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Original Scientific Article

MUNICIPAL WASTE AS A MEASURE OF THE REPRESENTATION OF THE CIRCULAR ECONOMY IN EUROPEAN COUNTRIES

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Abstract: The paper analyzes the generation and treatment of municipal waste in the European Union (EU) and the countries of Europe from 2010 to 2022, with a focus on: the amount of waste per capita (kg per capita), the structure of waste depending on economic activity (percentage), the share of treated waste in the total generated waste (percentage), as well as the structure of applied operations in waste disposal (percentage). We consider these indicators extremely important because they are necessary for greater representation of the circular economy. The main source of data for this research is the internationally recognized EUROSTAT database, and the data were downloaded electronically. Descriptive statistics methods were applied in the research, which showed that the average amount of municipal waste ranged from 273 kg per capita in Romania to 754 kg per capita in Denmark, which indicates pronounced differences in consumption patterns and efficiency of resource management. The highest average share of treated waste according to economic activities at the EU level was recorded in construction, while waste originating from agriculture, forestry and fishing has a negligible share. Most European countries fully treat generated municipal waste and have mechanisms for municipal waste treatment that differ depending on the observed country and region. The analysis also reveals uneven progress towards circular economy goals, with some countries recording a high degree of material recovery, while others still depend on traditional disposal methods. The results highlight the need for further investments in modern waste treatment technologies

and harmonization of policies among member states, in order to accelerate the transition to a sustainable and circular system.

Key words: *circular economy, municipal waste, recycling, Europe.*

INTRODUCTION

Due to the uncontrolled increase in soil degradation and the exploitation of natural resources, there has been an increase in waste and environmental pollution. That is why there was a need to abandon the principle of linear economy and introduce the so-called the principle of circular economy (Mitrović and Manić, 2020; Huysman et al., 2017; Kaivo-Oja, 2022). Due to the increased presence of waste in the environment, the question of the further survival of humanity arises (Čađenović, 2023; Vukadinović, 2018; Grujić Vučkovski et al., 2025).

The linear economic model of development implied the constant depletion of resources from the natural environment in order to realize the production process, which is why the state of the environment is called into question. The principle of the circular economy is based on the re-evaluation of used products and resources with the sole aim of reducing the amount of waste that ends up in nature (Vukelić et al., 2023; Ćurčić G., 2024; Ješić et al., 2024; Tan & Lamers, 2021; Busu, 2019; Vasiljević and Petrović, 2020; Korhonen et al., 2018).

At the end of 2015, the European Commission adopted an action plan for the circular economy and thereby made official the beginning of the application of the principles of the circular economy in all aspects of life (EC, 2015). Given that plastic represents a major threat to the environment, the European strategy for plastic waste was adopted in 2018 (EC, 2018). The purpose of this document is to highlight the importance of recycling plastic waste and plastic packaging in order to treat it more like a raw material and return it to the production process instead of ending up in nature (Ćurčić G., 2024). Therefore, the EU has set minimum limits for the recycling of municipal and packaging waste that should be achieved by 2025 and 2030 (EC, 2018a, 2018b), namely: recycling of municipal waste at least 55% by 2025 and 60% by 2030; recycling of packaging waste: at least 65% by 2025 and 70% by 2030.

The European Commission report from 2023 indicates that ten EU member states are at risk of not meeting the defined goals (EC, 2023).

After defining the thresholds for the recycling of municipal and packaging waste, the European Commission adopted the European Green Deal in 2019 (EC, 2019). This document encourages environmental protection so that by 2050, Europe will be the first continent with zero impact on the environment, i.e. without pollution.

The circular economy also has a social aspect because it affects the creation of new jobs (Radivojević, 2018). In this regard, the International Labor Organization (ILO, 2018) announced a few years ago that by introducing the principles of circular eco-

nomy, employment would increase at a rate of 0.1% per year, and there would be 50 million and 45 million more employed workers in the service sector and the waste management sector, respectively.

The selection of waste management indicators as key indicators of the circular economy is based on the classification used by the European Commission. Although the circular economy includes a wider range of activities (e.g. environmental, economic, social), indicators such as recycling rate, waste reuse rate, number of employees in the waste management and recycling sector, etc., represent concrete and measurable variables whose changes can be directly related to economic performance.

The importance of this topic stems from the fact that waste management represents one of the key challenges of sustainable development, both at the EU level and at the global level. The amount of waste per capita, the structure of the sectors that generate it and the representation of certain treatment methods directly affect the efficiency of resource use and the level of environmental pollution. The analysis of these aspects, based on relevant statistical indicators, provides the basis for the creation of policies that contribute to meeting the goals of the circular economy. The special value of the research lies in connecting economic activities, quantitative indicators of waste generation and methods of its treatment, which fills the gap in comparative studies of this type so far.

