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ASSESSING PROGRESS TOWARD ENVIRONMENTAL SUSTAINABILITY IN THE EUROPEAN UNION USING EUROSTAT SDG INDICATORS

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Abstract: *This research covers 27 European Union (EU) member states and focuses on Sustainable Development Goals (SDGs) 6, 7, 11, 12, 13, 14, and 15 from 2021 to 2023, using SDGs indicators sourced from Eurostat. The research aims to: a) determine if environmental sustainability has improved at the EU level; b) identify which individual SDGs indicators had the most significant impact on environmental sustainability; c) analyse overall trends in EU sustainability progress; and d) compare country-level differences. Using composite index methodology, repeated measures ANOVA with Bonferroni correction, and chain indices, the study finds: a) the composite index reliably assesses progress both for the EU and its member states; b) clean water and sanitation and life on land made the largest contributions to overall sustainability; c) environmental sustainability remained stable across the EU; and d) only minor variations were found among countries.*

Keywords: *environmental sustainability, EU, SDGs, composite indices.*

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1. Introduction

The 2030 Agenda for Sustainable Development, adopted in 2015, commits UN member states to the Sustainable Development Goals (SDGs) - 17 goals and 169 targets aimed at improving living standards by 2030 across economic, social, and environmental dimensions. General indicators allow cross-country comparisons. However, reports use differing methods and indicators, leading to divergent conclusions and affecting policy decisions (Lafortune et al., 2020). Excess information without a clear framework leads to confusion, making SDGs assessment outcomes ambiguous and difficult to use in practice (Janoušková et al., 2018).

The adoption of the 2030 Agenda has highlighted the need to effectively monitor environmental sustainability in line with the SDGs. To address this, composite indices are increasingly used to assess sustainability across different domains, analyse trends in SDGs achievement, and enable comparison of environmental performance. These indices allow for measurement across individual countries (Wackernagel et al., 2019; Wendling et al., 2020), country groups (Cook et al., 2017; Halkos & Zisiadou, 2018), regions within a country (Mukherjee & Kathuria, 2006), and specific ecosystems (Blumetto et al., 2019). Composite indices are most often used in global studies to facilitate cross-country comparisons, given that public policies are largely designed and implemented at the national level (Roberts, 2011; Usubiaga-Liaño & Ekins, 2021).

Many studies have evaluated overall progress on the SDGs (Kostetskaia & Hametner, 2022; Ricciolini et al., 2022), but discussions specifically focusing on environmental advances in SDGs implementation are sporadic (Moses & Tauringana, 2022). Integrating the environmental dimension into SDGs has thus emerged as a crucial issue among scholars (Elder & Olsen, 2019). The literature reviewed highlights a reciprocal link between environmental reporting and companies' environmental performance: high-quality environmental reporting can enhance both performance and market value (Clarkson et al., 2008; Plumlee et al., 2015; Qiu et al., 2016), while companies with stronger environmental performance are also more transparent in their reporting (Al-Tuwaijri et al., 2004). Nevertheless, many countries still face significant challenges in achieving sustainability, particularly in preserving environmental quality (Howes et al., 2017; Sinha et al., 2020; Sach et al., 2021; Aleksić et al., 2024).

Following the research aims, this paper presents a theoretical framework and reviews prior research on environmental sustainability progress, describes the methodology, discusses the results, and highlights areas for future research.

2. Literature Review

To monitor sustainable development progress globally, continentally, and nationally, practitioners increasingly use composite indices (Czupich, 2022). These enable country rankings across sustainability domains and support empirical research. For example, the SDGs Index ranks UN member states by progress toward the 17 SDGs in the 2030 Agenda. The Green Growth Index is broader, also including the Aichi

Biodiversity Targets and countries' progress on the Paris Climate Agreement (Sach et al., 2021). The Global Green Economy Index ranks countries using 20 quantitative and qualitative indicators across four dimensions: leadership and climate change, energy and resource efficiency, markets and investments, and the environment (Tamanini, 2021). Some national rankings focus solely on environmental factors, such as the Environmental Performance Index (EPI), which assesses about 180 countries on environmental health and ecosystem vitality. This index is based on the earlier Environmental Sustainability Index (ESI), developed by Yale and Columbia Universities with support from the World Economic Forum (WEF) and the European Commission Joint Research Centre.

Previous research on environmental progress highlights the value of composite index methods. Kozma (2024) examined EU member states using SDGs indicators from 2014 to 2018. His study found that sustainable development indicators can be greatly reduced without losing essential information by applying factor and correlation analysis. The resulting factors strongly align with major macroeconomic indicators, especially Gross Domestic Product (GDP) and Human Development Index (HDI), confirming their value. Kozma's findings indicate sustainable development can be tracked with a single composite indicator, the Composite Sustainable Development Goal Indicator (CSDGI), setting a new basis for measuring sustainability and simplifying cross-country comparisons.

