# Mapping Circular Economy Performance: EU Member States Analysis and Insights

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**Abstract.** *The concept of the circular economy was created around the desire to extend the life of products and, implicitly, their use in an economy. The waste reduction process is founded on the basis of the three R's - reduce, reuse, recycle, which aims to conserve natural resources. In order to determine the contribution made by the European Union (EU) states regarding the circular economy sector, a descriptive analysis was carried out at the level of the member countries, followed by the identification of their ranking regarding the performances recorded in accordance with the analyzed indicators, a final step being the realization of a cluster analysis through which to determine the similarities and differences between them. Among the results obtained, it was found that the countries in the center of the EU have among the highest values in terms of private investment related to circular economy sectors, but also for resource productivity, although they have among the lowest percentages of people employed in this field, but and among the largest greenhouse gas emissions from production activities.*

**Keywords**: *circular economy, resilience, sustainability, innovation, productivity.*

## Introduction

The concept of the circular economy, rooted in the principles of sustainability and resource conservation, has emerged as a vital paradigm shift in our approach to economic development. At its core, the circular economy seeks to extend the life of products, reduce waste, and preserve natural resources through the three fundamental principles of "reduce, reuse, recycle." This innovative approach not only mitigates environmental degradation but also fosters economic resilience and innovation.

In light of these transformative principles, we delve into an in-depth analysis of the European Union (EU) member states and their contributions to the circular economy. Our research aims to unveil the distinct roles and performances of EU countries in advancing circular economy

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initiatives. We achieve this by conducting a comprehensive examination of key indicators, followed by a rigorous cluster analysis that unveils the unique characteristics of these nations.

The European Union, with its diverse array of member states, provides a unique backdrop for this investigation. As we explore the circular economy landscape within the EU, we discern noteworthy variations in approaches and outcomes. These differences are crucial in understanding how member states are addressing waste reduction and resource conservation through the three-pronged strategy of "repair, reuse, recycle."

Our study focuses on several key objectives. Firstly, we aim to gauge the resilience exhibited by EU countries in the face of evolving economic and environmental challenges. Secondly, we seek to uncover the levels of innovation and competitiveness associated with the circular economy sector. Finally, we endeavor to identify the resource productivity of member states by analyzing indicators obtained from Eurostat, with the latest available data from 2021.

To offer a glimpse into our methodology, we employ six core indicators to assess circular economy performance. Resource productivity, a central metric in our analysis, is calculated as the ratio of GDP to domestic material consumption (DMC), representing the efficient use of resources in economic activities. Additionally, we employ the consumption footprint indicator, encompassing five critical areas: food, housing, mobility, appliances, and household goods. This indicator provides insights into the environmental impact of consumption patterns, allowing us to evaluate sustainability efforts in these domains.

Our research unfolds in two phases. Initially, we conduct a detailed statistical analysis of data collected from all 27 EU member states, revealing variations and trends across these nations. Subsequently, we employ cluster analysis—a powerful tool for classifying countries into distinct groups based on their circular economy performances. For this purpose, we employ the K-means algorithm, a widely recognized unsupervised shape recognition technique known for its effectiveness in clustering objects.

The significance of this research extends beyond mere data analysis. By gaining a comprehensive understanding of the circular economy performance within the EU, we hope to shed light on the strategies and approaches employed by member states. This knowledge is instrumental in fostering cooperation, promoting best practices, and charting a sustainable path forward for the European Union and beyond.

As we delve into the depths of circular economy performance within the EU, these insights serve as our compass, guiding us through the intricate tapestry of strategies, achievements, and disparities across member states. In the ensuing sections, we unravel the implications and opportunities that lie within each category, offering a comprehensive view of Europe's journey towards a more sustainable, resilient, and innovative circular economy.

## Literature review

The circular economy is a concept that aims to promote sustainable production and consumption practices by reducing resource usage and minimizing externalities (Camilleri, 2020). It involves implementing policies and measures that encourage businesses to minimize their environmental impact, such as reducing transportation, storage, packaging, and waste in industries like retail and food production (Camilleri, 2020). The circular economy has been recognized as a framework for addressing environmental and sustainability challenges in the European Union (Palm et al., 2021). It is seen as a way to achieve sustainable economic growth across the EU (Busu & Trica, 2019).

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The EU has taken steps to promote the circular economy through various initiatives and legislative frameworks. For example, the Circular Economy Action Plan of 2015 introduced measures to transition from a linear to a circular model of the economy (Duquennoi & Martínez, 2022). The EU revised legislative framework on waste, adopted within this action plan, has had an impact on the development of sustainable practices in industries like fashion (Jacometti, 2019). The EU's resource efficiency and circular economy agenda is motivated by the belief that increasing material productivity not only reduces environmental pressures but also improves the competitiveness of economies (Flachenecker, 2017). According to a study conducted by Clodnitchi and Tudorache (2022) it can be said that the actions aiming to reduce Green House Gas Emissions are strongly connected to an increase in Resource Productivity. Also, they showed that some EU countries were not supposed to reach their targets set for 2020, but they reached them, probably due to the reduction triggered by the COVID pandemic.

