

Spatial Differentiation of Environmental Responsibility among European Union Countries: Empirical Insights from the Hellwig Method

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ABSTRACT:

The European Union has been working hard to protect the environment for many years, aiming for climate neutrality and sustainable development. In the face of global climate change, ecosystem degradation, and pollution, the EU is setting ambitious targets within the framework of the European Green Deal.

This article aims to examine the spatial differences between EU countries in their efforts to ensure environmental security and sustainability.

Individual Member States, pursuing their own environmental protection strategies tailored to local conditions and challenges, are investing at different levels in environmental protection, greenhouse gas reduction, or renewable energy use. Therefore, the research hypothesis is that there is a significant spatial differentiation among the countries of the European Union in terms of the level of environmental activities undertaken.

The article analyses statistical data from the Eurostat database and uses the Hellwig method to construct a synthetic measure of development on the basis of four selected diagnostic variables in the field of environmental activities. The results of the study made it possible to systematise and group countries according to the intensity and effectiveness of the activities in the data analysed.

The countries that achieved the highest scores on the synthetic indicator—indicating the strongest commitment to sustainable environmental policy as well as the most effective efforts to cut greenhouse gas emissions and adopt green technologies—were Austria, Slovenia, Croatia, Finland, and Latvia. Conversely, the group of countries where the activities in the discussed area are far from sufficient included: Luxembourg, Ireland, Greece, Slovakia, Romania, Hungary, and Cyprus. The statistical analysis also showed a relationship between renewable energy use and a country's gross domestic product. This finding is not surprising, as rising GDP is generally linked to a higher proportion of renewable energy in total final energy consumption, though some fluctuations may occur due to the unstable global context.

Keywords: environmental responsibility, European Union countries, Hellwig method, sustainable development

1. Introduction

Environmentally responsible and long-term growth is a major challenge facing the world today and is considered the leading direction in global environmental policy and socio-economic progress (Barron et al., 2023; Raczkowska et al., 2021). It is a strategy that comprehensively addresses the long-term capacity of the economy and society to grow, while taking into account the protection of the natural environment. The concept of

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sustainable development is often associated with the so-called ecological awakening (Osuch-Rak & Proczek, 2016, p. 195).

The implementation of the sustainable development strategy is primarily entrusted to international organizations (such as the UN and OECD), and in Europe, particularly to the European Union. The environmental dimension plays a crucial role in this strategy, emphasizing the development of a competitive EU economy through a transition toward a “green economy”—one that is low-emission, minimizes greenhouse gas emissions, protects the natural environment, and prevents biodiversity loss. These objectives are reflected in the framework of the European Green Deal.

The purpose of this article is to examine the spatial differentiation among European Union countries in terms of activities related to ensuring environmental security and sustainable development. The article’s theoretical section draws on an overview of existing literature, whereas the empirical part relies on statistical information from Eurostat regarding pro-environmental actions carried out by EU member states.

The implementation of ambitious environmental goals within the European Union’s sustainable development strategies and programmes is highly spatially differentiated and remains insufficient. This is largely due to contemporary challenges such as globalization, population migration, socio-economic issues, and the political situation of individual EU member states.

2. Sustainable Development of the European Union

The idea of sustainable development has evolved into a key theme in academic discussions and has come to function as a guiding framework for development (Ruggerio, 2021). In the literature, sustainable development is emphasized in connection with various areas such as business (Mio et al., 2020; Kubiński et al., 2023), industry (Pineda, 2024; Azapagic, 2000), agricultural production (Atapattu et al., 2024; Rudnicki et al., 2023), urban development (Bhargava et al., 2023), and innovations and new technologies (Zuzek et al., 2022; Østergaard, 2022). It also serves as a conceptual foundation for issues such as the green economy (Al-Taai, 2021) and the circular economy (Lamba et al., 2023).