The study by Czupich et al. (2022) shows that a composite index based on multiple environmental variables can assess sustainability. Their study assessed environmental sustainability in the capital cities of EU member states. The constructed index includes both quantitative and qualitative indicators of environmental quality. The results show that Europe is spatially differentiated in environmental quality. The authors emphasise that composite indices are effective for monitoring sustainable development. These indices can help identify key challenges in improving environmental quality.

A recent study by Adamo et al. (2025) measured EU sustainability using composite indices for economic, environmental, and social dimensions. The study analysed 76 Eurostat SDG indicators for 2022. Two approaches were used to assign weights to indicators: equal weighting and indicator-correlation-based weighting. The results show Sweden ranks first, followed by Denmark and the Netherlands, for both approaches. Ireland and Belgium also perform well. In contrast, Greece, Cyprus, and Bulgaria appear consistently at the bottom. Adamo et al. (2025) also note that Germany excels in environmental performance. Meanwhile, Sweden and Denmark lead in the social dimension in both composite index methods.

Mikča & Huttmanova (2025) propose the construction of a composite sustainability index for EU member states that integrates the economic, environmental, and social dimensions of sustainable development. The index is constructed based on standardised indicators available in the Eurostat database, grouped into three dimensions (economic, environmental, and social). Sub-indices are first developed for each dimension and then aggregated into a single composite index, enabling cross-country comparability. The application of principal component analysis (PCA) and cluster analysis identified leading and lagging countries in terms of sustainability, thereby confirming the multidimensional nature of sustainable development and the

importance of an integrated approach to performance measurement. The results contribute to a better understanding of differences in sustainability levels across countries and provide a basis for designing environmental policies aimed at balanced progress in key areas.

Carrillo (2022) proposed a new methodological approach to composite indices based on indicator weighting and the geometric mean in the aggregation phase. The application of this methodology across 27 EU member states over the 2010–2020 period indicates improvements in sustainability, accompanied by convergence in sustainability performance over time.

The analysis of the aforementioned studies indicates the reliability of using composite indices for assessing sustainable development. Furthermore, recent methodological approaches to composite indices, including normalisation, multi-criteria ranking methods, and principal component analysis, contribute to improving the monitoring and understanding of the dynamics of progress in achieving the SDGs.

Sustainability assessment is an important instrument for designing environmental policies, plans, and projects, in which composite indices enable the planning, monitoring, and evaluation of the economic, environmental, and social dimensions of development in a balanced manner (Cetrulo et al., 2025). In this context, composite indices based on economic indicators can serve as a foundation for decision-making in the formulation of economic policy measures. Furthermore, their relationship with SDGs performance is becoming increasingly significant, as progress in environmental sustainability can promote sustainable economic growth through more efficient resource use and institutional management (Qureshi et al., 2025).

Findings in the literature indicate slow progress in achieving the SDGs and the possibility that the global community will not fully attain the goals set for 2030 (Sorooshian, 2024; Biermann et al., 2022; Chopra et al., 2022), as well as the growing importance of developing existing and new methodological approaches for monitoring and assessing progress in the field of sustainable development. Modern approaches to measuring sustainability complement traditional economic indicators. Specifically, these contemporary approaches are grounded in a broader framework that links economic performance to the 2030 Agenda's goals. Although extensive literature exists on sustainability measurement using composite indices and SDGs indicator analysis, this paper focuses on selected research that directly addresses the topic, with an emphasis on key methodological and empirical contributions.

3. Sample description and research methodology

This paper analyses progress in achieving environmental sustainability at the level of the EU and individual EU member states based on relevant environmental SDGs indicators from the Eurostat database, using a composite index methodology in order to address the following *research questions:*

1. Has progress in environmental sustainability been achieved at the EU level over the period 2021–2023, according to selected environmental SDGs indicators from the Eurostat database?

2. What is the contribution of selected environmental SDGs indicators achieving environmental sustainability in the EU during the observed period?
3. What is the trend in progress toward achieving environmental sustainability in the EU based on selected environmental SDGs indicators from the Eurostat database over the observed period?
4. Are there significant differences in environmental sustainability performance across EU member states based on selected environmental SDGs indicators from the Eurostat database over the observed period?

The aims of this paper are as follows:

- determine whether progress in environmental sustainability has been achieved at the EU level over the period 2021–2023;
- assess the extent to which progress in individual environmental SDGs has influenced environmental sustainability in the EU over the observed period;
- identify the trend in progress and the significance of differences in environmental sustainability at the EU level over the observed period;
- identify the trend in progress and the significance of differences in environmental sustainability across individual EU member states over the observed period.

In line with the research aim, the *following hypotheses* are formulated:

H1: Progress in environmental sustainability at the EU level can be assessed through the construction of an aggregate composite index of environmental sustainability based on SDGs indicators from the Eurostat database over the period 2021–2023.

H2: There are differences in the contribution of individual relevant SDGs to environmental sustainability at the EU level, which can be identified through the application of composite indices (both individual and aggregate) over the period 2021–2023.

