

## BIOECONOMY DEVELOPMENT LEVEL AT A MACRO SCALE AND FROM A REGIONAL PERSPECTIVE IN POLAND

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**Purpose:** Bioeconomy is a contemporary concept of economic development. It means focusing on increasing economic efficiency through a more extensive use of renewable environmental resources. The implementation of this concept causes structural changes in the economy and consumption at both macro, regional and local levels. The bioeconomy refers to the concept of sustainable development. The level of development of bioeconomy is important in enhancing regional cohesion in terms of economic and social development. The bioeconomy is the subject of both conceptual research and structural decision-making in economic development. The purpose of the article is to present economic diversification in Poland in 2010-2019 in relation to selected aspects of bioeconomy development.

**Design/methodology/approach:** In order to construct the indicator of the level of bioeconomy development in the regions, statistical characteristics were selected and weighted using a formula that favored the characteristics with the highest variability. Then, to illustrate the level of bioeconomy, a synthetic indicator was constructed to divide the regions into three categories: low-development regions, developing regions and developed regions.

**Findings:** The level of bioeconomy development in Polish regions shows great variation in both bioeconomy resources, economic indicators for the bioeconomy and innovation in the production process. Dispersion coefficient of regional level of bioeconomy points to the ongoing processes of regional divergence in the bioeconomy in Poland. Efficiency in the use of available resources, including the degree of renewable energy use and the level of innovation in the regions, was the most important factor in the development of the bioeconomy during the study period.

**Research limitations/implications:** The use of statistical methods should be comprehensive in order to present a picture of the subject of the research from multiple perspectives and the findings regarding other areas. Hence the need to use research methods that take into account the interdependence between different factors affecting socio-economic development both on a national and regional scale.

**Practical implications:** The development of bioeconomy is undoubtedly a factor influencing the socio-economic development of regions. However, it is not the only developmental stimulator. The activities of both national and regional authorities should be diversified, based on supporting various types of economic activity and investing in different branches and industries. A holistic approach to the issue of regional disparities that takes into account the

bioeconomy can lead to a narrowing of the development gap between different regions in the country.

**Social implications:** The development of bioeconomy is an opportunity to improve the quality of life and living conditions for the inhabitants of regions with resource potential and openness to apply new solutions and technologies in this area.

**Originality/value:** An attempt to identify the level of bioeconomy development in dynamic terms and its relationship to the positioning of regions in terms of the level of socio-economic development.

**Keywords:** bioeconomy, regional disparities, green growth, Polish and EU strategic documents.

**Category of the paper:** research paper.

## 1. Introduction

The terms "bioeconomy" and "bio-based economy" are the most commonly and interchangeably used terms in the scientific literature (Krzywonos, Marciszewska, Domiter, Borowiak, 2016; Birner, 2018). In turn, according to the OECD definition, the bioeconomy is the activity of applying biotechnology, bioprocesses and bioproducts to produce sustainable, green and competitive goods and services (Stan i kierunki, 2007). The bioeconomy is also "the activity of applying biotechnology, bioprocesses, and bioproducts to produce goods and services" (Gołębiewski, 2015). The bioeconomy concept represents an economic paradigm shift that has arisen as a result of ongoing environmental changes and the depletion of the planet's resources. The term bioeconomy itself is repeatedly used to classify resources, separate objects or build a new economic model.

Bioeconomy is reflected in the program documents of the European Union and Poland. Therefore, the paper attempts to examine the level of bioeconomy development in regions in Poland. From the point of view of its development, it is important not only to quantify the resources of the bioeconomy, but also the degree of its circularity (i.e. quantification of waste and by-products). In building a circular economy, it is necessary to use bioeconomy technologies, through which the ongoing changes in this sector can be intensified. The article is an attempt to look at the bioeconomy not only in a theoretical way but also in an analytical way. The theoretical part was based on a review of the literature, European Union program documents and Poland's strategic documents. In the practical part, an attempt was made to examine the level of bioeconomy development in 16 regions based on data collected from Statistics Poland. The article provides new knowledge on important factors affecting the development of the bioeconomy.

## 2. Bioeconomy – an overview of concepts and definitions

The issue of sustainable development has long gone beyond scientific considerations (Kot, 2016) and philosophical-ethical concepts. It is the subject of political decision-making stimulating economic and social behavior desirable from the point of view of the goals of this concept. One of the directions complementary to and supporting the implementation of sustainable development is to work towards building the bioeconomy. The concepts of bioeconomy and sustainable development are coherent and mutually reinforcing in the achievement of their objectives. The bioeconomy is a response to problems arising from a growing global population, rapid resource depletion, increasing pressures from environmental hazards, and climate change.

