effective monitoring mechanisms are essential for guiding sectoral transformation. Strengthening cooperation among regional stakeholders, including public institutions, research organizations, and businesses, may further support integrated bioeconomy initiatives. In particular, supporting biotechnology development, attracting investment, and fostering collaboration between science and industry may play a key role in unlocking the regional bioeconomy potential.

Further research is needed to better understand regional bioeconomy processes. Effective bioeconomy development requires not only technological innovation and resource availability, but also strong stakeholder cooperation, transparent governance, and social acceptance of bio-based solutions and biotechnological innovations. Research on stakeholder cooperation and public perception in the bioeconomy remains challenging due to the complexity of interactions between actors, differing interests, and the multidimensional nature of social attitudes; therefore, further research is needed.

Conflict of interest

The author declares no conflict of interest and assures that the work is the result of her own creation.

Literatura / References

- Agricultural Census in Poland. 2020 (<https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/psr-2020/powszechny-spis-rolny-2020-raport-z-wynikow,4,1.html>; in Polish; accessed: 10 Feb 2026).
- Aguiar A., Twardowski T., Wohlgemuth R. 2019. Bioeconomy for Sustainable Development. *Biotechnology J.*, 14(8): e1800638. <https://doi.org/10.1002/biot.201800638>
- Barra C., Falcone P.M. 2024. Institutional quality and bioeconomy performance in European countries: Unveiling the evidence. *Ecological Economics*, 220: 108188. <https://doi.org/10.1016/j.ecolecon.2024.108188>
- Bioeconomy Strategy. 2012. Innovating for sustainable growth: a bioeconomy for Europe. European Commission, Brussels, Belgium (<https://op.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51>; accessed: 10 Feb 2026).
- Bioeconomy Strategy. 2018. A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. European Commission, Brussels, Belgium (https://ec.europa.eu/knowledge4policy/publication/sustainable-bioeconomy-europe-strengthening-connection-between-economy-society_en; accessed: 7 Feb 2026).
- Bioeconomy Strategy. 2025. The Strategy for a Competitive and Sustainable EU Bioeconomy. European Commission, Brussels, Belgium (<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=cel-ex%3A52025DC0960>; accessed: 7 Feb 2026).
- Biomasa w Polsce 2022/2023. 2023. *Magazyn Biomasa*.
- Bachanek K.H., Drożdż W., Kolon M. 2025. Development of Renewable Energy Sources in Poland and Stability of Power Grids – Challenges, Technologies, and Adaptation Strategies.
- Briers S., Ackermann A., Linser S., Živojinović I., Martínez de Arano I., Klapper J., Amato M., Osés M.A., Orbe L.B., Boscaleri F., Koivula S., Rinn R., Versyck J., Wallius V., Wieland S. 2024. Shaping the bioeconomy: Public and private sector perceptions across European regions. *Current Research in Environmental Sustainability*, 8: 100264. <https://doi.org/10.1016/j.crsust.2024.100264>
- Briers S., Ackermann A., Živojinović I. et al. 2026. Pathways to bioeconomy development: A multi-regional perspective from Europe. *Ambio*, 55: 1264–1292. <https://doi.org/10.1007/s13280-025-02297-4>
- Chylek E., Kopiński J., Madej A. et al. 2017. Uwarunkowania i kierunki rozwoju biogospodarki w Polsce. Ministerstwo Rolnictwa i Rozwoju Wsi, Instytut Technologiczno-Przyrodniczy w Falentach, Warszawa-Falenty.
- D'Adamo I., Falcone P.M., Morone P. 2020. A New Socio-economic Indicator to Measure the Performance of Bioeconomy Sectors in Europe. *Ecological Economics*, 176: 106724. <https://doi.org/10.1016/j.ecolecon.2020.106724>
- De Schutter L., Giljum S., Hayha T. et al. 2019. Bioeconomy transitions through the lens of coupled social-ecological systems: a framework for place-based responsibility in the global resource system. *Sustainability*, 11(20): 5705. <https://doi.org/10.3390/su11205705>
- Dietz T., Börner J., Förster J.J., von Braun J. 2018. Governance of the bioeconomy: A global comparative study of national bioeconomy strategies. *Sustainability*, 10: 3190. <https://doi.org/10.3390/su10093190>
- Dolge K., Balode L., Laktuka K. et al. 2023. A Comparative Analysis of Bioeconomy Development in European Union Countries. *Environmental Management*, 71: 215–233. <https://doi.org/10.1007/s00267-022-01751-3>