H3: There is significant progress in environmental sustainability at the EU level, as measured by an aggregate composite index of environmental sustainability over the period 2021–2023.

H4: There are differences in environmental sustainability across individual EU member states, which can be identified based on their aggregate environmental sustainability indices over the observed period, using the rate of change of these indices.

To test the formulated hypotheses, *three methods* were applied:

a) *The composite index methodology* was applied to test the first and second hypotheses, enabling the construction of both individual and aggregate environmental sustainability indices, as well as the assessment of the

contribution of individual composite indices to the overall aggregate index for each EU member state over the 2021–2023 period.

b) *A repeated-measures ANOVA (with Bonferroni correction for multiple comparisons)* was applied to test the third hypothesis, examining whether there are changes in the values of the individual and aggregate composite indices for EU countries across the observed years.

c) *Chain indices* were used to test the fourth hypothesis by determining the rate of change in the aggregate environmental sustainability index across individual EU member states, which enabled the assessment of dynamics, trends, and differences in environmental progress over the observed period.

This paper used secondary data obtained from the Eurostat database for the 2021–2023 period (Eurostat, 2025), covering 27 EU member states. The selection of indicators for the analysis is based on the UN's grouping of the SDGs into the "five P" – People, Planet, Prosperity, Peace, and Partnerships. The selected area is "Planet," which includes the following SDGs related to the environment and climate: SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate action), SDG 14 (life below water), and SDG 15 (life on land). The selected SDG indicators are presented in Table 1.

Table 1. SDGs indicators from the Eurostat database were used in the construction of composite indices in this paper

SDGs	SDGs indicators	Measurement Unit	Symbols	Sign of impact
SDG 6	1. Population connected to at least secondary wastewater treatment	in %	I_1	+
	2. Biochemical oxygen demand in rivers	milligrams per litre	I_2	-
	3. Nitrate in groundwater	milligrams per litre	I_3	-
	4. Phosphate in rivers	milligrams per litre	I_4	-
	5. Water exploitation index, plus	in %	I_5	-
	6. Bathing waters with excellent quality by location	number	I_6	-
	7. Drought impact on ecosystems	square kilometre	I_7	-
SDG 7	8. Primary energy consumption	million tonnes of oil equivalent	I_8	-
	9. Final energy consumption	million tonnes of oil equivalent	I_9	-
	10. Final energy consumption in households per capita	kilogram of oil equivalent	I_{10}	-
	11. Energy productivity	euro per kilogram of oil equivalent	I_{11}	+

	12. Share of renewable energy in gross final energy consumption by secto	in %	I_{12}	+
	13. Energy import dependency by products	in %	I_{13}	-
	14. Population unable to keep home adequately warm by poverty status	in %	I_{14}	-
SDG 11	15. Road traffic deaths, by type of roads	number	I_{15}	-
	16. Premature deaths due to exposure to fine particulate matter (PM2.5)	number	I_{16}	-
	17. Recycling rate of municipal waste	in %	I_{17}	+
	18. Population connected to at least secondary wastewater treatmen	in %	I_{18}	+
	19. Share of buses and trains in inland passenger transport	in %	I_{19}	+
SDG 12	20. Raw material consumption (RMC)	thousand tonnes	I_{20}	-
	21. Consumption footprint - single weighted score	single weighted score	I_{21}	-
	22. Circular material use rate	in %	I_{22}	+
	23. Energy productivity	euro per kilogram of oil equivalent	I_{23}	+
	24. Average CO2 emissions per km from new passenger cars	grams per kilometre	I_{24}	-
SDG 13	25. Domestic net greenhouse gas emissions	tonnes per capita	I_{25}	-
	26. Net greenhouse gas emissions of the Land use, Land use change and Forestry (LULUCF) sector	thousand tonnes	I_{26}	-
	27. Average CO2 emissions per km from new passenger cars	grams per kilometre	I_{27}	-
	28. Climate related economic losses	million euro at constant prices	I_{28}	-
	29. Contribution to the international 100bn USD commitment on climate related expending	million euro	I_{29}	+
	30. Green bond issuance by corporates and governments	in %	I_{30}	+
	31. Share of renewable energy in gross final energy consumption by sector	in %	I_{31}	+

SDG 14	32. Surface of the marine protected areas	in %	I_{32}	+
	33. Bathing waters with excellent quality by location	coastal water - number	I_{33}	+
	34. Marine waters affected by eutrophication	square kilometre	I_{34}	+
SDG 15	35. Forest area	in %	I_{35}	+
	36. Surface of the terrestrial protected areas	in %	I_{36}	+
	37. Drought impact on ecosystems	square kilometre	I_{37}	-
	38. Biochemical oxygen demand in rivers	milligrams per litre	I_{38}	-
	39. Phosphate in rivers	milligrams per litre	I_{39}	-