The world population will grow by 30% over the next forty years, i.e. from 7 billion in 2020 to over 9 billion in 2050 (European Commission, 2012). Europe, like other geographical areas of the world, is part of a complex environmental, social, economic, cultural and political system. The processes taking place in the European space reflect to a large extent the challenges that the whole world is facing now and will face in the coming future. Europe is confronted with unprecedented and unsustainable exploitation of natural resources, significant and potentially irreversible climate change, a progressive process of biodiversity loss that threatens the stability of ecological and biogenic systems. The occurring adverse changes are intrinsically linked, and overcoming them requires research and innovative solutions to change lifestyles and harness the resources of all sectors of society and economic activity. The actions taken, as well as the results achieved, will support both the implementation of the concept of sustainable development and building the bioeconomy. The term bioeconomy refers to an economy in which biological land and aquaculture resources, as well as wastes, are used as raw materials for food and feed production, and for industrial and energy production. The bioeconomy also means a sustainable and balanced process of transforming renewable biological resources into food products, energy and other industrial goods. It is also defined as an economy that uses resources from the land, sea, and waste, including waste food, as inputs for energy and industrial production.

**Table 1.**  
*Selected definitions of bioeconomy*

Concept/definition	Source
“All economic activity derived from scientific and/or research activity focused on understanding mechanisms and processes at the genetic/molecular levels and its application to industrial process”	Enriquez, Martinez, 1998
“The sustainable, eco-efficient transformation of renewable biological resources into food, energy and other industrial products”	DG Research, 2005
“Encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy.”	En Route, 2007
“Transforming life science knowledge into new, sustainable, eco-efficient and competitive products.”	The Bioeconomy, 2009

Cont. table 1.

“Production models based on biological processes and natural ecosystems using natural materials, which consume minimal amounts of energy without generating waste, as all waste resulting from one process is the material for the next and as a result it is reused in the ecosystem.”	EC DG Research, 2011
“Sustainable production and processing of renewable mass into a wide range of food, medicinal, industrial and energy products and services, namely into different biomaterials to be used directly and as raw materials for manufacture of other products.”	Europa Bio, 2011
“Based on the use of research and innovation in the biological science to create economic activity and public benefit.”	The White House, 2012
“Can be understood as an economy where the basic building blocks for materials, chemicals and energy are derived from renewable biological resources, such as plant and animal sources.”	McCormick, 2013
“Is all-encompassing and comprises those parts of the economy that make responsible use of renewable biological resources from the land and water for the mutual benefit of business, society and nature.”	Nordic Council of Ministers, 2017

Source: the author's own study.

The definitions of bioeconomy presented in table 1 also emphasize biological and biomass resources as important inputs for the development of various economic activities, including industry and food production. In another view, bioeconomy involves the production of renewable biological resources and their subsequent processing into food, feed, bioproducts and bioenergy. The bioeconomy sector includes agriculture, forestry, fisheries, food, wood, paper, and some chemical and bioenergy industries. These activities have a high potential for innovation due to their ability to use the achievements of various fields and disciplines of science (biotechnologies, nanotechnologies, information technology, social sciences, science). The American interpretation of bioeconomy is similar to the European one, however, it places less emphasis on the sustainable development aspect. Bioeconomy is seen as the use of research and innovation in the life sciences to generate social benefits and stimulate economic activity. In the European Union, bioeconomy is understood as the integration of a wide range of natural and renewable biological resources – marine and terrestrial, biodiversity and materials of biological origin (plant, animal and microbial) in the processing and consumption of these resources. Despite the multiplicity of definitions of bioeconomy, in most cases they converge.

Bioeconomy can be seen not only as a new economic theory but also as:

- a paradigm shift in thinking about the management of scarce resources,
- a transformation of a traditional sector into a modern one through the use of modern technologies,
- a new direction in natural science research incorporating an interdisciplinary approach.

Bioeconomy is attracting increasing interest not only in terms of theoretical considerations. It is the subject of taking specific actions in the economic sphere and, what is very important, is the basis for building development strategies in individual countries and regional groupings.

Bioeconomy, like the market economy, is based not only on the efficient allocation of resources but also on their effective use. As such, it needs a new way of managing resources based on sustainability (Inoesu, 2013). It is now the basis of modern economic and social transformation.

