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ASSESSMENT OF EUROPEAN UNION COUNTRIES' POSITIONS IN THE CONTEXT OF CIRCULAR ECONOMY

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Abstract. *Purpose* – Assess the level of the circular economy in EU countries between 2020 and 2023, ranking them according to circular economy indicators and identifying changes in their positions.

Research methodology – The study used the European Commission's 2023 set of indicators to evaluate the performance of the circular economy across EU countries. Twenty-three indicators were selected based on data availability. Missing data were forecasted using the moving average method to ensure completeness for subsequent analysis. The CRITIC method was then applied to determine indicator weights and rank countries, followed by the TOPSIS multi-criteria decision-making approach to evaluate and compare national positions.

Findings – The results show stable circular economy levels across the EU but with clear gaps between leading and lagging countries. Germany, the Netherlands, and Italy perform strongest, while Bulgaria and Romania progress slowly due to structural constraints. Lithuania, Austria, and other mid-tier countries advance gradually, with ranking shifts revealing uneven implementation of the EU Circular Economy Action Plan. Overall, the findings compare national progress and highlight key drivers and barriers to the transition.

Research limitations – The study was constrained by incomplete and inconsistent EU statistical data, which required applying the Moving Average method to estimate missing values. In addition, the absence of a standardised composite indicator framework limited methodological comparability. Future research should prioritise improving data availability and creating unified guidelines for building composite indicators to strengthen reliability and cross-country benchmarking.

Practical implications – The results provide policymakers and industry stakeholders with a clear ranking of EU countries' progress in implementing circular economy principles, enabling targeted improvement strategies. The proposed methodology can be used to monitor national performance, allocate resources effectively, and develop standardised evaluation frameworks for sustainability initiatives.

Originality/Value – This study integrates the CRITIC and TOPSIS methods with the latest EU indicators – a combination rarely used in circular economy analysis. It offers a comprehensive multi-criteria assessment of EU countries, unlike earlier studies based on single or fragmented indicators.

Keywords: circular economy, sustainability, European Union, multi-criteria decision-making, CRITIC-TOPSIS.

JEL Classification: Q01, Q56, C38.

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1. Introduction

In today's world, the circular economy model is becoming increasingly relevant, as the traditional linear economy – based on resource extraction, production, consumption and waste disposal – is threatening the depletion of natural resources and causing environmental pollution. In recent years, the concept of the circular economy has gained popularity as a potential means of increasing public welfare while reducing dependence on natural resources and energy and minimizing waste throughout the product life cycle.

However, to effectively implement the circular economy's principles, progress must be accurately assessed and key areas for improvement identified. This requires a reliable, clear and universal assessment methodology to allow objective evaluation of the level of circular economy at national and international levels. Despite the growing importance of the circular economy, there is still a lack of standardized methods for assessing indicators in scientific literature. Existing indicators are often fragmented and not universally applicable across countries or sectors. This makes it difficult to measure progress and exchange best practices between countries. To better assess a country's level of circular economy, researchers are developing individual indicators that assess a specific area of a country's activity, comparing the results with those of other countries. However, most researchers and institutions believe that, due to the complexity of assessing the circular economy, it is necessary to evaluate composite indicators that cover different areas of a country's activities. Four main areas of composite indicators can be distinguished when analyzing them: consumption, waste management, recycling and innovation. However, despite numerous studies on this topic, researchers consistently highlight important challenges in their conclusions and recommendations. These include the lack of statistical data and the need to develop circular economy indicators at micro and macro levels that reflect economic and social aspects of a country. They also include the need for clear, flexible measures. Such measures are essential to encourage collaboration between scientists and policymakers in developing the most effective solutions to ensure a sustainable future for the world.

This article analyses why it is important to encourage countries to transition from a linear to a circular economic model. The study aims to assess the level of the circular economy in EU countries between 2020 and 2023, ranking them according to circular economy indicators and identifying changes in their positions. The latest set of indicators adopted by the European Commission is used for this assessment. The study also applies to a combination of multi-criteria decision-making methods (CRITIC and TOPSIS), which have not yet been widely used in circular economic assessments. The article analyses the most recent period (2020–2023), reflecting current changes following the implementation of the green course and the effects of the pandemic. An integrated assessment methodology covering four key areas of the circular economy has been developed. This allows us to assess which EU countries are leaders in the circular economy and which still need to pay more attention to their development. This methodology can be adapted for use in other countries or regions, which gives it both practical and scientific value. Previous studies have mostly focused on a single area, but this study's integrated approach enables an overall assessment of the circular economy in EU countries.

Existing studies assessing the circular economic performance of EU countries are limited by two main gaps. First, prior research typically employs fragmented indicator sets or examines only single CE dimensions (e.g., recycling rates or material productivity), resulting in incomplete cross-country comparisons. Second, no previous studies have combined the updated 2023 European Commission CE monitoring framework with an objective weighting technique such as CRITIC and a distance-based ranking method such as TOPSIS. This absence of an integrated, up-to-date, and methodologically consistent evaluation framework constitutes the specific research gap that this study addresses.

2. Literature review

The circular economy is the opposite of the linear economic model, which relies on the unrestricted use of natural resources and material flows (Mashovic et al., 2022). It promotes a variety of value creation mechanisms independent of the consumption of limited resources, encouraging growth from existing economic structures, products and materials (Zilia et al., 2024, Özçatalbaş, 2023). The concept of the circular economy is rooted in the need for sustainable development and recognition of the limitations of the traditional linear economy, which operates on a „make-use-dispose" model (Lahti et al., 2018; Žilinskienė & Žilinskas, 2020; Vishwakarma et al., 2024).