Source: Authors' based on the Eurostat database

The selection of SDG indicators presented in Table 1 is based on data from the Eurostat database, with each indicator having a defined direction of impact on sustainable development (positive or negative) and serving as a basis for constructing composite indices. The concept of composite indices is interdisciplinary, and it can be applied across various research disciplines (Saisana & Tarantola, 2002). The application of composite index methodology is an important tool in economic research. The term "composite index" describes indicators formed by aggregating multiple indicators, i.e., combining various units of measurement into a single composite measure. The trend of constructing composite indices across various fields leads to significant changes in data approaches. This process not only improves existing data collection methods but also identifies new data sources, which are crucial for thorough and reliable analysis (Nardo et al., 2008, p. 23). The key steps in the process of constructing composite indices are (Jovičić, 2006, p. 174; Mazziotta & Pareto, 2013, p. 71; Saltelli, 2007, p. 69; Nardo et al., 2008, p. 7; COIN, 2017): defining the theoretical framework, data selection and multivariate data analysis, data normalization, aggregation and weighting, uncertainty and sensitivity analysis, and interpretation of the obtained results. The aforementioned steps each have their importance, however, their interdependence within the overall process should be emphasised. There is no universal methodology within these steps, as each has its own advantages and limitations. It is important to select an appropriate approach based on the available data and the defined research objectives (Nardo et al., 2008).

The creation of a composite environmental index aims to condense complex information by combining multiple indicators into a single result (Stevens et al., 2023). Composite indices are a useful tool for tracking changes over time, enabling simpler communication of results to stakeholders and promoting accountability among countries regarding environmental protection (Dobbie & Dail, 2012; Nardo et al., 2005). In addition, composite indices can inform and shape public policies and draw the attention of environmental policymakers and media actors to environmental issues (Haberland, 2008).

In this paper, an aggregated composite environmental sustainability index was designed to represent a single dimension of sustainable development, as sustainable development is not a goal to be achieved but a continuous process that must be maintained (Hjorth & Bagheri, 2006). Its construction aims to assess country performance for comparison and ranking based on indicator values, thereby providing a basis for the formulation of public policies (Stevens, 2005; OECD, 2008). The applied index construction procedure represents a systematic methodological approach; however, a limitation of existing methods lies in the weighting of variables, which is often equal or determined arbitrarily (Agliardi et al., 2015). In this paper, a three-step IMF methodology (Svirydzenka, 2016) was applied, in accordance with OECD guidelines (2008): 1) Winsorizing and rescaling; 2) Weighting and aggregation of rescaled variables into sub-indices; and 3) Aggregation of sub-indices into a composite index.

Considering the large number of indicators (39) and their corresponding units of measurement, applying factor analysis to the selected indicators to determine their relative importance in the composite index's structure requires data normalisation, which was performed using the min–max transformation. Data normalisation was performed in line with the World Economic Forum methodology, which rescales the values of observed indicators to a 1-7 scale. The min–max method transforms indicators to a common scale (typically 1-7). The normalisation process involves subtracting the minimum value from each observed indicator value, then dividing the result by the difference between the indicator's maximum and minimum values (WEF, 2016, p. 41). Specifically, when the values of the selected indicators increase, the environmental sustainability of countries also increases, and the following transformation formula is applied to the indicator values (WEF, 2016, p. 41):

$$TI_{ji} = 6\ x\ \frac{I_{ji} - I_j^{min}}{I_j^{max} - I_j^{min}} + 1 \qquad (1)$$

TI_{ji} – transformed value of the jth indicator for the ith country

I_{ji} –value of indicator j^{th} for i^{th}country

I_j^{min} - sample minimum value of the jth indicator across all countries

I_j^{max} – sample maximum value of the jth indicator across all countries

When an increase in the value of an indicator leads to a decrease in environmental sustainability, the following transformation formula is applied (WEF, 2016, p. 41):

$$TI_{ji} = -\ 6\ x\ \frac{I_{ji} - I_j^{min}}{I_j^{max} - I_j^{min}} + 7$$

4. Results and discussion

After data normalisation, performed using the previously specified formulas (1 and 2), the factor analysis procedure is conducted, and the suitability of the data for its application is assessed using the KMO statistic and Bartlett's test. After the initial assessment, indicators that did not meet the adequacy criterion (KMO < 0.5) were identified, leading to an iterative procedure to eliminate them.

In the second iteration of the analysis, the final structure of the factor model was obtained by excluding indicators identified as inadequate from the correlation and anti-image matrices. In this process, the following indicators were excluded I_1 (SDG6), $I_{8,}$ I_9 and I_{11} (SDG 7), I_{19} (SDG 11), I_{20} and I_{22} (SDG 12), I_{28} (SDG 13), I_{34} (SDG 14), as well as I_{35} and I_{36} (SDG 15).

Following the aforementioned adjustments, all remaining indicators achieved satisfactory KMO values (above 0.5), confirming their suitability for further factor analysis. The final results presented in the study are based exclusively on this second iteration, which ensures a statistically valid and methodologically sound factor structure (Table 2).

