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# Circular economy: advancement of European Union countries

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## Abstract

**Background:** Circular economy (CE) is a development priority of the European Union and it is part of the EU industrial strategy. The transition to a more circular economy is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource-efficient and competitive economy. The author focuses her CE-related reflections and research in this paper on the macro-level (research subjects: 28 EU countries), the level which is least represented in scholarly publications addressing CE (as follows from the analysis of literature in the Scopus database). This study aims to fill this gap partially. The aim of this paper is to identify and group the EU-28 countries according to their advancement towards circular economy. CE indicators proposed by the European Commission were used for the analysis. Given the research subjects and after an analysis of the literature they were concluded to be the most adequate. The theoretical part was based on an analysis of the literature, whereas the empirical work used the principal components analysis, hierarchical and k-means clustering and a grade correspondence-cluster analysis.

**Results:** On the basis of the research, the existence of a “two-speed Europe” was identified in terms of EU countries' advancement towards CE. Leading countries, those most advanced in pursuing operation according to CE principles, include Germany, Belgium, Spain, France, Italy, the Netherlands and the United Kingdom. The second pole accommodates EU countries in which transformation towards CE is happening at the slowest pace. This group includes mainly countries of the Central and Eastern Europe and the countries of the south of Europe.

**Conclusions:** Differentiated levels of advancement of individual countries towards CE result inter alia from the adoption by some of the latter of different development strategies for their economies' transitioning to circular economy (according to recommendations of EU ministers at the Environment Council in June 2016) and also from the differences occurring in social and economic development (it is mostly noticeable between the EU-15 and the EU-13 countries). Unfortunately, as can be concluded from the effects obtained so far, only a few of the adopted development strategies may be considered effective in meeting the challenges of circular economy according to the European Union's standards.

**Keywords:** Circular economy, EU countries, Indicators

## Introduction

An increased interest of scholars, entrepreneurs and decision-makers in the issues of circular economy (CE) has been observed over the last few years.

The ideas of circular economy were developed at the start mainly on the scholarly ground—ecological

economics (e.g. [9, 18, 49]), environmental economics (e.g. Pearce and Turner [82]), functional service economy (performance economy) (e.g. Stahel [91]) or on the ground of industrial ecology (e.g. [54, 67, 88]). They have inspired the interest of decision-makers [16], [30] and of the business sector [20, 25] relatively recently (early twenty-first century).

The term “CE” is difficult to define. It results i.a. from the development of this concept in various areas, i.e. science, business or politics on various micro, meso and

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macro-planes. A number of definitions and interpretations of this concept have been established over the years (often very different, sometimes inconsistent). Their analysis shows that CE is considered in the categories of: a strategy [5, 55, 90], a new economic paradigm [45, 47], an industrial model [103], an industrial system [25, 56, 79], an economy system [68], an economic system [78] or a new “business and development model” [50].

It may be assumed that CE-related activity should result in a more sustainable and competitive operation of economic systems at the micro [8, 10, 23, 62, 64, 83], meso [3, 6, 22, 57, [60], 105], and macro [48, 63], Hacking and Xie 2019, [41, 53, 61, 71, 76] level, thus bringing economic, social and environmental benefits [12, 13, 14, 43, 51, 72, 89]. In assumption, implementation of circular economy is supposed to lead ultimately to building a system in which the implementation of sustainable development goals is coordinated in three dimensions: economy, society and natural environment [102].

Active steps in the framework of CE have been taken in the European Union since 2014, though relevant aspects appeared in EU regulations as early as in the 1970s. The following may be cited as examples: regulations concerning waste [36, 92, 93, 95], the assessment of the impact of some public and private undertakings on the environment [94], recycling of end-of-life vehicles [37], used electrical and electronic equipment [39], the adopted Sixth Environment Action Programme [38], Thematic Strategy on the Sustainable Use of Natural Resources [15], or Roadmap to a Resource Efficient Europe [30].

At the moment CE has become a priority of the European Union's economic policy. Closing the loop—an EU Action Plan for the Circular Economy [17] is considered the fundamental document here as it includes proposals for actions to be carried out in the EU in the coming years. They are intended to contribute to a change in the model of economic development, i.e. from a linear economy model to a circular economy model. The document also includes legal requirements which oblige member states to implement actions initiated at the EU level for selected areas, i.e. eco-innovation, eco-labelling, non-toxic environment, chemicals and also critical raw materials and fertilisers.

CE is defined there as “an economy, where the value of products, materials and resources is maintained (...) for as long as possible, and the generation of waste minimized” [17].

The EU has adopted a number of significant documents concerning CE recently, that is: Regulation (EU) 2018/848, Directive (EU) 2018/849, Directive (EU) 2018/850, Directive (EU) 2018/851 or Directive (EU) 2018/852. The EC has published the monitoring framework for the Circular Economy [31] and it has also

adopted a document “A New Circular Economy Action Plan. For a Cleaner and More Competitive Europe” [37].

From the perspective of CE development and of the transformation of economies towards CE, monitoring the implementation of its goals, undertaken actions, at all levels, i.e. micro, meso as well as macro, is fundamental [28]. The monitoring process is a difficult task, mainly as there is no single generally acceptable set of indicators or one such indicator [35], or as there is a great variety of indicators—which may result from a different understanding of the CE concept by individual stakeholders.

A lot of international organizations which currently deal with the issues of circular economy have brought forward their solutions for monitoring progress in implementing circular economy, for example the OECD [80], the World Bank [101], the WBCSD [99], the EEA [35], the Ellen MacArthur Foundation [24–27] and the EASAC [28].