When analyzing the principles of the circular economy, scientists formulate definitions and conceptual foundations for this concept, such as the closed-loop system, economic model development and environmental sustainability. They define the circular economy as a sustainable economic system that aims to achieve closed-loop material and energy flows (Kirchherr et al., 2017; Gudaitė, 2022), reducing waste and resource losses (Madyaningarum et al., 2024). This approach contrasts with the linear 'use-and-throw' model (Vishwakarma et al., 2024) by emphasizing reuse, recycling, repair and regeneration (European Union, n.d.; Muchangos, 2022). This approach reconciles economic growth with environmental protection (Bassi & Dias, 2019) by optimizing the use of natural resources and promoting social and economic sustainability (Popović & Radivojević, 2022).

Scientists agree that the principles of the circular economy, which promote sustainable resource use, recycling and waste reduction, are significantly more beneficial and effective than the linear economic model, which is based on resource extraction, single-use and waste disposal (Boorová, 2020). The three Rs of the circular economy – *reduce*, *reuse* and *recycle* – are key strategies for promoting sustainability and reducing environmental impact. These three strategies interact and reinforce each other to make more efficient use of resources and reduce waste generation (Li et al., 2024; Lai & Lee, 2022; Jayawardana et al., 2023; Murti et al., 2022).

It is important to note that the principles of the circular economy have evolved from the basic „3R" model into more comprehensive systems such as „6R", which adds three more principles: *repair*, *remanufacture* and *recover* (Rimantho et al., 2023). The „9R" model has been supplemented with three more principles: *refurbish*, *repurpose* and *rethink* (Alshemari et al., 2020). The 9R principles broaden the approach to sustainability, helping to address environmental and economic challenges throughout a product's life cycle.

The circular economy offers many advantages, providing competitive benefits such as optimization of material flows, savings in raw materials, promotion of research and development, and the ability to manufacture high-quality, long-lasting products (Lopes et al., 2025; Saravanan & Chandrasekar, 2025; Das et al., 2025). Circular processes also contribute to job creation (Mashovic et al., 2022). However, the circular economy's main advantage is its ability to reduce waste generation and increase resource efficiency (Lopes et al., 2025).

However, the circular economy also has its drawbacks. One of the main issues is the complexity of closing material cycles. The fragmented nature of supply chains often makes it difficult to fully integrate circular economy practices, since products must be designed, used and disposed of in a way that facilitates recycling and reuse (Saraswati et al., 2025). This complexity is further compounded by the need for cooperation between many stakeholders (Camilleri, 2025). If this cooperation is not managed effectively, it can lead to inconsistencies and inefficiencies. Additionally, the absence of clear guidelines on how to develop and implement circular economy models can hinder progress and innovation (Kambanou et al., 2025). There are also coordination and cooperation challenges, with stakeholders often lacking a common understanding of the concept of the circular economy, which can hinder the effective implementation of its objectives (Kanda et al., 2025). Society also often lacks understanding of and knowledge about the benefits and application of the circular economy (Szalmáné Csete & Esses, 2022).

The circular economy faces threats such as distorted competition due to subsidies, as well as volatility in the markets for raw materials and energy (Bocken et al., 2016). Furthermore, the lack of integration of the circular economy, coupled with the need for cooperation between various stakeholders, poses a significant challenge that can impede the progress of companies and countries alike (Franco & Giannoccaro, 2025). This complexity can lead to inefficiency, higher costs and confusion, ultimately reducing the potential benefits of the circular economy. Additionally, although circular economic initiatives often promote sustainability, they can inadvertently exacerbate existing inequalities if not managed responsibly (Kambanou et al., 2025). Another major threat is the circular economy's dependence on changes in consumer mindset (Camilleri, 2025). Successful integration requires significant changes in consumer behaviour, as consumers must alter their purchasing and waste disposal habits. Another threat relates to regulatory and legislative barriers. If government support is weak or inconsistent, it can stifle initiatives and discourage companies from adopting circular economic principles (Phan et al., 2025).

In summary, circular economy strategies emphasize the need to integrate circular economy principles across various sectors, increase resource efficiency, reduce environmental impact, and promote economic growth through sustainable practices. Each of these principles not only contributes to waste reduction and efficient resource use but also promotes creativity and innovation in industry. Given the strengths and opportunities of this economic system, but without forgetting its weaknesses and threats, the circular economy can become an effective strategy for addressing global environmental problems and promoting sustainable development in all areas of the economy.

The effectiveness of the circular economy can be measured using composite indicators that cover its various economic, social and environmental aspects (Moraga et al., 2019). As multidimensional phenomena cannot be measured by a single indicator, individual indicators and their weighting coefficients are combined to create a single composite indicator (Vranjanac et al., 2022).

It is important to note that the construction of methodologically complex indicators that measure multiple dimensions of the circular economy simultaneously has not yet been fully defined, despite attempts having been made to create composite circular economy indicators or indices (Pauliuk, 2018). Unfortunately, there is currently no set of specific indicators that countries could use to assess their level of implementation of circular economy principles (Janik & Szafraniec, 2019). Researchers (Vranjanac et al., 2022) point out that, when assessing a country's level of circular economy development, a wide range of indicators can be included in the analysis, such as the Environmental Performance Index (EPI), the Environmental Sustainability Index (ESI), the Sustainable Policy Index (SPI) and the Embodied Energy Index (EEI), among others.

In addition, the European Academies Science Advisory Council (EASAC) has proposed a combination of composite indicators (European Academies Science Advisory Council, 2016):

- energy productivity;
- GDP per capita;
- resource recycling rate;
- country population;
- CO_2 emissions.

However, research is also being conducted to develop an indicator to help assess a country's or city's progress in the field of the circular economy (see Table 1). This indicator may focus on a specific area of activity or be integrated into a composite indicator.