Table 2. KMO Statistics and Bartlett's Test Results in the Final (Second) Iteration

		SDG 6	SDG 7	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15
Kaiser-Meyer-Olkin-Measure of Sampling Adequacy		0.757	0.579	0.519	0.658	0.603	0.500	0.512
Bartlett's Test of Sphericity	*Chi-Square*	121.679	109.710	118.784	72.647	74.289	1.448	27.663
	df	15	6	6	3	15	1	3
	Sig.	0.000	0.000	0.000	0.001	0.001	0.229	0.001

Source: Authors' calculation - SPSS

Weighting and aggregation are key stages in constructing a composite index. This is primarily because the composite index's values largely depend on the methods used to calculate weights and the selected aggregation method. By applying the weight-calculation criteria, the values presented in Table 3 were obtained.

Table 3. Weights of the Components of the Aggregate Composite Index of Environmental Sustainability at the EU Level

SDG	Indicator	Ponder Value
SDG 6	I_2	0.166
	I_3	0.188
	I_4	0.217
	I_5	0.099

	I_6	0.164
	I_7	0.167
SDG 7	I_{10}	0.286
	I_{12}	0.236
	I_{13}	0.251
	I_{14}	0.227
SDG 11	I_{15}	0.401
	I_{16}	0.396
	I_{17}	0.153
	I_{18}	0.050
SDG 12	I_{21}	0.356
	I_{23}	0.336
	I_{24}	0.308
SDG 13	I_{25}	0.104
	I_{26}	0.064
	I_{27}	0.271
	I_{29}	0.085
	I_{30}	0.264
	I_{31}	0.213
SDG 14	I_{32}	0.500
	I_{33}	0.500
SDG 15	I_{37}	0.213
	I_{38}	0.379
	I_{39}	0.408

Source: Authors' calculation

By assigning weights to the normalised indicator values, weighted indicator values are obtained. These indicator values by country are presented in the following table:

Table 4. Values of Individual SDG Composite Indices by EU member states

Country	Year	KiCOR 6	KiCOR 7	KiCOR11	KiCOR12	KiCOR13	KiCOR14	KiCOR15
Austria	2021	5.033	4.075	6.453	3.449	3.160	0.845	6.452
	2022	5.064	3.825	6.442	3.555	3.767	0.845	6.476
	2023	5.073	4.140	6.455	3.730	4.722	0.845	6.512
Belgium	2021	4.016	3.424	6.122	2.946	3.176	3.489	5.086
	2022	4.098	3.523	6.109	3.199	4.218	3.489	5.022
	2023	4.060	3.476	6.210	3.804	3.753	3.510	5.153
Bulgaria	2021	4.116	3.568	5.328	3.121	2.152	1.456	5.040
	2022	4.124	3.694	5.397	3.186	2.210	1.456	4.962
	2023	4.077	3.900	5.134	3.278	2.492	1.463	4.946
Croatia	2021	5.590	4.172	5.762	3.150	2.753	2.781	6.351
	2022	5.645	3.994	5.732	3.094	2.674	2.789	6.188
	2023	5.527	4.146	5.798	3.125	3.254	2.810	6.214

Cyprus	2021	4.578	2.979	6.004	2.461	1.930	1.515	6.557
	2022	4.580	2.964	6.019	2.447	2.112	1.515	6.562
	2023	4.544	3.164	5.771	2.643	2.331	1.524	6.557
Czechia	2021	4.429	4.021	5.740	2.659	1.878	0.845	4.993
	2022	4.452	4.118	5.787	2.611	1.948	0.845	5.039
	2023	4.477	4.094	5.937	2.837	2.085	0.845	5.104
Denmark	2021	5.193	4.676	6.501	3.852	4.506	2.703	7.536
	2022	5.193	4.552	6.507	3.877	5.194	2.716	7.531
	2023	5.210	4.533	6.465	4.343	5.627	3.071	7.523
Estonia	2021	5.502	5.186	6.267	2.382	2.344	2.159	6.328
	2022	5.503	5.078	6.321	2.327	2.367	2.159	6.333
	2023	5.524	5.202	6.389	2.628	2.610	2.214	6.324
Finland	2021	5.582	4.109	6.284	3.069	3.963	1.655	6.306
	2022	5.578	4.323	6.383	3.318	4.703	1.669	6.311
	2023	5.589	4.557	6.410	3.844	5.815	1.690	6.297
France	2021	5.219	3.993	3.394	3.583	3.299	5.268	7.513
	2022	6.166	3.773	3.100	3.700	3.139	5.269	6.240
	2023	5.274	3.902	3.441	3.829	3.142	5.277	7.387
Germany	2021	4.763	3.747	3.611	3.230	2.951	4.215	6.097
	2022	5.089	3.502	3.402	3.417	3.456	4.208	5.698
	2023	4.798	3.577	3.534	3.259	2.671	4.215	6.119
Greece	2021	6.013	3.361	5.189	3.673	3.233	3.258	7.750
	2022	5.964	3.200	5.184	3.518	2.895	3.258	7.765
	2023	5.968	3.400	4.891	3.673	2.817	3.309	7.755
Hungary	2021	6.420	3.690	5.501	3.343	2.608	0.845	7.745
	2022	6.630	3.719	5.558	3.328	3.776	0.845	7.469
	2023	6.397	3.742	5.692	3.479	3.144	0.845	7.776
Ireland	2021	5.412	3.582	5.666	4.116	2.469	1.090	6.634
	2022	5.426	3.507	5.649	4.363	3.095	1.076	6.594
	2023	5.394	3.624	5.642	4.391	4.001	1.090	6.616
Italy	2021	3.386	3.549	2.225	3.147	3.062	4.524	4.941
	2022	3.624	3.535	1.689	3.079	3.208	4.527	4.629
	2023	3.419	3.663	2.108	3.256	3.195	4.547	4.971
Latvia	2021	5.704	4.735	6.334	2.705	3.121	1.959	6.320
	2022	5.682	4.735	6.494	2.799	3.767	1.960	6.295
	2023	5.717	4.876	5.699	2.773	3.000	1.967	6.200
Lithuania	2021	5.112	2.878	6.306	2.601	2.516	2.434	5.437
	2022	5.076	3.292	6.420	2.560	2.576	2.434	5.366
	2023	5.124	3.301	6.440	2.837	2.749	2.448	5.165
Luxembourg	2021	6.393	3.041	6.414	2.421	2.279	0.845	7.777