Some EU countries have created their “their own systems of indicators”, which in consequence makes it difficult to compare effects of CE-related activity between individual countries. These are, for example: the Netherlands [21, 86, 87], France [69], The French Ministry of Ecological and Solidarity Transition [97], Italy [52, 74], Portugal [75].

Measuring or monitoring CE has also been carried out by researchers, who built indicators for this purpose on the basis of their own reviews of the literature and analyses [46, 53, 58, 65, 71, 76, 77, 81, 100].

The question of the selection of indicators to CE assessment is a subject of discussions. They mainly focus on the measurement of the advancement of transformation towards CE [87] or of the efficiency of implementation of CE goals, on the identification of a difference between CE assessment indicators and linear economy assessment indicators [28], on establishing the reference point for which progress in implementing CE may be traced [55] or on the efficiency (national, regional or local) of measuring CE implementation [100].

By concluding that “In order to assess progress towards a more circular economy and the effectiveness of action at EU and national level, it is important to have a set of reliable indicators” [17], the European Commission undertook works on creating a CE monitoring framework, which was adopted in 2018. It is the EC's proposal on measuring progress in implementing CE in the EU and in member states. It consists of a set of indicators, taking into account the main elements of CE which are intended to measure the progress of actions aimed at a transformation towards CE at all stages of the life cycle of raw materials, goods and services and also at the innovation and competitiveness aspects.

These indicators are grouped into four areas of CE policy strictly relating to: production and consumption, waste management, secondary raw materials, competitiveness and innovation [34] and priority areas included in the EU action plan for the Circular Economy [17].

Most of the indicators included in the EU monitoring framework focus on waste, which, according to the European Economic and Social Committee, results to a great degree from the fact that “data on waste is strong, consistent and comparable. However, any future monitoring needs to move beyond waste and recycling (...)” [34].

Pursuant to the EU’s action plan for sustainable economy (Circular Economy Action Plan), the so-called European Green Deal, and the Annual Sustainable Growth Strategy 2020 [32], the Commission will update the framework for monitoring circular economy and will also reinforce the monitoring of national plans and measures that aim to accelerate their transition to circular economy.

The planned new CE indicators are intended to take into account the existing target areas and also the relationships between circularity, climatic neutrality and the goal of achieving zero emissions. It is assumed that indicators relating to the use of resources, including the consumption and material footprint, will also be developed. It is additionally assumed that the projects implemented under the “Horizon Europe” and the Copernicus data will contribute to improving circularity metrics (which are not yet reflected in official statistical data) at various levels [33].

In the works on CE indicators, it is also worth addressing the aspects which should be reflected mainly in the production and consumption area identified in the monitoring framework, which is pointed to by the European Economic and Social Committee [34]. This concerns in particular issues to which the EU pays particular attention, while it does not translate into CE indicators [17]. Such a situation takes place even in the case of designing products (Europroject) or specifying a consumer’s place in resource flows: “(...) any future monitoring needs to (...) focus on design, production and consumption” [34].

The relevant literature features numerous CE-focused studies, though a certain shortage may be noticed, especially when it comes to analyses on the macro-level, including comparative investigations.

Having the above in mind, this paper undertakes reflections in terms of CE at the macro-level, where 28 European Union member states (EU-28) are the research subjects, to fill the identified gap. The article focuses mainly on grouping the EU-28 countries according to their advancement towards circular economy. The aim of the paper is to assess the level of progress towards

circular economy of member states of the European Union in 2010–2018.

The following research tasks corresponding to the main goal are also presented in the study:

1. Grouping the analysed CE scales by means of the principal components analysis (PCA).
2. Grouping the EU-28 countries by means of hierarchical and k-means clustering.
3. Indication at the same time similar countries and similar scales by means of a grade correspondence-cluster analysis.

On the basis of a literature review and scoping review (initial assessment of the body and scope of available literature; it allows, i.a., to determine the type and scope of research conducted) [7], the author decided to use CE indicators proposed by the European Commission in its monitoring framework. To date, the said EU document is the only CE monitoring framework in the world developed at the pan-national level. Understandably, it focuses on the macro-dimension, which is also the subject of this analysis. The time horizon for the analysis covered the years 2010–2018.

This paper has the following structure. The introduction, which focuses on the presentation of relevant issues on the CE essence, possibilities to monitor it and the article’s aims, is followed by a section with information about the methodology applied. Section three presents results of the author’s analyses, while section four contains a discussion. The last section brings a summary of the article, which also includes limitations of the analyses presented in this paper and names possible directions of further research.

## Methods

On the basis of an analysis of the literature, the author decided to use the CE monitoring indicators proposed by the European Commission. To date they are the only framework for monitoring CE throughout the world developed at the pan-national level. Therefore, they focus on the macro-level which is also the subject of this analysis. The Eurostat database was the source of the data.

The spatial scope of the research covered 28 EU member states (EU-28). The time horizon for the analysis covered 2010–2018. The analyses began in 2010 due to the availability of statistical data and also due to the beginning of applicability of an important EU strategy—the Europe 2020 strategy (2010), in which aspects relating to CE were already included.

Conducting the research process was possible thanks to the use of an array of analyses. Statistical analyses

were computed by means of PQStat package, version 1.8.0.338 and GradeStat, version 2.5.