In 2018, the European Commission approved a set of indicators to assess progress in developing a circular economy, as well as the effectiveness of actions at the EU and national levels (European Commission, 2018). The aim of this system is to establish a means of monitoring the level of circular economic activity in a country. Notably, in 2023, the European Commission reviewed the 2018 circular economy monitoring system and introduced new indicators to improve the assessment of a country's level of circular economy (European Commission, 2023).

Table 1. Individual indicators to help assess the level of the circular economy (source: compiled by the authors)

Author	Indicator	Objective
United Nations Environment Programme (2021)	Food Waste Index	This indicator provides insights into the extent of food waste and monitors a country's progress towards achieving the Sustainable Development Goal of more efficient food supply chain management to reduce food waste by 2030. This indicator enables countries to be compared with each other.
Othman (2022)	CE Index	Create a regional indicator that can be used to assess countries' progress in implementing the principles of the circular economy.
Colasante et al. (2022)	Waste Circularity Index (WCI)	Quantitatively assess the results of the waste management process.
Kasztelan (2020)	Index of National Economies' Circularity (INEC)	Facilitate the process of evaluating and ranking countries based on their performance in terms of economic and environmental circulation.
Muscillo et al. (2021)	Circular City Index	Measure the progress of cities in transitioning to a circular economy model by assessing their resource efficiency, sustainability and innovation in areas such as energy, waste and transport.

The European Commission's indicators are divided into the following five thematic areas (Eurostat, n.d.): production and consumption, waste management, secondary raw materials, competitiveness and innovation, global sustainability and resilience.

The European Commission has identified 11 indicators that can be used to calculate the level of the circular economy in a country and monitor progress at EU and national levels. These indicators are material consumption; green public procurement; waste generation; total recycling rate; recycling rates for specific waste streams; contribution of recycled materials to raw material demand; trade in recycled raw materials; private investment; jobs and gross value added related to circular economy sectors; green innovation; and global sustainability and resilience (European Commission, 2023). Currently, this monitoring system is based on tables, graphs and maps presenting all the relevant indicators (Garcia-Bernabeu et al., 2020).

Thus, by identifying various circular economy indicators, it is possible to determine and compare a country's level of participation in the circular economy with that of other EU countries. As the indicators cover a range of categories, they provide valuable data to policymakers, businesses and the public, helping them to set priorities and evaluate the effectiveness of circular economic initiatives.

3. Methodology

To present a clear research plan, a research diagram has been created (see Figure 1).

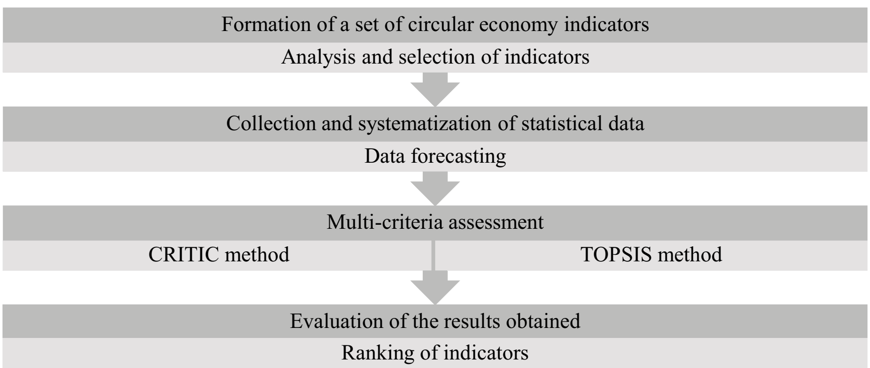

Figure 1. Research design

An analysis of the scientific literature has revealed that there is currently no specific set of indicators that countries could use to evaluate their level of participation in the circular economy. However, as this article aims to analyze the level of the circular economy in EU countries, it is more useful to use the set of indicators approved by the European Commission in 2023. This set is designed to assess progress in developing a circular economy at the EU level. This set of indicators is designed to assess progress in developing a circular economy at the EU level.

Table 2 summarizes the circular economic assessment indicators recommended by the European Commission and will form the basis of the empirical study.

Table 2. Information about the indicators used in the study (compiled by the authors, based on Eurostat, n.d.)

No.	Thematic area	Indicator	Indicator type	Unit of measurement	Is the indicator included in the study?	Marking of the indicator in the study
1.	Production and consumption	Resource productivity	Maximizing	Index	Yes	X_1
2.		Material footprint	Minimizing	ton per person	Yes	X_2
3.		Green public procurement	–	–	No, because the first data on green public procurement will only be available from 2023 onwards.	–
4.		Total waste generation per capita	Minimizing	kilograms per person	Yes	X_3
5.		Generation of waste excluding major mineral wastes per GDP unit	Minimizing	kilograms thousand EUR	Yes	X_4
6.		Generation of municipal waste per capita	Minimizing	kilograms per person	Yes	X_5
7.		Food waste	Minimizing	kilograms per person	Yes	X_6
8.		Generation of packaging waste per capita	Minimizing	kilograms per person	Yes	X_7
9.		Generation of plastic packaging waste per capita	Minimizing	kilograms per person	Yes	X_8
10.	Waste management	Recycling rate of municipal waste	Maximizing	%	Yes	X_9
11.		Recycling rate of all waste excluding major mineral waste	–	–	No, because there is insufficient statistical data.	–
12.		Recycling rate of overall packaging	Maximizing	%	Yes	X_{10}
13.		Recycling rate of plastic packaging	Maximizing	%	Yes	X_{11}
14.		Recycling rate of WEEE separately collected	Maximizing	%	Yes	X_{12}