A widely recognized explanation of sustainable development stems from the 1987 Brundtland Report created by the World Commission on Environment and Development. It characterizes sustainable development as a form of progress that fulfils current needs without limiting the capacity of future generations to satisfy theirs. In this report, environmental and economic goals are linked with social objectives through the assumption of equitable opportunities for resource distribution, and the durability of growth is seen as the foundation of intergenerational justice. This is a vision of progress whose overarching goal is the integration of ecologically conditioned development at the local, regional, and global levels with efficient resource management and socially just development (Urbaniec, 2015: 148). Sufficiency, efficiency, and consistency are three elementary approaches for a society within planetary boundaries (Fischer et al., 2023). It is highlighted that sustainable development involves striving to maintain harmony between economic progress, environmental protection, and social welfare (Mansah, 2019). Sustainable development corresponds to heterodox economics through its comprehensive, diverse, and cross-disciplinary perspective. It considers factors such as time — addressing the needs of both current and future generations — as well as

institutional influences, which traditional economic theories tend to neglect (Szydło, 2023:155).

Sustainable development is reflected in numerous documents, agreements, and international conferences, including those organized by the United Nations (UN), the Organisation for Economic Co-operation and Development (OECD), and the European Union (EU). The initiatives undertaken aim to implement the principles of sustainable development, with particular emphasis on restoring ecological balance, combating climate change, assessing progress made, and defining new priorities (Coscieme *et al.*, 2021; Seifi *et al.*, 2020).

As part of the 2030 Agenda (“Transforming Our World: The 2030 Agenda for Sustainable Development”), UN member states adopted 17 Sustainable Development Goals (SDGs), which, along with 169 detailed targets, constitute the core of the global Sustainable Development Strategy for 2030 (Baum, 2021, p. 17). Sustainable development goals are listed in the document: „Transforming Our World. The 2030 Agenda for Sustainable Development” (UN, 2015).

Sustainable development issues are being introduced within the European Union, which is considered a global leader in implementing this concept—both at the level of national policy and in terms of concrete action (Raczkowska *et al.*, 2021: 17). EU documents and strategies emphasize the necessity of incorporating sustainable development not only at the level of the Union as a whole but also within individual member states (EC, 2020).

In the European Union, particular attention is given to actions aimed at achieving long-term environmental goals, including the transition to a low-carbon, resource-efficient economy utilizing energy- and resource-saving technologies, the establishment of a sustainable transportation system, and the preservation of biodiversity, water resources, and other critical natural assets (Osuch-Rak *et al.*, 2016, p. 201). The “Europe 2020” strategy (EC, 2010) and “Towards A Sustainable Europe by 2030” (EC, 2019) form the foundation for sustained and sustainable economic growth in EU countries across three key areas: knowledge-based, eco-friendly, and equitable growth.

Sustainable growth refers to building a competitive EU economy by focusing on the green economy—low in greenhouse gas emissions, protective of the natural environment, and committed to preventing biodiversity loss (Szydło, 2023; Adamowicz, 2022). Within this strategy, the environmental pillar has been significantly strengthened, which aligns with the European Green Deal—a program that commits to transforming the European economy into a zero-emissions system (Dziembała, 2025: 71). The implementation of the strategy is intended to enhance resource efficiency within a circular economy, ensure the preservation of biodiversity, and mitigate pollution (Rowan & Galanakis, 2020). The attainment of climate neutrality necessitates the active engagement of all relevant stakeholders across diverse sectors, including construction, energy, transportation, agriculture, food production, and biodiversity management (Szpilko & Ejdyś, 2022: 10).

The transition toward a “green economy” requires systemic changes. Therefore, sustainability transitions are considered within the context of socio-technical systems (Petrović, 2024; Bidmon, 2021). The concept of sustainability transitions is the subject of research focused on its nature and defining characteristics—highlighting, in particular,

multi-dimensionality and co-evolution, which emphasize the multiplicity of elements within socio-technical systems as well as their openness and inherent uncertainty due to innovations and initiatives that are difficult to predict (Köhler et al., 2019).

ICT-driven innovation is being increasingly identified as a crucial factor in facilitating sustainability transitions. Only radical innovations lead to changes in the structure of socio-technical systems that underlie patterns of production and consumption (Mäkitie et al., 2023). It is noted that digitalization augments the energy transition and green finance in the pursuit of environmental sustainability (Sheraz et al., 2024). The successful implementation of the European Green Deal strategy will also require political courage to overcome resistance to change, as well as the introduction of numerous political, economic, and social measures, along with substantial financial commitment (Szpilko & Ejdyś, 2022: 11).

