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Considerations regarding similarities and disparities of waste generation and treatment in the European Union

Marian Zaharia[1,*], **Rodica-Manuela Gogonea**[2]

[1] Petroleum-Gas University of Ploiesti, 39 Bucharest Avenue, 100680 Ploiesti, Romania
[2] Bucharest University of Economic Studies, 15-17 Dorobanti St., Sector 1, 010552 Bucharest, Romania

marianzaharia53@gmail.com (M.Z.); manuela.gogonea@gmail.com (R.M.G.)

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ABSTRACT: In the development of today's society, protecting the environment is an essential element for a sustainable economy. A priority place in the activity of protecting the environment belongs to the waste reduction process, which represents the major, permanent and sustained concern worldwide. In this context, the research aims, on the one hand, to highlight the evolution of waste generation and treatment in the period 2004-2020 for the EU member states, and on the other hand, to identify the similarities and disparities between these countries at the level of 2020. Time series analysis and the cluster analysis were carried out on the basis of 12 variables selected for the study. The obtained results highlight, on the one hand, the existence of a process of reducing the quantity of waste per capita, as well as the increase in the performances of the member states regarding their recovery and recycling, and on the other hand, it highlighted the existence of significant disparities between the member states regarding more chosen waste generation, which means that there is still a lot to be done for an efficient management of this process, and for achieving the objectives set at the level of the European Union.

KEYWORDS: environment, waste generation, waste treatment, cluster analysis, EU

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1. INTRODUCTION

Ensuring a sustainable future, both at European and global level, requires paying a lot of attention to the problem of waste. First of all, it is necessary to reduce the quantity of waste, both in the ensemble and per inhabitant, a necessity highlighted since the 80s of the last century (Luttrell, 1989; Peretz et al., 1997) and becoming a first necessity in the last decade. For this purpose, both waste reduction in production processes (Bait, et al. 2020) and food waste (Jang & Lee, 2022) are required.

At the same time as the actions to reduce waste generation, when prevention is not possible, it is necessary to reuse, recycle and recover them (Năstase, 2022). For this, it is necessary to implement and develop an effective management system for them (Amasuomo & Baird, 2016; De-La-Torre-Jave et al., 2020), so as to ensure the reuse and recycling of a large percentage of the produced waste (Tocan, 2018).

The connection of these two directions of action led to the emergence of two concepts, which have become paradigms of the sustainable economy. A first paradigm is the "circular economy", which replaces the old linear concept of production-consumption-waste (Steffen et al., 2015), and which aims to reintroduce waste into the economic circuit (Tamasiga et al., 2022) and maintain the added value of products as long as possible, both to improve quality environment, as well as for waste disposal (Stankevičius et al., 2020). A second paradigm is "Zero Waste" (Awogbemi, Kallon, & Bello, 2022). This

* Corresponding author: marianzaharia53@gmail.com ; Tel.: +40 744 654 830

requires awareness and the creation of a positive attitude towards waste disposal (Zaman & Lehmann, 2011; Watson, 2020)),

Under the imperative of sustainable development, the reduction of waste generation, as well as the identification of ways to reuse and recycle them, towards a circular economy, was and is constantly in the attention of the European Commission and all the bodies of the European Union.Thus, at the level of the European Union, since 2008, through Directive 98/EC of the European Parliament and of the Council (Directive 2008/98/EC, 2008), in addition to establishing a hierarchy of waste, it highlighted the need to establish national waste management plans, as well as programs to prevent their generation. Amended by EU Directive 825 from 2018 (Directive 2018/851/EC, 2018), it strengthens the waste prevention rules and sets as objectives for the recycling of municipal waste, the minimum shares of 55% until 2025, 60% until 2030, and 65% until 2035.

In this context, the research carried out aimed at identifying the similarities and disparities between the member states of the European Union regarding both the generation and recovery of waste. Taking into account these objectives and the fact that, in the specialized literature, one of the most used ways of analyzing the positioning of states regarding the issue of waste generation and recovery is the cluster methodology (Amicarelli et al., 2021; Pocol et al., 2020), in the analyzes performed, we also used this method.

2. DATA SERIES AND METHODOLOGY

In accordance with the objectives of the research undertaken, two sets of main data series were selected. The first of these concerns the generation of hazardous and non-hazardous waste and contains the data series calculated at the annual level, expressed in kilograms per capita, regarding the generation of waste, by waste category and NACE Rev. 2 activity (WASGEN) (Zaharia et al., 2017). The second group of data refers to waste management operations and contains the series of data on waste treatment and recovery (WASTRT) (Eurostat, 2023 b).

Starting from these data series, the research sought to highlight the evolution of waste generation and treatment at the level of the current member states of the European Union, in the period 2004 - 2020, as well as the identification of similarities and disparities between the member states, from this point of view, at the level 2020 (the last year for which there are official data). Two cluster analyzes were performed, one on generation and the second on waste disposal. The variables included in the analysis and their meanings are presented in Table 1.

Table 1. The list of variables, by waste category, included in the analysis.