	2022	6.395	3.251	6.410	2.644	2.582	0.845	7.765
	2023	6.392	3.327	6.432	2.967	2.552	0.845	7.777
Malta	2021	6.161	3.732	5.796	2.818	2.737	1.280	7.777
	2022	6.099	3.733	5.766	3.012	3.067	1.280	7.777
	2023	6.151	3.864	5.850	3.106	3.179	1.280	7.777
Netherlands	2021	5.912	3.950	6.156	3.444	3.613	2.709	7.482
	2022	5.924	3.715	6.069	3.392	4.014	2.758	7.456
	2023	5.911	3.885	6.178	3.755	4.619	3.090	7.486
Poland	2021	4.980	4.199	2.616	2.841	2.551	2.472	5.495
	2022	5.138	4.117	3.462	2.906	2.663	2.477	5.343
	2023	5.128	4.127	3.673	2.992	2.765	2.485	5.435
Portugal	2021	4.366	4.072	5.533	3.588	4.567	1.468	4.791
	2022	4.522	3.970	5.418	3.444	4.098	1.472	4.544
	2023	4.364	3.846	5.473	3.702	4.873	1.472	4.761
Romania	2021	4.219	4.406	4.780	3.812	2.954	2.358	4.436
	2022	4.477	4.180	3.900	3.943	2.917	2.358	4.136
	2023	4.069	4.490	4.148	4.027	3.262	2.365	4.464
Slovakia	2021	4.811	4.006	6.137	3.383	2.806	0.845	5.508
	2022	4.907	3.765	6.209	3.368	3.766	0.845	5.418
	2023	4.820	3.959	6.265	3.442	2.805	0.845	5.539
Slovenia	2021	5.530	4.501	6.603	3.166	2.454	1.204	7.036
	2022	5.576	4.470	6.649	3.186	2.552	1.204	6.952
	2023	5.514	4.496	6.630	3.293	3.826	1.232	7.025
Spain	2021	2.402	3.789	4.755	3.082	3.329	2.934	2.692
	2022	2.489	3.597	4.381	2.972	3.308	2.936	2.306
	2023	2.517	3.565	4.263	3.164	3.291	3.356	1.813
Sweden	2021	5.531	5.488	6.318	3.885	5.834	2.112	7.717
	2022	6.260	5.564	6.315	4.233	6.553	2.115	7.714
	2023	6.282	5.425	6.010	4.360	6.611	2.137	7.692

Source: Authors' calculation

After applying the weighting procedure, the individual KiEO values were aggregated to calculate the AKiEO for each EU member state over the period 2021–2023. Specifically, the KMO values for these indices were below 0.5, indicating insufficient shared variance and inadequate data for inclusion in a common factor structure. Such indicators do not contribute to a reliable explanation of the environmental sustainability dimension, and their retention could lead to result distortion. By excluding indicators with low KMO values, it was ensured that the AKiEO reflects actual changes in environmental performance. The AKiEO defined in this way has the following structure:

AKiEO = 0.327*KiSDG 6 + 0.127*KiSDG 7 + 0.228*KiSDG11 + 0.319*KiSDG 15

Table 5. Dynamics of the AKiEO in EU member states (2021–2023)

