Towards Sustainability: Advancing Bioeconomy Development in the EU

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Abstract: The bioeconomy involves the use of renewable biological resources such as crops, forests, fish, animals and micro-organisms to produce food, materials and energy. There is great optimism within the European Union about the benefits and opportunities that its development will bring. The path taken by the community of states towards sustainability involves creating a set of accessible indicators to measure the development of the bioeconomy at the EU member state level. The indicators should be largely identical to those of the green economy. The aim is to describe the development of the bioeconomy in the EU using a set of selected indicators. Furthermore, the paper should answer the question: Are there the same driving forces in the development of the bioeconomy as in the case of the green economy? The results showed that the bioeconomy is developing at the EU level. Additionally, correlations were found between several indicators. A question for future direction remains whether the indicators should be expanded, particularly to include socio-cultural or other factors.

Keywords: bioeconomy, EU, indicators, sustainable development
JEL Classification: Q56, O13

1 Introduction

The bioeconomy can be defined as the use of renewable biological resources to produce energy, materials and food in particular (European Commission, n. d.). The main goal of bioeconomy is linked to the basic development concept - sustainable development (World Commission on Environment and Development, 1987). According to FAO (2022), the bioeconomy includes the production, use and protection of biological resources. It also expands the bioeconomy by total knowledge capital, technology and innovation. All activities within the bioeconomy should offer a sustainable solution in all sectors of the economy. McCormick & Kautto (2013) state that there is great optimism associated with the bioeconomy in Europe due to the benefits and the large number of opportunities. The connection with the concept of sustainability represents the key, as it is a basic prerequisite for European countries to avoid the risks associated with the implementation of the bioeconomy. According to the authors, bioeconomy has the power to balance economic, social and ethical aspects. Aguilar, Twardowski & Wohlgemuth (2019) add that, overall, the key factors for the success of the bioeconomy vary globally. These can include various elements of high-tech bioeconomies, but also advanced and basic bioeconomies of the primary sector.

From a geographical perspective, the role of the EU is crucial. According to Patermann & Aguilar (2018), the EU has determined and comes currently first when speaking about determining trends in the bioeconomy within Europe and beyond. Activities related to the Horizon 2020 Program and the creation of a public-private partnership of bio-based industries were particularly important to the EU Strategy on Bioeconomy. If we examine the bioeconomy within the EU, it can be concluded that Germany, the Benelux countries and the Scandinavian countries have the most developed bioeconomy. Aguilar & Twardowski (2022) add that there is consensus in the discourse that the bioeconomy must have a circular character in line with sustainable development. Overall, we can summarize that it represents an effective solution to global problems. Important is the basis of the bioeconomy, which consists of innovation and new technologies that address new socio-economic and political changes.

The bioeconomy at EU level can be measured in several ways. Dolge et al. (2023) created the bioeconomy sustainability index, which contained 13 indicators. Index followed EU countries between 2016-2018. The highest score was recorded in Denmark, Sweden, Germany, the Netherlands and Belgium. Conversely, the lowest values were found in Latvia, Estonia and Hungary. The indicators covered the following areas: socio-economic impact, resource sustainability, innovation, funding and government support. The development of the bioeconomy in the EU can also be monitored at the level of employment and added value. Ronzon et al. (2020) state that since 2016, employment in the

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area of the bioeconomy at the level of the entire community has been growing. In the same way, labour productivity is continuously increasing. However, structural differences between countries were noted, which were reflected in different productivity levels. Eastern Europe, Portugal and Greece have bioeconomies focused more on biomass from fisheries, aquaculture, agriculture and forestry. The countries of Central Europe and Estonia, on the other hand, are more diversified in the direction of the manufacturing sector. Another research that aimed to define the indicators of the bioeconomy was created by Woźniak, Tyczewska & Twardowski (2021). The authors state that environmental factors are most often used to achieve strong sustainability. Environmental indicators include sustainable management of resources. Social and economic indicators are also used. Social ones mainly comprise indicators regarding the transfer of knowledge, social and human capital. Economic indicators then focus on innovation, infrastructure, financial capital or research and development activities. Kardung & Drabik (2021) used 41 indicators in the EU states to measure progress within the bioeconomy in the years 2006-2016. Overall, there have been positive developments, but also differences. The share of renewable sources and recycling grew. On the contrary, in Germany, Latvia, and Slovakia there was a regression in agro-environmental indicators. Research and development grew within the private sector. For the public sector, it decreased. Performance indicators based on an output-based approach can also be used to measure development within the EU in the years 2008-2017. Ronzon, Iost & Philippidis (2022a) state that the agricultural and food sectors were key in the transition in the primary industrial sector of the bioeconomy. Uneven development at the level of EU countries was also detected. The bioeconomy also applies to the service sector. Ronzon, Iost & Philippidis (2022b) tracked the contribution of bioeconomy services to GDP between 2008 and 2017. Services in the bioeconomy grew faster than overall economic growth. The development of the bioeconomy can also be measured through the production-based land footprint (Liobikiene et al., 2020). Even with this indicator, a trend can be noted that almost all EU countries show increasing footprint to biocapacity ratios.