However, the circular economy is not without its challenges and criticisms. Some argue that the current implementation of circular economy policies tends to be incremental and may not go far enough in addressing sustainability issues (Palm et al., 2021; Streimikiene, 2022). There is a need to challenge the current technocentric consensus and explore alternative approaches within the boundaries of the circular economy (Palm et al., 2021). Additionally, the progress towards a circular economy in EU countries has been uneven, with different factors contributing to this unevenness (Polyakov et al., 2021; Ngo, 2022). Evaluating the level of development of the circular economy in EU member countries requires the analysis of various indicators in areas such as production and consumption, waste management, secondary raw materials, and competitiveness and innovation (Fura et al., 2020).

In conclusion, the circular economy is a concept that aims to promote sustainable production and consumption practices by reducing resource usage and minimizing externalities. The EU has implemented various initiatives and legislative frameworks to promote the circular economy, but there are challenges and criticisms that need to be addressed. Evaluating the level of development of the circular economy in EU countries requires the analysis of various indicators in different areas. Overall, the circular economy has the potential to contribute to sustainable economic growth and address environmental and sustainability challenges in the EU.

## Methodology

Observing the EU context regarding the values recorded by the member states in terms of circular economy indicators leads to the determination of the degree to which countries try to limit waste by applying the three R's - repair, reuse, recycle. The objectives of this study focus on determining the degree of resilience of the EU countries, as well as the innovation and competitiveness associated with this sector, simultaneously with the identification of the productivity of the resources related to the member states. In this sense, six indicators obtained by querying the database made available by Eurostat were chosen, the last year for which there were data at the time of the current research being 2021.

According to the definitions provided by Eurostat, resource productivity is calculated as the ratio between GDP and domestic material consumption (DMC - which designates the total annual amount of materials that are directly used by an economy). The consumption footprint indicator (which shelters five areas: food, housing, mobility, appliances, and household goods) is an estimator of environmental impacts of consumption. It is calculated by combining data related to the environmental impact and consumption intensity of representative products. Greenhouse gases emissions from production activities includes emissions from all manufacturing activities, excluding emissions from households for heating, transport and other domestic activities. Private investment and Gross added value related to circular economy sectors represents Gross investment in tangible goods and Value added at factor cost in three sectors: the recycling sector, the repair and reuse sector and the rental and leasing sector. Persons employed in circular economy sectors refers to the number of persons employed in the three sectors described above, expressed as a percentage of all employees. Table 1 provides hyperlinks to Eurostat's extensive explanations of how to calculate and define these indicators.

A first step in carrying out this research was to statistically analyze the data obtained for the 27 EU member states to determine if there are notable differences between them.

In extension of the descriptive statistics, a cluster analysis was carried out to determine the grouping of the countries through the prism of the performances obtained for the six analyzed indicators.

Cluster analysis involves grouping a set of objects into distinct classes so that the objects within the classes are as homogeneous as possible among themselves, but also differ from the objects of the other classes (Bratchell, 1989). For this process of grouping countries into clusters, an unsupervised shape recognition algorithm, K-means, was used, and RStudio was used for data processing. The K-means algorithm was chosen because it is among the most used methods for grouping objects into clusters. The algorithm involves initializing a number of k clusters of the researcher, and based on this number, places the objects into classes so that the distance between them and the corresponding centroids is minimal (Bratchell, 1989). According to a literature study carried out for journals, proceedings and books published between 1984 and 2021 (written only in English) and based on keywords containing "k-means" 44,433 articles were discovered. (Ikotun, Ezugwu, Abualigah, Abuhaija, & Heming, 2023).

Following the application of these methods, it is desired to determine the performance of the three areas of the analyzed economy, namely Production and consumption, Global sustainability and resilience and Competitiveness and innovation.

## Results and discussions

In this section, indicators related to the circular economy at the level of the 27 EU member states will be analyzed. The data to be discussed were collected from Eurostat for the year 2021. Next, a cluster analysis is carried out to determine the grouping of countries according to the degree of homogeneity between them.

### *Descriptive data analysis*

The data analyzed regarding the level at which the EU member states are with regard to the circular economy describe areas such as Production and consumption, Global sustainability and resilience, but also Competitiveness and innovation. For the indicators chosen to represent these three categories, it will be possible to observe the statistical analysis, but also how the EU27 countries rank.

**Table 1. Circular economy indicators**

| Label | Name | Unit of measure |
| --- | --- | --- |
| **Production and consumption** | | |
| rp | Resource productivity | Euro per kilogram, chain linked volumes (2015) |
| **Global sustainability and resilience** | | |
| cf | Consumption footprint | Index, 2010=100 |
| ghge | Greenhouse gases emissions from production activities | Kilograms per capita |
| **Competitiveness and innovation** | | |
| inv | Private investment related to circular economy sectors | Percentage of gross domestic product (GDP) |
| gva | Gross added value related to circular economy sectors | Percentage of gross domestic product (GDP) |
| pe | Persons employed in circular economy sectors | Percentage of total employment - numerator in full-time equivalent (FTE) |

Source: Authors' own research using data from EUROSTAT.

For the three categories analyzed, six indicators relevant to this study were identified, and they can be seen in Table 1, with both their name and the unit of measure presented.

