Analysis of the Circular Economy Performance of the European Union and Serbia

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Abstract

Recently, due to its character, more and more attention has been paid to the application of the circular economy principle at the level of the national economy and in all sectors. Based on this, in this study, the performances of the circular economy of the countries of the European Union and Serbia are comparatively analyzed based on the AHP-EDAS method. The research in this study using the given methodology showed that the top five countries in terms of circular economy performance are in order: Luxembourg, the Netherlands, Belgium, Estonia, and Austria. The worst performances of the circular economy are in Romania. The positioning of the leading countries of the European Union is as follows: Germany is in sixth place, France is in eleventh place and Italy is in ninth place. The positioning is satisfactory. Serbia is positioned in the seventeenth place. Compared to the leading countries of the European Union, it is positioned worse. It is better positioned than Croatia (twenty-third place). Compared to Slovenia (twelfth place), it is positioned worse. To improve the performance of the circular economy, it is necessary, in principle, to manage dependence on the import of materials, municipal waste, waste, renewable energy, and other relevant factors as efficiently as possible. In this sense, it is necessary to define a strategy and an action plan for achieving the expected value of the key parameters of the circular economy. The application of the circular economy principle contributes to the preservation of the environment.

Keywords: *performance, circular economy, European Union, Serbia, AHP-EDAS method*

JEL classification: M10, M21

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1. Introduction

In recent times, the issue of the circular economy has been very topical. Due to its character in the relevant literature, special attention is paid to the analysis of the problem of applying the circular economy principle. The issue of the circular economy is comprehensively investigated from various relevant angles. We will only point out some aspects here. In the literature, considerable attention is paid to the effects of applying the circular economy principle in the countries of the European Union (Alivojvodic & Kokalj, 2024; Mazur-Wierzbicka, 2021; Friant et al., 2021; Alberich et al., 2023; Marković et al., 2023; Radovan et al., 2023; The Word Bank - Squaring the Circle: Policies From Europe's Circular Economy Transition, 2022).

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The problems of applying the principle of circular economy in Serbia also receive significant attention in the literature (Ilić & Nikolić, 2016; Kosanović et al., 2021; Abramović et al., 2024; Mihajlov et al., 2021; Radovanov et al., 2023; Stiljkovic et al., 2023; Vukelič et al., 2023). Significant attention in the literature is devoted to the sectoral analysis of the circular economy problem (Amicarelli et al., 2024; Krstić et al., 2024; Stošić & Šmelcerović, 2023). In the literature, special attention is paid to the specifics of the application of the circular economy principle in the countries of the Western Balkans (Bjelić et al., 2024). When analyzing the circular economy problem, in addition to classic analysis, DEA models are also applied in the literature (Radovanov et al., 2023). Likewise, multi-criteria decision-making methods are increasingly being applied in the literature (Marković et al., 2023). The application of multicriteria analysis provides more accurate results of research into the circular economy problem. In this study, bearing this in mind, the problems (i.e. positioning) of the circular economy of the countries of the European Union and Serbia are comparatively analyzed based on the AHP-EDAS method. Knowing the positioning of the circular economy of the countries of the European Union and Serbia provides a realistic basis for improvement in the future by defining an adequate strategy and action plan.

2. Research methodology

The research on the circular economy problem of the European Union and Serbia in this study is based on the AHP-EDAS approach. Therefore, we will briefly indicate their characteristics.

Analytic Hierarchy Process (AHP) method

Given that the weighting coefficients of the EDAS method are determined using the AHP method, we will briefly refer to its characteristics.

The Analytical Hierarchy Process (AHP) method takes place through the following steps (Saaty, 2008):

Step 1: Formation of the matrix of comparison pairs

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

Step 2: Normalization of the comparison pair matrix

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, i, j = 1, \dots, n \quad (2)$$

Step 3: Determination of relative character, i.e. vector weights

$$w_i = \frac{\sum_{i=1}^{n} a_{ij}^{*}}{n}, i, j = 1, \dots, n \quad (3)$$

The consistency index - CI (consistency index) represents a measure of the deviation of *n* from λ_{max} and can be represented by the following formula:

$$CI = \frac{\lambda_{max} - n}{n} \quad (4)$$

If CI < 0.1 of the estimated value of coefficient a_{ij} is consistent, the deviation of λ_{max} from *n* is negligible. This means, in other words, that the AHP method accepts an inconsistency of less than 10%.

Using the consistency index, the consistency ratio CR = CI/RI can be calculated, where RI is the random index.

EDAS method

The EDAS (Evaluation based on Distance from Average Solution) method is a new multi-criteria decision-making method (Keshavarz Ghorabaee et al., 2015). It is very useful when we have conflicting criteria. The selection of the best alternative is made according to the distance from the average solution (AV). There are two measures of desirability: (1) positive distance from the average (PDA), and (2) negative distance from the average (NDA). They show the difference between each (alternative) and average solution. The assessment of the desirability of the alternatives is carried out according to the higher values of PDA and lower values of NDA. A high value of PDA or a lower value of NDA indicates that the selection (alternative) is better than the average solution.