Selection of relevant diagnostic variables which would fully characterize the discussed issue carries great importance in the research. The assessment of diagnostic variables in these terms was conducted taking into account the following principles: universality, measurability, availability of quantitative data, data quality, interpretability, variables impact, content validity, transparency and possibility of aggregation [66, 104].

The first stage in the research process was to identify all indicators employed by the EC in its monitoring framework. Then, the features of the least diagnostic value were eliminated from the original set of features, finally classifying 13 circular economy indicators.

The research takes into account partial indicators which include information for all EU member states, indicators for which the data were aggregated (self-sufficient for raw material; contribution of recycled material to raw materials demand) and those not entirely developed or included in statistics (Green Public Procurement, Food waste).

The second stage involved preparation of the data for the analysis. In the first phase it consisted in averaging the data for 2010–2018 for each country and for the 13 indicators to create 13 scales. In the second phase of the process, the said scales were standardized for min/max in order to obtain a set of results on the same scale which would be suitable for multidimensional analyses. Names of scales were changed to symbols for practical reasons, whereby:

- Generation of municipal waste per capita (cei\_pc031).
- Generation of waste excluding major mineral wastes per GDP unit (cei\_pc032).
- Generation of waste excluding major mineral wastes per domestic material consumption (cei\_pc033).
- Recycling rate of municipal waste (cei\_wm011).
- Recycling rate of all waste excluding major mineral waste (cei\_wm010).
- Recycling rate of packaging waste by type of packaging (cei\_wm020).
- Recycling rate of e-waste (cei\_wm050).
- Recycling of biowaste (cei\_wm030).
- Recovery rate of construction and demolition waste (cei\_wm040).
- Circular material use rate (cei\_srm030).
- Trade in recyclable raw materials (cei\_srm020).
- Private investments, jobs and gross value added related to circular economy sectors (cei\_cie010).
- Patents related to recycling and secondary raw materials (cei\_cie020).

Statistical analyses were conducted in the third stage of the research process. It opened with an analysis of principal components, by means of which the analysed scales were grouped. Bartlett's test,  $\chi^2 = 229.90$ ,  $df = 78$ ,  $p < 0.0001$ , was used to verify the hypothesis that correlation coefficients between the variables are zero (that is, the correlation matrix is the identity matrix). The Keiser–Mayer–Olkin test— $KMO = 0.5560$  was also employed, which was used to verify the degree of correlation between primary variables, that is the strength of evidence for the validity of analysing principle components. In the next stage, hierarchical clustering (by means of the agglomerative procedure) and  $k$ -means clustering were conducted by grouping the examined EU member states. The last analysis to conduct was the grade correspondence-cluster analysis, which allowed a demonstration of similar countries and similar scales at the same time. The probability value was assumed significant at  $p < 0.05$ , and a highly significant probability value was assumed at  $p < 0.01$ .

## Results

### Principal component analysis

The probability value for the Bartlett's test indicates the truth of the hypothesis which claims a significant difference between the correlation matrix obtained and the identity matrix, that is a significant variable correlation. The estimated KMO coefficient is at an average level at 0.5560. Therefore, the premises for conducting the principal components analysis can be deemed as sufficient.

The eigenvalues obtained from Table 1 demonstrate that four principal components are sufficient to describe the data well and at the same time to simplify their 13-dimension structure. The eigenvalue for the

**Table 1** Eigenvalues—principal components analysis

Component number	Eigenvalue	Variance %	Cumulative sum	Cumulative %
1	4.9402	38.0013	4.9402	38.0013
2	2.0426	15.7124	6.9828	53.7137
3	1.6699	12.8455	8.6527	66.5592
4	1.1811	9.0852	9.8338	75.6444
5	0.9488	7.2988	10.7826	82.9433
6	0.7945	6.1116	11.5771	89.0548
7	0.4416	3.3972	12.0188	92.4521
8	0.3282	2.5243	12.3469	94.9764
9	0.2431	1.8700	12.5900	96.8464
10	0.1805	1.3883	12.7705	98.2347
11	0.1253	0.9638	12.8958	99.1986
12	0.0740	0.5689	12.9698	99.7675
13	0.0302	0.2325	13.0000	100.0000

first component is 4.9402 and the percentage of variance explained by it is 38.0013. The second component explains significantly fewer variances, i.e. 15.7124% and its eigenvalue is 2.04. According to the Keiser criterion, it is the first four components that will be sufficient in interpretation since their eigenvalue is greater than 1. Taking into account the first 4 principal components allows an explanation of 75.6444% of the variation observed.

Factor loadings are included in Table 2.

According to the data included in Table 3:

Component 1 is best explained by:

1. cei\_wm011,
2. cei\_wm010,
3. cei\_wm030,
4. cei\_srm030.

Component 2 is best explained by:

1. cei\_pc031,
2. cei\_pc032,
3. cei\_pc033.

Component 3 is best explained by:

1. cei\_wm020,
2. cei\_cie010,
3. cei\_cie020.

Component 4 is best explained by:

1. cei\_wm050,
2. cei\_wm040,
3. cei\_srm020.