Variables	Significations of variables	Types
ANA	All NACE activities plus households	Generation
AFF	Agriculture, forestry and fishing	
MQR	Mining and quarrying	
MNF	Manufacturing	
EGS	Electricity, gas, steam and air conditioning supply	
WSR	Water supply; sewerage, waste management and remediation activities	
CNS	Construction	
HSH	Households	
WTR	Waste recovery (total)	Treatment
RER	Recovery - energy recovery	
RBF	Recovery - backfilling	
RCY	Recovery - recycling	

The main analysis method used to analyse the disparities and similarities between the 27 states was the Hierarchical Clustering method. For this, two shape matrices were generated:

$$Y = \left\| y_{ij} \right\|_{i=\overline{1,n}, j=\overline{1,m}} \tag{1}$$

In (1), $n$is the number of states subject to the analysis (n=27, both in the case of waste generation and treatment) and $m$is the number of variables taken into account for determining clusters

Among the variables included in Table 1, ANA (global variable in the analysis of waste generation) and ETR (global variable, in the analysis of waste treatment) were not included in the generation of clusters. Under these conditions, initially, $m=7$ for waste generation, and $m=3$ for waste treatment. On the elements of Y matrix, we applied Z transformation:

$$z_{ij} = \frac{y_{ij} - \bar{y}_j}{\sigma_j}, \quad where \quad \bar{y}_j = \frac{\sum_{i=1}^{n} y_{ij}}{n}, \quad \sigma_j = \sqrt{\frac{\sum_{i=1}^{n} \left(y_{ij} - \bar{y}_j\right)^2}{n-1}} \tag{2}$$

Proximity Matrix (3) was generated using, as a measure, the square of the Euclidean distance:

$$W = \left\| w_{ij} \right\|_{i=\overline{1,n}, j=\overline{1,m}}, \quad w_{ij} = \sum_{i=1}^{n} \left(z_{ik} - z_{ij}\right)^2, \; j = \overline{1,m}, \; k = \overline{1,m} \; j \neq i, \; k \neq i, \; w_{ii} = 0 \tag{3}$$

For distance between clusters determination, Ward's method was used. Being two clusters A and B and x_i an item (a cluster or an individual element, not included yet in a cluster) to include in a cluster, the distance between cluster A and cluster B is defined as follows:

$$\Delta(A,B) = \sum_{i \in A \cup B} \left\| x_i - m_{A \cup B} \right\|^2 - \sum_{i \in A} \left\| x_i - m_A \right\|^2 - \sum_{i \in B} \left\| x_i - m_{\mathbf{B}} \right\|^2 - \frac{n_{A \cap B}}{n_{A \cup B}} \left\| m_A - m_B \right\|^2 \tag{4}$$

In (4), $m_i$is the centroid and n_i is the number of elements from clusters i.

Welch' Robust Tests of Equality of Means was used to test the statistical significance of the averages of the variables at the cluster level, with the following assumptions:

H_0: there is no significant difference between the means of variables at clusters level (the analysed variable's belonging to the clusters is not statistically significant).

$$\exists \; m_i = m_j, \quad i = \overline{1,r}, \; j = \overline{1,r}, \; i \neq j \tag{5}$$

H_1: there is a significant difference between the means of the analysed variables.

$$m_i \neq m_j, \quad \forall \; i = \overline{1,r}, \; j = \overline{1,r}, \; i \neq j \tag{6}$$

The condition for accepting the null hypothesis (H_0) is:

$$F_{stat} < F_{\alpha, df_1, df_2} \quad equivalent\,to \quad Sig.F > \alpha \tag{7}$$

In (7), df1 and df2 represent the degrees of freedom of F distributed, and α is the significance threshold. A confidence level of 95%, corresponding to the significance threshold α=0.05, was used to test the statistical hypotheses. The tools used were SPSS and Excel with Real Statistical Resource Pack (Zaiontz, 2023).

3. AN OVERVIEW

The evolutions of the total quantities of waste, including All NACE activities plus households (ANA), generated at the level of the European Union states, are characterized by a general downward trend. Thus, per capita, from a maximum of 26,050 kilograms, recorded in 2004, in Bulgaria, the quantities generated fluctuated with relatively small amplitudes on a downward trend, reaching 20,993 kilograms per capita in 2020, a value recorded in Finland. It is a significant reduction, of 5,057 kilograms per capita, representing a decrease of 19.41 percentage points.

It should be noted that, in the same period, due to economic and social development, the minimum level of the quantity of waste generated increased slightly, from 556 kilograms per capita, a value recorded in 2004, in Latvia, to 1,483 kilograms per capita, a value recorded in 2020, in Croatia.

These evolutions led to the reduction of the gap between the member states regarding the generation of waste, from 25,454 kilograms per capita in 2004 to 19,510 kilograms per capita in 2020, a decrease of 5,984 kilograms per capita, which represents a reduction of 23.47%.In this context, in Romania, it should be emphasized that, although during the entire analyzed period, per capita, the quantity of waste generated, although it was above the EU27 average, decreased significantly, from 17,215 kilograms per capita, in 2004 , to 7,338 kilograms per capita, which represents a reduction of 58.42%.

Regarding the categories of waste, the main characteristics of this where determined (Zaiontz, 2023). The results obtained, at the level of 2020, are presented in Table 2. Analyzing the Std. Dev., compared to Mean, it results that the averages, on a general level, are not significant, which leads to the need for a clustering based on significance criteria.