Suppose we have *n* alternatives and *m* criteria. The procedure of the EDAS method is as follows (Keshavarz Ghorabaee et al., 2015; Lukić, 2021, 2023):

Step 1: Selection of the most important criteria describing the alternatives.

Step 2: Formation of the decision matrix (X) as follows:

$$X = [X_{ij}]_{n\,x\,m} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nm} \end{bmatrix}, \quad (5)$$

where: *Xij* denotes the performance value of the i -th alternative about the j -th criterion.

Step 3: Determining the average solution according to all criteria as follows:

$$AV = [AV_j]_{1\,x\,m}, \quad (6)$$

where is:

$$AV_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}. \quad (7)$$

Step 4: Calculation of the positive distance from the average (*PDA*) and the negative distance from the average (*NDA*) of the matrix according to the type of criterion (benefit and costs) as follows:

$$PDA = \left[\left[PDA_{ij}\right]\right]_{n\,x\,m}, \quad (8)$$

$$NDA = \left[\left[NDA_{ij}\right]\right]_{n\,x\,m}. \quad (9)$$

If the *jth* criterion is beneficial:

$$PDA_{ij} = \frac{\max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j}, \quad (10)$$

$$NDA_{\boldsymbol{ij}} = \frac{max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j}, \quad (11)$$

and if the *jth* criterion is non-beneficial:

$$PDA_{ij} = \frac{\max\left(0, \left(AV_j - X_{ij}\right)\right)}{AV_j}, \quad (12)$$

$$NDA_{\boldsymbol{ij}} = \frac{max\left(0, \left(X_{ij} - AV_j\right)\right)}{AV_j}, \quad (13)$$

where: PDA_{ij} and $NDA_{\boldsymbol{ij}}$ denote the positive and negative distances of the *i* -th alternative from the average solution in terms of the *j* -th criterion, respectively.

Step 5: Determining the weighted sum *of PDA* and *NDA* for all alternatives as follows:

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij}; \quad (14)$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij}. \qquad (15)$$

where: w_j the weight of the j -th criterion.

Step 6: Normalization of *SP* and *SN* values for all alternatives as follows:

$$NSP_i = \frac{SP_i}{max_i(SP_i)}; \qquad (16)$$

$$NSN_i = 1 - \frac{SN_i}{max_i(SN_i)}. \qquad (17)$$

Step 7: Calculating the mean value (*AS*) for all alternatives as follows:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i), \qquad (18)$$

where is: $0 \leq AS_i \leq 1$.

Step 8: Ranking the alternatives according to the descending mean (*AS*). The alternative with the highest *AS* value is the best.

3. Results and discussion

Numerous circular economy indicators have been created (The Word Bank, OECD, Eurostat statistics, literature). They are used as criteria in multicriteria analysis. In this study, circular economy indicators from Eurostat statistics were used as criteria. Alternatives are the member states of the European Union and Serbia. Table 1 shows selected relevant criteria according to available empirical data, alternatives, and original input data.