- Eurostat. 2008. NACE Rev. 2 Statistical Classification of Economic Activities in the European Community. Eurostat. Methodologies and Working Papers: Luxembourg, s. 367 (<https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-ra-07-015>; accessed: 24 Feb 2026).
- FAO. 2021. Aspirational principles and criteria for a sustainable bioeconomy (<https://openknowledge.fao.org/items/152324b8-6d78-4d55-b61f-274649c8422d>; accessed: 20 March 2026).
- Ferreira V., Fabregat-Aibar L., Terceno A. 2022. Research trends and hotspots in bioeconomy impact analysis: a study of economic, social and environmental impacts. *Environ. Impact. Assess. Rev.*, 96: 106842.
- Głębiewski J. 2015. Bioeconomy in Poland: condition and potential for development of the biomass market. Materials from 150th Seminar – European Association of Agricultural Economists.
- Haarich S. 2017. Bioeconomy development in EU regions: mapping of EU Member States/ regions' research and innovation plans and strategies for smart specialisation (RIS3) on bioeconomy. Final Report, Framework Contract: 2014.CE.16.BAT Lot 2. Specific Contract: RTD/F1/PP-03681-2015. European Commission, Brussels, Belgium (<https://data.europa.eu/doi/10.2777/84684>; accessed: 7 Feb 2020).
- Haarich S., Kirchmayr-Novak S. 2022. Bioeconomy strategy development in EU regions. [W:] J. Sanchez Lopez, M.T. Borzacchiello, M. Avraamides (red.), Publications Office of the European Union, Luxembourg. <https://doi.org/10.2760/065902>, JRC128740
- Heimann T. 2018. Bioeconomy and SDGs: Does the bioeconomy support the achievement of the SDGs? *Earth's Future*, 7: 43–57. <https://doi.org/10.1029/2018EF001014>
- Hofer M., Lindorfer M., Gurgurovci S. 2025. Unlocking regional bioeconomy transitions: Co-creation, stakeholder engagement, and systemic change in rural Europe. *Open Research Europe* (<https://open-research-europe.ec.europa.eu/articles/5-392#ref-6>; accessed: 20 March 2026).
- Kelleher L., Henchion M., O'Neill E. 2019. Policy Coherence and the Transition to a Bioeconomy: The Case of Ireland. *Sustainability*, 11(24): 7247. <https://doi.org/10.3390/su11247247>
- Kraska E.M., Mach L., Kilianska K. 2024. Applying Shift-Share Analysis to Assess the Growth Potential of Crucial Bioeconomy Sectors in Poland. *European Research Studies Journal*, 0(4): 1536–1551.
- Laasonen V. 2024. Building dynamic capabilities in the transition toward a knowledge-based bioeconomy: a case study of three Finnish regions. *Reg Stud.*, 58(6): 1308–1319. <https://doi.org/10.180/00343404.2023.2249499>
- Li X., Yu Z., Salman A. et al. 2021. The role of financial development indicators in sustainable development-environmental degradation nexus. *Environ. Sci. Pollut. Res.*, 28: 33707–33718. <https://doi.org/10.1007/s11356-021-13037-y>
- Lokko Y., Heijde M., Schebesta K., Scholtes P., Montagu M.G. 2018. Biotechnology and the bioeconomy – Towards inclusive and sustainable industrial development. *New Biotech.*, 40: 5–10. <https://doi.org/10.1016/j.nbt.2017.06.005>
- Meyer R. 2017. Bioeconomy strategies: contexts, visions, guiding implementation principles and resulting debates. *Sustainability*, 9(6): 1031. <https://doi.org/10.3390/su9061031>
- O'Brien M., Wechsler D., Bringezu S., Schaldach R. 2017. Toward a systemic monitoring of the European bioeconomy: gaps, needs and the integration of sustainability indicators and targets for global land use. *Land Use Policy*, 66: 162–171.
- Park H., Grundmann P. 2023. What does an inclusive bioeconomy mean for primary producers? An analysis of European bioeconomy strategies. *Journal of Environmental Policy & Planning*, 25(3): 225–241. <https://doi.org/10.1080/1523908X.2022.2094353>
- Patermann Ch., Aguilar A. 2018. The origins of the bioeconomy in the European union. *New Biotechnol.*, 40: 20–24. <https://doi.org/10.1016/j.nbt.2017.04.002>
- Patermann Ch., Aguilar A. 2021. A bioeconomy for the next decade. *EFB Bioeconomy Journal*, 1: 100005. <https://doi.org/10.1016/j.bioeco.2021.100005>
- Pender A., Kelleher L., O'Neill E. 2024. Regulation of the bioeconomy: Barriers, drivers and potential for innovation in the case of Ireland. *Cleaner and Circular Bioeconomy*, 7: 100070. <https://doi.org/10.1016/j.clcb.2023.100070>
- Pink M., Kielbasa B., Tamáš V., Pereira F.M.D.S.M., Santamarta J.C., Cruz Pérez N., Rodríguez-Alcántara J.S., Luty L. 2024. Perception and awareness of the bioeconomy: an empirical study of chosen European academia. *Int. J. Sustain. High. Educ.*, 25(6): 1137–1155. <https://doi.org/10.1108/IJSHE-01-2023-0002>