A successful EU sustainable development policy depends on the availability of information and data regarding the extent to which its objectives are being met. The primary monitoring tools in this regard are the Sustainable Development Indicators (SDIs). Currently, environmental priorities within climate action (Goal 13) are monitored based on indicators such as net greenhouse gas emissions, net greenhouse gas emissions from land use, land use change and forestry, average CO₂ emissions per kilometre from new passenger cars, climate-related economic losses, green bond issuance, and contributions to the international USD 100 billion commitment on climate-related expenditure.

Findings from the United Nations Framework Convention on Climate Change (2024) and the “State of the Global Climate” report by the World Meteorological Organization (2024) clearly indicate a continued increase in greenhouse gas emissions, currently at the highest level in the history of measurements. This trend contributes to the intensification of the greenhouse effect and global warming. The Kyoto Protocol and the Paris Agreement represent significant milestones in global climate strategy; however, a variety of factors have limited their overall effectiveness in addressing global warming and broader climate change, ultimately resulting in their failure (Mravcová, 2025: 59).

A comprehensive assessment of the European Green Deal, as presented in the report “Delivering the EU Green Deal: Progress towards targets 2025” (Marelli et al., 2025) and in the “Sustainable Development in the European Union: Monitoring Report on Progress Towards the SDGs in an EU Context (2023),” clearly shows that current environmental protection efforts are not delivering the expected outcomes and require further support.

The full implementation of environmental objectives, as outlined in European strategies, poses a significant challenge—particularly with regard to the migration crisis, social and economic challenges, globalization, and the political situation of individual member states. Some European governments remain sceptical about climate change and its consequences for the quality of life on Earth (Duradoni et al., 2025; Duijndam et al., 2020). The lack of political will and the prioritization of other challenges may significantly affect the realization of sustainability targets within the framework of the European Union’s development strategy.

Evidence from the literature suggests that the realization of the goals and assumptions of sustainable development and the European Green Deal is a long-term

process requiring the involvement of all actors, including the governments of member states. Therefore, the following research hypothesis was formulated: there is significant spatial differentiation among EU countries in terms of the level of pro-environmental activities undertaken.

3. Methods

To evaluate the extent of pro-environmental activities in European Union countries and verify the proposed research hypothesis, a technique from the field of numerical taxonomy was applied—namely, the development pattern method. The analysis was carried out in several key stages: selection of statistical indicators reflecting pro-environmental actions, construction of synthetic indicators of ecological competitiveness for the 27 EU member states (EU-27), and application of the k-means clustering method to group the EU-27 countries.

The analysis employed the Hellwig method (1968), which allows for the creation of synthetic measures based on specific diagnostic measures representing multiple aspects of the subject under analysis. The dataset consisted of key indicators related to pro-environmental performance at the EU-27 level. The year 2021 was adopted as the reference period due to the unavailability of complete data for subsequent years. Statistical data were obtained from the Eurostat database.

The evaluation included four key indicators, assigned numbers from 1 to 4, as presented in Table 1.

Table 1: List of Indicators Used in the Analysis

Indicator	Type of Variable
X ₁ – Net greenhouse gas emissions in 2021 [% of 1990 level]	Stimulant
X ₂ – Share of renewable energy in gross final energy consumption in 2021 [%]	Stimulant
X ₃ – Expenditure on environmental protection in 2021 [% of GDP]	Stimulant
X ₄ – Environmental protection investments in the total economy in 2021 [% of GDP]	Stimulant

Source: The authors' research

The application of the Hellwig method requires the construction of an observation matrix in the form presented below:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix} \quad (1)$$

where:

x_{ij} – denotes the value of the j -th variable in the i -th region ($i = 1, 2, \dots, n; j = 1, 2, \dots, m$).