Initial data

Table 1

		Material import dependency, 2021, Percentage	The recycling rate of municipal waste, 2021, Percentage	Generation of municipal waste per capita, 2021, Kilograms per capita	Generation of waste excluding major mineral wastes per GDP unit, 2020, Kilograms per thousand euro, chain-linked volumes (2010)	Waste generation per capita, 2020, Kilograms per capita, Hazardous and non-hazardous - Total	Material footprint, 2021, Tones per capita, Raw material consumption	Resource productivity, 2021, Euro per kilogram	Circularity rate, 2021, (%)	The overall share of energy from renewable sources, 2021, (% of gross final energy consumption)
		C1	C2	C3	C4	C5	C6	C7	C8	C9
	European Union - 27 countries (from 2020)	22.6	49.8	532	65	4,815	14,763	2.2676	11.4	21,962
A1	Belgium	72.9	55.5	755	105	5,899	12,799	3.7288	23.7	13.007
A2	Bulgaria	15.3	28.2	445	419	16,785	22,594	0.4533	4.8	19,447
A3	Czech	33.2	43.3	570	83	3,598	17,942	1.4296	11.4	17,671
A4	Denmark	37.6	57.6	769	36	3,453	26,845	2.4017	8.0	41,009
A5	Germany	39.9	69.3	651	53	4,824	16,003	3,038	12.7	19,395
A6	Estonia	29.3	30.3	395	412	12,163	29,829	0.8418	15.9	37,442
A7	Ireland	32.9	0.0	0.0	24	3,248	10,717	3.8897	1.9	12,376
A8	Greece	41.6	17.5	509	74	2,651	12,088	1.6346	3.5	22,017
A9	Spain	39.1	42.2	467	64	2,230	10,35	2.7285	6.9	20,736
A10	France	35.4	43.8	565	47	4,593	13,978	3.1579	18.7	19,204
A11	Croatia	35.5	31.4	447	88	1,483	13,866	1.2947	5.7	31,285
A12	Italy	47.3	51.9	495	74	2,942	11,989	3,537	19.0	19,158
A13	Cyprus	31.9	14.0	650	43	2,491	25,161	1.3664	2.8	19,069
A14	Latvia	31.4	44.1	461	110	1,501	19,341	1.1061	5.6	42,098
A15	Lithuania	37.9	44.3	480	105	2,396	23,079	0.9664	4.2	28,166
A16	Luxembourg	89.6	55.3	793	26	14,618	31,083	4.5864	4.1	11,730
A17	Hungary	27.9	34.9	416	91	1,759	14,896	1.1198	7.3	14,134
A18	Malta	70	13.6	611	46	6,847	12,371	2.3752	12.8	12,672
A19	Netherlands	82.1	57.8	515	64	7,175	7,484	5.2406	28.5	12,988
A20	Austria	43.3	62.5	835	52	7,728	21,488	2,475	12.8	34,573
A21	Poland	19.7	40.3	362	150	4,492	18,408	0.8539	9.1	15,613
A22	Portugal	30.2	30.4	513	78	1,612	16,945	1.3102	2.6	33,982
A23	Romania	10	11.3	302	107	7,338	31,451	0.4243	1.4	23,871
A24	Slovenia	45.3	60.8	511	69	3,576	18,673	1.7563	10.1	25,000
A25	Slovakia	45.2	48.9	497	92	2,340	13,595	1.53	8.2	17,419
A26	Finland	18.3	39.0	630	61	20,993	46,145	1.0232	1.6	42,854
A27	Sweden	22.5	39.5	418	47	14,664	27,857	1.9225	6.2	62,686
A28	Serbia	13.5	16.8	442	324	8,499	19,396	0.4015	0.0	25,255
	Statistics (N Valid 28, Missing 0)									
	I mean	38.5286	38.7321	518.0000	105.1429	6139.2143	19.5133	2.0212	8.9107	24.8163
	Median	35.4500	41.2500	503.0000	74,0000	4045.0000	18.1750	1.5823	7.1000	20.0915
	Std. Deviation	19.55368	17.64626	167.32382	103.70389	5177.28561	8.45363	1.29641	7.05761	12.09504
	Minimum	10.00	.00	.00	24.00	1483.00	7.48	.40	.00	11.73
	Maximum	89.60	69.30	835.00	419.00	20993.00	46.15	5.24	28.50	62.69

Note: Author's statistics
Source: Eurostat

The data in Table 1 provide interesting information about the circular economy of the countries of the European Union and Serbia. We will point out some of them. In 2021, the highest circular rate in the European Union was in the Netherlands (28.50%), but the lowest in Romania (1.4%). In the leading countries of the European Union, the circular rate is Germany (12.7%), France (18.7%) and Italy (19.0%). It is therefore the largest in Italy. The circular rate in Slovenia (10.1%) is higher than in Croatia (5.7%). (There is no data for Serbia.)

The productivity of the resource in 2021 in the European Union was the highest in the Netherlands (5.24 Euro per kilogram) and the lowest in Romania (0.4243 Euro per kilogram). In the leading countries of the European Union, the productivity of the resource is Germany (3,038 Euros per kilogram), France (3,1579 Euros per kilogram), and Italy (3,537 Euros per kilogram). So the poster is in Italy. The productivity of the resource in Croatia is (1.2947 Euro per kilogram), in Slovenia, it is (1.7563 Euro per kilogram) and in Serbia, it is (0.4015 Euro per kilogram). Compared to Croatia and Slovenia, resource productivity in Serbia is worse.

In 2021, the municipal waste recycling rate in the European Union was the highest in Germany (69.30%), but the lowest in Romania (11.3%). The municipal waste recycling rate in Croatia is 31.4%, Slovenia is 60.8% and Serbia is 16.8%. In Serbia, the rate of municipal waste recycling is significantly lower than in Croatia and Slovenia. (There is no data for Ireland.)

The use of energy from renewable sources mitigates the negative effects of energy waste on the environment. Sweden (62.69%) has the largest use of energy from renewable sources within the European Union. The lowest is in Luxembourg (11.73%). The use of energy from renewable sources in Serbia (25.25%) is lower than in Croatia (31.28%), but slightly higher than in Slovenia (25.00%).

The weighting coefficients of the criterion were determined using the AHP method. They are shown in Table 2. (In this study, the calculations are the author's.)