- Ronzon T., Piotrowski S., Tamosiunas S. et al. 2020. Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU. *Sustainability*, 12(11): 4507. <https://doi.org/10.3390/su12114507>
- Schlaile M.P., Friedrich J., Porst L. et al. 2025. Bioeconomy innovations and their regional embeddedness: results from a qualitative multiple-case study on German flagship innovations. *Prog. Econ. Geogr.*, 3(1): 100044. <https://doi.org/10.1016/j.peg.2025.100044>
- Skorwider-Namiotko J. 2015. Level of development of bioeconomy in Poland according to the regional approach – measurement trial. *Economic and Regional Studies*, 8(1): 55–72. <https://doi.org/10.22004/AG.ECON.265101>
- Stake R.E. 1995. *The art of case study research*. International Educational and Professional Publisher, Sage, Thousand Oaks, CA.
- Statistical Yearbook of the Regions – Poland 2022. 2022 (<https://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny-wojewodztw-2022>; in Polish; accessed: 30 March 2026).
- Strategy. 2023. *The Strategy for the development of hydrogen Wielkopolska until 2030, with a perspective until 2040*. 2023. Marshal Office of the Wielkopolska Region [in Polish]. Contractor: NEXUS Consultants sp. z o.o. Majewski W., Foltynowicz M., Pelc T.F., Siatkowski M. (Eds.) (<http://iw.org.pl/wp-content/uploads/2023/06/The-Strategy-for-the-development-of-hydrogen-Wielopolska-until-2030-with-a-perspective-until-2040-summary.pdf>; accessed: 30 Jan 2026).
- Vivien F.D., Nieddu M., Befort N. et al. 2019. The hijacking of the bioeconomy. *Ecol. Econ.*, 159: 189–197. <https://doi.org/10.1016/j.ecolecon.2019.01.027>
- Szarka N., Laverde L.G., Thran D. et al. 2023. Stakeholder engagement in the co-design of regional bioeconomy strategies. *Sustainability*, 15(8): 6967. <https://doi.org/10.3390/su15086967>
- Trigkas M., Karagouni G. 2023. State/academia key stakeholders' perceptions regarding bioeconomy: evidence from Greece. *Sustainability*, 15: 9976. <https://doi.org/10.3390/su15139976>
- Wei X., Liu Q., Pu A., Wang S. et al. 2022. Knowledge mapping of bioeconomy: a bibliometric analysis. *J. Clean. Prod.*, 373: 133824. <https://doi.org/10.1016/j.jclepro.2022.133824>
- Woźniak E., Twardowski T. 2018. The bioeconomy in Poland within the context of the European Union. *N Biotechnol.* 40(Pt A): 96–102. <https://doi.org/10.1016/j.nbt.2017.06.003>. Epub 2017 Jun 21. PMID: 28647548.
- Woźniak E., Tyczewska A., Twardowski T. 2021a. Bioeconomy development factors in the European Union and Poland. *New Biotechnology*, 60: 2–8. <https://doi.org/10.1016/j.nbt.2020.07.004>
- Woźniak E., Tyczewska A., Twardowski T. 2021b. A Shift Towards Biotechnology: Social Opinion in the EU. *Trends in Biotechnology*, 39(3): 214–218. <https://doi.org/10.1016/j.tibtech.2020.08.001>
- Woźniak-Gientka E. 2025. Integration of bioeconomy within regional policy frameworks: a case study of the Wielkopolska Voivodeship. *BioTechnologia*, 106(2): 195–208. <https://doi.org/10.5114/bta/205149>

Resources

- ⁱ Central Statistical Office <https://new.stat.gov.pl/en>
- ⁱⁱ Local Data Bank <https://bdl.stat.gov.pl/bdl/start>
- ⁱⁱⁱ Poland Energy Regulatory Office <https://www.ure.gov.pl/en>
- ^{iv} Poland Agricultural and Food Quality Inspection <https://www.gov.pl/web/ijhars/udostepnianie-informacji-o-producentach-w-rolnictwie-ekologicznym-1>
- ^v Energy Regulatory Office <https://www.ure.gov.pl/en>

Rozwój regionalnej biogospodarki w Polsce – studium przypadku województwa wielkopolskiego

Zarys treści: W artykule poddano analizie ekonomiczne i środowiskowe uwarunkowania rozwoju biogospodarki w województwie wielkopolskim. Wykorzystując podejście studium przypadku oraz analizę wskaźnikową, określono strukturę sektorów biogospodarki, zatrudnienie oraz potencjał biomasy. Wyniki wskazują, że regionalna biogospodarka stanowi istotny, choć strukturalnie tradycyjny segment gospodarki regionu, zdominowany przez rolnictwo, przemysł spożywczy oraz sektory oparte

na wykorzystaniu drewna, przy ograniczonym udziale działalności badawczo-rozwojowej i zaawansowanej biotechnologii. Badanie wnosi wkład do literatury dotyczącej rozwoju regionalnej biogospodarki, podkreślając rolę struktur gospodarczych, innowacji oraz zasobów w kształtowaniu ścieżek jej rozwoju.

Słowa kluczowe: analiza regionalna, biogospodarka, Polska, strategia, zrównoważony rozwój

Data przekazania tekstu: 12.05.2026; data zaakceptowania tekstu: 20.07.2026.

Article submitted: 12.05.2026; article accepted: 20.07.2026.