**Table 2. Descriptive statistics**

| Statistics | ghge | cf | rp | gva | inv | pe |
| --- | --- | --- | --- | --- | --- | --- |
| Mean | 7041.28 | 103.85 | 1.87 | 1.69 | 0.69 | 1.83 |
| Median | 7148.93 | 102.00 | 1.58 | 1.60 | 0.70 | 1.80 |
| Mode | #N/A | 113.00 | #N/A | 1.50 | 0.70 | 1.50 |
| Standard Deviation | 2412.35 | 10.11 | 1.16 | 0.54 | 0.33 | 0.64 |
| Kurtosis | 0.32 | 1.31 | -0.23 | 0.81 | 0.21 | -0.29 |
| Skewness | 0.79 | 0.79 | 0.77 | 0.45 | 0.37 | 0.05 |
| Minimum | 3839.46 | 88.00 | 0.34 | 0.50 | 0.10 | 0.40 |
| Maximum | 13377.35 | 133.00 | 4.65 | 2.90 | 1.40 | 3.10 |
| Count | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 |

Source: Authors' own research.

Table 2 presents descriptive statistics from the level of the 27 EU member states for the year 2021, where significant discrepancies between the minimum and maximum values can be noted (for Consumption footprint the maximum value is 1.5 times higher compared to the minimum, over time what for Private investment related to circular economy sectors the maximum value is 14 times higher, closely followed by Resource productivity, where it is 13.67 times higher). It is also noted that in all cases the asymmetry is positive, a sign that small values are predominant.

For the Greenhouse gases emissions from production activities indicator, it is noted that in 2021, for the EU mean, the value recorded was 7041.28 kilograms per capita, the values of the member states deviating, on average, by 2412.35 kilograms from the previously mentioned value. However, 50% of the states have values of this indicator exceeding 7148.93 kilograms per capita (there were no states with the same values recorded for this indicator in the analyzed year). Regarding the Consumption footprint, at the level of the EU average, it is noted that the value of the index is 103.85 (reported to the base level of 2010). The values recorded by the analyzed countries for this year deviating, on average, by 10.11 from the mean. Also, 50% of the countries have values lower than the median, which recorded the value of 102 of this index, and the value with the highest frequency of occurrence is 113. For Resource productivity it is noted that the average value is 1.87 euros per kilogram, the values deviating, on average, by 1.16 euros from this value. In addition to this information, it is also observed that 50% of the states have lower values compared to the median (1.58 euros per kilogram). As in the case of greenhouse gas emissions, there were no repeating values for this indicator, which is why the mode could not be calculated.



For the indicator that determines Gross added value related to circular economy sectors, it is noted that for the EU average the average is 1.69% of GDP, the values deviating, on average, by 0.54% from this percentage. For investments, it should be noted that the average for EU27 countries is 0.69% of GDP, the values deviating, on average, by 0.33% from this value, 50% of countries registering percentages exceeding 0.7%, this being the most common value for the analyzed year regarding this indicator. The average number of people employed in this sector at the EU level is 1.83% of the total employment, the states having a number of employees, which deviates on average by 0.64% from this percentage. For the median, it is noted that 50% of the states have a value greater than 1.80%, and the most frequently encountered value is 1.50%.

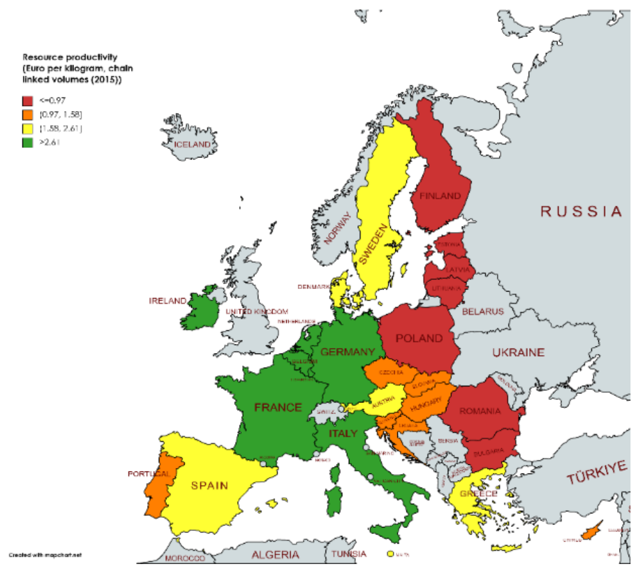


**Figure 1. Resource productivity**

Source: Authors' own research.

Figure 1 shows the map of the EU (countries marked in gray being non-EU) through the prism of the values recorded by these states regarding the Resource productivity indicator. It can be very clearly noted that most of the states in the east of the EU recorded the lowest values in the analyzed year (having values lower than 0.97 euros per kilogram), while the countries in the central-western area present the highest values (with values exceeding 2.61 euros per kilogram).

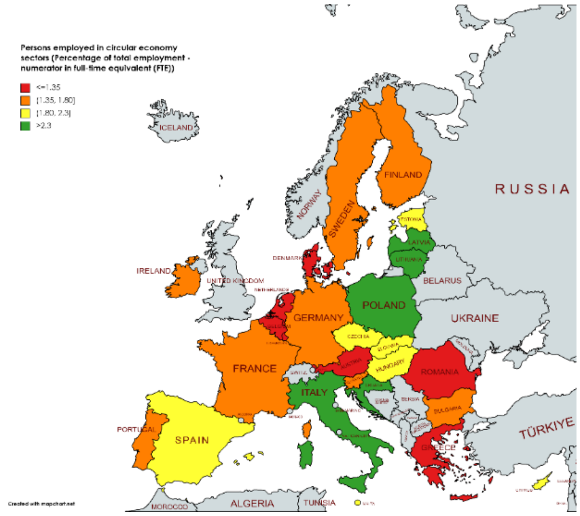


**Figure 2. Persons employed in circular economy sector**

Source: Authors' own research.