**Table 2** Factor loadings—principal components analysis

Number	Component 1	Component 2	Component 3	Component 4
cei_pc031	−0.4493	−0.4670	−0.1856	0.0030
cei_pc032	0.3459	0.8625	−0.0697	0.0476
cei_pc033	−0.3245	0.8371	−0.0411	−0.2100
cei_wm011	−0.9053	0.0333	−0.2846	0.0901
cei_wm010	−0.7140	−0.2667	−0.2442	−0.3286
cei_wm020	−0.6770	0.0652	−0.4580	0.2939
cei_wm050	0.0189	0.3047	−0.5741	0.6004
cei_wm030	−0.8413	−0.1411	−0.3101	−0.0768
cei_wm040	−0.3993	0.1913	0.0221	−0.4437
cei_srm030	−0.7512	0.3781	0.0353	−0.3380
cei_srm020	−0.6495	0.0405	0.3855	0.3849
cei_cie010	−0.6918	0.0783	0.5661	0.1767
cei_cie020	−0.6272	0.0578	0.6179	0.2744

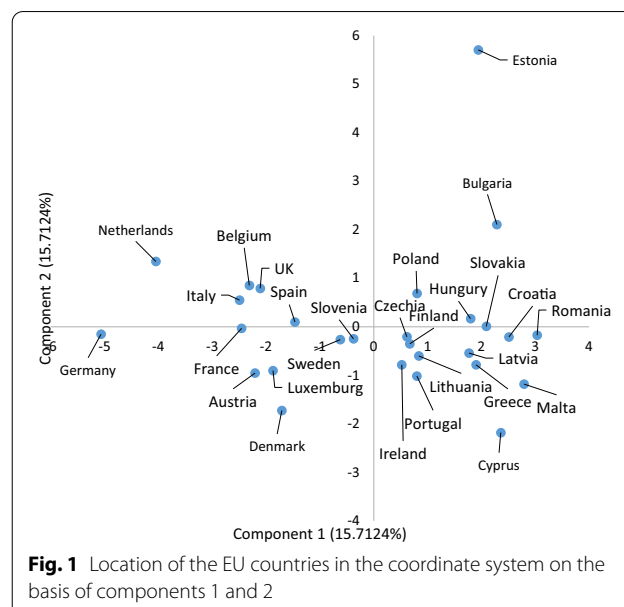
**Table 3** Contribution of variables—principal components analysis

Number	Component 1	Component 2	Component 3	Component 4
cei_pc031	4.0860	10.6789	2.0627	0.0008
cei_pc032	2.4214	36.4177	0.2907	0.1915
cei_pc033	2.1316	34.3053	0.1011	3.7341
cei_wm011	16.5917	0.0541	4.8520	0.6878
cei_wm010	10.318	3.4830	3.5706	9.1430
cei_wm020	9.2783	0.2084	12.5636	7.3153
cei_wm050	0.0072	4.5450	19.7399	30.5244
cei_wm030	14.3283	0.9743	5.7603	0.4992
cei_wm040	3.2276	1.7915	0.0294	16.6692
cei_srm030	11.4224	6.9980	0.0744	9.6745
cei_srm020	8.5380	0.0802	8.8997	12.5408
cei_cie010	9.6863	0.3004	19.1889	2.6428
cei_cie020	7.9632	0.1634	22.8666	6.3765

The location of the EU countries on the coordinate system on the basis of components 1 and 2 is presented in Fig. 1.

The next stage of the research process involved hierarchical and k-means clustering in order to group the EU member states.

The hierarchical cluster analysis shows that there are two groups of countries. The first group includes: Belgium, the Netherlands, Denmark, Luxembourg, Austria, Germany, Spain, France, Italy and the UK. The other countries form the second group cluster Fig. 2.

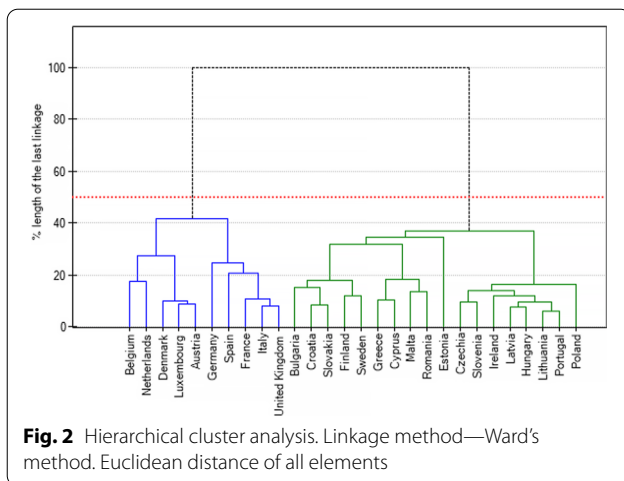


**Fig. 1** Location of the EU countries in the coordinate system on the basis of components 1 and 2

**Table 4** Cluster analysis, k-means clustering

		cel_pc031	cel_pc032	cel_pc033	cel_wm011	cel_wm010	cel_wm020	cel_wm050	cel_wm030	cel_wm040	cel_srm030	cel_srm020	cel_cie010	cel_cie020
Cluster 1	Average	0.49	0.04	0.33	0.69	0.72	0.71	0.4	0.54	0.8	0.46	0.34	0.35	0.23
	S.D	0.2	0.03	0.19	0.15	0.17	0.12	0.15	0.22	0.23	0.23	0.33	0.36	0.28
Cluster 2	Average	0.3	0.18	0.2	0.27	0.37	0.46	0.41	0.13	0.64	0.13	0.05	0.03	0.06
	S.D	0.2	0.26	0.23	0.15	0.21	0.19	0.28	0.11	0.3	0.13	0.08	0.04	0.13
ANOVA	F	6.1824	3.3309	2.5633	52.4637	22.1832	17.288	0.0068	43.1187	2.5734	22.5895	12.0006	12.9916	4.5798
	p	0.0197	0.0795	0.1215	<0.0001	0.0001	0.0003	0.9348	<0.0001	0.1208	0.0001	0.0019	0.0013	0.0419





As seen in the data obtained when applying a cluster analysis by means of k-means clustering, the EU-28 countries were divided into two clusters (Table 4).