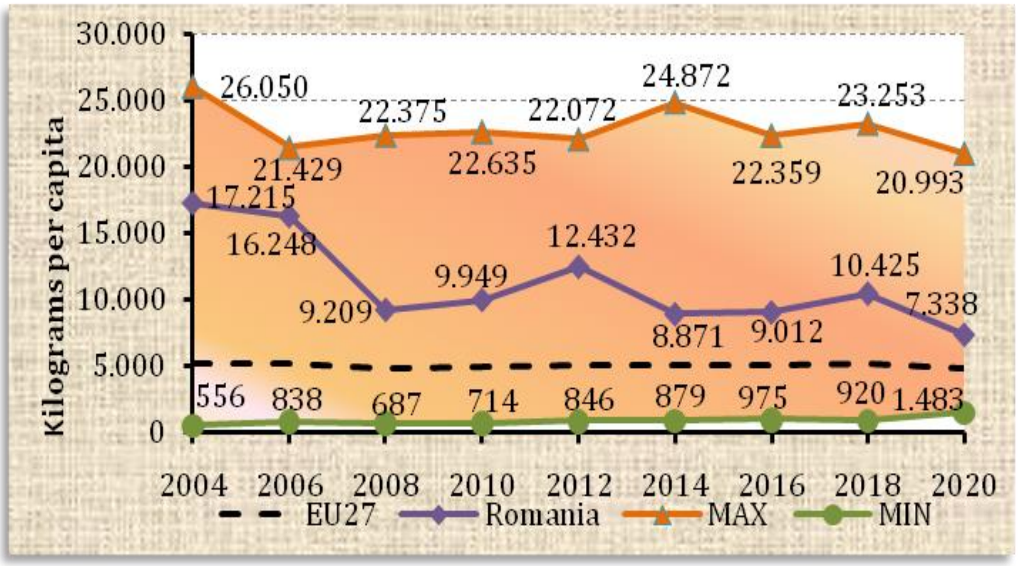

Figure 1. The waste evolution of All NACE activities plus households in EU 27.
Source: Prepared by the authors based on WASGEN data series.

This conclusion is also underlined by the characteristic values of the shapes of the distributions (Kurtosis and Skewness) which indicate that, except to some extent MSM, the distributions of the variables are not normal. On the other hand, the very large amplitude of the range of variation of the MQR (Mining and quarrying) values leads to the conclusion of very large differences between the analyzed states. However, taking into account that these differences are generated by objective conditions, namely by the existence and development of these industries in the analyzed states, the MQR variable will not be included in the cluster analysis regarding waste generation by category.

Table 2. The main characteristics of the variables corresponding to the categories of generated waste.

	AFE	MQR	MNF	EGS	WSR	CNS	HSH
Mean	62.93	1,938.15	629.93	282.22	440.11	1,882.96	431.07
Std. Error	12.20	848.92	114.18	156.96	63.92	492.27	17.68
Std. Dev.	63.39	4,411.12	593.29	815.58	332.16	2,557.90	91.86
Kurtosis	4.04	4.77	9.49	24.12	12.70	9.06	-0.08
Skewness	1.77	2.43	2.77	4.82	3.06	2.74	-0.26
Range	281.00	15,768.00	2,931.00	4,262.00	1,718.00	11,945.00	399.00
Minimum	0.00	1.00	59.00	0.00	135.00	63.00	221.00
Maximum	281.00	15,769.00	2,990.00	4,262.00	1,853.00	12,008.00	620.00

Source: calculated by authors using SPSS

Parallel to the measures taken to reduce the quantity of waste generated, with the effects highlighted above, more and more attention has been paid to waste management, especially waste recovery through actions aimed at energy recovery, backfilling and recycling.

The results obtained in the last decade are relatively positive, but very different from one state to another. The available data series highlighted three peculiarities. Thus, the quantities of waste recovered in Luxembourg and Finland were more than two and three times higher than the maximums recorded in the other 25 member states. However, these quantities decreased, from 24,136 kilograms per capita, a value recorded in 2010, in Luxembourg, and from 11,392 kilograms per capita, in Finland, reaching in 2020, to 17,839 kilograms per capita, in Luxembourg, and 4,017 kilograms per capita in Finland. At the same time, in Estonia, the quantity of waste recovered increased from 6,403 kilograms per capita in 2010 to 11,614 kilograms per capita in 2020.

In the case of the other 24 member states (Figure 2), in the last decade, the largest quantities of recovered waste were recorded in the Netherlands, between 2010 and 2018 (from 6,978 kilograms per capita in 2010 to 7,330 kilograms per capita, in 2018), as well as in Belgium, in 2020.