### 3. Bioeconomy in the policy documents of the European Union

In February 2012, the European Commission adopted the strategy “Innovating for Sustainable Growth: A Bioeconomy for Europe” strategy. As emphasized, this strategy is not just an additional piece of EU legislation. Its purpose is to guide joint efforts within the EU to support a sustainable and rapidly changing sector of the economy. It is emphasized that a strongly developed bioeconomy sector will be an important factor in stabilizing the functioning as well as the development of Europe under the existing constraints. Now and in the future, when the world's population reaches 9 billion in 2050 and resources will dwindle or will be completely exhausted, Europe will need renewable biological resources, not only for healthy food and feed, but also materials and other natural products and biofuels. The development of bioeconomy, sustainable production and exploitation of natural resources will enable the production of more goods using fewer resources and producing less waste. Implementation of this strategy, as envisioned by the European Commission, will be possible using actions already taken under existing policies, such as the Common Agricultural Policy, the Common Fisheries Policy, and European initiatives such as Horizon 2020, which was launched in 2014. The main objective of the strategy is a more innovative development of low emission economy taking into account the requirements of sustainable agriculture and fisheries, food safety, the use of renewable natural resources for industrial purposes while maintaining biodiversity and respecting environmental principles (Schmid, Padel, Levidow, 2012). The operational plan for the strategy is based on three main lines of action:

- development of new technologies and processes for bioeconomy,
- development of markets and competitiveness in bioeconomy sectors
- lobbying politicians and beneficiaries to integrate actions to develop the bioeconomy.

The development of bioeconomy is expected to lead to the achievement of the policy objectives of the European Strategy and Operational Plan for the Development of a Sustainable Bioeconomy by 2020. These include:

- strengthening Europe's position as a leader in life sciences,
- optimizing the innovation and knowledge transfer system,
- developing research on the safety and financial accessibility of healthy foods,
- activities for the development of sustainable agriculture and maritime economy,
- increasing the efficiency of agriculture, food and other industries and distribution systems,
- maintaining the competitiveness of European industry and agriculture,
- development of industries with low emissions from coal combustion,
- GHG emissions and waste reduction.

Another important document of the European Union is the Europe 2020 Strategy. The development of bioeconomy has been a key part of its implementation and realization of sustainable and inclusive growth. The development of bioeconomy in Europe will bring many benefits. The most important ones include maintaining and creating conditions for further economic growth, increasing the number of jobs in rural, coastal, and industrial areas, reducing the economy's dependence on traditional energy sources, and increasing the scale of production of basic goods in accordance with the principles of sustainable development. These benefits are mentioned in various program documents of the European Union, therefore the role of the strategy “Innovating for Sustainable Growth: A Bioeconomy for Europe” is to support activities of key importance to many areas of the European Union. The importance of the bioeconomy sector in Europe is very high. In an increasingly difficult environment for sustaining and growing national economies, but also the European Union as a whole, it is an essential element for maintaining a competitive position.

The bioeconomy sector has an annual turnover of €2 trillion and employs more than 22 million people in various sectors. This represents about 9% of the total EU workforce (European Commission, 2012). It is also a strong rationale for taking action to more closely integrate efforts across sectors to increase the potential and efficiency of manufacturing biotechnology-based products. Today, Europe is seen as a leader in many areas of biotechnology and related sciences. However, the U.S. and China are also increasingly interested in the bioeconomy as evidenced by the amounts they are spending on developing biotechnology to build the bioeconomy. Today, the bioeconomy sector is among the most important and largest sectors in the European Union, encompassing agriculture, fisheries, forestry, food and chemical industries. The bioeconomy encompasses the processes of economic growth and employment, two of the most important elements of economic, social, and political stability. The stimulators, constraints, threats and opportunities for the bioeconomy are interrelated and form a complex system. This complicates the ability to lead efforts to develop an advanced bioeconomy. Undoubtedly, the assumptions and policies of the European Union in the implementation of sustainable development principles support the development of bioeconomy. Central to this is the commitment and determination of politicians, policy makers and economic forces to fund and promote innovations that enable the implementation of sustainable development principles as an imperative for the operation and development of an advanced bioeconomy in Europe. This is especially important for the long-term development perspective, which must prevail over short-term economic benefits. Sustainable development and the bioeconomy are inextricably linked both in terms of concepts, policies, actions, and building structures that benefit economies and societies. The above discussion of bioeconomy in Europe can be summarized in the words of J. Potočník: *The European bio-economy cannot compete on a global level by delivering only basic agricultural commodities. We must look to providing a sound institutional and financial framework, based on a rational consideration of the issues at stake. All participants in the chain – farmers, industry, regulators and consumers – will need to get together to make the bio-economy work* (EC, 2005).

#### 4. Bioeconomy in Poland's strategic documents

Although Poland has not developed a separate strategic document for bioeconomy development, actions related to its development have already been included in the National Development Strategy 2007-2015 (Ministry of Regional Development, 2006). The following projects were listed in it:

- raising the technological level of the economy through increased expenditures on research and development as well as innovation,
- development of eco-innovation,
- modernization of fisheries and fish processing,
- promoting and providing financial support for efficient energy generation technologies,
- support for projects related to wastewater treatment, provision of high quality potable water,
- waste management and rehabilitation of degraded areas,
- air protection, protection against noise, vibration,
- supporting the construction of wastewater treatment plants and sewer systems,
- measures limiting the release of harmful substances, including from agriculture, into water,
- implementation of actions reducing emissions of CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub> and dust from the municipal and household sector and industry, especially from the energy sector, as well as thermal renovation projects.