For the number of employed people, the situation seems to have changed almost radically compared to the one presented in Figure 1, from Figure 2 it can be observed that the countries with the highest values presented for resource productivity have among the lowest values of the number of employees in the circular economy field (with the exception of Italy which has among the highest values for both indicators). For eastern countries, also, the situation differs for most states, where they are registered among the most employees in this sector (over 1.80%).

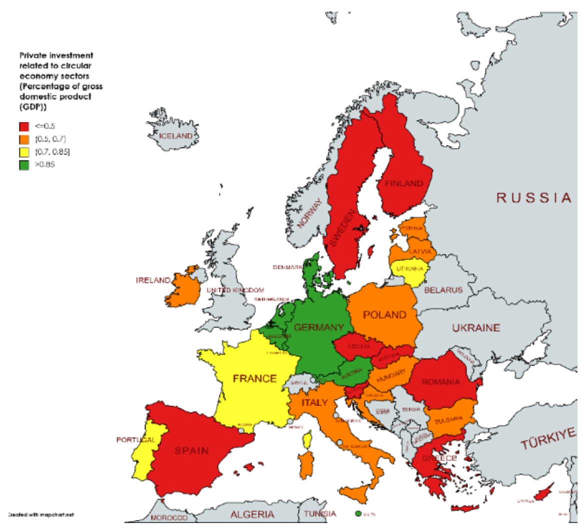


**Figure 3. Private investments**

Source: Authors' own research.

For private investments in this sector of the circular economy, it is noteworthy that the countries in the center and Malta give the highest percentages of GDP (over 0.85%). With the exception of Lithuania, France and Portugal (where values are between 0.71% and 0.85%), all other states have values lower than or equal to 0.7% of GDP (Figure 3).

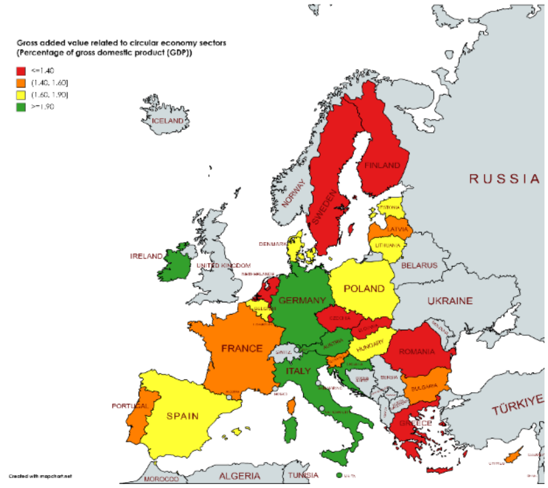


**Figure 4. Gross added value**

Source: Authors' own research.

For Gross added value related to circular economy sectors, the situation seems somewhat better compared to that of private investments, countries such as Germany, Austria, Croatia, Italy, Malta and Ireland having values exceeding 1.90% of GDP allocated for this indicator, the other countries showing values that fall between 1.40% and 1.90% (Figure4).

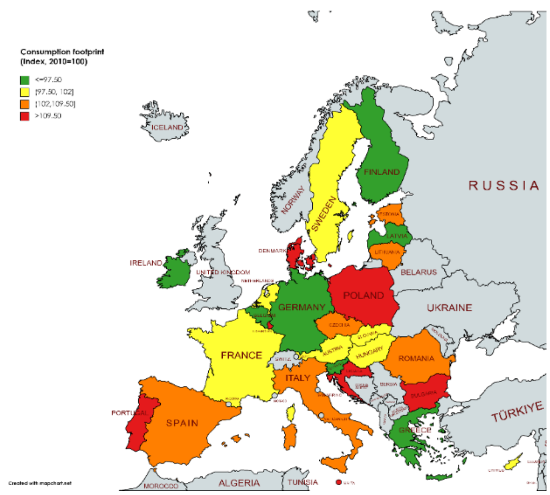


**Figure 5. Consumption footprint**

Source: Authors' own research.

For the indicator presented in Figure 5, it is noted that there is not necessarily a geographical component in the description of the level at which the European countries are in relation to this indicator, there are different colors in all geographical areas. Thus, it is noted that Finland, Latvia, Greece, Slovenia, Germany, Belgium and Ireland have the lowest values of this indicator (below

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97.50), while Poland, Bulgaria, Croatia, Malta, Portugal, Luxembourg and Denmark have values of exceed 109.50.

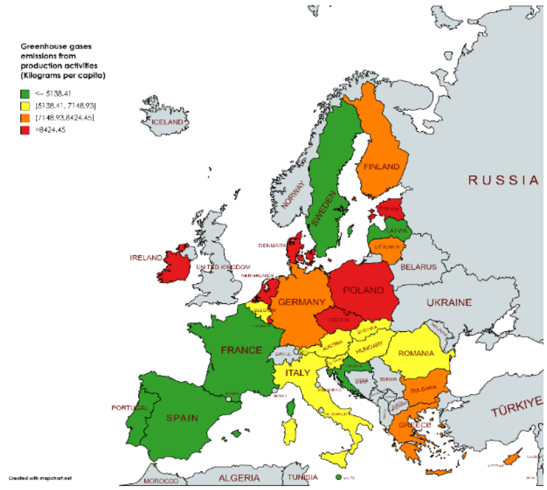

**Figure 6. Greenhouse gases emissions**

Source: Authors' own research.