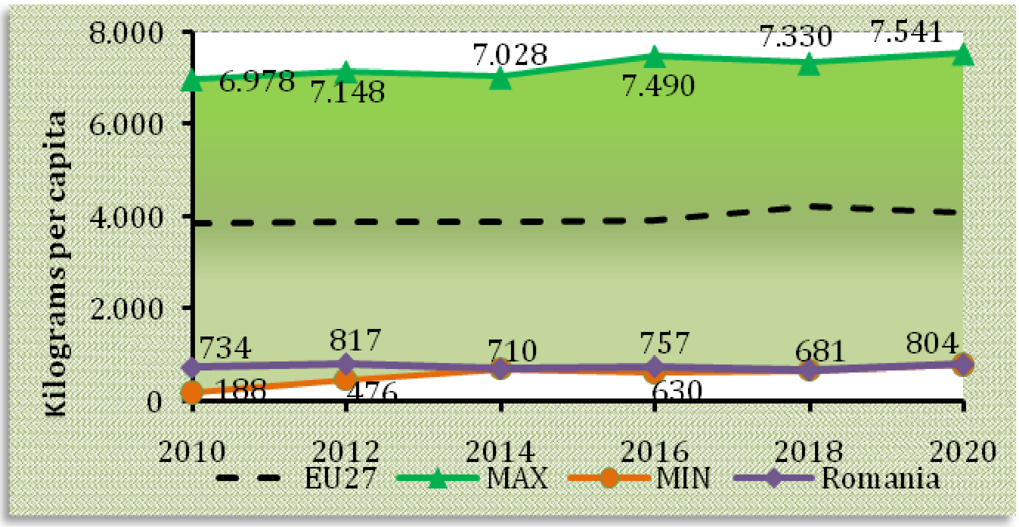

Figure 2. The waste evolution of All NACE activities plus households in EU 27.
Source: Prepared by the authors based on WASREC data series.

At the opposite pole, the lowest quantities of recovered waste were recorded in Croatia, between 2010 and 2012 (188 and 476 kilograms per capita), and, with the exception of 2016, in Romania, which, starting from 2018, maintains in last place among the EU member states from this point of view.

4. WASTE GENERATION, SIMILARITIES AND DISPARITIES

In order to identify and analyze the similarities and disparities between the member states of the European Union regarding the generation of waste, six of the seven categories of waste were included in the analysis: Agriculture, forestry and fishing (AFF), Manufacturing (MNF), Electricity, gas, steam and air conditioning supply (EGS), Water supply; sewerage, waste management and remediation activities (WSR), Construction (CNS) and Households (HSH).The Mining and quarrying (MQR) category was not included for the reasons highlighted previously.The cluster generation dendogram is illustrated in Figure 3.

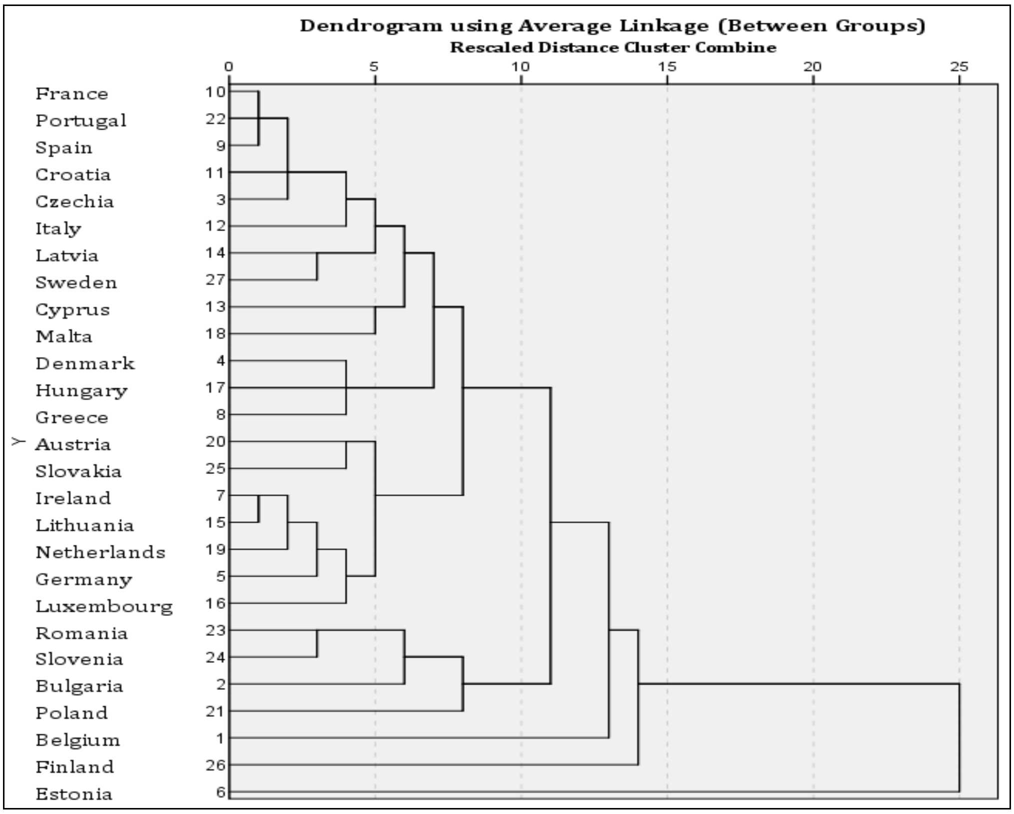

Figure 3. Dendrogram of clusters generation by AFF, MNF, EGS, WAR, CNS and HSH.

As a result of the performed tests and analyses, a structure with nine clusters resulted (Table 3), four of which include only one state. From the point of view of the analysis carried out, these four states (Belgium, Estonia, Poland and Finland) are exceptions determined by certain values of the classification criteria used.

Table 3. Structure of clusters generated by AFF, MNF, EGS, WSR, CNS and HSH.