In the next step, standardization of the values of the variables x_j in the studied population must be performed. The following formulas were used for the calculations (Marakova et al., 2016):

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (2)$$

where:

z_{ij} – standardized value of the j -th variable in the i -th country

i – country number,

j – variable number,

x_{ij} – values of the j -th variable in the i -th country

\bar{x}_j – the arithmetic mean of the j -th variable

S_j – the standard deviation of the j -th variable

Based on the standardized variables, synthetic measures of the level of pro-environmental activities were calculated using Z. Hellwig's development pattern method, and country rankings were compiled. The synthetic measure of pro-environmental activities was computed as a composite taxonomic indicator reflecting the "distance" of each country from the theoretical model of optimal pro-environmental performance, representing a country with the highest level of ecological competitiveness.

In the next step, the Euclidean distances from the reference (model) object were calculated:

$$d_{i0} = \sqrt{\sum_{j=1}^m (t_{ij} - x_{0j})^2} \quad (3)$$

where:

d_{i0} – the Euclidean distance between the i -th object and the reference (model) object

t_{ij} – the standardized value of the j -th variable in the i -th territorial unit

$i = 1, 2, \dots, n,$

$j = 1, 2, \dots, m,$

Taking the above assumptions into account, the synthetic measure can be calculated using the following formula:

$$S_i = 1 - \frac{d_{i0}}{d_0} \quad (4)$$

where:

d_{i0} – the Euclidean distance between the i -th object and the reference (model) object

d_0 – the critical distance of a given unit from the reference (model) object:

$$d_0 = \bar{d}_{i0} + 2 \cdot S_0 \quad (5)$$

\bar{d}_{i0} – the arithmetic mean of the taxonomic distances between the i -th object and the reference (model) object

$$\bar{d}_{i0} = \frac{1}{n} \cdot \sum_{i=1}^n d_{i0} \quad (6)$$

S_0 – the standard deviation of taxonomic distances between all objects and the reference object

$$S_0 = \sqrt{\frac{1}{n} \sum_{i=1}^n (d_{i0} - \bar{d}_0)^2} \quad (7)$$

Z. Hellwig's development pattern method makes it possible, based on the calculated taxonomic indicators of pro-environmental activity, to create a hierarchy of EU countries according to their level of engagement in pro-environmental efforts. This is made possible by the values of the synthetic measure (S_1), which range from 0 to 1.

4. Results

Table 2 presents data for the 27 member states of the European Union in the context of four environmental variables and a synthetic indicator of ecological competitiveness. The diagnostic variables include greenhouse gas emissions, the share of renewable energy, expenditure on environmental protection, and environmental protection investments in relation to GDP.

Table 2 Statistical Characteristics of Diagnostic Variables and Synthetic Indicators of Ecological Competitiveness of EU-27 Countries According to the Criterion of Environmental Responsibility

Region NUTS 2	Diagnostic Variable Values				Standardization				Euclidean Distance	Synthetic Indicator
	X ₁	X ₂	X ₃	X ₄	t ₁	t ₂	t ₃	t ₄	d ₁	M ₁
Belgium	78.4	13.1	3.3	0.5	0.14	-0.96	2.06	0.58	5.19	0.3207
Bulgaria	54.9	19.4	2.0	0.5	-0.73	-0.44	-0.01	0.58	5.86	0.2328
Czech Republic	65.5	17.6	2.9	0.7	-0.34	-0.59	1.42	1.82	4.96	0.3509
Denmark	56.2	41.8	2.0	0.4	-0.69	1.41	-0.01	-0.04	5.19	0.3199
Germany	60.2	19.3	2.3	0.4	-0.54	-0.45	0.47	-0.04	5.80	0.2407
Estonia	38.5	37.3	2.0	0.4	-1.34	1.04	-0.01	-0.04	5.76	0.2451
Ireland	110.4	13.0	0.8	0.2	1.32	-0.97	-1.91	-1.29	7.23	0.0529
Greece	72.5	22.0	1.3	0.2	-0.08	-0.23	-1.12	-1.29	6.79	0.1103
Spain	96.6	20.5	1.8	0.3	0.81	-0.35	-0.32	-0.67	5.78	0.2433
France	75.7	19.3	2.0	0.4	0.04	-0.45	-0.01	-0.04	5.69	0.2543
Croatia	77.2	31.2	2.0	0.6	0.09	0.54	-0.01	1.20	4.63	0.3941
Italy	75.2	18.9	2.5	0.4	0.02	-0.48	0.79	-0.04	5.42	0.2903
Cyprus	147.2	19.1	1.2	0.2	2.69	-0.47	-1.28	-1.29	6.43	0.1580