Weight coefficients of the criterion

Table 2

		1	2	3	4	5	6	7	8	9	WEIGHTS	
		C1	C2	C3	C4	C5	C6	C7	C8	C9		
1	C1	1.00	1.00	1.50	2.00	1.00	1.00	2.00	2.00	3.00	**0.1520**	
2	C2	1.00	1.00	2.00	2.50	2.00	1.00	1.00	1.00	4.00	**0.1590**	
3	C3	0.67	0.50	1.00	2.00	2.00	2.00	1.00	1.00	5.00	**0.1399**	
4	C4	0.50	0.40	0.50	1.00	1.00	2.00	2.00	1.00	4.00	**0.1133**	
5	C5	1.00	0.50	0.50	1.00	1.00	1.00	1.00	1.00	3.00	**0.0968**	
6	C6	1.00	1.00	0.50	0.50	1.00	1.00	1.00	2.00	3.00	**0.1086**	
7	C7	0.50	1.00	1.00	0.50	1.00	1.00	1.00	2.00	2.00	**0.1042**	
8	C8	0.50	1.00	1.00	1.00	1.00	0.50	0.50	1.00	2.00	**0.0896**	
9	C9	0.33	0.25	0.20	0.25	0.33	0.33	0.50	0.50	1.00	**0.0366**	
											1.0000	
											Consistency Ratio	**0.0464**

The most characteristic criterion in this particular case is therefore C2 - Recycling rate of municipal waste. The target performances of the circular economy can be achieved to some extent by adequate management of municipal waste recycling.

The calculation procedure and the results of the EDAS method are shown in Table 3 and Figure 1.

Calculation procedure and results of the EDAS method

Table 3

		weights of criteria	0.152	0.159	0.1399	0.1133	0.0968	0.1086	0.1042	0.0896	0.0366
		kind of criteria	1	1	1	1	1	1	1	1	1
			C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
		A1	72.9	55.5	755	105	5,899	12,799	3.7288	23.7	13.007
		A2	15.3	28.2	445	419	16,785	22,594	0.4533	4.8	19,447
		A3	33.2	43.3	570	83	3,598	17,942	1.4296	11.4	17,671
		A4	37.6	57.6	769	36	3,453	26,845	2.4017	8	41,009
		A5	39.9	69.3	651	53	4,824	16,003	3,038	12.7	19,395
Initial Matrix		**A6**	29.3	30.3	395	412	12,163	29,829	0.8418	15.9	37,442
		A7	32.9	0	0	24	3,248	10,717	3.8897	1.9	12,376
		A8	41.6	17.5	509	74	2,651	12,088	1.6346	3.5	22,017
		A9	39.1	42.2	467	64	2,230	10,35	2.7285	6.9	20,736
		A10	35.4	43.8	565	47	4,593	13,978	3.1579	18.7	19,204
		A11	35.5	31.4	447	88	1,483	13,866	1.2947	5.7	31,285
		A12	47.3	51.9	495	74	2,942	11,989	3,537	19	19,158
		A13	31.9	14	650	43	2,491	25,161	1.3664	2.8	19,069
		A14	31.4	44.1	461	110	1,501	19,341	1.1061	5.6	42,098
		A15	37.9	44.3	480	105	2,396	23,079	0.9664	4.2	28,166
		A16	89.6	55.3	793	26	14,618	31,083	4.5864	4.1	11.73
		A17	27.9	34.9	416	91	1,759	14,896	1.1198	7.3	14,134
		A18	70	13.6	611	46	6,847	12,371	2.3752	12.8	12,672
		A19	82.1	57.8	515	64	7,175	7,484	5.2406	28.5	12,988
		A20	43.3	62.5	835	52	7,728	21,488	2,475	12.8	34,573
		A21	19.7	40.3	362	150	4,492	18,408	0.8539	9.1	15,613
		A22	30.2	30.4	513	78	1,612	16,945	1.3102	2.6	33,982
		A23	10	11.3	302	107	7,338	31,451	0.4243	1.4	23,871
		A24	45.3	60.8	511	69	3,576	18,673	1.7563	10.1	25
		A25	45.2	48.9	497	92	2,340	13,595	1.53	8.2	17,419
		A26	18.3	39	630	61	20,993	46,145	1.0232	1.6	42,854
		A27	22.5	39.5	418	47	14,664	27,857	1.9225	6.2	62,686
		A28	13.5	16.8	442	324	8,499	19,396	0.4015	0	25,255
		Average Solution	38.5286	38.7321	518.0000	105.1429	6139.2143	19.5133	2.0212	8.9107	24.8163