End of Table 1

No.	Thematic area	Indicator	Indicator type	Unit of measurement	Is the indicator included in the study?	Marking of the indicator in the study
15.	Secondary raw materials	Circular material use rate	Maximizing	%	Yes	X_{13}
16.		End-of-live recycling input rates	–	–	No, these statistics are for the European Union as a whole, rather than individual EU countries.	–
17.		Imports from non-EU countries	Maximizing	Thousand tons	Yes	X_{14}
18.		Exports to non-EU countries	Maximizing	Thousand tons	Yes	X_{15}
19.		Intra EU trade	Maximizing	Thousand tons	Yes	X_{16}
20.		Private Investments	Maximizing	% of GDP	Yes	X_{17}
21.	Competition and innovation	Persons employed	Maximizing	% of all employees	Yes	X_{18}
22.		Gross value added	Maximizing	% of GDP	Yes	X_{19}
23.		Patents related to waste management and recycling	Maximizing	Unit	Yes	X_{20}
24.	Global sustainability and resilience	Consumption footprint	Minimizing	Index	Yes	X_{21}
25.		GHG emissions from production activities	Minimizing	kilograms per person	Yes	X_{22}
26.		Material import dependency	Minimizing	%	Yes	X_{23}
27.		EU self-sufficiency for raw materials	–	–	No, these statistics are for the European Union as a whole, rather than individual EU countries.	–

As shown in Table 2, only 23 of the 27 indicators presented by the European Commission will be analyzed in the study. The decision to analyze certain indicators and not others was based on the availability of statistical data. When analyzing the data for EU countries, it was noted that there was a significant lack of statistical data or that the data was completely unavailable. To enable the study to be carried out, data for the missing years will be projected. Forecasting is the process of using past data to estimate what will happen in the future (Sakdiyah et al., 2021). The Moving Average Method (MA) will be used to calculate a certain number of past observations to forecast future values (Gunarti et al., 2023; Skvarciany et al., 2025). The Moving Average method was chosen because it provides stable estimates for short and incomplete time series without requiring strong model assumptions. Compared with more complex forecasting techniques, it ensures transparency and consistency across all EU countries' datasets. The moving average method is calculated using the following equation (Sakdiyah et al., 2021):

$$F_{t+1} = \frac{Y_t + Y_{t-1} + Y_{t-2} + \ldots + Y_{t-n+1}}{n}, \quad (1)$$

where, F_{t+1}, – $t+1$ forecast for the period; Y_t – actual value of period t; n – number of values.

Once a set of indicators and statistical data has been compiled, the next step is to analyze and evaluate it to determine the level of the country's circular economy. Scientists often face challenges in reconciling environmental and economic aspects, as these are often contradictory (Kraviarová et al., 2024). Multi-Criteria Evaluation (MCE), Multi-Criteria Decision-Making Analysis (MCDM) and Multi-Criteria Analysis (MCA) can be used for this purpose, as they allow different factors to be evaluated and an optimal balance to be found (Kraviarová et al., 2024). The main stages of multi-criteria evaluation are (Taherdoost & Madanchian, 2023): identifying criteria; selecting alternatives; determining criterion weights; evaluating alternatives; and ranking them according to the selected multi-criteria evaluation method.

The study uses the CRiteria Importance Through Intercriteria Correlation (CRITIC) method, which determines the weights of the criteria being analyzed (Karakiş, 2021). The method is based on the evaluation of differences between the alternatives under consideration, which is characteristic of multi-criteria decision-making problems (Skvarciany et al., 2025). It is one of the most objective weighting methods, according to which the weights of the criteria are determined based on the data in the matrix, rather than on the opinions of experts or the preferences of decision-makers. After completing all the steps of the CRITIC method in the study, the weights of the analyzed criteria are obtained, which indicate the influence of each indicator on the evaluation.

After determining the weights of the analyzed criteria, a multi-criteria evaluation was performed to allow comparison of the alternatives and identification of the best solution. The study opted for the TOPSIS method, which is widely used in various fields of research thanks to its clarity and effectiveness in decision-making. The method is based on the principle that the optimal solution is the one closest to the positive ideal alternative and farthest from the negative ideal alternative (Skvarciany et al., 2025). A positive ideal solution maximizes the maximizing criteria and minimizes the minimizing criteria (Pangsri, 2015). Conversely, a negative ideal solution maximizes the minimizing criteria or minimizes the maximizing criteria and is therefore considered the worst alternative. The main steps of the TOPSIS method are the selection of criteria and alternatives and the construction of a decision matrix (Hajduk, 2021). CRITIC was selected because it provides objective, data-driven weights based on indicator variability and inter-correlation, while TOPSIS enables a clear ranking by measuring each country's proximity to ideal performance. Combined, these methods ensure an unbiased weighting process and a transparent, robust multi-criteria evaluation.

4. Results and discussion

To perform statistical data analysis, decision matrices are first compiled for the year under review, presenting the values for each EU country according to the relevant circular economy criteria. It is important to note that ensuring the data is both complete and accurate is essential for the study to produce reliable results. Therefore, where indicator values were missing, they were predicted using the moving average method.

Each circular economy indicator included in this study's set of indicators was then assigned to a type. Circular economic indicators for which a lower value is favorable, e.g., raw material consumption and greenhouse gas emissions from production activities, were assigned to minimizing indicators. Those for which a higher value is more favorable, such as the municipal waste recycling rate and the circular material use indicator, were assigned to maximizing indicators.

Analysis of the data shows that Germany had the highest municipal waste recycling rate in 2020, while Malta had the lowest. The circular economy indicator matrix for 2021 shows that Bulgaria has the highest total waste generation per capita, while Ireland has the lowest. Similarly, Denmark has the highest greenhouse gas emissions from manufacturing activities and Sweden has the lowest. As these are both minimizing indicators, countries with lower values demonstrate more efficient use of resources and more sustainable production processes.