2 Methods

The aim is to describe the development of the bioeconomy in the EU using a set of selected indicators. In this paper, the indicators will be monitored at EU-27 level. For the current situation, data from 2020-2022 are used, according to availability at Eurostat. Only for the Recycling rate of all waste excluding major mineral waste, data from 2018 was used as more recent data was not available for all countries. The second period used was Eurostat data from 2013-2014, which marks the beginning of the post-crisis period in the EU. The indicators were selected mainly with regard to their quantitative measurability and comparability. The selection of specific indicators was inspired in particular by the Cudlínová, Vávra & Lapka (2015) study, which dealt with the greening of the EU economy.

The following indicators were chosen:

- Organic crop area by agricultural production methods and crops (Percentage of total utilised agricultural area) – 2013; 2020
- Recycling rate of all waste excluding major mineral waste (Percentage) – 2014; 2018
- Net greenhouse gas emissions (Tonnes per capita) – 2013; 2021
- Gross domestic expenditure on research and development (R&D) (Percentage of gross domestic product (GDP)) – 2013; 2022
- Value added in biomass producing and converting sectors (Current prices, million euro) – 2014; 2020
- Renewables and biofuels available for final consumptions (Thousand tonnes of oil equivalent percentage share) – 2013; 2021

A total of three indicators are coincident with the article by Cudlínová, Vávra & Lapka (2015), who examined the development of the green economy in the EU. These are the indicators *Gross domestic expenditure on R&D*, *Greenhouse gas emissions per capita* and *Renewables*. The indicator *Value added in biomass producing and converting sectors (Current prices, million euro)* was based on the methodology of Lasarte-López et al. (2023). These are selected NACE sectors (see Table 1) divided by the total NACE for all sectors. Value added in biomass producing and converting sectors relative to the total value added of the economy (all sectors) allows comparisons across countries. Other indicators were selected by the author.

Table 1 Selected NACE sectors for the indicator (Value added in biomass producing and converting sectors)

Section (NACE)	***Description***
A01	Agriculture
A02	Forestry
A03	Fishing
C10; C11; C12	Food, beverage and tobacco industry
C13; C14; C15	Bio-based textiles
C16; C31	Wood products and furniture
C17	Paper and paper products
C20; C21; C22	Bio-based chemicals, pharmaceuticals and plastics (excl. biofuels)
C2014; C2059	Liquid biofuels (bioethanol and biodiesel)

Source: Own processing according to Lasarte-López et al. (2023)

The procedure for the analytical part is as follows. First, the change in the values of the indicators between the observation periods was calculated. A correlation analysis of the change between the periods was then carried out, but also for the two periods separately. Subsequently, the change in the values of the indicators was subjected to factor analysis. IBM SPSS Statistics was used for statistical calculations.

3 Research results

This section will first describe the overall development of the bioeconomy in the EU based on selected indicators. Subsequently, the indicators were subject to correlation analysis. The correlation analysis was carried out in both periods of interest, and the change correlation was then calculated.

For the indicator "Organic crop area by agricultural production methods and crops", the change between periods at EU level was 3.19%. At the national level, the highest change was recorded in Austria (7.29%), Estonia (6.76%), and Italy (5.36%). The lowest change was measured in Poland (-1.2%), Ireland (0.46%), and Malta (0.56%).

The indicator "Recycling rate of all waste excluding major mineral waste" has shown the highest changes in Lithuania (15%), Slovakia (10%), Croatia (9%), and Hungary (9%). Conversely, the lowest values were observed in Portugal (-14%), Estonia (-9%), and the Netherlands (-6%). It should be noted that data for Greece and Latvia were not available. At the EU-wide level, this change amounted to 2%.

The amount of GHG emissions at the EU level decreased by 0.9 tonnes per capita. The largest reductions were observed in Luxembourg (-5.2), Estonia (-2.9), and Malta (-2.7). Conversely, the largest increases were recorded in Latvia (2.8), Lithuania (1.5), and Poland (0.8).

Gross domestic expenditure on research and development (R&D) at the EU level increased by 0.14%. The highest increases were recorded in Belgium (1.1%), Greece (0.67%), and Croatia (0.63%). In some countries, however, the indicator value actually declined, including Ireland (-0.61%), Slovenia (-0.45%), and Finland (-0.32%).

The value of "Value added in biomass producing and converting sectors" at the EU level decreased by €0.06 million. The highest increases were observed in Lithuania (€1.36 million), Latvia (€0.63 million), and Greece (€0.62 million). The largest decreases were recorded in Ireland (-€1.78 million), Romania (-€1.37 million), and Bulgaria (-€1.08 million).

The value of "Renewables and biofuels available for final consumption" at the EU level increased by 1.94%. The largest increases were recorded in Finland (6.94%), Cyprus (6.18%), and Sweden (5.61%). However, in some countries, the value decreased, specifically in Hungary (-4.18%), Romania (-1.81%), and Latvia (-1.44%).