		weights of criteria	0.152	0.159	0.1399	0.1133	0.0968	0.1086	0.1042	0.0896	0.0366
			C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
		A1	0.8921	0.4329	0.4575	0.0000	0.0000	0.0000	0.8449	1.6597	0.0000
		A2	0.0000	0.0000	0.0000	2.9851	1.7341	0.1579	0.0000	0.0000	0.0000
		A3	0.0000	0.1179	0.1004	0.0000	0.0000	0.0000	0.0000	0.2794	0.0000
		A4	0.0000	0.4871	0.4846	0.0000	0.0000	0.3757	0.1883	0.0000	0.6525
		A5	0.0356	0.7892	0.2568	0.0000	0.0000	0.0000	0.5031	0.4253	0.0000
Do+		**A6**	0.0000	0.0000	0.0000	2.9185	0.9812	0.5286	0.0000	0.7844	0.5088
		A7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9245	0.0000	0.0000
		A8	0.0797	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A9	0.0148	0.0895	0.0000	0.0000	0.0000	0.0000	0.3499	0.0000	0.0000
		A10	0.0000	0.1308	0.0907	0.0000	0.0000	0.0000	0.5624	1.0986	0.0000
		A11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2607
		A12	0.2277	0.3400	0.0000	0.0000	0.0000	0.0000	0.7500	1.1323	0.0000
		A13	0.0000	0.0000	0.2548	0.0000	0.0000	0.2894	0.0000	0.0000	0.0000
		A14	0.0000	0.1386	0.0000	0.0462	0.0000	0.0000	0.0000	0.0000	0.6964
		A15	0.0000	0.1438	0.0000	0.0000	0.0000	0.1827	0.0000	0.0000	0.1350
		A16	1.3255	0.4278	0.5309	0.0000	1.3811	0.5929	1.2692	0.0000	0.0000
		A17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A18	0.8168	0.0000	0.1795	0.0000	0.1153	0.0000	0.1751	0.4365	0.0000
		A19	1.1309	0.4923	0.0000	0.0000	0.1687	0.0000	1.5928	2.1984	0.0000
		A20	0.1238	0.6136	0.6120	0.0000	0.2588	0.1012	0.2245	0.4365	0.3932
		A21	0.0000	0.0405	0.0000	0.4266	0.0000	0.0000	0.0000	0.0212	0.0000
		A22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3693
		A23	0.0000	0.0000	0.0000	0.0177	0.1953	0.6118	0.0000	0.0000	0.0000
		A24	0.1758	0.5698	0.0000	0.0000	0.0000	0.0000	0.0000	0.1335	0.0074
		A25	0.1732	0.2625	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A26	0.0000	0.0069	0.2162	0.0000	2.4195	1.3648	0.0000	0.0000	0.7268
		A27	0.0000	0.0198	0.0000	0.0000	1.3886	0.4276	0.0000	0.0000	1.5260
		A28	0.0000	0.0000	0.0000	2.0815	0.3844	0.0000	0.0000	0.0000	0.0177

		weights of criteria	0.152	0.159	0.1399	0.1133	0.0968	0.1086	0.1042	0.0896	0.0366
			C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
		A1	0.0000	0.0000	0.0000	0.0014	0.0391	0.3441	0.0000	0.0000	0.4759
		A2	0.6029	0.2719	0.1409	0.0000	0.0000	0.0000	0.7757	0.4613	0.2164
		A3	0.1383	0.0000	0.0000	0.2106	0.4139	0.0805	0.2927	0.0000	0.2879
		A4	0.0241	0.0000	0.0000	0.6576	0.4376	0.0000	0.0000	0.1022	0.0000