A circular economy matrix has been created for 2022 to determine how well EU countries are performing in achieving their circular economy goals. Analysis of statistical data shows that Cyprus generates the most food waste, while Spain generates the least. The analysis also revealed that the Netherlands had the highest rate of circular material use in 2022, while Romania had the lowest.

The 2023 circular economy indicator matrix shows that Belgium has the highest plastic packaging waste recycling rate, while Malta has the lowest. Furthermore, it can be concluded that employment in the circular economy sector was highest in Estonia and lowest in Greece in 2023. Since both indicators maximize, higher values reflect a country's more advanced implementation of circular economy principles.

The circular economy indicator matrices are therefore used in the study to assess which EU countries are leading the way in the circular economy and which still need to make efforts to integrate circular economy measures.

The level of the circular economy in EU countries is assessed based on a set of indicators (see Table 3) using the CRITIC method. First, to ensure comparability between the 23 criteria, their initial values are normalised in the circular economy indicator matrix. Normalisation eliminates the influence of measurement units and enables further analysis of the importance of the criteria. After the data has been normalised, further CRITIC method calculations are performed, including the calculation of standard deviations σ_j and mutual correlation coefficients of the criteria. Additionally, an assessment is made of the amount of information and contrast of the criteria C_j, reflecting the importance of each criterion in the evaluation process. The weight of each criterion is then calculated based on the results obtained w_j, showing its significance in the overall evaluation of the circular economy.

The analysis (see Table 3) shows that in 2020 and 2021, the criterion reflecting employment in the circular economy sector X_{18} will have the greatest impact on the final assessment of the circular economy levels of EU countries, as its weight (w_j) is the highest. This indicator shows the number of people employed in three sectors related to the circular economy: the recycling sector, the repair and reuse sector, and the rental and leasing sector. Meanwhile, the

Table 3. Elements of the CRITIC Method: Analysis of Indicators for 2020–2021 (source: compiled by the authors)

Indicators	2020 σ_j	2020 C_j	2020 w_j	2021 σ_j	2021 C_j	2021 w_j
X_1	0.187	3.732	0.035	0.181	3.662	0.033
X_2	0.226	4.856	0.045	0.226	4.939	0.045
X_3	0.274	5.928	0.055	0.277	6.023	0.055
X_4	0.245	5.697	0.053	0.241	5.645	0.051
X_5	0.256	4.716	0.044	0.250	4.680	0.043
X_6	0.212	4.972	0.046	0.210	4.953	0.045
X_7	0.266	4.480	0.041	0.265	4.610	0.042
X_8	0.216	4.058	0.038	0.188	3.750	0.034
X_9	0.250	4.142	0.038	0.268	4.620	0.042
X_{10}	0.239	3.959	0.037	0.249	4.162	0.038
X_{11}	0.243	4.999	0.046	0.259	5.237	0.048
X_{12}	0.227	5.022	0.046	0.235	5.664	0.052
X_{13}	0.259	4.499	0.042	0.251	4.535	0.041
X_{14}	0.270	4.887	0.045	0.272	5.098	0.046
X_{15}	0.236	4.118	0.038	0.223	4.040	0.037
X_{16}	0.248	4.103	0.038	0.244	4.125	0.038
X_{17}	0.248	4.387	0.041	0.252	4.415	0.040
X_{18}	0.273	7.374	0.068	0.278	7.486	0.068
X_{19}	0.187	3.721	0.034	0.185	3.513	0.032
X_{20}	0.239	4.433	0.041	0.219	4.034	0.037
X_{21}	0.220	4.882	0.045	0.240	5.404	0.049
X_{22}	0.261	4.788	0.044	0.252	4.717	0.043
X_{23}	0.237	4.307	0.040	0.244	4.470	0.041

criterion with the least influence on the assessment of a country's circular economy level in 2020 and 2021 is gross value added related to circular economy sectors X_{19}, as this criterion has the lowest weight (w_j). This indicator shows the economic value created by economic sectors belonging to the circular economy.

As shown in Table 4, the analysis indicates that the criterion reflecting total waste generation per capita X_3 will have the greatest impact on the final assessment of EU countries' circular economy levels in 2022 and 2023. This indicator shows the total amount of waste generated per capita in the country. Conversely, the criterion that will have the least impact on the circular economy assessment of EU countries in 2022 and 2023 is total value X_{19} added in circular economy sectors.

The results obtained provide a better understanding of which circular economy indicators are most important for assessing EU countries' progress in implementing circular economy principles, and they provide a basis for further analysis and strategic decision-making. The results show that, during the analysed period, there was a recurring trend whereby the gross value-added indicator related to circular economy sectors had the least weight w_j in the

Table 4. Elements of the CRITIC Method: Analysis of Indicators for 2022–2023 (source: compiled by the authors)

Indicators	2022 σ_j	2022 C_j	2022 w_j	2023 σ_j	2023 C_j	2023 w_j
X_1	0.184	3.813	0.035	0.188	3.731	0.035
X_2	0.220	4.842	0.045	0.222	5.025	0.047
X_3	0.285	6.173	0.057	0.283	6.249	0.058
X_4	0.239	5.571	0.052	0.244	5.712	0.053
X_5	0.253	4.909	0.045	0.247	4.705	0.044
X_6	0.223	5.299	0.049	0.224	5.252	0.049
X_7	0.278	4.818	0.045	0.283	4.773	0.044
X_8	0.197	3.909	0.036	0.191	3.725	0.034
X_9	0.273	4.747	0.044	0.267	4.511	0.042
X_{10}	0.241	4.201	0.039	0.246	4.241	0.039
X_{11}	0.278	5.540	0.051	0.289	5.677	0.053
X_{12}	0.207	4.592	0.043	0.238	5.138	0.048
X_{13}	0.264	4.694	0.043	0.243	4.278	0.040
X_{14}	0.268	4.983	0.046	0.294	5.541	0.051
X_{15}	0.236	4.264	0.040	0.239	4.291	0.040
X_{16}	0.239	4.052	0.038	0.249	4.173	0.039
X_{17}	0.262	4.600	0.043	0.242	4.317	0.040
X_{18}	0.209	4.918	0.046	0.206	4.829	0.045
X_{19}	0.188	3.471	0.032	0.184	3.397	0.031
X_{20}	0.217	3.925	0.036	0.224	4.094	0.038
X_{21}	0.229	5.113	0.047	0.225	5.083	0.047
X_{22}	0.272	5.014	0.046	0.257	4.768	0.044
X_{23}	0.244	4.483	0.042	0.246	4.471	0.041

results, while the employment and total waste generation per capita indicators in the circular economy sector had the greatest weight.