For Greenhouse gases emissions from production activities (Figure 6), it is noted that the countries with the highest recorded values are Estonia, Poland, the Czech Republic, Luxembourg, the Netherlands, Denmark and Ireland (with over 8424.45 kg per capita).

***Cluster analysis***

For the grouping of countries into classes, several scenarios were chosen to be analyzed to determine the best way to classify EU countries so that the states within the clusters are as homogeneous as possible.

The first step they took to perform this analysis was to standardize the data. Then the Euclidean distance between the countries was calculated and two different clustering methods were chosen, namely ward and complete.

To determine the optimal number of classes, the NbClust package was used, which contains a series of indices that calculate the number of clusters and propose, based on a minimum and maximum number of classes chosen by the researcher, the optimal number that should be chosen.

```
*******************************************************************
* Among all indices:
* 7 proposed 2 as the best number of clusters
* 8 proposed 3 as the best number of clusters
* 7 proposed 4 as the best number of clusters
* 1 proposed 5 as the best number of clusters

                   ***** Conclusion *****

* According to the majority rule, the best number of clusters is  3
```

**Figure 7. Nbclust (ward.D2)**

Source: Authors' own research.

According to Figure 7, it is noted that according to the indices in the NbClust package, by the ward method, three classes of a number of eight indices are proposed, followed by two and four classes proposed of seven indices each.

```
*******************************************************************
* Among all indices:
* 8 proposed 2 as the best number of clusters
* 8 proposed 3 as the best number of clusters
* 2 proposed 4 as the best number of clusters
* 6 proposed 5 as the best number of clusters

                   ***** Conclusion *****

* According to the majority rule, the best number of clusters is  2
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**Figure 8. Nbclust (complete)**

Source: Authors' own research.

As for Figure 8, two and three classes of eight indicators each are chosen by the complete method.

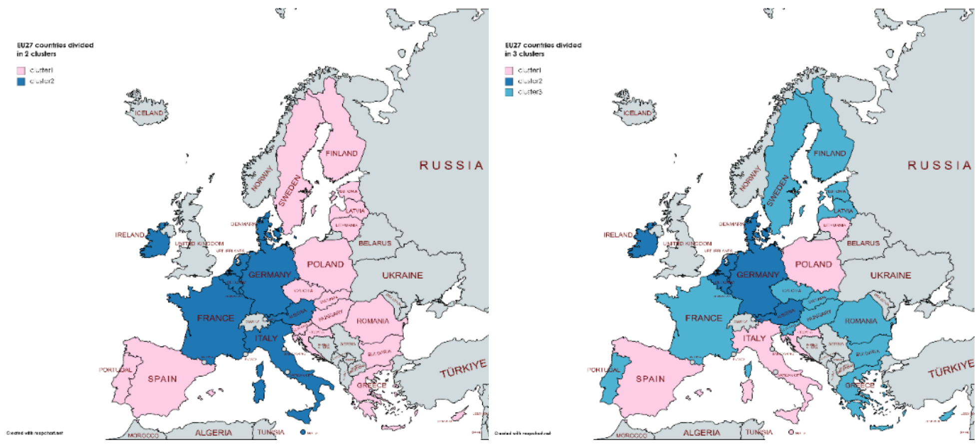
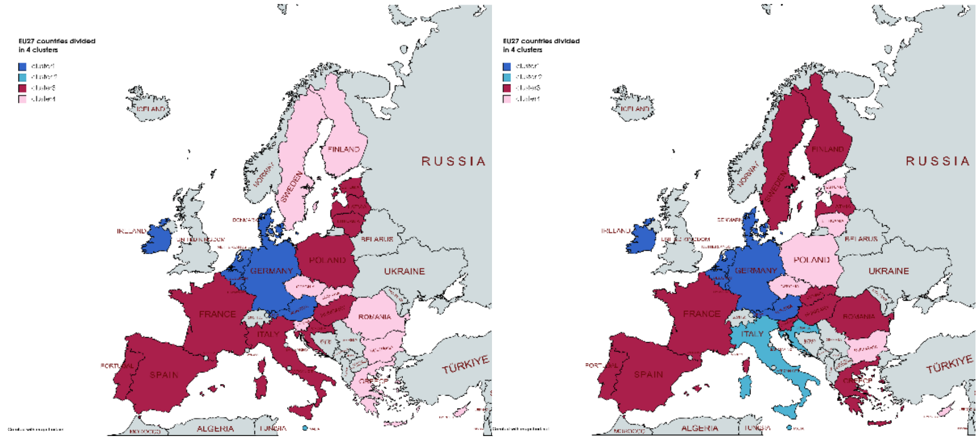



**Figure 9. Distribution on 2, respectively 3 classes**

Source: Authors' own research.

According to the classification of the EU countries into two clusters, it is noted that the east and the west seem to be divided, with the exception of Spain and Portugal, which belong to the first cluster. The countries belonging to the second cluster are characterized by larger Private investment related to circular economy sectors, having a smaller number of employees working in this sector, but also higher values of the Resource productivity indicator.

For the division into three distinct classes, it is noted that the countries in the second cluster are characterized by higher emission values, also having significant values in the field of personal investments, with the lowest percentages of employees in this sector, but also those more values of for Resource productivity. The first cluster shows high values of the indicator Gross added value related to circular economy sectors and medium to high values regarding personal investments. They are also described by the highest percentages of employees in this field in the EU, having low to medium values for Resource productivity. The third cluster is characterized by low to medium values of the Consumption footprint and Greenhouse gases emissions from production activities indicators; the same principle can be stated for Private investment and Gross added value related to circular economy sectors. Also, this cluster also presents low values of the indicator related to productivity, but also average values of the number of employees in this sector.




***(a)*** ***(b)***

**Figure 10. Distribution in 4 classes**

Source: Authors' own research.

For the division into four classes there are two ways of grouping countries with similar performances. What can be noted very clearly is the fact that the first cluster is identical regardless of the chosen method. This cluster is described by medium to high values of emissions, investments and the indicator related to productivity, also having a small number of employees in this sector.