Latvia	94.9	42.1	1.3	0.5	0.75	1.43	-1.12	0.58	4.84	0.3660
Lithuania	34.6	28.2	1.8	0.5	-1.49	0.28	-0.32	0.58	6.09	0.2017
Luxembourg	81.2	11.7	0.9	0.0	0.24	-1.07	-1.75	-2.53	8.17	-0.0699
Hungary	61.7	14.1	1.4	0.5	-0.48	-0.87	-0.96	0.58	6.46	0.1541
Malta	83.4	12.6	2.0	0.3	0.32	-1.00	-0.01	-0.67	6.22	0.1852
Netherlands	76.8	13.1	1.9	0.4	0.08	-0.96	-0.16	-0.04	6.08	0.2039
Austria	98.9	34.8	3.6	0.5	0.90	0.83	2.53	0.58	3.45	0.547
Poland	84.2	15.6	2.4	0.5	0.35	-0.75	0.63	0.58	5.25	0.3120
Portugal	77.3	34.0	1.8	0.4	0.10	0.76	-0.32	-0.04	5.16	0.3240
Romania	29.1	23.9	2.4	0.3	-1.69	-0.07	0.63	-0.67	6.53	0.1444
Slovenia	109.0	25.0	2.4	0.8	1.27	0.02	0.63	2.44	3.90	0.4886
Slovakia	52.7	17.4	1.9	0.3	-0.82	-0.60	-0.16	-0.67	6.57	0.1400
Finland	105.6	42.8	1.9	0.3	1.15	1.49	-0.16	-0.67	4.69	0.3859
Sweden	24.2	62.5	2.1	0.5	-1.87	3.12	0.15	0.58	5.47	0.2830
UE-27	69.9	21.9	2.2	0.4	-0.18	-0.23	0.31	-0.04	5.53	0.2754
Arithmetic mean	74.71	24.73	2.00	0.41	0.0	0.0	0.0	0.0	5.68	0.2555
Standard deviation	26.97	12.11	0.63	0.16	1	1	1	1	0.98	0.1278
Coefficient of variation	36%	49%	31%	40%					17%	50%
Max	147.20	62.53	3.60	0.80	2.69	3.12	2.53	2.44	8.17	0.5475
Min	24.20	11.73	0.80	0.00	-1.87	-1.07	-1.91	-2.53	3.45	-0.0699

Source: The authors' research

The lowest level of greenhouse gas emissions in 2021 compared to 1990 was recorded in Sweden (24.2%), while the highest was observed in Cyprus (147.2%). In terms of the share of renewable energy in gross energy consumption, Sweden also stood out with a value of 62.53%, whereas Luxembourg recorded the lowest share at 11.73%.

Expenditure on environmental protection as a percentage of GDP was highest in Austria (3.6%) and lowest in Ireland (0.8%). Environmental protection investments reached their highest level in Slovenia (0.8% of GDP), while Luxembourg reported no expenditures in this area.

Other countries distinguished by a high level of renewable energy use include Finland, Latvia, and Denmark. Ireland, on the other hand, despite its relatively high greenhouse gas emissions, allocated very limited resources to environmental protection. The average level of greenhouse gas emissions in the EU was 69.9% of the 1990 value, indicating overall progress in pollution reduction.

The coefficient of variation for certain variables—such as the share of renewable energy sources (49%)—indicates significant disparities among countries. Environmental expenditures and investments remain relatively low in most member states. Romania and Lithuania, despite moderate levels of expenditure, ultimately achieved results well below the EU average. Interestingly, even countries with strong economies, such as Germany and France, did not score highly in terms of environmental competitiveness, which highlights that GDP alone does not accurately reflect spending on sustainable development. It should be noted that high GDP only means larger public budgets that can be allocated to investments in renewable energy sources, infrastructure modernisation, or innovations that reduce emissions. However, only a comparison of GDP with actual environmental expenditure allows us to assess whether a country is exploiting its potential or neglecting opportunities. In contrast, Slovenia and Finland stand out positively due to their balanced approach to emissions, energy use, and environmental investments. The average value of the synthetic measure M (0.2555) and its standard deviation (0.1278) indicate significant disparities among EU member states. The variation in variable values suggests that environmental policies should be more closely tailored to the specific characteristics of each country. Belgium, the Czech Republic, and Croatia achieved results above the average, which may indicate the effectiveness of their pro-environmental actions.