The first cluster is made up of the following countries: Belgium, Denmark, Germany, Spain, France, Italy, Luxembourg, the Netherlands, Austria and the United Kingdom.

The following were placed in the second cluster: Bulgaria, Czechia, Estonia, Ireland, Greece, Croatia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovenia, Slovakia, Finland and Sweden.

Both of these clusters differ significantly ( $p < 0.01$ ) in terms of the generation of municipal waste per capita scale, where the results are higher for the first cluster.

Results of scales: generation of waste excluding major mineral wastes per GDP unit and generation of waste excluding major mineral wastes per domestic material consumption are not significantly different ( $p > 0.05$ ) between clusters.

Results of scales: recycling rate of municipal waste, recycling rate of all waste excluding major mineral waste and recycling rate of packaging waste by type of packaging are significantly different ( $p < 0.01$ ) between clusters, where the results are higher for the first cluster.

In the case of the recycling rate of e-waste scale, there is no significant difference ( $p > 0.05$ ) between clusters.

Results of the recycling of biowaste scale are significantly different ( $p < 0.01$ ) between clusters, where the results are higher for the first cluster.

In the case of the recovery rate of construction and demolition waste scale, there is no significant difference ( $p > 0.05$ ) between clusters.

Results of scales: circular material use rate, trade in recyclable raw materials and private investments, jobs and gross value added related to circular economy

sectors are significantly different ( $p < 0.01$ ) between clusters, where the results are higher for the first cluster.

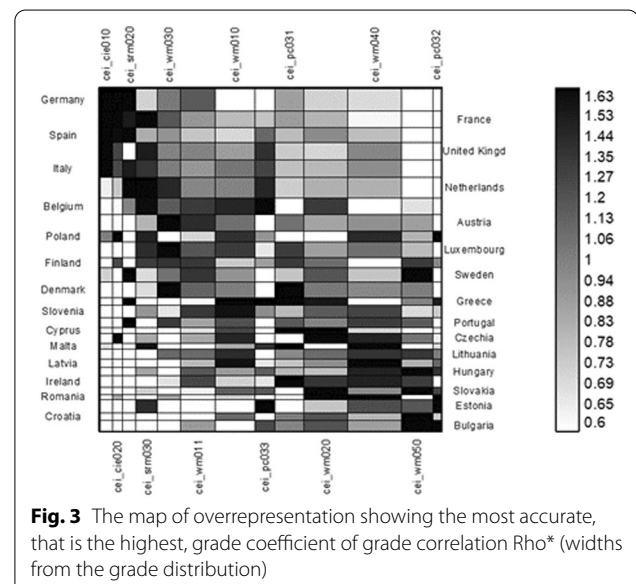
For the patents related to recycling and secondary raw materials scale, the difference between clusters is significant ( $p < 0.05$ ).

The last stage of the research process involved conducting the grade correspondence-cluster analysis allowing a demonstration of similar countries and similar scales at the same time.

The map in Fig. 3 presents three pieces of information, that is:

1. Column width shows what share in the matrix is taken by values of a given variable.
2. Row height shows what share in the matrix is taken by values of a given country.
3. Colour intensity shows the overrepresentation coefficient—the more this coefficient is greater than 1, the more overrepresented the real result is in relation to the theoretical value expected for an even distribution. The more this coefficient is lower than 1, the more underrepresented the real result is in relation to the theoretical value expected for an equal distribution.

The overrepresentation map in Fig. 3 shows that countries such as Germany, France, Spain, the United Kingdom and Italy are a group of similar entities with strong overrepresentation for scales: *cei\_cie010*, *cei\_cie020* and *cei\_srm020*. A completely opposite group of countries is formed by Bulgaria, Croatia, Estonia or Romania. However, a visual analysis of this map does not allow a clear



classification of the countries into clusters, which is why a cluster analysis was conducted.

As seen in the data included in Fig. 4, there are three clusters in the context of the analysed CE indicators.

The first cluster is made up of: Germany, France, Spain, the United Kingdom, Italy, the Netherlands and Belgium with relatively high overrepresentation of scales:

1. private investments, jobs and gross value added related to circular economy sectors,
2. patents related to recycling and secondary raw materials,
3. trade in recyclable raw materials,
4. circular material use rate,
5. recycling of biowaste.

This means that these countries lead in the above-mentioned actions. At the same time, their scales are highly underrepresented there:

1. recovery rate of construction and demolition waste,
2. recycling rate of e-waste,
3. generation of waste excluding major mineral wastes per GDP unit.

The third cluster made up of Cyprus, Czechia, Malta, Lithuania, Latvia, Hungary, Ireland, Slovakia, Romania, Estonia, Croatia and Bulgaria is the opposite of the first cluster, that is it demonstrates relatively high overrepresentation of scales: recovery rate of construction and demolition waste, recycling rate of e-waste and generation of waste excluding major mineral wastes per GDP unit and high underrepresentation of scales: private investments, jobs and gross value added related to circular economy sectors, patents related to recycling and secondary raw materials, trade in recyclable raw materials, circular material use rate and recycling of biowaste.

The second cluster accommodates countries with average results and includes Austria, Poland, Luxembourg, Finland, Sweden, Denmark, Greece, Slovenia and Portugal.