		A5	0.0000	0.0000	0.0000	0.4959	0.2142	0.1799	0.0000	0.0000	0.2185
Do-		**A6**	0.2395	0.2177	0.2375	0.0000	0.0000	0.0000	0.5835	0.0000	0.0000
		A7	0.1461	0.0000	0.0000	0.7717	0.4709	0.4508	0.0000	0.7868	0.5013
		A8	0.0000	0.5482	0.0174	0.2962	0.5682	0.3805	0.1913	0.6072	0.1128
		A9	0.0000	0.0000	0.0985	0.3913	0.6368	0.4696	0.0000	0.2257	0.1644
		A10	0.0812	0.0000	0.0000	0.5530	0.2519	0.2837	0.0000	0.0000	0.2262
		A11	0.0786	0.1893	0.1371	0.1630	0.7584	0.2894	0.3594	0.3603	0.0000
		A12	0.0000	0.0000	0.0444	0.2962	0.5208	0.3856	0.0000	0.0000	0.2280
		A13	0.1720	0.6385	0.0000	0.5910	0.5942	0.0000	0.3240	0.6858	0.2316
		A14	0.1850	0.0000	0.1100	0.0000	0.7555	0.0088	0.4527	0.3715	0.0000
		A15	0.0163	0.0000	0.0734	0.0014	0.6097	0.0000	0.5219	0.5287	0.0000
		A16	0.0000	0.0000	0.0000	0.7527	0.0000	0.0000	0.0000	0.5399	0.5273
		A17	0.2759	0.0989	0.1969	0.1345	0.7135	0.2366	0.4460	0.1808	0.4305
		A18	0.0000	0.6489	0.0000	0.5625	0.0000	0.3660	0.0000	0.0000	0.4894
		A19	0.0000	0.0000	0.0058	0.3913	0.0000	0.6165	0.0000	0.0000	0.4766
		A20	0.0000	0.0000	0.0000	0.5054	0.0000	0.0000	0.0000	0.0000	0.0000
		A21	0.4887	0.0000	0.3012	0.0000	0.2683	0.0566	0.5775	0.0000	0.3709
		A22	0.2162	0.2151	0.0097	0.2582	0.7374	0.1316	0.3518	0.7082	0.0000
		A23	0.7405	0.7083	0.4170	0.0000	0.0000	0.0000	0.7901	0.8429	0.0381
		A24	0.0000	0.0000	0.0135	0.3438	0.4175	0.0431	0.1311	0.0000	0.0000
		A25	0.0000	0.0000	0.0405	0.1250	0.6188	0.3033	0.2430	0.0798	0.2981
		A26	0.5250	0.0000	0.0000	0.4198	0.0000	0.0000	0.4938	0.8204	0.0000
		A27	0.4160	0.0000	0.1931	0.5530	0.0000	0.0000	0.0488	0.3042	0.0000
		A28	0.6496	0.5663	0.1467	0.0000	0.0000	0.0060	0.8014	0.0000	0.0000

			C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
		A1	0.1356	0.0688	0.0640	0.0000	0.0000	0.0000	0.0880	0.1487	0.0000
		A2	0.0000	0.0000	0.0000	0.3382	0.1679	0.0171	0.0000	0.0000	0.0000
		A3	0.0000	0.0188	0.0140	0.0000	0.0000	0.0000	0.0000	0.0250	0.0000
		A4	0.0000	0.0775	0.0678	0.0000	0.0000	0.0408	0.0196	0.0000	0.0239
		A5	0.0054	0.1255	0.0359	0.0000	0.0000	0.0000	0.0524	0.0381	0.0000
PDA		**A6**	0.0000	0.0000	0.0000	0.3307	0.0950	0.0574	0.0000	0.0703	0.0186
		A7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0963	0.0000	0.0000
		A8	0.0121	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A9	0.0023	0.0142	0.0000	0.0000	0.0000	0.0000	0.0365	0.0000	0.0000
		A10	0.0000	0.0208	0.0127	0.0000	0.0000	0.0000	0.0586	0.0984	0.0000
		A11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0095
		A12	0.0346	0.0541	0.0000	0.0000	0.0000	0.0000	0.0781	0.1015	0.0000

			C1	C2	C3	C4	C5	C6	C7	C8	C9
		A13	0.0000	0.0000	0.0357	0.0000	0.0000	0.0314	0.0000	0.0000	0.0000
		A14	0.0000	0.0220	0.0000	0.0052	0.0000	0.0000	0.0000	0.0000	0.0255
		A15	0.0000	0.0229	0.0000	0.0000	0.0000	0.0198	0.0000	0.0000	0.0049
		A16	0.2015	0.0680	0.0743	0.0000	0.1337	0.0644	0.1322	0.0000	0.0000
		A17	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A18	0.1242	0.0000	0.0251	0.0000	0.0112	0.0000	0.0183	0.0391	0.0000
		A19	0.1719	0.0783	0.0000	0.0000	0.0163	0.0000	0.1660	0.1970	0.0000
		A20	0.0188	0.0976	0.0856	0.0000	0.0251	0.0110	0.0234	0.0391	0.0144
		A21	0.0000	0.0064	0.0000	0.0483	0.0000	0.0000	0.0000	0.0019	0.0000
		A22	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0135
		A23	0.0000	0.0000	0.0000	0.0020	0.0189	0.0664	0.0000	0.0000	0.0000
		A24	0.0267	0.0906	0.0000	0.0000	0.0000	0.0000	0.0000	0.0120	0.0003
		A25	0.0263	0.0417	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		A26	0.0000	0.0011	0.0302	0.0000	0.2342	0.1482	0.0000	0.0000	0.0266
		A27	0.0000	0.0032	0.0000	0.0000	0.1344	0.0464	0.0000	0.0000	0.0559
		A28	0.0000	0.0000	0.0000	0.2358	0.0372	0.0000	0.0000	0.0000	0.0006