Country	AKiEO			Chain indices AKiEO (%)	
	2021.	*2022.*	*2023.*	*2022/2021.*	*2023/2022.*
Austria	5.687	5.670	5.728	99.71	101.01
Belgium	4.761	4.777	4.823	100.33	100.97
Bulgaria	4.617	4.626	4.572	100.21	98.83
Croatia	5.692	5.628	5.632	98.88	100.08
Cyprus	5.330	5.334	5.290	100.07	99.17
Czechia	4.855	4.901	4.961	100.93	101.22
Denmark	6.172	6.156	6.147	99.74	99.85
Estonia	5.899	5.900	5.935	100.00	100.60
Finland	5.785	5.835	5.870	100.87	100.60
France	5.379	5.188	5.356	96.45	103.24
Germany	4.797	4.698	4.776	97.93	101.68
Greece	6.042	6.009	5.966	99.46	99.28
Hungary	6.287	6.284	6.339	99.95	100.88
Ireland	5.627	5.605	5.615	99.62	100.18
Italy	3.638	3.493	3.646	96.00	104.41
Latvia	5.921	5.942	5.760	100.36	96.94
Lithuania	5.204	5.248	5.205	100.84	99.19
Luxembourg	6.413	6.436	6.453	100.35	100.27
Malta	6.284	6.257	6.310	99.57	100.85
Netherlands	6.219	6.165	6.217	99.13	100.84
Poland	4.507	4.692	4.767	104.11	101.60
Portugal	4.730	4.663	4.677	98.58	100.31
Romania	4.440	4.199	4.266	94.59	101.59
Slovakia	5.233	5.221	5.269	99.78	100.91
Slovenia	6.124	6.118	6.121	99.91	100.04
Spain	3.206	3.002	2.823	93.63	94.03
Sweden	6.401	6.648	6.561	103.85	98.70

Source: Authors' calculation

Based on the obtained values of the aggregate composite environmental sustainability index and the rate of change in environmental sustainability determined using chain indices, heterogeneity in the dynamics of the AKiEO across EU member states can be observed over the 2021–2023 period. In 2022, compared to the previous year, the highest positive growth in the AKiEO was recorded in Poland (+4.11%) and Sweden (+3.85%), indicating progress in environmental sustainability. The largest declines were recorded in Spain (-6.37%), Romania (-5.41%), Italy (-4.00%), and France (-3.55%). The obtained results indicate that 2022

represented a period of deterioration in environmental performance for the selected countries, which may be associated with energy and economic shocks in the EU.

In 2023, compared to the previous year, a partial improvement was observed in a larger number of countries. Italy (+4.41%), France (+3.24%), and Germany (+1.68%) stand out in particular, suggesting an improvement in environmental performance following the negative trends observed in the previous year. Spain continues its negative trend in 2023. Countries with traditionally high levels of environmental sustainability, such as Luxembourg, Sweden, Denmark, and Slovenia, record stable index values with minor fluctuations, indicating a high level of environmental maturity and limited scope for significant changes. Overall, the results on the rate of change confirm changes in environmental sustainability performance in the EU over the 2021–2023 period, thereby supporting the third hypothesis (H3) regarding significant, but not uniform, progress across member states.

Prior to conducting the repeated-measures analysis of variance (ANOVA), descriptive statistics for the AKiEO by year were computed (Table 6). The results indicate slight fluctuations in the mean values of the AKiEO index over the 2021–2023 period, with an almost identical level of dispersion across all three observed years.

Table 6. Descriptive Statistics of the Index across Years

Year	N	Mean	Std. Deviation
2021.	27	5.3796	0.84389
2022.	27	5.3591	0.84389
2023.	27	5.3735	0.84389

Source: Authors' calculation - SPSS

To examine whether the mean value of the AKiEO changes significantly over time across EU countries, a repeated-measures analysis of variance (ANOVA) was applied, along with a Bonferroni correction for multiple comparisons. The results of pairwise comparisons between years indicate that there are no statistically significant differences in the mean index values between 2021 and 2022 ($p = 0.921$), between 2021 and 2023 ($p = 1.000$), or between 2022 and 2023 ($p = 1.000$).

The results indicate that, although there are individual fluctuations at the country level (as also confirmed by the rate of change in the AKiEO in Table 5), there is no statistically significant change in the average AKiEO at the aggregate EU level over the 2021–2023 period.

Based on the above, it can be concluded that the research results *confirm the first hypothesis*, as progress in environmental sustainability in the EU can be monitored using an aggregated composite index based on SDG indicators from the Eurostat database. Furthermore, *the second hypothesis is also confirmed*, as there are differences in the contribution of individual components. The index structure ($AKiEO = 0.327 \cdot KiSDG6 + 0.127 \cdot KiSDG7 + 0.228 \cdot KiSDG11 + 0.319 \cdot KiSDG15$)

shows that the largest contributions come from clean water and sanitation (SDG 6) and life on land (SDG 15), while the contribution of affordable and clean energy is smaller (SDG 7). *The third hypothesis is not confirmed*, as the Bonferroni test results did not indicate statistically significant differences in the individual and aggregate indices between the observed years ($p > 0.05$), suggesting a relatively stable level of environmental sustainability over the 2021–2023 period. *The fourth hypothesis is confirmed*, as chain indices indicate differences in the movement of the aggregate composite environmental sustainability index across EU countries over the observed period. *Poland and Sweden* were leaders in environmental progress in 2022 compared to 2021. *Spain, Romania, Italy, and France* recorded declines in the AKiEO in 2022 compared to 2021. In 2023, compared to 2022, a partial improvement was observed in *Italy, France and Germany*, while *Bulgaria, Cyprus, Latvia, Lithuania, and Sweden* recorded a slight decline in the aggregate environmental sustainability index.