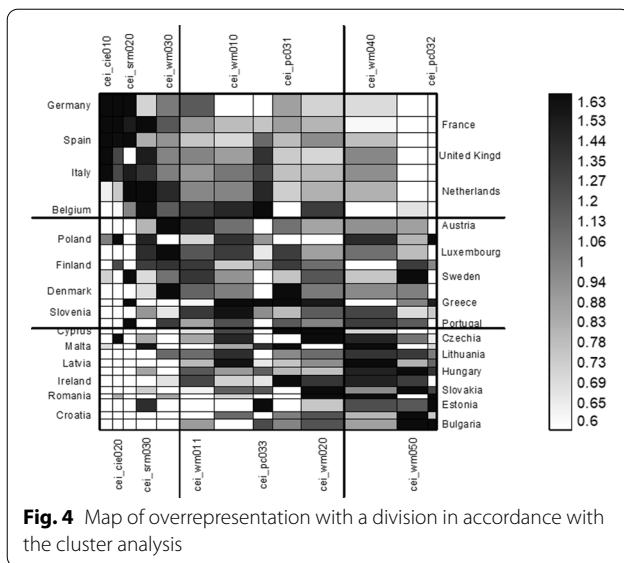
The columns extremely far apart include scales which are not correlated or that are even negatively correlated, e.g. the higher the private investments, jobs and gross value added related to circular economy sectors scores, the lower the generation of waste excluding major mineral wastes per GDP unit scores.

Table 5 shows all estimated correlation coefficients of the Spearman's rank between the analysed indicators. Generation of waste excluding major mineral wastes per GDP unit is negatively correlated with the majority of the other indicators save for generation of waste excluding

**Table 5** Spearman's rank correlation coefficient

	cei_cie010	cei_cie020	cei_srm020	cei_srm030	cei_wm011	cei_wm010	cei_pc033	cei_pc031	cei_wm020	cei_wm040	cei_wm050	cei_pc032
cei_cie010	1.000											
cei_cie020	0.862	1.000										
cei_srm020	0.619	0.545	1.000									
cei_srm030	0.652	0.601	0.420	1.000								
cei_wm011	0.597	0.572	0.627	0.601	1.000							
cei_wm010	0.455	0.435	0.504	0.567	0.608	1.000						
cei_pc033	0.398	0.290	0.440	0.358	0.430	0.289	1.000					
cei_pc031	0.333	0.054	0.225	0.150	0.475	0.184	0.073	1.000				
cei_wm020	0.464	0.420	0.490	0.652	0.770	0.577	0.332	0.291	1.000			
cei_wm040	0.250	0.230	0.144	0.395	0.440	0.166	0.249	1.000	0.047	1.000		
cei_wm050	−0.084	−0.105	−0.031	0.215	0.040	−0.062	0.258	−0.062	0.047	1.000	0.082	
cei_pc032	−0.414	−0.192	−0.205	−0.174	−0.409	−0.294	0.178	−0.768	−0.382	0.082	1.000	





major mineral wastes per domestic material consumption and recycling rate of e-waste.

The inference conducted on the basis of the statistical analyses concerning transformation of EU countries towards circular economy led to the emergence of the “two-speed-Europe”.

Leading countries, those most advanced in pursuing operation according to CE principles, include Germany, Belgium, Spain, France, Italy, the Netherlands and the United Kingdom. These are the countries of the so-called Old Union (i.e. those which have been joined by other European countries after 2004), economically highly developed countries.

The second pole accommodates EU countries in which transformation towards CE is happening at the slowest pace. This group is made up of: Cyprus, Czechia, Malta, Lithuania, Latvia, Hungary, Ireland, Slovakia, Romania, Estonia, Croatia and Bulgaria. Therefore, with the exception of Ireland these are mainly countries of the Central and Eastern Europe (after the political transformation) and the countries of the south of Europe.

## Discussion

It may be assumed that the countries that are most advanced in their transformation towards the CE (highly industrialized countries) began to feel i.a. problems of excessive waste generation, exhaustion of resources, environmental pollution, increasing consumerism or unbalanced consumption much earlier than the economies of European countries which are developing more slowly (e.g. countries which belonged to the Eastern Bloc and only since the end of the 1980s or the 1990s have their economies been operating according to the principles of free market and competitive economy).

The above problems reached the countries of the Central and Eastern Europe with a certain delay, therefore their activities aimed at implementing CE may be slightly slower in time, though they do occur.

These countries’ lesser involvement in CE implementation may also be down, e.g. to the lack of a sufficiently developed infrastructure to process waste or to societies’ lower CE-related awareness.

Another essential matter is the issue of financing activities which serve the implementation and functioning of economies of the Union’s countries according to CE principles. Certainly, the countries’ switching to circular economy is beneficial for the natural environment and in consequence for the people, but it does require greater CE awareness from the regulator, governing authorities, consumers and society in general in terms of implementation of advanced technologies and this, in turn, requires time and financial outlays.

The European Commission promotes CE-related activities emphasizing that the implementation of CE systems will have a positive impact on resource efficiency and will bring crucial economic benefits to EU countries.

The differentiated levels of advancement of individual EU countries towards CE also result from the adoption by some of them of different development strategies concerning their economies’ transitioning to circular economy (according to recommendations of EU ministers at the Environment Council in June 2016) and also from their different approach to implementing CE. Some of them, in particular those belonging to the group of countries more advanced in their transformation towards CE, had undertaken activities compliant with the CE concept even before it was recognized by the European Commission as one of the most essential ones.