Current legislation related to bioeconomy development in Poland include:

- Renewable Energy Sources Act (Ustawa o odnawialnych źródłach energii, 2015).
- Strategy for Responsible Development until 2020 (with an outlook to 2030) (Strategia na rzecz Odpowiedzialnego Rozwoju do roku 2020 (z perspektywą do 2030 r.)) (Resolution No. 8 of the Council of Ministers, 2017).
- Sustainable Rural, Agricultural and Fisheries Development Strategy 2030 (Strategia zrównoważonego rozwoju wsi, rolnictwa i rybactwa 2030) (Resolution No. 123 of the Council of Ministers, 2019).
- National Energy and Climate Plan 2021-2030: assumptions and targets and policies and actions (Krajowy plan na rzecz energii i klimatu 2021-2030: założenia i cele oraz polityki i działania).
- National Smart Specialization (Krajowa Inteligentna Specjalizacja – KIS) (<https://smart.gov.pl/>).

The Act on Renewable Energy Sources sets out not only the rules and conditions for the generation of electricity from: renewable energy sources, agricultural biogas – in renewable energy source installations, bioliquids; but also defines the mechanisms and instruments

supporting them. It contains the definition of: biogas, biomass, biocarbon, geothermal energy, hydropower, renewable energy source. It may seem that the bioeconomy is seen in the context of increasing the use of renewable energy.

The Strategy for Responsible Development until 2020 (with an outlook to 2030) indicates that the bioeconomy is one of three technological revolutions taking place. The importance of using renewable energy sources including geothermal energy and biomass was emphasized.

In the third mentioned document, the following actions related to bioeconomy were indicated in objective 1: striving to maximize the use of waste as raw materials and dissemination of bioeconomy solutions in rural areas, with particular emphasis on the economic use of agricultural waste and waste from agricultural and fish processing, development of innovation and creation of new enterprises specialized in it. It has been pointed out that the bioeconomy encompasses "the production of renewable biological resources and the conversion of these resources and the resulting processing waste into value-added products such as food, feed, bioproducts and bioenergy. An important aspect of bioeconomy development is the potential for rural economic diversification and the creation of new, attractive jobs in these areas".

In the National Energy and Climate Plan 2021–2030 based on the principles of sustainable development, the priorities related to: decarbonizing the economy, increasing the share of renewable energy sources in gross energy consumption, and increasing energy efficiency play a significant role. Biogas and bioenergy from biomass of forestry, agricultural and food origin, as well as from waste management play an important role in their implementation.

In the KIS, the main objective is to *focus investment on research, development and innovation (R&D&I) in areas with the greatest innovative and competitive potential of the country, the development of which will contribute to economic growth and improve the quality of life of society and the state of the environment* (KIS). Reference can be made to the following national specializations that are related to the bioeconomy i.e.:

- KIS 2. Innovative technologies, processes and products of the agrifood as well as forestry and timber sector.
- KIS 3. Biotechnological and chemical specialty chemical processes and products and environmental engineering.

## **5. Research purpose and method**

The purpose of the research was to determine the level of bioeconomy development in Poland based on selected diagnostic characteristics in 2010-2019. Development is a complex process and required consideration of many variables in the research conducted. The choice of features was made in a substantive manner, guided also by their relevance to the analyzed phenomenon, unambiguity, logic, as well as their availability and completeness of information



for all regions (Gorzela, 1979). The study used variables that characterized as much as possible the level of bioeconomy development in the regions. They were divided into three areas (O) i.e.: endogenous resources in the regions, bioeconomy in economic indicators and ongoing innovation processes supporting production processes. Together, they define the level of the bioeconomy. The extent of information that each variable carried was tested using Pearson's correlation coefficient.

In order to construct the indicator of bioeconomy development level in the regions, statistical characteristics in which it did not exceed the value of  $r = 0.7$  were adopted. The selected variables were given weights by means of the formula below, which favors the features with the highest variability, i.e. the ones that differentiate the studied phenomenon the most (Łuniewska, Tarczyński, 2006):

$$w_j = \frac{V_j}{\sum_{j=1}^m V_j} \quad (j = 1, 2, \dots, m) \quad (1)$$

where:

$w_j$  – weight of the  $j$ -th variable,

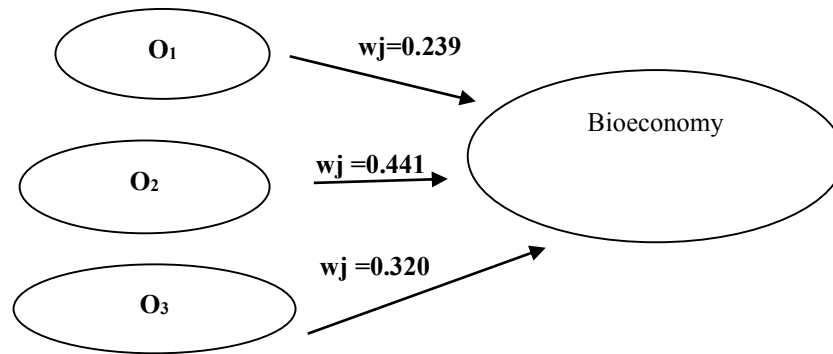
$V_j$  – coefficient of variation of the  $j$ -th diagnostic variable before normalization.