In cluster two, the only constant is Malta, noting that in the map on the left (a) it singularly represents a distinct class presenting by far the lowest value of emissions and the highest value of consumption footprint and among the highest values of investments and added value (see Appendix). For the map on the right (b), it can be seen that in addition to Malta, Italy and Croatia also join this class, being categorized as one with high values of Consumption footprint and among the lowest in terms of Greenhouse gases emissions from production activities. It also presents among the highest values recorded for Gross added value related to circular economy sectors, but also medium to high values in terms of the number of employees in this field.

For clusters two and three, it can be noted that although aspects remained unchanged (the southwest remained within cluster three), there are countries that changed their class of origin in the two scenarios discussed. The countries in these two clusters are characterized by low to medium values of indicators in the field of Global sustainability and resilience, but also of those in the field of Competitiveness and innovation, with the exception of the percentages of employed people which are medium to high. Also, for the Resource productivity indicator, the values are low to medium (see Appendix).

**Table 3. Variability**

| Model | Total | Within | Between | r |
|---|---|---|---|---|
| 2 clusters | 156 | 112.95 | 43.05 | 0.38 |
| 3 clusters | 156 | 89.69 | 66.31 | 0.74 |
| 4 clusters (1) | 156 | 76.81 | 79.19 | 1.03 |
| 4 clusters (2) | 156 | 76.92 | 79.08 | 1.028 |

Source: Authors' own research

Table 3 presents the four proposed scenarios from the point of view of variability decomposition. For such a model, it is desirable that the variability within classes be as small as possible, and that between classes be as large as possible. In this case "r" represents the ratio between the variance between classes and that within classes, and it is required that it has a value as high as possible. In this case 1.03 is the highest value and is attributed to the division into four classes, where Malta forms a cluster by itself.

### *Discussions and recommendations*

The European Green Deal represents the EU's plan towards a climate-neutral continent, which aims to eliminate greenhouse gas emissions, as well as economic growth decoupled from resource use, investing heavily in achieving these objectives (European Commission, 2024). Therefore, the indicators analysed in the current study, especially consumption footprint and greenhouse gas emissions, contribute significantly to the achievement of this European goal. Together with resource productivity, another indicator of EU sustainability, used in evaluating the implementation of European policies, these indicators help visualize the impact of the economy on the environment, being desirable that for the first two indicators described, EU countries reach values as low as possible, while for the last indicator a value as high as possible is expected.

Based on the geographical representation of the clusters in Figure 10 a, it was found that cluster 1 is characterised by high values of the resource productivity indicator, which is defined as the volume of GDP produced per unit of direct material consumed. From this expression it is understood that it is desirable for this indicator to be as high as possible, which in the case of this indicator is achieved. Also, private investments are among the highest in the EU for this cluster (except Ireland), however, the values for gross added value are as varied as possible in the countries that make up this cluster. Regarding the consumption footprint (referring to the impact on the environment caused by consumption activities), it is desirable that the values of this indicator be as low as possible, for this group medium to low values are noted, with the exception of Denmark and Luxembourg, and in terms of greenhouse gas emissions, with the exception of Belgium, where the values are average, the other countries face a very large number of them. The last indicator analyzed refers to people employed in this field, with medium to low percentages being observed. For this cluster, it is recommended to immediately find solutions to reduce greenhouse gas emissions, as well as to hire a number of people in this field.

The second cluster consists of a single country, namely Malta, where although resource productivity, private investments and gross added value related to circular economy sectors and people employed in this sector are high, they still face a very high consumption footprint; nevertheless, greenhouse gas emissions retain among the lowest values in the EU.