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Table 3: Classification of EU-27 Countries by Level of Environmental Responsibility

Region NUTS 2	Synthetic Indicator M	Level	
Austria	0.5475029	HIGH	
Slovenia	0.4886173		
Croatia	0.3940869		
Finland	0.3858801		
Latvia	0.3659967		
Czech Republic	0.3508667	MEDIUM	
Portugal	0.3240199		
Belgium	0.320723		
Denmark	0.3199152		
Poland	0.3120474		
Italy	0.2902924		
Sweden	0.2830062		
UE-27	0.2753502		
France	0.2543464	LOW	
Estonia	0.2450541		
Spain	0.2433017		
Germany	0.2407249		
Bulgaria	0.2327508		
Netherlands	0.2038951		
Lithuania	0.2017322		
Malta	0.1851784		
Cyprus	0.1580006		VERY LOW
Hungary	0.1540532		

Romania	0.1443612	
Slovakia	0.1399543	
Greece	0.1103344	
Ireland	0.0529054	
Luxembourg	-0.069889	

Source: The authors' research

Table 3 presents the classification of European Union countries according to their level of environmental responsibility, measured using the synthetic indicator M. The synthetic indicator of ecological competitiveness shows that Austria ranked highest, with a score of 0.5475, and was included in the group of countries with a high level of environmental responsibility. This group also includes Slovenia, Croatia, Finland, and Latvia, which achieved relatively high indicator values. Countries such as the Czech Republic, Belgium, Denmark, and Poland were classified as moderately environmentally responsible. The EU-27 average was 0.2754, indicating that 15 countries did not reach this level. Poland scored 0.3120 on the synthetic measure M, placing it above the EU average.

France, Estonia, Spain, and Germany were placed in the low-responsibility group, despite being economically developed countries. Even lower levels of responsibility were observed in countries such as Cyprus, Hungary, and Romania, which were classified as having very low environmental responsibility. Ireland and Luxembourg obtained the lowest indicator values, reflecting their weak position in the area of environmental protection.

In summary, the obtained research results confirm the validity of the research hypothesis H: there is significant spatial differentiation among European Union countries in terms of the level of pro-environmental activities undertaken.

The confirmation of the research hypothesis encourages a broader view of regional diversity in the European Union and reflection on its consequences for the functioning of cohesion policy. The results of the analysis reveal that, despite the measures taken so far at the EU level, there are still significant disparities in environmental responsibility and the pace of ecological transformation. This means that the current model of EU fund distribution may not fully correspond to the actual needs of individual regions. In this context, there is a need to thoroughly reconsider the existing funding priorities and better align them with local conditions. A more individualized approach, taking into account the specific characteristics of the economy, the level of development, and the adaptive capacity of regions, could contribute to levelling out the pace of ecological progress. Thus, it would not only strengthen territorial cohesion but also ensure a more equitable and effective adaptation to climate change in all EU Member States.

One of the key pro-environmental actions implemented by EU member states is the use of renewable energy, which plays an increasingly important role in the economy. Its development contributes to the creation of new jobs, particularly in sectors related to the construction and maintenance of photovoltaic, wind, and biogas installations. Investments in renewable energy sources also stimulate the advancement of modern technologies and innovation, which in turn fosters industrial modernization and enhances the competitiveness of the economy on the international stage. Based on statistical data obtained from Eurostat, a correlation was identified between the use of renewable energy and the level of Gross Domestic Product (GDP) in EU countries, as illustrated in Figure 1.