**Table 2.**

*A set of diagnostic variables describing the level of bioeconomy development*

Areas influencing the level of development of bioeconomy (O)	Explanatory variables	Weights (w <sub>j</sub> )
Bioeconomy resources (O <sub>1</sub> )	Percentage of business entities operating in bioeconomy related sections (sections A, C, D, E)	0.018
	Share of employed in bioeconomy sectors (sections A, C, D, E) in employment in the economy	0.035
	Share of the area of organic farms in the agricultural land area (in ha)	0.161
	Share of gross value of fixed assets in bioeconomy in total economy	0.025
Bioeconomy in economic indicators (O <sub>2</sub> )	Reforestation and afforestation (in ha)	0.125
	Share of gross added value in GDP produced in the bioeconomy sector in gross added value produced in the region (in %)	0.024
	Share of energy from renewable energy carriers in electricity production [%]	0.166
	Share of recycled industrial waste in waste generated per year [%]	0.127
Innovation in the production process (O <sub>3</sub> )	Percentage of innovative enterprises in industry (in %)	0.029
	Percentage of innovative enterprises in services (in %)	0.065
	Outlays on research and development per one employee in the economy (in thousand PLN)	0.118
	Share of sold production of new and/or significantly improved products in total sales value of products (%)	0.108

Source: own study, Local Data Bank.



**Figure 1.** The importance of elements influencing the level of bioeconomy development.

Source: the author's own study.

The diagnostic variables were subject to unitarization which ensured the comparability of the various characteristics and eliminated non-additive values from the calculations. All variables were stimulants, therefore, from the point of view of the study conducted, they were normalized according to the following formula:

$$x_{ijt} = \frac{x_{ijt} - \min x_{ijt}}{d} \quad (2)$$

where:  $d$  – difference between maximum and minimum of a given variable in the examined time range.

The normalization of the variables carried out in this way allowed for comparability of the indicator of the level of bioeconomy development obtained in the next step. Diagnostic variables were reduced to comparability not only in terms of provinces, but also in terms of the adopted research period. The diagnostic variables presented in Table 1 were used to determine the synthetic indicator of the level of bioeconomy development. The bioeconomy development indicator has been calculated using the following formula:

$$BIO_{rt} = \frac{1}{n} \sum_{j=1}^n w_j x_{jt} \quad (j = 1, 2, \dots, m)$$

where:

$BIO_{rt}$  – synthetic indicator of the level of bioeconomy development in the voivodeship in year  $t$ ,

$t$  – designation of years,

$j$  – number of the variable (feature) used to construct the indicator,

$n$  – total number of variables used to construct the indicator,

$x_{ij}$  – value of the “ $j$ ” feature for the specified “ $t$ ” year,

$w_i$  – weight given to the “ $i$ ” feature in the index;  $\sum w_i = 1$ .

This indicator takes values in the range from  $[0,1]$ . A value closer to one means that the region is characterized by a high level of the analyzed phenomenon.

Based on the synthetic indicator of bioeconomy development level, the total was divided into 3 groups. First, the synthetic indicator's spread was calculated according to the formula:

$$\text{rozstep}_t = \text{BIOmax}_{rt} - \text{BIOmin}_{rt}$$

$$k_t = \frac{1}{3} d_t$$

The parameter  $k_t$  was then determined, according to which the following grouping procedure was applied:

- with a high level of bioeconomy development  $\text{BIO}_{rt} \in [\max \text{BIO}_{rt} - k_t, \max \text{BIO}_{rt}]$ ,
- with an average level of bioeconomy development,  $\text{BIO}_{rt} \in [\max \text{BIO}_{rt} - 2k_t, \max \text{BIO}_{rt} - k_t]$ ,
- with low levels of bioeconomy development  $\text{BIO}_{rt} \in [\max \text{BIO}_{rt} - 3k_t, \max \text{BIO}_{rt} - 2k_t]$ .

In the next part of the article, the Pearson correlation coefficient was used to look for the relationship between the indicator of the bioeconomy development level and the level of socio-economic development of the region and GDP per capita. The ready-to-use indicator presented in the article by J. Kot, E. Kraska (Kot, Kraska, 2021) was used for this purpose.