Once the weights of the analysed indicators have been determined, a multi-criteria assessment is performed using the TOPSIS method. This method is used in the study to calculate the circular economy levels of the selected group of alternatives (EU countries) for the period 2020–2023. Analysing the obtained results allows us to not only assess the progress of individual countries but also compare their differences and trends. This enables the leading EU countries in the field of the circular economy to be identified.

After normalisation, a weighted decision matrix is created in which the normalised criterion values are multiplied by their respective weights, which were determined using the CRITIC method. This considers the importance of each criterion in the overall assessment. The positive and negative ideal solutions are then determined and the alternatives separated from them.

Based on the data presented in Table 5, it can be concluded that Germany was closest to the ideal solution throughout the entire period analysed, as its values for S_j^+ are the lowest (from 0.028 to 0.030), while its S_j^- values are among the highest (from 0.061 to 0.063). This shows that Germany has the best assessed results. The Netherlands also stands out with similar results, with low S_j^+ values (from 0.034 to 0.037) and high values for S_j^- (around 0.059–0.060). These results for the Netherlands also indicate a high level of circular economy. Meanwhile, countries with high values for S_j^+ and low values for S_j^-, such as Bulgaria (values for S_j^+ range from 0.065 to 0.067, while values for S_j^- range from 0.028 to 0.029) and Estonia (values S_j^+ range from 0.063 to 0.065, values S_j^- range from 0.030 to 0.035), it can be concluded that these countries are lagging behind in the circular economy.

Table 5. Results of separating alternatives between positive and negative ideal solutions (source: compiled by the authors)

	In 2020		In 2021		In 2022		In 2023	
	S_j^+	S_j^-	S_j^+	S_j^-	S_j^+	S_j^-	S_j^+	S_j^-
Ireland	0.0544	0.0457	0.0547	0.0462	0.0556	0.0481	0.0558	0.0472
Austria	0.0521	0.0426	0.0524	0.0424	0.0538	0.0441	0.0534	0.0436
Belgium	0.0416	0.0494	0.0419	0.0490	0.0439	0.0511	0.0433	0.0506
Bulgaria	0.0653	0.0289	0.0654	0.0288	0.0669	0.0284	0.0664	0.0285
Czech Republic	0.0517	0.0443	0.0523	0.0440	0.0540	0.0452	0.0533	0.0453
Denmark	0.0535	0.0422	0.0529	0.0431	0.0547	0.0438	0.0543	0.0435
Estonia	0.0629	0.0304	0.0634	0.0306	0.0647	0.0348	0.0642	0.0348
Greece	0.0564	0.0432	0.0552	0.0435	0.0571	0.0444	0.0575	0.0439
Spain	0.0373	0.0532	0.0387	0.0535	0.0405	0.0547	0.0401	0.0548
Italy	0.0361	0.0515	0.0367	0.0512	0.0380	0.0527	0.0366	0.0535
Cyprus	0.0586	0.0444	0.0582	0.0432	0.0596	0.0433	0.0600	0.0428
Croatia	0.0537	0.0480	0.0541	0.0476	0.0545	0.0470	0.0545	0.0461
Latvia	0.0545	0.0445	0.0546	0.0453	0.0550	0.0470	0.0545	0.0467
Poland	0.0434	0.0437	0.0452	0.0430	0.0463	0.0450	0.0444	0.0463
Lithuania	0.0539	0.0448	0.0536	0.0448	0.0545	0.0448	0.0542	0.0442
Luxembourg	0.0601	0.0368	0.0603	0.0385	0.0597	0.0404	0.0598	0.0395
Malta	0.0578	0.0426	0.0576	0.0436	0.0591	0.0449	0.0587	0.0439
Netherlands	0.0359	0.0575	0.0343	0.0591	0.0366	0.0597	0.0371	0.0592
Portugal	0.0533	0.0440	0.0545	0.0444	0.0560	0.0449	0.0551	0.0446
France	0.0347	0.0518	0.0371	0.0504	0.0389	0.0513	0.0367	0.0532
Romania	0.0556	0.0390	0.0554	0.0393	0.0574	0.0396	0.0567	0.0394
Slovakia	0.0545	0.0455	0.0542	0.0457	0.0558	0.0464	0.0554	0.0461
Slovenia	0.0525	0.0459	0.0531	0.0453	0.0547	0.0463	0.0541	0.0456
Finland	0.0609	0.0357	0.0610	0.0365	0.0630	0.0387	0.0635	0.0372
Sweden	0.0554	0.0389	0.0549	0.0391	0.0563	0.0411	0.0557	0.0404
Hungary	0.0555	0.0441	0.0549	0.0439	0.0566	0.0442	0.0563	0.0444
Germany	0.0284	0.0611	0.0295	0.0607	0.0302	0.0631	0.0298	0.0627

An analysis of Lithuania's scores S_j^+ and S_j^-. from 2020 to 2023 shows that the country's position remained stable and average throughout this period. The distances from the positive ideal solution S_j^+ remained relatively small (ranging from 0.054 to 0.055), but the distances to the negative ideal solution S_j^-, which ranged from 0.044 to 0.045, were not among the largest. Therefore, Lithuania was not close to the best solution or the best alternative. These results indicate that Lithuania is neither one of the strongest countries in the circular economy, such as Germany or the Netherlands, nor one of the weakest.