The third group analyzed generally shows average values for all categories of indicators analysed, leaving room for significant improvements for all the aspects presented. For the last cluster, medium to low values are noted for most of the evaluated indicators, a sign that there is a relatively small number of employees in this field, as well as personal investments and gross added value could increase to help reduce the negative impact on the environment. However, with the exception of Bulgaria and Romania, the countries composing cluster four show average to low consumption footprints, but all have average carbon emission values. Although facing understaffing and low investment, countries of the fourth cluster do not show such bad values of environmental sustainability indicators.

The opportunities planned by European leaders for the transition to climate neutrality associated with economic growth relate to technological change and job creation to achieve this goal (European Council, 2024). Therefore, encouraging innovation and investments, as well as policies implemented in the green economy, are essential to reduce the negative impact on the environment. The countries that make up the last two clusters presented need to be given greater interest, as it is necessary to work with both the mentality of citizens and green finance.

## Conclusion

The practical application of the circular economy refers to the reduction of material waste to a minimum, this being a good way to reduce the pollution related to this exaggerated consumption of limited resources. Thus, it is encouraged to reduce the amount of waste by identifying those materials that can be reused instead of disposable ones, but also by finding new ways to use old products.

In order to test the productivity, resilience and innovation of this sector through the lens of the EU member states, six indicators were chosen for three areas through which the circular economy can be observed: Production and consumption (resource productivity), Global sustainability and resilience (consumption footprint and greenhouse gas emissions from production activities) and Competitiveness and innovation (private investment and gross added value related to circular economy sectors and persons employed in circular economy sectors).

From the point of view of the descriptive statistics, it was found that there are significant discrepancies between the EU member states, in the context in which the country with the highest greenhouse gas emissions from production activities produces 3.5 times more such emissions compared to the one with the lower values. It is found that at the EU average level, 7041.28 kilograms per capita of greenhouse gas emissions from production activities are produced, the average productivity of resources is 1.87 euros per kilogram, private investments in this field are 0.69% of GDP, while the added value is of 1.69% of GDP, and the percentage of employees is 1.83%.

Regarding the European ranking associated to resource productivity, it can be seen that most of the countries in the east and north-east of the EU register values lower than or equal to 0.97 euros per kilogram, while the countries in the central area register values exceeding 2.61 euros per kilogram. The highest percentages of circular economy employees are found in Latvia, Lithuania, Poland, Slovenia and Italy, where the values exceed 2.3%. The same principle does not apply to countries such as Romania, Greece, Austria, Denmark, the Netherlands, Belgium and Luxembourg, where the percentage of these employees does not exceed 1.35%, the rest of the countries having values between 1.36% and 2.3%. On the topic of private investment and gross added value related to circular economy sectors presents among the highest percentages in both fields, with values exceeding 0.85% and 1.90% of GDP, respectively. Countries such as Sweden, Finland, Romania, Greece, the Czech Republic and Slovakia, being at the opposite pole, where the values do not surpass 0.5% and 1.40% of GDP, respectively. For the consumption footprint, it is noted that countries such as Finland, Latvia, Greece, Germany, Slovenia, Belgium and Ireland have values of this index below 97.50, while Denmark, Luxembourg, Poland, Bulgaria, Croatia, Malta and Portugal register values above 109.50. For greenhouse gases emissions from production activities, Sweden, Latvia, Croatia, Malta, France, Spain and Portugal have good values of 5138.41 kilograms per capita, while Estonia, Poland, the Czech Republic, Denmark, the Netherlands, Luxembourg and Ireland show values of over 8424.45 kilograms per capita.