	Qi+	Si+
A1	0.5052	0.7494
A2	0.5232	0.7762
A3	0.0578	0.0858
A4	0.2295	0.3405
A5	0.2573	0.3818
A6	0.5720	0.8485
A7	0.0963	0.1429
A8	0.0121	0.0180
A9	0.0530	0.0786
A10	0.1905	0.2827
A11	0.0095	0.0142
A12	0.2683	0.3980
A13	0.0671	0.0995
A14	0.0528	0.0783
A15	0.0476	0.0707
A16	0.6741	1.0000
A17	0.0000	0.0000
A18	0.2178	0.3231
A19	0.6295	0.9338
A20	0.3149	0.4672
A21	0.0567	0.0841
A22	0.0135	0.0201
A23	0.0873	0.1296

	Qi+	Si+
A24	0.1295	0.1922
A25	0.0681	0.1010
A26	0.4404	0.6533
A27	0.2399	0.3558
A28	0.2737	0.4060
MAX	0.6741	

			C1	C2	C3	C4	C5	C6	C7	C8	C9
		A1	0.0000	0.0000	0.0000	0.0002	0.0038	0.0374	0.0000	0.0000	0.0174
		A2	0.0916	0.0432	0.0197	0.0000	0.0000	0.0000	0.0808	0.0413	0.0079
		A3	0.0210	0.0000	0.0000	0.0239	0.0401	0.0087	0.0305	0.0000	0.0105
		A4	0.0037	0.0000	0.0000	0.0745	0.0424	0.0000	0.0000	0.0092	0.0000
		A5	0.0000	0.0000	0.0000	0.0562	0.0207	0.0195	0.0000	0.0000	0.0080
NDA		**A6**	0.0364	0.0346	0.0332	0.0000	0.0000	0.0000	0.0608	0.0000	0.0000
		A7	0.0222	0.0000	0.0000	0.0874	0.0456	0.0490	0.0000	0.0705	0.0183
		A8	0.0000	0.0872	0.0024	0.0336	0.0550	0.0413	0.0199	0.0544	0.0041
		A9	0.0000	0.0000	0.0138	0.0443	0.0616	0.0510	0.0000	0.0202	0.0060
		A10	0.0123	0.0000	0.0000	0.0627	0.0244	0.0308	0.0000	0.0000	0.0083
		A11	0.0119	0.0301	0.0192	0.0185	0.0734	0.0314	0.0375	0.0323	0.0000
		A12	0.0000	0.0000	0.0062	0.0336	0.0504	0.0419	0.0000	0.0000	0.0083
		A13	0.0262	0.1015	0.0000	0.0670	0.0575	0.0000	0.0338	0.0614	0.0085
		A14	0.0281	0.0000	0.0154	0.0000	0.0731	0.0010	0.0472	0.0333	0.0000
		A15	0.0025	0.0000	0.0103	0.0002	0.0590	0.0000	0.0544	0.0474	0.0000
		A16	0.0000	0.0000	0.0000	0.0853	0.0000	0.0000	0.0000	0.0484	0.0193
		A17	0.0419	0.0157	0.0275	0.0152	0.0691	0.0257	0.0465	0.0162	0.0158
		A18	0.0000	0.1032	0.0000	0.0637	0.0000	0.0398	0.0000	0.0000	0.0179
		A19	0.0000	0.0000	0.0008	0.0443	0.0000	0.0669	0.0000	0.0000	0.0174
		A20	0.0000	0.0000	0.0000	0.0573	0.0000	0.0000	0.0000	0.0000	0.0000
		A21	0.0743	0.0000	0.0421	0.0000	0.0260	0.0062	0.0602	0.0000	0.0136
		A22	0.0329	0.0342	0.0014	0.0292	0.0714	0.0143	0.0367	0.0635	0.0000
		A23	0.1125	0.1126	0.0583	0.0000	0.0000	0.0000	0.0823	0.0755	0.0014
		A24	0.0000	0.0000	0.0019	0.0389	0.0404	0.0047	0.0137	0.0000	0.0000
		A25	0.0000	0.0000	0.0057	0.0142	0.0599	0.0329	0.0253	0.0071	0.0109
		A26	0.0798	0.0000	0.0000	0.0476	0.0000	0.0000	0.0515	0.0735	0.0000
		A27	0.0632	0.0000	0.0270	0.0627	0.0000	0.0000	0.0051	0.0273	0.0000
		A28	0.0987	0.0900	0.0205	0.0000	0.0000	0.0007	0.0835	0.0000	0.0000

	Qi-	Si-
A1	0.0587	0.8674
A2	0.2847	0.3570
A3	0.1347	0.6957
A4	0.1297	0.7071
A5	0.1045	0.7641
A6	0.1650	0.6272
A7	0.2930	0.3381
A8	0.2979	0.3271
A9	0.1970	0.5551
A10	0.1385	0.6873
A11	0.2543	0.4257
A12	0.1404	0.6829
A13	0.3558	0.1963
A14	0.1981	0.5526
A15	0.1737	0.6078
A16	0.1530	0.6545
A17	0.2736	0.3820
A18	0.2246	0.4928
A19	0.1295	0.7074
A20	0.0573	0.8707
A21	0.2223	0.4979
A22	0.2834	0.3598
A23	0.4427	0.0000
A24	0.0996	0.7751
A25	0.1561	0.6475
A26	0.2523	0.4301
A27	0.1852	0.5816
A28	0.2935	0.3372
MAX	0.4427	