After the literature review, we can ask the following research question: *"To what extent do the amounts of generated waste, structure according to economic activities and its treatment differ between EU member states, and how do these differences reflect progress towards the goals of the circular economy"?*

MATERIAL AND METHODOLOGY

In the paper, the parameters of the circular economy were observed through the following variables: the amount of generated waste per capita (kg per capita), the amount of waste depending on the activity from which it originates (percentage), the share of treated municipal waste in relation to the generated amounts (percentage) and the way municipal waste is treated (percentage). The parameters were observed in the period from 2010 to 2022, and average values were calculated based on them.

The area of observation is the level of EU and 35 individual European countries, namely: Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Humgary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Iceland, Norway, Switzerland (except in case of analysis of generated waste by economic activities due to unavailability of data), Bosnia and Herzegovina, Montenegro, North Macedonia, Albania, and Serbia.

After the database with variables and values was created, the method of descriptive statistics was applied in order to determine the average values of generated

waste according to individual European countries and for the EU area, the minimum and maximum values, the largest and smallest deviations from the mean values were established, and trends in the average annual rate of change were observed.

The presentation of the research results was carried out in tabular and graphic form. The graphic presentation of the data was performed using bar charts in order to visually show the differences in the proportions and structure of waste treatment.

The obtained results were used as a basis for formulating conclusions and recommendations in the field of waste management.

The author's calculation and graphic display was done using the Microsoft Excel software tool.

RESULTS AND DISCUSSION

The analysis begins with the presentation of the results of descriptive statistics, which provides a basic insight into the amount of waste generated and enables an understanding of the variability between the observed indicators. Average values, range, minimum and maximum values, as well as deviations from the average (standard deviation) and average annual rate of change (AARC) of this indicator were analyzed through descriptive statistics (Table 1).

Table 1. Amounts of generated waste in EU and European countries (kg per capita), 2010-2022

Country	Average	Min	Max	St. Dev.	Cv, %	AARC
EU	500	479	534	16,6	3,3	0,2
Belgium	497	409	755	131,6	26,5	3,5
Bulgaria	461	418	554	37,9	8,2	-1,1
Czechia	370	0	570	151,0	40,8	5,4
Denmark	754	0	862	227,6	30,2	-0,7
Germany	623	602	651	14,9	2,4	0,1
Estonia	353	280	405	42,7	12,1	1,7
Ireland	415	0	637	288,6	69,6	0,5
Greece	504	482	532	15,0	3,0	-0,2
Spain	472	448	510	16,1	3,4	-0,5
France	539	516	564	16,7	3,1	0,0
Croatia	419	379	478	32,1	7,7	2,0
Italy	500	486	542	15,8	3,2	-0,9
Cyprus	657	619	711	27,0	4,1	-0,5
Latvia	399	323	478	53,0	13,3	3,0
Lithuania	450	404	480	21,2	4,7	1,2
Luxembourg	720	607	815	81,1	11,3	0,5
Hungary	393	379	420	13,2	3,4	0,1
Malta	637	604	697	27,6	4,3	-0,1

Netherlands	526	473	571	26,0	4,9	-1,6
Austria	630	560	835	111,1	17,6	3,0
Poland	321	272	370	28,7	8,9	1,2
Portugal	485	439	516	27,0	5,6	-0,1
Romania	273	247	313	22,6	8,3	-0,3
Slovenia	459	362	511	43,1	9,4	-0,1
Slovakia	377	304	497	72,2	19,1	3,4
Finland	527	470	630	48,6	9,2	0,9
Sweden	440	395	455	17,4	3,9	-0,9
Iceland	539	0	702	177,0	32,8	3,5
Norway	622	421	799	156,3	25,1	4,2
Switzerland	708	677	733	14,8	2,1	-0,4
Bosnia and Herzegovina	344	311	356	12,3	3,6	0,3
Montenegro	468	0	545	141,9	30,3	0,2
North Macedonia	342	0	467	156,4	45,8	2,3
Albania	304	0	491	183,0	60,3	-1,1
Serbia	351	259	473	65,4	18,6	2,2

Source: Author's calculation based on EUROSTAT Database (2025).

The average amount of municipal waste per capita in the EU in the period 2010-2022 is 500 kg, with a relatively low coefficient of variation (3.3%) and an AARC of 0.2%, which indicates little variability in the overall observed period. Denmark (754 kg), Luxembourg (720 kg) and Switzerland (708 kg) recorded the highest average values of generated waste per capita, while the lowest values were observed in Romania (273 kg), Albania (304 kg) and Poland (321 kg) and are significantly below the EU average.