Cluster	Structure of clusters
A	Bulgaria, Romania, Slovenia
B	Czech Republic, Spain, France, Croatia, Italy, Latvia, Portugal, Sweden
C	Denmark, Greece, Hungary
D	Germany, Ireland, Lithuania, Luxembourg, Netherlands, Austria, Slovakia
E	Cyprus, Malta
F	Belgium
G	Estonia
H	Poland
J	Finland

The analysis of the results of testing the statistical significance of the averages of the variables AFF, MNF, EGS, WSR, CNS and HSH recorded at the level of the five clusters, which contain at least two member states (clusters A-E), highlights the fact that for five variables $Sig.F < \alpha = 0.05$ (Table 4), which leads to the rejection of the null hypothesis (H0) and the acceptance of the alternative hypothesis (H1). Consequently, there is a significant difference between the means of the analyzed variables. Regarding the CNS variable, $Sig.F = 0.71 > \alpha = 0.05$ .However, given that $Sig.F = 0.71 < \alpha = 0.10$ (which corresponds to a confidence level of 90%), we will consider statistically significant the averages of the CNS variable, with a probability of 0.9.

Table 4. Welch' Robust Tests of Equality of Means of AFF, MNF, EGS, WSR and HSH.

Variables	Statistic[a]	df1	df2	Sig.
AFF	4.262	4	7.029	0.046
MNF	10.719	4	4.671	0.014

EGS	23.071	4	6.138	0.001
WSR	11.286	4	6.172	0.005
CNS	3.893	4	5.808	0.071
HSH	4.869	4	5.605	0.048

a. Asymptotically F distributed.

Source: Calculated by authors, using SPSS

The characteristics of the clusters are shown in Table 5. The similarities and disparities between the countries included in the analysis are highlighted by the attributes of the clusters in relation to the characterization indicators of the waste generation category. Considering that countries with a large volume of waste are in an unfavorable situation from the point of view of sustainability, it is necessary to adopt measures appropriate to the field, to drastically reduce them in favor of environmental protection as an important element in the economic sustainability of each country.

For the first indicator in the category of waste generation, Agriculture, forestry and fishing (AFF), it can be highlighted that the largest quantity of waste is recorded in the countries of cluster D (Germany, Ireland, Lithuania, Luxembourg, Netherlands, Austria, Slovakia) . Thus, the Netherlands has the dominant position with 281 kilograms per capita, and Germany is the last with 12 kilograms per capita. Cluster B, with an average of 64.50 kilograms per capita, also includes countries with significant quantities of waste, ranging between 6 kilograms per capita (Italy) and 140 kilograms per capita (Croatia). In the middle of the waste generation ranking for AFF is cluster A, with Bulgaria in first place (129 kilograms per capita) and Slovenia in last (27 kilograms per capita). Romania ranks among them with 37 kilograms per capita. The countries with the lowest quantities of generated waste are those in cluster C (Denmark, Greece, Hungary), with a variation amplitude of 37 kilograms per capita, and those in cluster E with 23 and 24 kilograms per capita, respectively, for Malta and Cyprus. The other 4 clusters (F, G, H, I) with only one country included, the quantity of waste generated for AFF ranges from 0 kilograms per capita (Finland, cluster F) to 147 kilograms per capita (Estonia cluster G).

Table 5. Mean values (centroids of clusters) generated by AFF, MNF, EGS, WSR and HSH.

Clusters	Nr. of countries	Means of variables					
		AFF	MNF	EGS	WSR	CNS	HSH
A	3	64.33	563.33	512.33	255.33	183.33	284.67
B	8	64.50	317.63	46.63	486.13	1,066.25	453.63
C	3	52.33	266.00	153.33	240.67	948.33	507.00
D	7	85.14	717.29	61.57	422.29	3,828.57	451.00
E	2	23.50	147.50	1.00	165.00	3,033.50	402.00
F	1	36.00	1,233.00	86.00	1,853.00	1,796.00	463.00
G	1	147.00	2,990.00	4,262.00	561.00	1,194.00	414.00
H	1	7.00	721.00	296.00	602.00	582.00	349.00
J	1	0.00	1,719.00	173.00	204.00	2,476.00	448.00

Source: Calculated by authors using SPSS.

Regarding the generation of waste in the field of Manufacturing, the average values of the quantity of waste determined by clusters are higher than in the case of AFF, for the first five clusters (A-E). The difference consists, on the one hand, in the inversion of the places obtained by clusters A and B, and on the other hand, in the value oscillations corresponding to the countries within the clusters. In the case of cluster D, which contains the largest quantity of waste compared to the other clusters, the fluctuation is 158 kilograms per capita, higher than in the case of AFF, in first place being Luxembourg, with 953 kilograms per capita, and in last place Slovakia, with 562 kilograms per capita.

A significant quantity of waste is also recorded by the countries of cluster A, occupying the second place by: Bulgaria (710 kilograms per capita), Slovenia (639 kilograms per capita) and Romania (341 kilograms per capita). Sweden, with 454 kilograms per capita, and Croatia, with 111 kilograms per capita, are the countries that, by the quantities of waste from the Manufacturing sector, represent the limits for cluster B, which corresponds to an average value of 317.63 kilograms per capita. The absolute amplitude of the variation of waste generated by MNF for cluster C is 161 kilograms per capita, between a maximum of 349 kilograms per capita in Greece and a minimum of 188 kilograms per capita in Denmark.