## 6. Results of the conducted research

The ranking positions held by the voivodeships in terms of the areas that make up the synthetic indicator of the level of bioeconomy development are shown in Table 2. In the area of bioeconomy resources, the ratio of its minimum value (in Mazowieckie Voivodeship) to its maximum value (in Zachodniopomorskie Voivodeship) in 2010 was as 1:4.53, while in 2019 – 1:8.67 (Mazowieckie to Warmińsko-Mazurskie). Zachodniopomorskie, Warmińsko-Mazurskie and Lubuskie Voivodeships had the most resources used in bioeconomy related production. The highest economic indicators related to bioeconomy were recorded in Podlaskie, Warmińsko-Mazurskie, Pomorskie, and Kujawsko-Pomorskie Voivodeships. In this area, the ratio of the minimum level to the maximum level in 2010 was as 1:4.16 (Zachodniopomorskie: Warmińsko-Mazurskie) and in 2019 – 1:6.08 (Warmińsko-Mazurskie: Pomorskie). In terms of innovation in the production process, the ratio of the minimum level to the maximum level in 2010 was at 1:52 (Lubuskie: Pomorskie), in 2019 it decreased to 1:407 (Świętokrzyskie: Mazowieckie).

**Table 3.**

*Classification of regions in the areas that make up the synthetic indicator of the level of development of the bioeconomy in 2010 and 2019*

Area/Voivodeships	Bioeconomy resources		Bioeconomy in economic indicators		Innovation in the production process		Synthetic indicator of development level of bioeconomy	
	2010	2019	2010	2019	2010	2019	2010	2019
DOL	8	10	11	16	8	4	12	12
KUJ	14	13	3	4	7	12	6	9
LBL	7	3	9	13	10	9	9	14
LUB	3	3	13	9	16	13	10	7
ŁDZ	11	11	15	15	12	6	16	16
MAŁ	9	14	7	5	4	1	5	3
MAZ	16	16	8	14	2	2	8	8
OPL	12	8	14	10	13	15	14	15
PDK	4	5	5	7	3	5	3	6
PDL	5	4	2	2	14	11	4	4
POM	13	12	4	1	1	3	2	2
ŚLK	15	15	10	11	5	8	13	11
ŚWK	6	6	6	8	11	16	7	13
WRM	2	1	1	3	9	10	1	1
WLK	10	9	12	12	6	7	11	10
ZACH	1	2	16	6	15		15	5

Legend: DOL – Dolnośląskie, KUJ – Kujawsko-Pomorskie, LBL – Lubelskie, LUB – Lubuskie, ŁDZ – Łódzkie, MAŁ – Małopolskie, MAZ – Mazowieckie, OPL – Opolskie, PDK – Podkarpackie, PDL – Podlaskie, POM – Pomorskie, ŚLK – Śląskie, ŚWK – Świętokrzyskie, WRM – Warmińsko-Mazurskie, WLK – Wielkopolskie, ZACH – Zachodniopomorskie.

Source: own study, Local Data Bank.

**Table 4.**

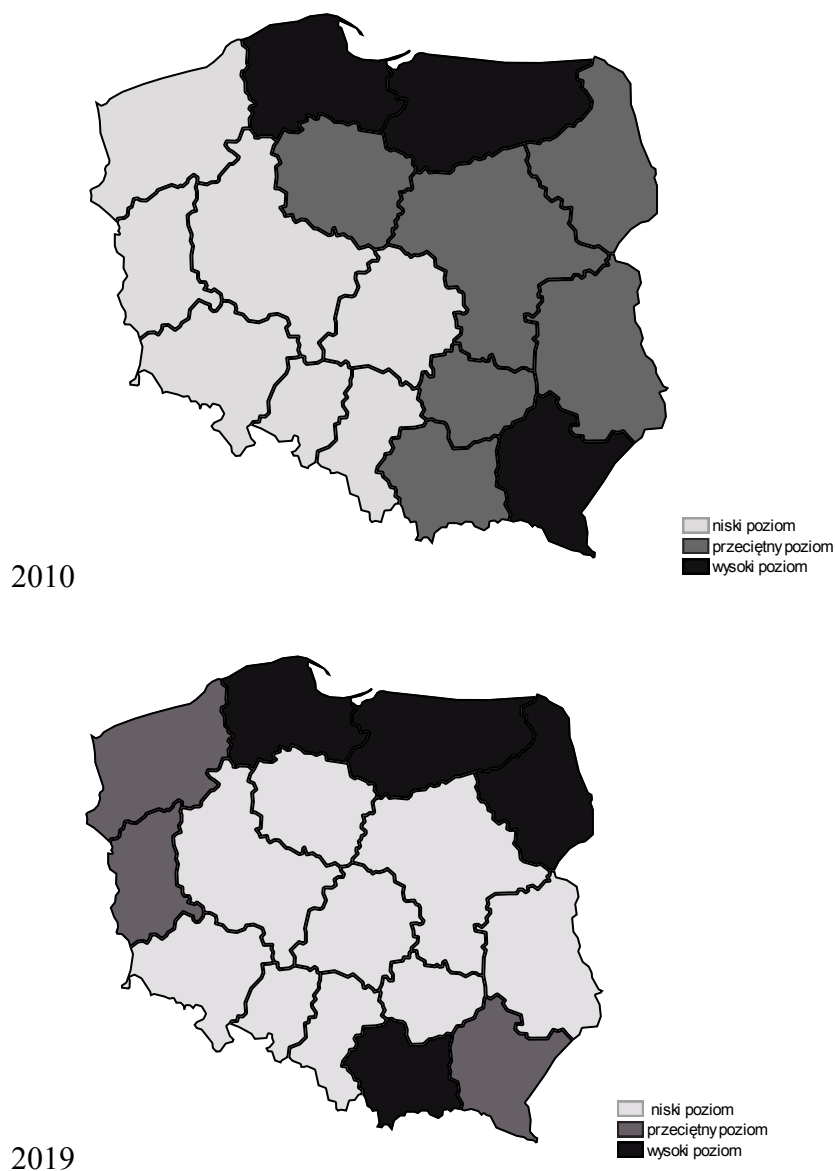
*The value of synthetic indicator of bioeconomy development level in 2010-2019*