Overall, the results of EU countries changed very little during the review period. This suggests that their position according to the assessed criteria was stable. Germany consistently maintained the best indicators and stood out most strongly in all periods.

Finally, to assess the level of circular economy of each alternative, its relative proximity to the positive ideal solution P_j. was calculated. This indicator shows how close a country is

Table 6. Ranking of EU countries in the circular economy for 2020–2023
(source: compiled by the authors)

	In 2020	In 2021	In 2022	In 2023
Ireland	11	10	8	11
Austria	15	17	15	14
Belgium	6	6	6	6
Bulgaria	27	27	27	27
Czech Republic	10	12	12	9
Denmark	18	15	17	17
Estonia	26	26	26	26
Greece	19	19	19	19
Spain	5	4	4	5
Italy	4	3	3	3
Cyprus	20	21	22	22
Croatia	8	8	9	10
Latvia	16	14	10	8
Poland	7	7	7	7
Lithuania	13	13	14	15
Luxembourg	24	24	24	24
Malta	21	20	20	20
Netherlands	2	2	2	2
Portugal	14	16	16	16
France	3	5	5	4
Romania	22	23	23	23
Slovakia	12	11	13	13
Slovenia	9	9	11	12
Finland	25	25	25	25
Sweden	23	22	21	21
Hungary	17	18	18	18
Germany	1	1	1	1

to achieving the best possible result by considering the distance to both the positive and negative ideal solutions. The higher the relative proximity, the higher the country's circular economy level. The obtained data revealed how each country achieved its circular economy goals during the 2020–2023 period and how they compare with each other according to these indicators. Comparing countries' achievements shows both stability and change, reflecting their efforts and strategies to implement circular economy principles. To provide further insight into the results obtained, the ranking of EU countries for the review period will continue.

The ranking is based on the relative proximity of each alternative (EU country) to the positive ideal solution (P_j), which determines how close it is to the best possible solution. The higher an alternative's value, the closer it is to the ideal positive solution, and the higher its ranking. This process enables an objective comparison of all analysed countries and identifies which contribute most to the development of the circular economy and which still have room for improvement.

The ranking of EU countries in the circular economy for the period 2020–2023 (see Table 6) revealed a clear and relatively stable position for each country, with only minor changes occurring over time. Germany was the clear leader throughout the entire review period, ranking first every year, with the best results and the most robust implementation of circular economy policies. The Netherlands remained in second place throughout the analysed period, also demonstrating very high stability of results and consistent progress. Italy and France retained third and fourth place respectively, with minor fluctuations (France falling to fifth place in 2021–2022) having no significant impact on their high overall ratings. Spain was also among the best-performing countries, remaining stable in fourth or fifth place.

Countries in the middle of the rankings, such as Austria, the Czech Republic, Denmark, Portugal and Ireland, experienced only minor changes in their ratings over the four years, which did not affect their position in the rankings. Notably, Latvia demonstrated significant progress, rising from 16th place in 2020 to 8th place in 2023, indicating substantial advancements in its circular economy indicators.

Lithuania's position in the EU countries' ranking in the field of the circular economy remained stable between 2020 and 2023, placing it firmly in the middle of the ranking. In 2020 and 2021, Lithuania ranked 13th, indicating a solid, though not the best, position for the country. This signals that Lithuania maintained sufficient circular economy indicators during this period but did not rise to the group of countries with the highest ratings. In 2022, Lithuania fell to 14th place and then to 15th place in 2023, although these changes are not drastic. This slow and moderate decline shows that other EU countries have made faster progress in the circular economy than Lithuania, slightly weakening our country's relative position in the ranking.

The countries with the lowest rankings – Bulgaria, Estonia, Finland, Luxembourg and Romania – showed almost unchanged results throughout the period, remaining in 22nd to 27th place. This reveals fundamental structural challenges hindering progress in these countries.

A comparative analysis of EU country rankings was also carried out to determine how circular economy levels changed between 2020 and 2023.

Table 7. Change in the ranking of European Union countries between 2020 and 2023 (source: compiled by the authors)

	In 2020	In 2023	Change
Ireland	11	11	—
Austria	15	14	▲1
Belgium	6	6	—
Bulgaria	27	27	—
Czech Republic	10	9	▲1
Denmark	18	17	▲1
Estonia	26	26	—
Greece	19	19	—
Spain	5	5	—
Italy	4	3	▲1
Cyprus	20	22	▼2
Croatia	8	10	▼2
Latvia	16	8	▲8
Poland	7	7	—
Lithuania	13	15	▼2
Luxembourg	24	24	—
Malta	21	20	▲1
Netherlands	2	2	—
Portugal	14	16	▼2
France	3	4	▼1
Romania	22	23	▼1
Slovakia	12	13	▼1
Slovenia	9	12	▼3
Finland	25	25	—
Sweden	23	21	▲2
Hungary	17	18	▼1
Germany	1	1	—

Table 7 summarises the changes in EU country ratings from 2020 to 2023. While the ratings of EU countries in the circular economy have remained largely stable, there have been some notable individual changes. The top positions remained almost unchanged: Germany retained first place, the Netherlands remained in second place, Italy rose from fourth to third place, and Spain and Belgium remained stable in fifth and sixth place. Some states in the middle group significantly improved their positions: for example, Latvia rose from 16th to 8th place and Sweden from 23rd to 21st, demonstrating faster progress in implementing the circular economy. Meanwhile, other middle-ranking and weaker countries experienced a decline: Cyprus, Croatia, Lithuania and Portugal all fell two places. France, Romania, Slovakia and Hungary saw minor changes, each falling one place, while Slovenia fell three places. Most countries, including Ireland, Belgium, Bulgaria, Estonia, Spain, Luxembourg and Finland, maintained their positions from 2020 to 2023, indicating a stable, albeit unprogressively, level of circular economy activity.