Following the cluster analysis, the countries in the middle of the EU (Ireland, Denmark, France, Germany, Luxembourg, the Netherlands, Belgium, Italy, Malta and Austria) are classified as the countries with the highest values of private investments related to circular economy sectors, but also of resource productivity, but also among the lowest percentages of employees in this field. Of these, Malta has the highest values of private investment and gross added value related to circular economy sectors, but also among the lowest emissions, as well as the highest consumption footprint.

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## References

Bratchell, N. (1989). Cluster analysis. Chemometrics and Intelligent Laboratory Systems, 105-125.

Busu, M. and Trica, C. (2019). Sustainability of circular economy indicators and their impact on economic growth of the european union. Sustainability, 11(19), 5481. https://doi.org/10.3390/su11195481

Camilleri, M. (2020). European environment policy for the circular economy: implications for business and industry stakeholders. Sustainable Development, 28(6), 1804-1812. https://doi.org/10.1002/sd.2113

Charrad, M., Ghazzali, N., Boiteau, V., & Niknafs, A. (2014). NbClust: An R Package for Determining the Relevant Number of Clusters in a Data Set. Journal of Statistical Software.

Clodniţchi,R. & Tudorache,O. (2022). Resource efficiency and decarbonisation of economies in the European Union. Management & Marketing,17(2) 139-155. https://doi.org/10.2478/mmcks-2022-0008

Duquennoi, C. and Martínez, J. (2022). European union's policymaking on sustainable waste management and circularity in agroecosystems: the potential for innovative interactions between science and decision-making. Frontiers in Sustainable Food Systems, 6. https://doi.org/10.3389/fsufs.2022.937802

European Commission. (2024, 02 15). European Commission. Retrieved from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Council. (2024, 01 04). Retrieved from Climate change: what the EU is doing: https://www.consilium.europa.eu/en/policies/climate-change/

Flachenecker, F. (2017). The causal impact of material productivity on macroeconomic competitiveness in the european union. Environmental Economics and Policy Studies, 20(1), 17-46. https://doi.org/10.1007/s10018-016-0180-3

Fura, B., Stec, M., & Miś, T. (2020). Statistical evaluation of the level of development of circular economy in european union member countries. Energies, 13(23), 6401. https://doi.org/10.3390/en13236401

Jacometti, V. (2019). Circular economy and waste in the fashion industry. Laws, 8(4), 27. https://doi.org/10.3390/laws8040027

Ikotun, A. M., Ezugwu, A. E., Abualigah, L., Abuhaija, B., & Heming, J. (2023). K-means clustering algorithms: A comprehensive review, variants analysis, and advances in the era of big data. Information Sciences, 178-210.

Ngo,Q. (2022). Are small and medium enterprises beneficial from the adoption of green market orientation under the intensity of market competition? A strategic alignment perspective. Management & Marketing,17(4) 543-564. https://doi.org/10.2478/mmcks-2022-0030

Palm, E., Hasselbalch, J., Holmberg, K., & Nielsen, T. (2021). Narrating plastics governance: policy narratives in the 1411uropean plastics strategy. Environmental Politics, 31(3), 365-385. https://doi.org/10.1080/09644016.2021.1915020

Polyakov, M., Khanin, I., Bilozubenko, V., Korneyev, M., & Shevchenko, G. (2021). Factors of uneven progress of the european union countries towards a circular economy. Problems and Perspectives in Management, 19(3), 332-344. https://doi.org/10.21511/ppm.19(3).2021.27

Streimikiene, D. (2022). Community based social marketing for greenhouse gas emission reduction in households. Management & Marketing,17(4) 485-502. https://doi.org/10.2478/mmcks-2022-0027

# Appendix

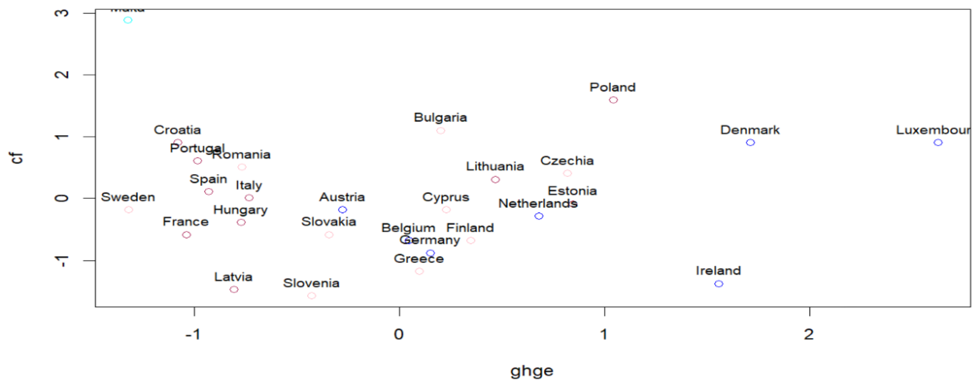


**Figure 11. Consumption footprint and Greenhouse gases emissions from production activities (4.1 scenario)**

Source: Authors' own research.

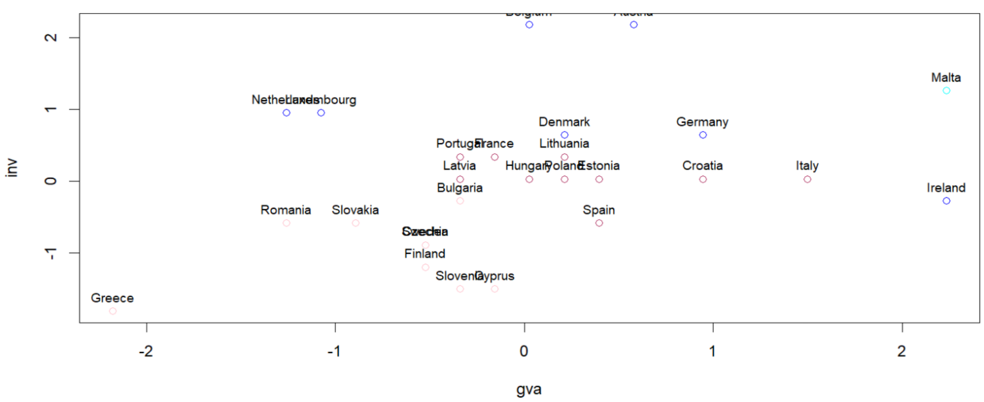


**Figure 12. Private investment and Gross added value related to circular economy sectors (4.1 scenario)**

Source: Authors' own research.

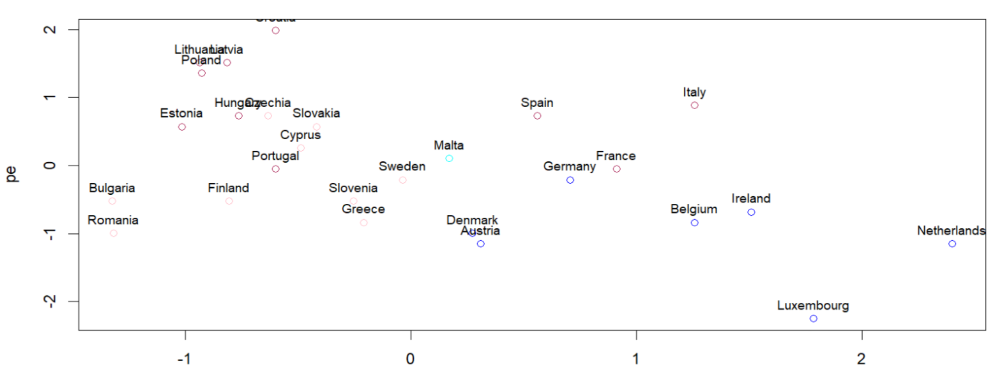


**Figure 13. Resource productivity and Persons employed in circular economy sectors (4.1 scenario)**