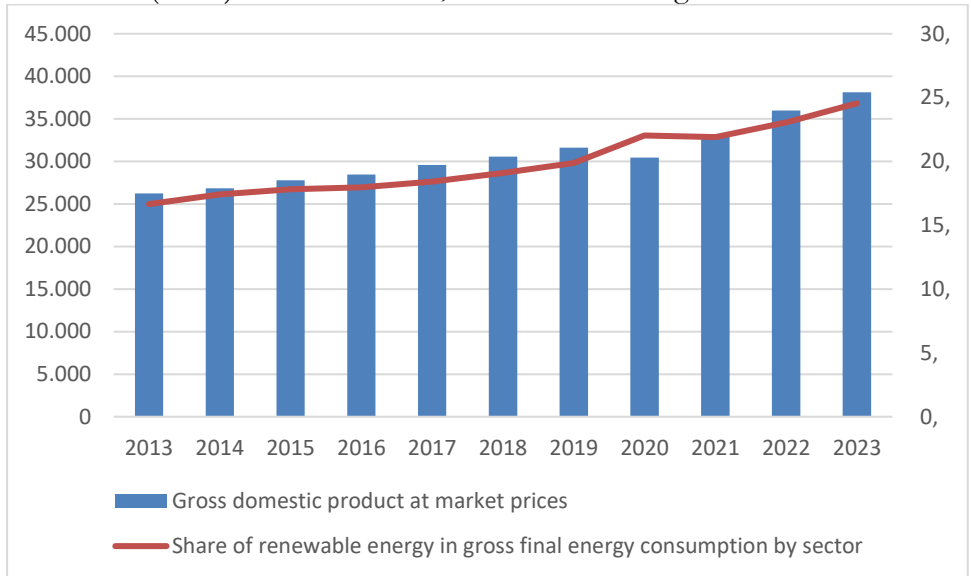


Figure 1: Relationship between the Use of Renewable Energy and GDP Level in EU Countries
 Source: The authors' research.

Statistical data show that as gross domestic product (GDP) grows, so does the share of renewable energy in gross final energy consumption, which means that developing economies are increasingly investing in modern, environmentally friendly energy technologies. As countries achieve higher levels of national income, their financial capacity to support the energy transition increases through the construction of renewable energy infrastructure, subsidising innovative solutions, and implementing environmentally friendly public policies.

5. Discussion

The modern world is facing an escalating climate and environmental crisis. As a response to these issues, the European Union (EU) has implemented a proactive stance,

establishing ambitious environmental policy goals. Member states are required to transform their economies toward sustainable development, which entails not only ecological responsibility for future generations but also real costs and political and social dilemmas.

The presented research findings partially confirm existing empirical studies. According to other researchers, differences in pro-environmental actions among EU countries have a clear territorial dimension and are strongly associated with historical context (Kern & Alber, 2008), level of economic development (Manta *et al.*, 2024), institutional quality (Polzin *et al.*, 2016), and regional specificities (Mazziotta & Truffer, 2019).

The economic and social diversity of EU countries results in a varied pace and capacity for implementing pro-environmental measures. Empirical studies confirm that Northern and Western European countries—such as Sweden, Finland, and Denmark—achieve significantly higher results in environmental efficiency and eco-innovation than Central and Eastern European countries. For instance, the Environmental Performance Index report (Block *et al.*, 2024) indicates that Nordic countries dominate in terms of environmental quality and the implementation of green policies, whereas countries like Bulgaria, Romania, and Latvia rank much lower.

Horbach, Rammer, and Rennings (2012) emphasize that territorial differences in eco-innovation result from variations in economic structures and the level of cooperation between the public and private sectors. Western European countries, particularly Germany and the Netherlands, are characterized by strong technological clusters and effective regulatory policies, which foster the development of green technologies. In contrast, in Eastern European countries, institutional barriers and the lack of adequate infrastructure hinder the rapid implementation of innovations.

In the context of environmental responsibility, environmental education and public awareness are gaining increasing importance. Contemporary research confirms that citizens' knowledge about climate change and its consequences directly influences their support for pro-environmental policies and their willingness to change daily consumption and energy-use habits (Moser, 2009). Environmental education—conducted both within the formal education system and through media, non-governmental organizations, and public campaigns—is instrumental in forming pro-environmental attitudes.