The lowest quantity of waste generated by MNF is recorded, as in AFF, also for Cyprus (236 kilograms per capita) and Malta (59 kilograms per capita). Taking into account the average values of the quantities of waste generated by MNF for all 9 clusters, it can be noted that the largest quantities are recorded by three of the four clusters that include only one country each: 2,990 kilograms per capita in Estonia (cluster G), 1,719 kilograms per capita in Finland (cluster I) and 1233 kilograms per capita in Belgium (cluster F).Among all the quantities of waste generated, regardless of the variable included in the analysis, the largest quantity belongs to Estonia (cluster G), of 4,262 kilograms per capita, for the field of Electricity, gas, steam and air conditioning supply (EGS). For the other three clusters that include only one country each, the quantity of waste generated by EGS is 296 kilograms per capita in Poland (cluster H), 173 kilograms per capita in Finland (cluster I), and 86 kilograms per capita in Belgium (cluster F).

The quantities of waste generated by EGS for the other five clusters (A-E) oscillate between an average of 512.33 kilograms per capita in cluster A (maximum of 878 kilograms per capita in Bulgaria and minimum of 225 kilograms per capita in Romania), and 1.00 kilograms per capita in cluster E (0 kilograms per capita in Malta and 2 kilograms per capita in Cyprus). Between clusters A and E, in descending order of the quantities of waste generated by EGS, there is cluster C with variation between 185 kilograms per capita in Hungary and 135 kilograms per capita, in Denmark, cluster D, with fluctuating quantities between a maximum of 128 kilograms per capita, in Slovakia, and a minimum of 26 kilograms per capita in Netherlands, as well as cluster B.

The quantities of waste generated by the Water supply field; sewerage, waste management and remediation activities (WSR) are to some extent at the level of those recorded for MNF, but the ranking of the clusters in relation to the average values recorded by clusters A-E is different. The largest quantities of WSR waste are recorded by cluster B (the maximum of 725 kilograms per capita in Italy and the minimum of 241 kilograms per capita in Croatia), then by cluster D with values ranging between 578 kilograms per capita, in Germany, and 209 kilograms per capita in Slovakia, and cluster A, with values between a maximum of 487 kilograms per capita, in Bulgaria, and a minimum of 135 kilograms per capita, in Slovenia.

At the end of the ranking, the countries with the best position in terms of the quantity of waste generated by WSR are those in cluster C, the values varying between 301 kilograms per capita, in Greece, and 162 kilograms per capita in Hungary, and those in cluster E , with an average of 165 kilograms per capita. As with the other variables (AFF, MNF and EGS), the F-I clusters are characterized by a high disparity. Belgium with 1853 kilograms per capita is the dominant of all clusters in terms of the quantity of waste generated by WSR, while Poland records 602 kilograms per capita, in Estonia, 561 kilograms per capita, and in Finland 204 kilograms per capita.

If for the four analyzed variables (AFF, MNF, EGS and WSR) cluster E had the most favorable position from the point of view of sustainability, through the smallest quantities of waste recorded, in the case of the Construction category (CNS), the situation is different, in meaning that it holds the second place, a rather unfavorable position for sustainable economic development, with values between 4,818 kilograms per capita in Malta and 1,249 kilograms per capita in Cyprus. Also, the CNS inducer highlights particularities at the level of three clusters. Thus, cluster D, occupying the first place with the largest quantity of waste generated by CNS, is characterized by the largest amplitude of 11,808 kilograms per capita (from 200 kilograms per capita, in Lithuania, to 12,008 kilograms per capita, in Luxembourg). Then, a significant disparity is given by the amplitude of 3,002 kilograms per capita that characterizes cluster B, occupying the 3rd place (with values between the maximum of 3,148 kilograms per capita, in France, and the minimum of 146 kilograms per capita, in Latvia) and the length the range of variation of cluster C, of 1,445 kilograms per capita (between 1892 kilograms per capita, in Denmark, and 447 kilograms per capita, in Hungary).

Regarding the quantity of waste generated by Households (HSH), the highest average quantity of waste belongs to cluster C, with 507 kilograms per capita (the maximum of 620 kilograms per capita in

Denmark and the minimum of 422 kilograms per capita in Greece), followed by cluster B, with 453.63 kilograms per capita and cluster D with an average of 451 kilograms per capita, the extreme values being recorded in the Netherlands (532 kilograms per capita) and Luxembourg (321 kilograms per capita).

The last two places regarding the average quantity of waste generated by HSH belong to clusters E and A. The variation in the quantity of waste generated by MSM for clusters F, G, H and I is quite small (114 kilograms per capita), the largest quantity belonging to Belgium (463 kilograms per capita), and the lowest Poland (349 kilograms per capita).

5. WASTE TREATMENT SIMILARITIES AND DISPARITIES

The identification and analysis of similarities and disparities between the member states of the European Union in terms of the results obtained in waste treatment was based on waste management operations, respectively: energy recovery (RER), backfilling (RBF), and recycling (RCY). The cluster generation dendogram is illustrated in Figure 4.