Thus, the study showed that EU countries can be divided into distinct groups based on the level of their circular economy. There are clear leaders (Germany, the Netherlands and Italy), while the countries lagging has essentially remained unchanged. The leading countries are developing their circular economies consistently by promoting innovation, improving legal regulation and ensuring effective waste management policies.

Those in the middle (Austria, the Czech Republic, Denmark, Portugal, Latvia and Lithuania) have the potential to be sustainable, but face challenges relating to infrastructure and developing recycling systems. The weakest performers (Bulgaria, Estonia, Romania, Luxembourg and Finland) face greater challenges in integrating circular economy principles into their economic models. Future progress in the circular economy will depend on additional investment, strategic decision-making and the implementation of sustainable innovations in each country. However, implementing circular economy principles and objectives is a long-term process and changes in national positions often require several years of consistent change and strategic investment.

This study differs from previous assessments of EU countries' circular economy (CE) performance in three keyways. First, it integrates the CRITIC and TOPSIS methods with the European Commission's updated 2023 CE indicator set. Such a combined methodological framework has not been widely applied in existing CE rankings, which typically rely either on expert-based weighting or single-method composite indices. Second, unlike earlier studies that focus on isolated CE dimensions – such as waste management, material use, or innovation – this research provides a comprehensive multi-criteria evaluation covering all five thematic areas of the EU monitoring framework. Third, by analysing the period 2020-2023, the study captures CE dynamics during the implementation of the EU Circular Economy Action Plan and post-pandemic transition, offering a more up-to-date and comparable cross-country assessment.

5. Conclusions

An analysis of scientific literature provided insights into the fundamental principles of the circular economy. This holistic approach to sustainability aims to reduce environmental pollution and conserve resources, as well as address important social challenges. It is an integrated model of sustainable development that focuses on conserving resources in the value chain, reducing waste, and promoting reuse and recycling. It reduces the ecological footprint and creates long-term economic and social benefits. Indicator analysis is a strategic tool that promotes innovation, international cooperation and changes in consumer behavior.

To present the research methodology properly and in a structured manner, the main stages of the research were identified: the formation of a set of circular economic indicators; the collection and systematization of statistical data; a multi-criteria assessment; and the evaluation of the obtained results. To create a complete matrix of circular economy indicators, it was necessary to forecast missing indicator values; for this purpose, data forecasting using the moving average method was employed. Additionally, the CRITIC method was employed to determine the indicators' significance in the study. The TOPSIS multi-criteria evaluation method was used to assess and rank the circular economy levels of EU countries. Applying these methods ensured an objective and reasonable assessment, enabling the positions of countries to be determined according to their circular economic indicators.

The study's limitations may introduce several analytical biases. Incomplete and inconsistent EU-level data required forecasting with the Moving Average method, which may smooth real variability and bias country comparisons. Additionally, the absence of a standardized composite indicator framework may affect methodological comparability, potentially influencing the weighting structure in CRITIC and the resulting TOPSIS rankings.

The results of the study show that the level of the circular economy in EU countries remained relatively stable between 2020 and 2023. However, there were significant differences between leading and lagging countries. Germany, the Netherlands and Italy achieved the best results, with consistently high relative proximity indicators showing that the principles of the circular economy are well integrated into these countries' economic structures, policies and innovations. France and Spain also stood out thanks to their robust strategies, investments in a sustainable economy, and efficient waste management systems. Meanwhile, Austria, the Czech Republic, Denmark, Portugal, Latvia and Lithuania remained in the middle of the ranking, demonstrating steady but not particularly rapid progress, which suggests a moderate transition to a circular economy. Conversely, countries such as Bulgaria, Estonia, Romania, Luxembourg, and Finland remained at the bottom of the ranking due to the slow pace of circular economy transformation. This is primarily driven by limited investment, insufficient technological readiness, and sluggish reforms. Their results reflect structural issues such as weak recycling infrastructure, low use of secondary raw materials, and limited consumer and business engagement. Taking these factors into account, it can be argued that accelerating the development of the circular economy requires not only improving recycling infrastructure and promoting innovation, but also strengthening political support, raising public awareness, and promoting circular business models.

The structure of the ranking remained largely unchanged during the analyzed period: the leading countries maintained their positions, while there was fluctuation within the middle and lower groups. The countries in the top group – Germany, the Netherlands, Italy, Spain and Belgium – remained virtually unchanged in the ranking, indicating a consistent and systematic application of circular economy principles. This is supported by a well-developed waste management infrastructure, high recycling rates and policies that promote innovation. Meanwhile, countries with average and lower ratings have seen more significant fluctuations in their positions. Some countries, such as Latvia and Sweden, significantly improved their positions, indicating faster implementation of circular economy solutions and improved performance. Conversely, countries such as Lithuania, Cyprus, Croatia and Portugal experienced a slight decline in their ratings, possibly due to slower implementation of structural reforms or the limited effectiveness of circular economy policy measures. Overall, changes in the circular economy ratings of EU countries during this period were mainly driven by differences in their readiness and ability to implement the EU Circular Economy Action Plan, which came into force in 2020. Those with strong institutional, technological and regulatory frameworks demonstrated greater stability and resilience in the face of external shocks, such as the pandemic and energy crisis, while those less prepared experienced slower progress and greater fluctuations in their circular economy performance.

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