Region	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
DOL	0.279	0.261	0.293	0.274	0.218	0.204	0.177	0.177	0.218	0.212
KUJ	0.350	0.358	0.357	0.300	0.256	0.270	0.239	0.238	0.270	0.247
LBL	0.291	0.256	0.296	0.254	0.225	0.184	0.255	0.202	0.248	0.197
LUB	0.288	0.318	0.369	0.385	0.273	0.259	0.264	0.252	0.293	0.281
ŁDZ	0.186	0.178	0.209	0.203	0.180	0.174	0.165	0.171	0.177	0.193
MAŁ	0.351	0.350	0.356	0.346	0.323	0.303	0.339	0.301	0.344	0.350
MAZ	0.313	0.317	0.315	0.314	0.236	0.224	0.221	0.226	0.278	0.260
OPL	0.240	0.239	0.237	0.256	0.213	0.203	0.203	0.186	0.248	0.195
PDK	0.399	0.407	0.404	0.426	0.372	0.295	0.298	0.282	0.301	0.294
PDL	0.357	0.378	0.427	0.461	0.370	0.365	0.335	0.312	0.401	0.347
POM	0.428	0.447	0.461	0.399	0.368	0.314	0.373	0.334	0.390	0.389
ŚLK	0.278	0.254	0.277	0.275	0.221	0.209	0.214	0.191	0.226	0.213
ŚWK	0.328	0.329	0.317	0.285	0.231	0.269	0.215	0.199	0.222	0.207
WRM	0.494	0.540	0.539	0.516	0.375	0.382	0.383	0.375	0.402	0.408
WLK	0.285	0.315	0.291	0.268	0.187	0.212	0.199	0.184	0.224	0.225
ZACH	0.239	0.300	0.330	0.350	0.323	0.316	0.294	0.291	0.324	0.311

Source: as in Table 2.

In 2010, the following voivodeships were included in the regions with a high level of bioeconomy development: Warmińsko-Mazurskie, Pomorskie and Podkarpackie. Regions that represented an average level were: Podlaskie, Mazowieckie, Kujawsko-Pomorskie, Lubelskie, Świętokrzyskie and Małopolskie. Regions with a low level of bioeconomy development

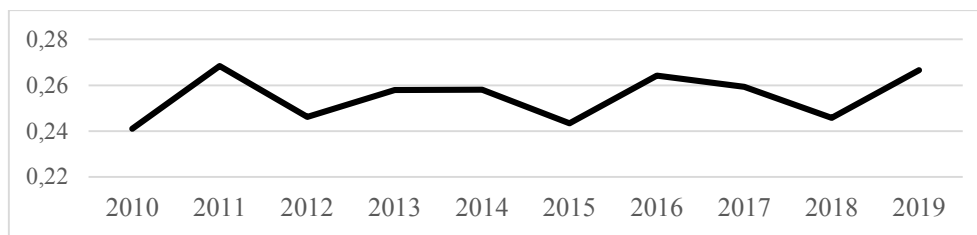
include: Zachodniopomorskie, Lubuskie, Wielkopolskie, Dolnośląskie, Łódzkie, Opolskie, Śląskie (Figure 2). In 2019, the composition of the groups changed. Four regions were classified as having a high level of bioeconomy development: Pomorskie, Warmińsko-Mazurskie, Podlaskie and Małopolskie. The average level of bioeconomy development was observed in three voivodeships: Podkarpackie, Zachodniopomorskie and Lubuskie. The largest group was composed of voivodeships with low levels of bioeconomy development.