Table 7. ANOVA Results

(I) factor 1	(J) factor 1	Mean Difference (I-J)	Std. Error	Sig[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	*Upper Bound*
1	2	0.021	0.020	0.921	-.030	0.071
	3	0.006	0.022	1.000	-.051	0.063
2	1	-0.021	0.020	0.921	-0.071	0.030
	3	-0.014	0.015	1.000	-0.054	0.025
3	1	-0.006	0.022	1.000	-0.063	0.051
	2	0.014	0.015	1.000	-0.025	0.054

Based on estimated marginal means

*[a]. Adjustment for multiple comparisons: Bonferroni

Source: Authors' calculation - SPSS

5. Conclusion

The conducted research enabled an assessment of progress in environmental sustainability at the EU level and across its member states over the 2021–2023 period, based on SDGs indicators from the Eurostat database. The application of the composite index methodology enabled the aggregation of a large number of heterogeneous indicators into a single composite environmental sustainability index for each EU member state, which provides a valid framework for monitoring environmental performance at both the EU and the individual member state levels.

The obtained research results showed that the composite index methodology is a suitable tool for monitoring environmental sustainability at the EU level and across EU member states, as well as for identifying the relative contribution of individual areas of environmental sustainable development to overall progress in environmental protection. The largest contribution to the aggregate environmental sustainability index at the EU level came from areas related to water resource management and the

preservation of life on land, confirming their key importance for the environmental dimension of sustainable development. At the same time, the results of the Bonferroni test did not indicate statistically significant differences in the aggregate composite environmental sustainability index across the observed years, suggesting a relatively stable level of environmental sustainability in the EU over the studied period. However, the analysis of chain indices showed that there are different changes in the values of the aggregate composite environmental sustainability index across EU member states, indicating heterogeneous dynamics of progress.

As limitations of the conducted research, the relatively short time period of the analysis and the lack of up-to-date data for certain indicators can be identified, which may affect the validity of the assessment of long-term trends in environmental sustainable development at the EU level and in its individual member states. Future research could include a longer time period, incorporate additional indicators, and apply more advanced multivariate and econometric approaches, such as panel models, structural modelling, DEA efficiency analysis, or machine learning methods, to more precisely identify the factors influencing environmental sustainability. To better understand the determinants and drivers of environmental sustainability within national policies implemented by EU member states, specific macroeconomic indicators of environmental sustainability can be linked with institutional and regulatory factors.

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OCENA NAPRETKA U OSTVARIVANJU EKOLOŠKE ODRŽIVOSTI U EU ZASNOVANA NA COR INDIKATORIMA EUROSTAT BAZE PODATAKA

Apstrakt: *Istraživanjem u ovom radu je obuhvaćeno 27 zemalja EU i polazi se od njihovih indikatora ciljeva održivog razvoja (COR indikatori) iz oblasti COR 6, 7, 11, 12, 13, 14 i 15 u periodu 2021–2023. godine, preuzetih iz Eurostat baze podataka. Ciljevi istraživanja su da se: a) utvrdi da li je ostvaren napredak u ekološkoj održivosti na nivou EU; b) identifikuje u kojoj meri je napredak u ostvarivanju pojedinih relevantnih COR uticao na ekološku održivost u EU; c) utvrdi trend kretanja napretka ekološke održivosti na nivou EU i d) identifikuju razlike u ostvarivanju ekološke održivosti u zemljama EU. Postavljeni ciljevi su realizovani primenom: metodologije kompozitnih indeksa, Repeated Measures ANOVA uz Bonferoni korekciju i lančanih indeksa. Rezultati sprovedenog istraživanja u posmatranom periodu ukazuju sledeće: a) da je metodologija kompozitnih indeksa dala pouzdane informacije za ocenu ostvarenog napretka ekološke održivosti na makroekonomskom nivou EU i pojedinih njenih članica; b) da postoji različit doprinos pojedinačnih komponenti ekološke održivosti na ukupan napredak na nivou EU, pri čemu najveći doprinos imaju komponente čiste vode i sanitarnih uslova, kao i očuvanje života na kopnu; c) da postoji relativno stabilan nivo ekološke održivosti na nivou EU i d) da postoje male razlike u ostvarivanju napretka u ekološkoj održivosti između pojedinih zemalja EU.*

Ključne reči: *ekološka održivost, EU, COR indikatori, kompozitni indeksi.*