An increasing number of EU citizens are demanding concrete action on environmental protection. According to Eurobarometer (2023), as many as 77% of EU citizens believe that combating climate change should be a priority for all national governments. Public support for climate policies is growing particularly strongly among younger generations, who perceive the environmental crisis as a fundamental threat. At the same time, there are significant differences in the approach to environmental issues among Member States, resulting from different socio-economic conditions, institutional traditions, and models of political culture. In countries with high levels of civic participation, public pressure is more often reflected in the adoption of ambitious pro-environmental regulations, while in countries where economic priorities dominate, or there is greater scepticism towards EU policies, the process is much slower.

These differences affect both the pace of implementation of sustainable development strategies and the way in which environmental responsibility is defined and distributed among public institutions, the private sector, and citizens.

Numerous studies clearly indicate territorial disparities in pro-environmental actions undertaken within the European Union. This situation calls for a climate policy that is both ambitious and flexible, adapted to local social, economic, and environmental conditions. Only under such circumstances will a truly fair and effective ecological transformation of the entire European community be possible.

6. Implications and further research

The modern economy faces the challenge of reconciling economic growth with the preservation of the natural environment. In the era of accelerating climate change and increasing social and regulatory pressure, countries are compelled to take effective actions aimed at reducing greenhouse gas emissions, implementing low-emission technologies, and promoting renewable energy. The energy transition and sustainable environmental policy have become not only pressing challenges but also opportunities for modern, resilient, and sustainable development.

In this regard, it is especially crucial to assess the degree to which individual countries are meeting sustainable development objectives and the outcomes they are achieving in the field of climate protection. Based on the statistical analysis conducted using the Hellwig method, the intensity and effectiveness of actions undertaken by EU member states were assessed, and both leaders and countries requiring intensified efforts were identified. The results clearly indicate differences in how EU countries approach environmental protection. Only five countries—Austria, Slovenia, Croatia, Finland, and Latvia—can be considered highly environmentally responsible. In contrast, seven EU member states are implementing pro-environmental measures at a very low level.

The statistical data analysis confirms the research hypothesis H: there is significant spatial differentiation among European Union countries in terms of the level of pro-environmental activities undertaken. Results demonstrate that disparities in environmental responsibility persist, signalling the necessity of reforming EU funding priorities. Tailored regional policies could mitigate uneven progress and ensure fairer climate adaptation across member states.

Based on the analysis, it can be clearly stated that there is a need to continue and intensify pro-environmental activities in European Union countries, with particular emphasis on countries with low and very low levels of environmental responsibility. These countries are clearly lagging in achieving climate targets, reducing greenhouse gas emissions, and implementing renewable energy sources. In their case, thorough systemic reforms are necessary, both at the legislative and institutional levels, as well as increased financial expenditure on environmental investments. It is in this context that the interaction between governance reforms and technological innovation, which together determine the ability of Member States to maintain long-term environmental responsibility, becomes crucial. Governance reforms set the regulatory, organisational, and financial framework necessary to pursue ambitious climate policies, while technological innovations provide the tools to implement them effectively. These two elements, working

in tandem, enhance the effectiveness of the measures taken and allow for more consistent implementation of environmental objectives, particularly in countries with lower levels of ecological transition.

At the same time, countries with high levels of environmental responsibility, despite achieving relatively good results, cannot afford to rest on their laurels. It is essential to further intensify efforts focused on continuously improving climate policies, increasing energy efficiency, and implementing innovative technological solutions. Only such an approach will maintain the pace of the energy transition and allow these countries to continue playing a leadership role in sustainable development at the European level.

The conducted assessment of EU member states based on their level of environmental responsibility also confirms that many of them continue to struggle with balancing the three key dimensions: reducing greenhouse gas emissions, developing renewable energy sources, and increasing environmental investments. These disparities highlight the need for better integration of actions in these areas, ensuring that the ecological transformation is not only effective but also lasting.

As part of their further research, the authors intend to conduct a comparative analysis in selected countries of the impact of legislation, financial incentive systems, and the level of civil society involvement on environmental protection outcomes. This approach will make it possible to identify both differences between countries and changes in environmental policies in the long term.

In addition, the authors plan to extend their research beyond Europe to identify global policy patterns, different models of environmental governance, and examples of effective practices. The conclusions from such analyses could be used to identify strategies that promote ecological balance and support sustainable economic transformation.

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