		Si	Si	RANKING
Belgium	A1	0.808	0.808	3
Bulgaria	A2	0.567	0.567	7
Czechia	A3	0.391	0.391	15
Denmark	A4	0.524	0.524	10
Germany	A5	0.573	0.573	6
Estonia	A6	0.738	0.738	4
Ireland	A7	0.241	0.241	22
Greece	A8	0.173	0.173	26
Spain	A9	0.317	0.317	19
France	A10	0.485	0.485	11
Croatia	A11	0.220	0.220	23
Italy	A12	0.540	0.540	9
Cyprus	A13	0.148	0.148	27
Latvia	A14	0.315	0.315	20
Lithuania	A15	0.339	0.339	18
Luxembourg	A16	0.827	0.827	1
Hungary	A17	0.191	0.191	24
Malta	A18	0.408	0.408	14
Netherlands	A19	0.821	0.821	2

		Si	Si	RANKING
Austria	A20	0.669	0.669	5
Poland	A21	0.291	0.291	21
Portugal	A22	0.190	0.190	25
Romania	A23	0.065	0.065	28
Slovenia	A24	0.484	0.484	12
Slovakia	A25	0.374	0.374	16
Finland	A26	0.542	0.542	8
Sweden	A27	0.469	0.469	13
Serbia	A28	0.372	0.372	17

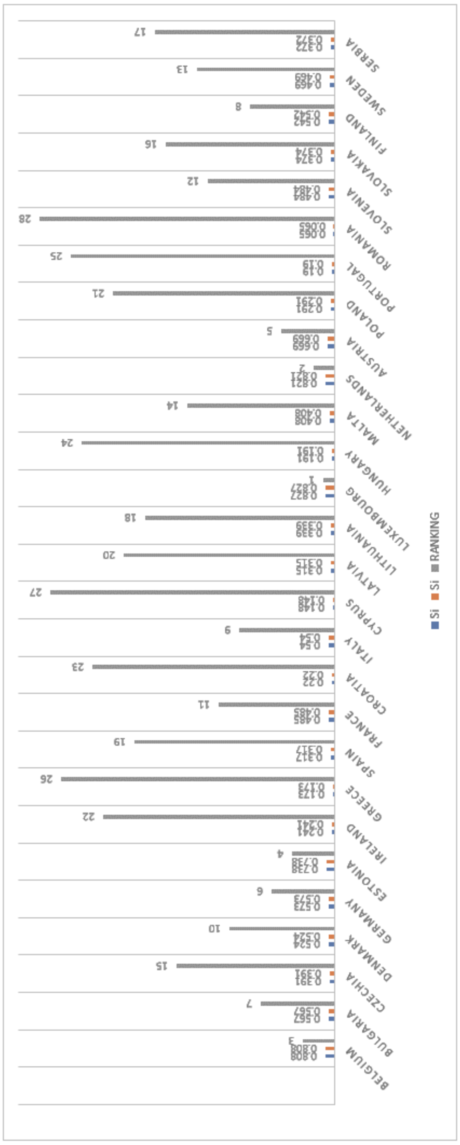

Figure 1. Ranking
Source: Author's picture

The research in this study showed that the top five countries in terms of circular economy performance are in order: Luxembourg, the Netherlands, Belgium, Estonia, and Austria. The worst performances of the circular economy are in Romania. The positioning of the leading countries of the European Union is as follows: Germany is in sixth place, France is in eleventh place and Italy is in ninth place. The positioning is satisfactory.

According to the performance of the circular economy, Serbia is positioned in seventeenth place. Compared to the leading countries of the European Union, it is positioned worse. It is better positioned than Croatia (twenty-third place). Compared to Slovenia (twelfth place), it is positioned worse.

To improve the performance of the circular economy, it is necessary, in principle, to manage dependence on the import of materials, municipal waste, waste, renewable energy, and other relevant factors as efficiently as possible. In this sense, it is necessary to define a strategy and an action plan to achieve the expected value of the key parameters of the circular economy. The application of the circular economy principle contributes to the preservation of the environment.

4. Conclusion

The results of the research in this study showed that the top five countries in terms of circular economy performance are in order: Luxembourg, the Netherlands, Belgium, Estonia, and Austria. The worst performances of the circular economy are in Romania. The positioning of the leading countries of the European Union is as follows: Germany is in sixth place, France is in eleventh place and Italy is in ninth place. The positioning is satisfactory.

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