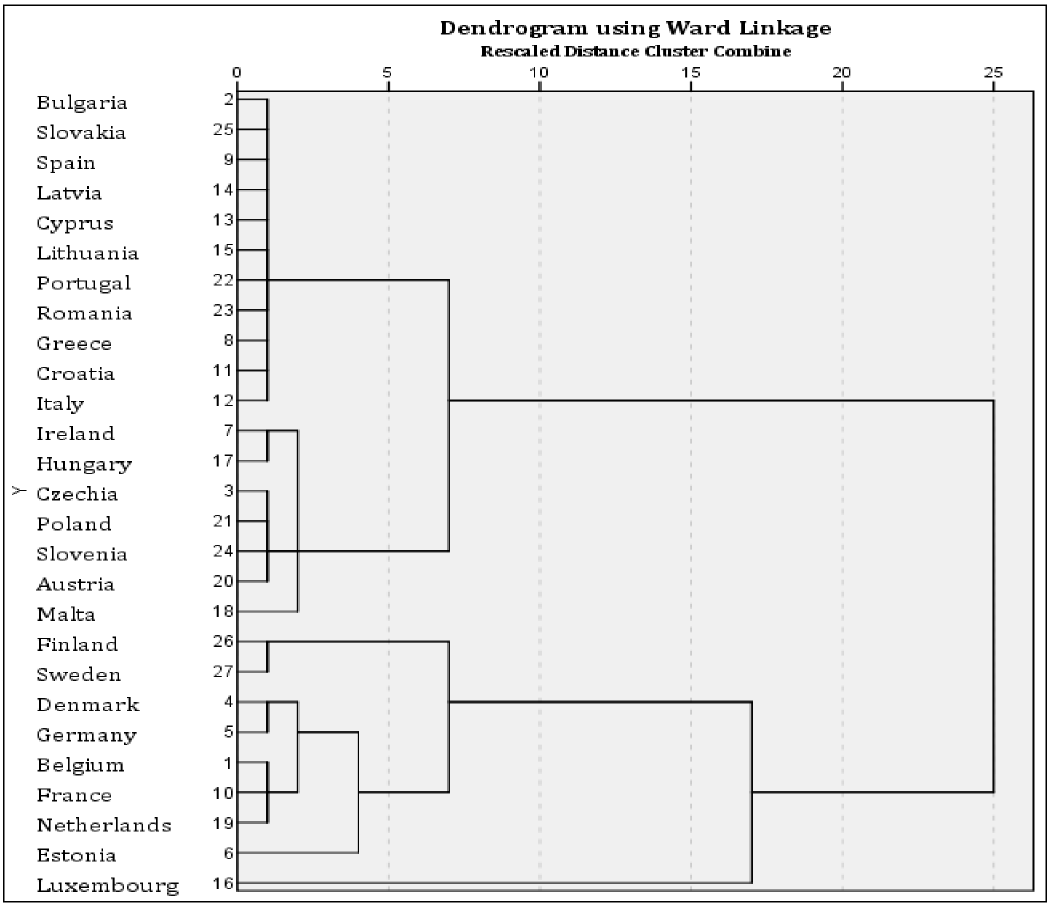

Figure 4. Dendrogram of clusters generation by RER, RBF and RCY.

Following the tests and analyzes performed, a structure with six clusters resulted (Table 6). Among them, cluster A includes 11 states, cluster B includes 7 states, cluster C includes 2 states, cluster D includes 5 states, and clusters E and F contain only one state each.

Table 6. Structure of clusters by treatment of wastes (RER, RRB, RCY).

Clusters	Structure of clusters
A	Bulgaria, Greece, Spain, Croatia, Italy, Cyprus, Latvia, Lithuania, Portugal, Romania, Slovakia
B	Czech Republic, Ireland, Hungary, Malta, Austria, Poland, Slovenia
C	Finland, Sweden
D	Belgium, Denmark, Germany, France, Netherlands
E	Estonia
F	Luxembourg

Welch' Robust Tests of Equality of Means (Table 7), carried out at the level of the four clusters, which contain at least two member states (clusters A-D), highlight the fact that for all variables $Sig.F < \alpha = 0.05$,which leads, also in this case, to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1). Consequently, there is a significant difference between the means of RER, RBF and RCY variables.

Table 7. Welch' Robust Tests of Equality of Means of RER, RRB and RCY.

Variables	Statistic[a]	df1	df2	Sig.
RER	20.358	3	3.772	0.008
RBF	9.562	3	3.674	0.032
RCY	8.856	3	7.081	0.009

a. Asymptotically F distributed.

Source: Calculated by authors, using SPSS.

Table 8. Mean values (centroids of clusters) generated by RER, RRB and RCY.

Cluster	Nr. of countries	Means		
		RER	RBF	RCY
A	11	108.45	53.64	845.18
B	7	98.86	1469.86	1,402.14
C	2	994.50	279.50	1,804.00
D	5	472.80	532.80	2,595.80
E	1	254.00	1,652.00	4,981.00
F	1	476.00	5,015.00	6,412.00

Source: Calculated by authors using SPSS.