Table 2 shows the correlation analysis of indicators in the post-crisis period. If expenditure on research and development increases, the recycling rate and organic crop area also rise, and value added in biomass producing and converting sectors decreases. Conversely, when the value added in biomass producing and converting sectors increases, the recycling rate decrease. The final statistically significant relationship indicates that as renewables and biofuels available for final consumptions rise, so does the organic crop area by agricultural production methods and crops, and conversely, GHG emissions decrease.

Table 2 Person correlation of the previous period

	Organic crop area (2013)	Recycling rate (2014)	GHG emissions (2013)	Gross domestic expenditure on R & D (2013)	Value added (bioeconomy) (2014)	Renewables and biofuels available (2013)
Organic crop area (2013)	--					
Recycling rate (2014)	0.169	--				
GHG emissions (2013)	-0.087	0.169	--			
Gross domestic expenditure on R & D (2013)	**0.477***	**0.468***	0.120	--		
Value added (bioeconomy) (2014)	-0.373	**-0.415***	-0.335	**-0.562****	--	
Renewables and biofuels available (2013)	**0.462***	-0.273	**-0.580****	0.093	0.124	--

Source: Own processing; Note: *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

In the current period, fewer correlation relationships were found, but all the identified relationships hold true as in the previous period. If expenditure on research and development increases, the organic crop area rises, and value added in biomass producing and converting sectors decreases. Similarly to the previous case, when the renewables and biofuels available for final consumptions increases, the organic crop area rises and emissions decreases. (see Table 3).

Table 3 Person correlation of the current period

	Organic crop area (2020)	Recycling rate (2018)	GHG emissions (2021)	Gross domestic expenditure on R & D (2020)	Value added (bioeconomy) (2020)	Renewables and biofuels available (2021)
Organic crop area (2020)	--					
Recycling rate (2018)	0.054	--				
GHG emissions (2021)	-0.117	0.116	--			
Gross domestic expenditure on R & D (2020)	**0.515****	0.371	-0.014	--		
Value added (bioeconomy) (2020)	-0.247	-0.099	-0.380	**-0.394***	--	
Renewables and biofuels available (2021)	**0.543****	-0.233	**-0.419***	0.192	0.010	--

Source: Own processing; Note: *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Table 4 shows the correlation analysis of changes between observed periods. Only one relationship was identified that was not found in the previous individual correlation analyses. As the availability of renewables and biofuels for final consumption increases, the recycling rate decreases.

Table 4 Person correlation of change between periods

	Organic crop area	Recycling rate	GHG emissions	Gross domestic expenditure on R & D	Value added (bioeconomy)	Renewables and biofuels available
Organic crop area	--					
Recycling rate	-0.152	--				
GHG emissions	-0.015	0.248	--			
Gross domestic expenditure on R & D	-0.017	-0.038	0.053	--		
Value added (bioeconomy)	0.231	0.207	0.172	0.308	--	
Renewables and biofuels available	-0.128	**-0.438***	-0.153	0.021	0.103	--

Source: Own processing; Note: *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Subsequently, a factor analysis was conducted to identify the underlying (latent) factors influencing the set of observed variables. In other words, factor analysis would simplify and clarify possible hidden relationships between the observed variables. Factor analysis was conducted for the changes between periods. Extraction was done by principal component analysis (PCA), rotation by Varimax method with Kaiser Normalization. First, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy was conducted to determine the suitability of data for factor analysis. The value was 0.339, indicating that factor analysis cannot be performed on this sample, as the value is below 0.5.

4 Conclusions

The aim of the paper was to describe the development of the bioeconomy at EU level. Using the indicators, it was found that the development of the bioeconomy is mostly positive, especially when considering aggregate values for all EU countries. It should be noted that the reduction in biomass value added amounted to several hundred million euros. The geographical distribution is also heterogeneous. For example it cannot be stated that Western Europe is better off than Eastern Europe. In this regard, the factor mentioned by Ronzon et al. (2020) may also play a role. Eastern Europe and some Southern European countries have a bioeconomy more focused on fisheries, aquaculture, agriculture, and forestry, while Central European countries have greater diversification, including a stronger orientation towards the manufacturing sector.

As in the case of the Cudlínová, Vávra & Lapka (2015) research, the correlation of changes between observed periods regarding the available renewables and biofuels and GHG emissions is not confirmed. The research by Cudlínová, Vávra, and Lapka (2015) also focused on the green economy before and after the crisis. In their case, the development could be explained, based on factor analysis, by two components – economic and innovative. If we assume that the green economy precedes the bioeconomy, it should also be possible to explain the development of the bioeconomy using simple macroeconomic indicators. However, in this case, this assumption was not confirmed. Authors such as Dolge et al. (2023) include additional areas in the measurement of the bioeconomy: socio-economic impact, resource sustainability, innovation, funding, and government support. This diversity of indicators is also supported by the research of Woźniak, Tyczewska, and Twardowski (2021). This raises the question of whether the bioeconomy has a much broader scope compared to the green economy. Such a perspective would challenge conclusions that argue that the green economy is the overarching concept (e.g. Loiseau et al., 2016).

For further research and measurement of bioeconomy development, it is necessary to consider the broader areas that the bioeconomy encompasses. It appears that basic macroeconomic indicators, which were previously used to measure the green economy, are no longer sufficient to provide an explanation.

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