Thus, in Germany, as early as in 2002 separation of the economic growth from the use of materials was adopted as one of its economic goals, whereas in 2012 it adopted a statute which promotes circular economy and circular material use. In 2016 a document German Resource Efficiency Programme II: Programme for the sustainable use and conservation of natural resources [4] was published, whereas in 2019 a new law on packaging (Packaging Act) [84] entered into force. A lot of national initiatives or programmes that encourage CE are taken up in Germany, e.g. the German national resource efficiency programme ProgRes [4] or Program VDI [96].

The Netherlands is considered to be one of the European pioneers of CE-related initiatives, where activities relating to the CE concept were introduced in 2011 and in 2013 a report entitled “Opportunities for a circular economy in the Netherlands” was drawn up [2]. It identified opportunities for generating economic growth and increasing employment thanks to innovation in

circular economy. In 2016, the Netherlands adopted a national programme Circular Economy in the Netherlands by 2050. It focuses on the main categories of the Dutch economy, i.e. biomass and food, construction, plastics, manufacturing and consumer goods. Reduced use of natural resources and making the import of natural resources independent, and thus increased supply security of raw materials, are the most desired effects of transformation towards CE in the Netherlands.

In turn in the United Kingdom the initiative called the Waste and Resources Action Plan (WRAP) has been developing since 2000. However, no circular economy strategy common to all regions has been drawn up. Nevertheless, CE is included in the industrial strategy “Building a Britain fit for the future”. CE-related actions are supported by the 25-year Environmental Plan and the forthcoming Resource and Waste Strategy. Neither England nor Wales has drafted a regional CE strategy, whereas there is one in Scotland where in 2016 the government adopted a strategy to pursue circular economy. The two key elements of the strategy are: to develop a more comprehensive approach to producer responsibility by setting up a single framework for all product types which concern reuse, repair and remanufacture, while more fully exposing and addressing the costs of recycling and disposal; and to reduce all food waste by 33% by 2025 [70].

France is another country advanced towards CE, where an action plan for moving to a circular economy was developed in 2013 and the French Circular Economy Institute was established. In 2018 France adopted its Roadmap for Circular economy—50 measures for a 100% circular economy [97]. The strategy for a circular economy in France presumes, i.e., a reduction of natural resource use related to French consumption: a 30% reduction in relation to GDP between 2010 and 2030, a 50% reduction in the amount of non-hazardous waste landfilled by 2025 compared to 2010, 100% of plastics recycled, and a reduction of greenhouse gas emissions (by 8 million tonnes of CO<sub>2</sub> each year thanks to plastic recycling). France participated in the circular economy North Sea Roundabout project [59]. At the moment it is the first EU country which transposed European directives on circular economy onto national law [44].

Moving on, Italy introduced its strategy “Towards a Model of Circular Economy for Italy—Overview and Strategic Framework” in 2017 [74]. Its aim is to direct the public opinion towards the concept of circular economy. It is the so-called integrated strategy—it focuses mainly on horizontal tools and policies. As seen in the report entitled Circular Economy Network, ENEA, Rapporto sull’Economia Circolare in Italia 2019, the Italian economy has one of the highest CE-monitoring indicators in

the EU. This concerns the following five parameters: production, consumption, waste management, secondary raw materials and competitiveness and innovation.

At the beginning of June 2020 the Spanish Government published *España Circular 2030*, the new Strategy for Circular Economy in Spain until 2030 (2020). It contains circular economy objectives and a series of strategic orientations for the period 2020–2030. The strategy: sets up a series of objectives for 2020–2030 which will, inter alia, allow a 30% reduction in the national consumption of resources and a 15% reduction in waste generation (as compared to 2010); contributes to Spain’s efforts to transition to a sustainable, decarbonized, resource-efficient and competitive economy; and takes the form of successive 3-year action plans providing for concrete measures to deliver on circular economy. A number of CE-related initiatives at the national, regional, level are undertaken in Spain (“Seville Declaration” [19], “Extremadura 2030”—strategy for CE of the region of Extremadura [40]).

Belgium adopted a national CE strategy entitled *Towards a Belgium as pioneer in the Circular Economy* in 2014. The Roadmap contains 21 measures that aim to increase the potential of the circular economy by sharing and repairing products and sustainable waste management [42]. It has significant results especially in the area of recycling.

As seen in the above analysis, out of the EU countries most advanced in their transformation towards CE, only the United Kingdom does not have a national CE strategy. Such strategies have been created in other countries. Apart from this, CE strategies have been drawn up in these countries at the regional and local level. They relate to bottom-up initiatives taken by local self-government structures (often—cities). Of course, national CE-related strategies are also created in the EU countries in which transition to CE is proceeding at the slowest pace. Among the countries least advanced towards CE the following have relevant strategies: Malta (Sustainable Development Vision for 2050), Ireland (Towards a Resource Efficient Ireland: A National Strategy to 2020), or Slovakia (Slovak Republic towards green economy). It needs to be emphasized that officially these countries have committed to transform their economies in accordance with the CE idea, yet despite the undertaken legislative activity and other initiatives taken in this scope they are only at the initial phase of implementation. Special focus in these countries must be given to their further legislative activity, new social initiatives and new technological solutions in the field of, e.g. eco-innovation in order to accelerate their transformation towards CE.

On the basis of an assessment of the review of analyses and reports and documents presented in the literature,

one may assume that the disproportion between individual countries in terms of their transformation towards CE will continue for the next few years.