The characteristics of the clusters are presented in Table 8. The largest quantity of waste from the energy recovery (RER) category is registered at the level of cluster C. in Finland with 1,127 kilograms per capita and Sweden with 862 kilograms per capita. The next places in the ranking of clusters are occupied by cluster F, which includes only Luxembourg, with a quantity of 476 kilograms per capita, followed by cluster D, with 472.80 kilograms per capita, with the extreme values in Denmark (605 kilograms per capita) and France (333 kilograms per capita). At a significant difference of approximately 220 kilograms per capita is cluster E, represented only by Estonia (254 kilograms per capita), then cluster A, with an average quantity of 108.45 kilograms per capita (the extreme values being 208 kilograms per capita, in Cyprus and 37 kilograms per capita in Greece). The last place is occupied by cluster B.

With regard to the treatment of backfilling waste (RBF), Luxembourg stands out with 5015 kilograms per capita (cluster F), Estonia with 1,652 kilograms per capita (cluster E) and cluster B with approximately 1,470 kilograms per capita (between the maximum of 2,970 kilograms per capita, registered in Malta, and the minimum of 830 kilograms per capita, registered in Hungary).

The other clusters are characterized by low quantities of treated waste (RBF), of approximately 532 kilograms per capita in cluster D (with extreme values between 1,197 kilograms per capita, in Germany and 441 kilograms per capita in France), of approximately 279 kilograms per capita , in cluster C (between a maximum of 380 kilograms per capita, in Sweden and a minimum of 179 kilograms per capita, in Finland) and only 53.64 kilograms per capita, in cluster A (the maximum of 185 kilograms per capita being recorded in Greece and the minimum of 5 kilograms per capita registered in Italy)

An interesting situation is recorded regarding recycling waste (RCY), in the sense that the resulting average quantities are in ascending order from the first to the last cluster. Although the average value is the lowest in cluster A, RCY oscillating between 2,059 kilograms per capita in Italy and 370 kilograms per capita in Romania. At the opposite pole. as in the case of RBF, Luxembourg with 6,412 kilograms per capita (cluster F) and Estonia with 4,981 kilograms per capita (cluster E) dominate and record the best results in waste recycling.

6. CONCLUSIONS

Given the need for sustainable development in all areas of economic and social life, the problem of waste represents, at the level of the EU member states, a permanent concern. From the analysis of the evolution of waste generation and management, based on the time series from 2004 to 2020, a general downward trend has emerged at the level of all European Union states regarding waste generation per capita. Romania was also included in this process, although, during the analysis period, the quantity of waste generated was above the EU average.

At the same time, there has been an increase in interest for a more efficient management of them, through actions aimed at energy recovery, backfilling and recycling. However, there are significant differences between the member states. Thus, particularly large increases, well above the EU average, regarding the reuse and recycling of waste were registered in Luxembourg, Finland and Estonia. Significant positive results were also recorded in the Netherlands and Belgium. Unfortunately, in this process, Romania is in last place with the worst performance in waste management.

The research carried out also aimed at the integrated analysis, based on several indicators, of the similarities and disparities between the EU member states regarding, on the one hand, the generation of waste, and on the other hand, their management.

The cluster analysis on waste generation revealed the existence of nine groups (four include only one country each: Belgium, Estonia, Poland and Finland). A series of disparities were highlighted between the clusters in the quantity of waste generated per capita, primarily regarding construction (CNS) as well as manufacturing (MNF). Smaller differences were recorded in water supply; sewerage, waste management and remediation activities (WSR), as well as at households (HSH).

Regarding the results of the cluster analysis regarding the performances obtained by the member states in waste management, a structure consisting of six clusters resulted, two of which contain only one state each (Estonia and Luxembourg). The most significant disparity between clusters was recorded for recycling (RCY), followed by backfilling (RBF). The smallest disparities between clusters were recorded in energy recovery (RER).

Overall, most disparities between EU member states concern the quantity of waste generated per capita. Thus, out of the nine clusters, four include only one state each, which means that they have no similarities with the others regarding waste generation, and only two clusters include a relatively large number of states (7 and 8 states, respectively), highlighting the existing similarities between these. In the case of waste recovery, the disparities between the EU member states are smaller, evidenced by the grouping into six clusters, of which only two include a single state. At the same time, the larger number of states included in three of the clusters highlights the greater degree of similarity between states regarding waste treatment than in the case of waste generation.

7. LIMITS AND FUTURE RESEARCH DIRECTIONS

Given that the paper provides an overview of the similarities and disparities between EU member states regarding waste generation and treatment, based on the data series available in the Eurostat databases, it has several limitations, among which the most important are volatility, fluidity and generality.

The volatility is due to the fact that the paper provides the existing image at the level of 2020, after which, certainly, changes have occurred in waste management at the level of the analyzed states.

The fluidity, as well as the degree of generality, are given by the number and content of the indicators used: 7 indicators for generating industrial waste (without distinguishing between hazardous and non-hazardous waste), only 1 indicator for generating household waste and only 3 indicators of waste treatment

On the other hand, although all EU member states have the same environmental legislation, the high degree of heterogeneity is also determined by the industrial structure, specific to each country, a fact that directly influences the amount and structure of industrial waste.

In order to remove these limitations, we intend to resume this first approach, both through a new analysis based on the new series of data that will be available, and by refining the research based on the various types of waste, in accordance with European directives, not only through cross-sectional analyses, but also analyzes based on time series, through distinct approaches regarding, on the one hand, industrial waste, and on the other municipal waste, studies that will lead to much more consistent conclusions.

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