Very high coefficients of variation (over 30%), observed in countries such as Ireland (69.6%), Albania (60.3%), North Macedonia (45.8%) and the Czech Republic (40.8%), indicate significant oscillations in waste generation in the analyzed period. On the other hand, countries like Switzerland (2.1%), Germany (2.4%) and Greece (3.0%) have very stable amounts of waste per capita because the coefficient of variation does not show significant deviations.

Looking at average annual rates of change (AARC), the largest growth in waste per capita was recorded in the Czech Republic (5.4%), Norway (4.2%) and Slovakia (3.4%), while the largest reductions were present in the Netherlands (-1.6%), Bulgaria (-1.1%) and Albania (-1.1%).

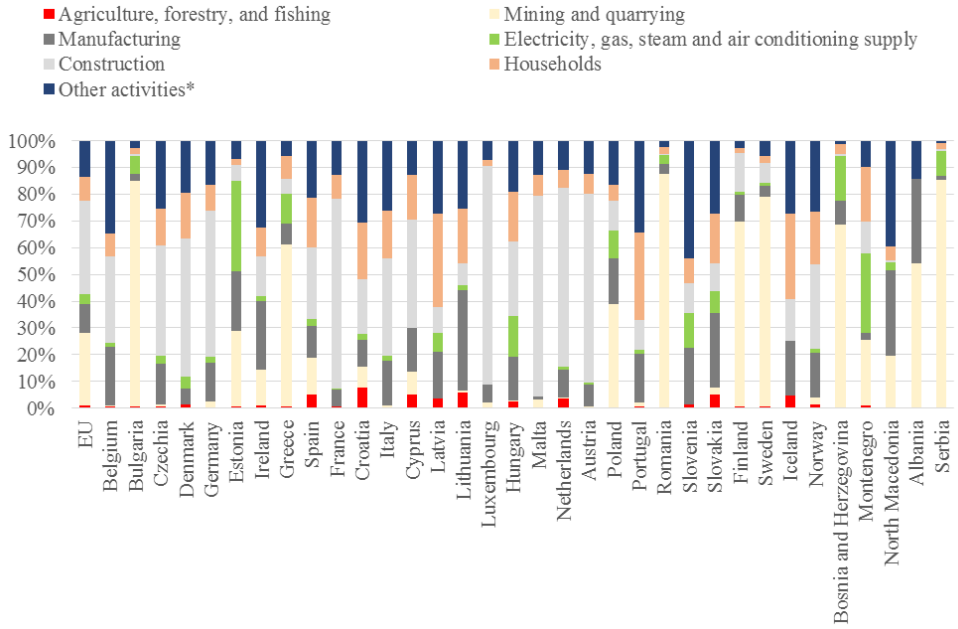
These results show us that there are changes in generated waste per capita at the territorial level, which can affect the waste management system and national policy.

On Graph. 1 an overview of the average share of generated waste according to activities in the EU and the countries of Europe from 2010 to 2022 is given.

The structure of generated waste by activity varies significantly among European countries, which reflects differences in economic specialization and industrial structu-

re. At the EU level, the largest average share of waste by activity in the period 2010-2022 comes from construction (35.2%), followed by the mining sector (27.3%) and the processing industry (10.8%). There are significant deviations from this aggregate view at the national level of European countries. Countries such as Romania, Serbia and Bulgaria record a marked dominance of the mining and quarrying sector in the total amount of waste (87.2%, 85.3% and 84.5% respectively). In contrast, construction activities represent the main source of waste in countries such as Luxembourg, Malta and France with an average share of over 70% (81.6%, 75.3% and 71.1% respectively). The generated waste originating from the processing sector is the highest in Lithuania with 37.8% and North Macedonia with 32.1%, which is significantly above the EU average with 10.8%. The share of waste from the agriculture, forestry and fishing sectors in the total waste is negligible and does not exceed the average value of 7.6% as determined in Croatia. Households generally have a smaller contribution to the generation of waste, although there are countries that record a participation of over 30%, with a higher share recorded in countries such as Latvia 35%, Portugal 32.8% and Iceland 31.9%. The "other activities" category, which includes various smaller sectors, is particularly pronounced in countries such as Slovenia, North Macedonia, Belgium and Portugal.

Graph. 1. Average share of generated waste according to activities in the EU and European countries, 2010-2022



Source: Author's visualization based on EUROSTAT Database (2025).