As part of CE implementation, the European Union now attributes special importance to waste management. This is reflected, for example, in the indicators accommodated within the CE monitoring framework [31], among which those concerning waste constitute a significant group. When analysing the indicators adopted by the EU, it is clear that recycling is among the few major CE elements [55]. On the basis of only those indicators that pertain to recycling, one can also identify groups of EU countries with a different level of advancement in applying it.

A similar case is with waste management in the European Union, where groups of countries moving at different speeds may also be named. When it comes to municipal waste, we may even identify a “multi-speed” EU, under which three groups of countries are indicated, that is Recovery, Transition and Landfilling Countries [85]. It certainly translates into progress of individual countries falling under specific groups in the context of their advancement towards CE. It must be emphasized that the EU’s long-term goal is to transform Europe into the so-called recycling society [17], that is one that avoids waste production, and if it occurs, it uses it as a resource. Appropriate waste management is a fundamental element ensuring resource efficiency and sustainable economic development of European countries, which is all in line with CE principles.

Actions to best support individual countries in their transformation towards CE are being now taken in the European Union. These actions involve, inter alia, creating incentives to invest in the area of CE by ensuring financial support under structural and investment funds, creating relevant market mechanisms and eliminating market flaws. One may hope that due to the emerging (as well as planned and prepared) documents of the European Commission concerning CE and CE-related documents or strategies developed by individual countries, transformation of EU countries towards CE will be more dynamic. However, in order for it to happen, it is necessary (apart from the already-signalled issues) to take actions intended to increase CE awareness.

## Conclusions

Given the current social and economic situation of the EU countries and the state of the natural environment, it seems there is no other option but to transition to CE. We are observing a global population growth and we are experiencing a barrier of a limited amount of raw materials throughout the world, hence the need to turn towards recycling and towards prevention of waste generation.

The European Union plays a key role in disseminating the CE concept. It has published a number of CE-related documents and it has obliged its member states to perform processes associated with transforming their economies towards CE.

The measurement and assessment of the undertaken activities in terms of putting CE into effect are fundamental issues for the proper implementation of CE. The monitoring should also apply to the progress of transformation towards CE [77] or to the efficiency of implementation of CE goals [34] at various levels (macro, meso and micro).

Reports, strategies and documents of international institutions as well as many scholarly publications feature an array of guidelines for constructing indicators for measuring CE at various levels. The European Commission too has created their own monitoring framework [34]. The proposed set of CE indicators is constantly being improved. The indicators created may be used further to conduct comparative analyses, e.g. between countries i.a. in terms of their progress in transitioning to CE [1], [98].

Given the above, the aim of this paper is to identify and group the EU-28 countries according to their advancement towards circular economy. Apart from an analysis of the literature, selected statistical analyses have been conducted. After a CE literature review, looking closely at the macro-level, the author decided to choose indicators which were selected by the European Commission for monitoring CE in the EU.

The following results were obtained in the course of the research. The hierarchical cluster analysis showed that there are two groups of countries. The first group includes: Belgium, the Netherlands, Denmark, Luxembourg, Austria, Germany, Spain, France, Italy and the UK. The other countries are in the second cluster.

The same results were obtained when applying k-means clustering. The next analysis, the grade correspondence-cluster analysis, allowed identification of three groups of EU countries. The first one was made up of Germany, France, Spain, the United Kingdom, Italy, the Netherlands and Belgium, the second included Austria, Poland, Luxemburg, Finland, Sweden, Denmark, Greece, Slovenia and Portugal, while the third comprised Cyprus, Czechia, Malta, Lithuania, Latvia, Hungary, Ireland, Slovakia, Romania, Estonia, Croatia and Bulgaria. When comparing results obtained in these analyses, it may be concluded that the EU country most advanced in its transformation towards CE is Germany, while the least advanced countries include: Cyprus, Czechia, Malta, Lithuania, Latvia, Hungary, Ireland, Slovakia, Romania, Estonia, Croatia and Bulgaria, thus with the exception of Ireland—these are

mainly the countries of the Central and Eastern Europe (after the political transformation) and the countries of the south of Europe.

Summing up the results, notice certainly needs to be given to the limitations of the analysis, of which the author is aware. They included the period for which the statistical data used in the analysis were available (2010–2018) and the lack of data for certain indicators that fall under the EC's monitoring framework—which made it impossible to take them into account in the analysis. It also needs to be borne in mind that the measurement of the transformation towards CE at the macro-level is difficult and carries a risk of error. Moreover, the final result will always derive from assumptions that must be made for the analysis. The analysis performed in this paper may be further developed by, i.e. expanding the analysed time frame (according to available data), selecting other indicators, applying other statistical methods or constructing econometric models.

The analysis presented in the paper is a starting point for further research in the area of the subject-matter addressed in the article, i.a. conducting an in-depth analysis of actions for transforming a linear economy into a circular economy in the EU countries or investigating the impact of transformation of the economy towards CE on the economic growth and social and economic development in individual EU countries. A challenge in this regard would involve constructing a model of measurement of the progress of transformation towards CE and its impact on the social and economic development, which would take into account a cause-and-effect sequence of a change in the behaviour (and its dynamics in time) of all participants of the social and economic life (including producers, consumers, the public sector, academic and research institutions, non-governmental organizations, etc.) The author assumes that it will be the subject of interest of further research and analyses carried out by her.

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#### Authors' contributions

The author read and approved the final manuscript.

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