**Figure 2.** The level of bioeconomy development in regions in 2010 and 2019.

Source: the author's own study.

The dispersion coefficient of regional bioeconomy development level in 2010 was at 24.10%, then increased in 2011 to 26.83% (Chart 3). It took its lowest values at around 25% between 2012 and 2015, after which it gradually increased. On this basis, it can be concluded that during the studied period there were processes of regional divergence in the level of bioeconomy development in Poland.



**Figure 3.** Classical analysis of the convergence of the level of bioeconomy development in Poland in 2010-2019.

Source: own development.

The study also examined the relationship between the level of bioeconomy development and: the level of socio-economic development of regions and the level of GDP per capita. The Pearson coefficient of correlation between the level of bioeconomy development and the level of socio-economic development was statistically significant in the following voivodeships: Dolnośląskie, Kujawsko-Pomorskie, Małopolskie, Mazowieckie, Opolskie, Podkarpackie, Pomorskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie. Negative correlation in this case means too small a share of bioeconomy in socio-economic development of these regions. The negative Pearson coefficient of correlation between the level of bioeconomy development and the size of GDP per capita should be interpreted similarly. The lack of significant correlation between the level of bioeconomy development and the level of socio-economic development and GDP per capita in the regions indicates that the use of simple statistical methods can lead to incomplete and sometimes erroneous conclusions. The search for other more advanced methods is therefore required.

**Table 5.**

*Correlation of the level of bioeconomy development with the level of socio-economic development and GDP per capita in the region*

Voivodeship	Level of socio-economic development	PKB per capita
DOL	-0.796 *	-0.668*
KUJ	-0.848*	-0.763*
LBL	-0.681	-0.641
LUB	-0.376	-0.454
ŁDZ	-0.683	-0.220
MAŁ	-0.717*	-0.210
MAZ	-0.869*	-0.510
OPL	-0.921*	-0.518
PDK	-0.949*	-0.812*
PDL	-0.547	-0.337
POM	-0.779*	0.435
ŚLK	-0.935*	-0.711*
ŚWK	-0.761*	-0.805*
WRM	-0.912*	-0.674*
WLK	-0.868*	-0.614*
ZACH	0.080	0.219

\* statistically significant correlation at the adopted significance level of  $\alpha = 0.05$ .

Source: the author's own study.

The study indicated that the level of bioeconomy development in Polish regions petrified between 2010 and 2019. At the same time, there was an increase in regional variations across the different groups of indicators studied. Regions in the group of the most developed ones in terms of socio-economic development did not have the highest level of bioeconomy development.

## 7. Summary

In view of current climate changes and depletion of the planet's natural resources, humanity is facing new challenges beyond achieving sustainable competitive advantages of particular economic groupings, countries, regions. Protecting the planet's environment and natural resources is a global value. The bioeconomy is a course of action that becomes an instrument in achieving it. The development of bioeconomy has not only an axiological, but also an economic and social dimension. This is reflected in the program documents of the European Union and Poland. Bioeconomy considerations should include not only global, but also national aspects and regional perspectives. With regard to the European Union, the development of the bioeconomy is intended to increase the cohesion of the member countries. However, an equally important issue is the impact of the bioeconomy in reducing interregional disparities within countries. The results of the study indicate that when it comes to Poland, the level of bioeconomy development in individual regions is not related to their classification according to the level of socio-economic growth. Changes in the level of bioeconomy development across regions between 2010 and 2019 were small and indicated increasing disparities. Thus, in Poland, the phenomenon of divergence of regional development in terms of the level of bioeconomy development has occurred. Regions belonging to the group of the most developed in terms of socio-economic development were not characterized by the highest level of bioeconomy development. In light of the research results obtained, it cannot be expected that the development of the bioeconomy in individual regions will lead to a reduction in regional disparities in the short to medium term.

The authors are aware that depending on the measurement methods and variables adopted, a different indicator of the level of development of the bioeconomy can be obtained. The results obtained based on the research conducted with the method used by the authors indicate the low effectiveness of the state's regional policy in reducing interregional disparities. This is evidenced by the deepening dispersion coefficient of the regional level of bioeconomy development over the 2010-2019 period. The study period is long enough for positive trends to emerge in terms of reducing regional disparities that may be the result of influence from both central and local government regional policy actors. The evaluation of interregional and regional policies in light of the research obtained is not positive. It is also significant that the

regions with the highest synthetic level of bioeconomy development in the years studied are not among the regions with the highest level of socioeconomic development. One can conclude from this that the bioeconomy is not a leading factor in the socio-economic development of regions.

Also important is the fact that a group of factors related to renewable resources has the greatest impact on the level of bioeconomy development in the region. This suggests that bioeconomy development policies should focus on measures to support the development of renewable energy and increase the level of recycling (recycled industrial waste).

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