* Other activities include the following sectors: services (except wholesale of waste and scrap); water collection, treatment and supply; sewerage; remediation activities and other waste management services; waste collection, treatment and disposal activities; materials recovery.

The observed heterogeneity emphasizes the need to adapt waste management policies to the specific structural profile of the economy of each country. Although EU-level strategies provide a general framework, the sectoral concentration of waste generation requires targeted solutions at the national and regional level in order to promote the efficient use of resources and align with circular economy goals.

On Graph. 2. an overview of the average share of treated waste in total waste in the EU and European countries is given, whereby the countries are ranked from the highest to the lowest share.

Graph. 2. Average share of treated waste in total waste in the EU and European countries, 2010-2022

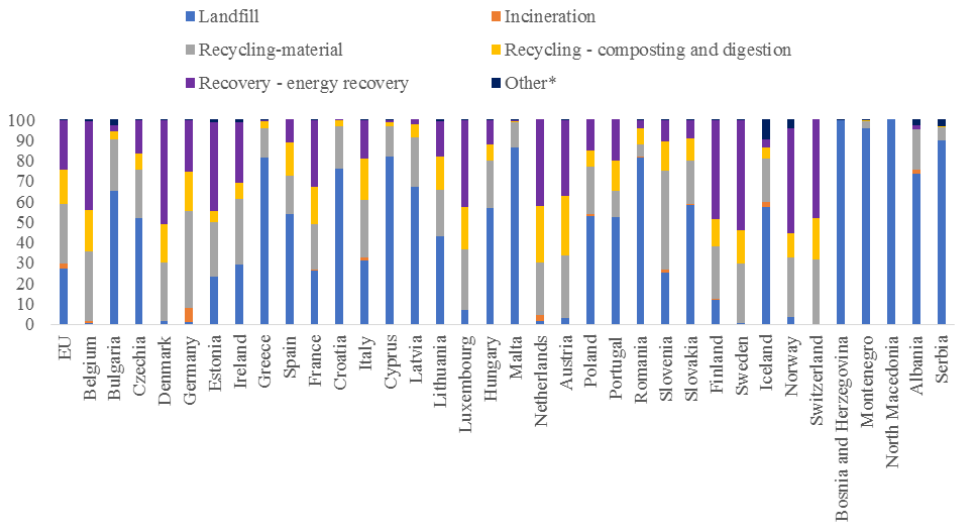
Source: Author's visualization based on EUROSTAT Database (2025).

On Graph. 2. we see that most countries achieve complete treatment of waste in relation to the generated. while the lowest value was recorded in Bosnia and Herzegovina (78%) and is significantly below the average for the EU. Apart from Bosnia and Herzegovina, countries such as Slovenia and Serbia record the lowest share of treated waste, which shows a lower efficiency of waste recording and management.

According to the data presented above, we can conclude that most European countries have almost complete coverage of treated in relation to generated waste.

Finally, a presentation of the average values of the applied operations in the handling of municipal waste (Graph. 3.) from 2010 to 2022, for the following operations: landfill, incineration, recycling material, Recycling - composting and digestion, Recovery - energy recovery and others.

Graph. 3. Applied operations in handling municipal waste in EU and European countries, 2010-2022



Source: Author's visualization based on EUROSTAT Database (2025).
* Other meaning and preparing for reuse.

There are significant differences between countries in terms of the dominant waste management strategy. While countries such as Germany, the Netherlands, Sweden, Denmark and Belgium have a minimal share of landfilling and a high share of recycling and energy use of waste, the countries of the Western Balkans (Serbia, Albania, Montenegro, Bosnia and Herzegovina) still rely heavily on landfilling. Also, high percentages of material recycling and waste composting are evident in Austria, Belgium and Switzerland, while countries such as Bulgaria, Romania, Cyprus, Latvia and Greece record limited application of these methods.

The results presented above show us the different levels of technological development of countries in the manipulation of waste, and therefore the levels of implementation of the principles of the circular economy.

CONCLUSION

The analysis shows that the generation of waste per capita and by sector of economic activity reflects not only the level of consumption and the intensity of industrial production, but also different patterns of technological equipment and efficiency among the observed countries.

Observed differences in the amount of municipal waste treated in relation to the total amount generated indicate an uneven degree of implementation of measures for recycling, composting and other forms of waste treatment. It is particularly significant that the structure of waste disposal and processing operations reveals the extent to which countries still depend on the disposal of municipal waste in landfills versus solutions offered by the circular economy, which has direct implications for the achievement of sustainable development goals and the reduction of negative environmental impact. These findings point to the need for more intensive investments in waste processing infrastructure and the harmonization of waste management policies at the level of the EU.

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