Circular Economy and Recycling of Electronic Products in the European Union

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Abstract. *The plan proposed within the 2030 Agenda through its specific objectives regarding sustainable development as well as through the approach to achieving a circular economy, is part of a strategy at European level for improving and preserving the environment in a sustainable manner. The recycling process as a component of the strategy has and will have a major impact on the environment. In this article, a data mining analysis is carried out regarding the recycling rate of electronic and electrical products at the European level. The analysis is carried out for two moments of time, namely the year 2018 and the year 2021. Following the clustering process of the countries from the European Union (EU), it is easier to see which countries have similar behavior from this point of view. At the same time, taking into account the two years, it is possible to observe the dynamics of the created clusters and how the European countries succeed to manage the recycling process of electronic and electrical products three years apart. The two moments were chosen taking into account the COVID-19 pandemic, the period in which, the teleworking way has occurred. For this reason, many employees had to purchase the necessary things and transform at least one room into an office. The authors' contributions consisted in the pre-processing of data sets, the application of data mining algorithms, obtaining the results and their interpretation in the given context, commenting on the results obtained and providing answers to the research questions. The work is structured in five sections, respectively Introduction, Literature review, Methodology, Results and Discussion and Conclusion.*

Keywords: circular economy, recycling, 2030 Agenda, European Union, data mining

Introduction

Within the European Union (EU), Agenda 2030 represents a plan of major importance, a plan that was approved and adopted in 2015 by all EU member countries. Within this agenda, 17 Sustainable Development Goals (SDGs) are proposed and described, each aimed at improving the aspects that influence the daily life of all citizens (Alpopi et al., 2022). The implementation of the 2030 Agenda implies the realization of policies and actions that are in agreement with the SDGs in order to offer countries the best possible conditions for the implementation of specific

DOI: 10.2478/picbe-2024-0078

actions in order to achieve the objectives (Rădulescu, Angheluta et al., 2022). Among the main aspects present in the 2030 Agenda, we can mention the integrated approach of several aspects (such as economic, social, environmental, etc.) (Rădulescu, Mănescu et al., 2023) to achieve sustainable development, digitization, and innovation (Mogos et al., 2021), following the achievement of the European Green Deal, climate resilience and Net-Zero Commitments, strengthening global health infrastructure (Burlacu, 2018).

A new concept used in recent years is that of the circular economy (Rădulescu et al., 2022). Starting from this concept, we want to design and build an economic system that minimizes the consumption of resources and at the same time maximizes the use of the resources used. These things become possible through actions such as recycling, reuse and the manufacture of products made from materials that have as little impact on the environment as possible (Burlacu, Bran et al., 2022).

The objective of this research is to realize a comparison for countries from EU regarding the recycling rate of the waste resulting from the disposal of electrical and electronic devices (EED) between year 2018 and year 2021. The degree of novelty of the author's approach consists in using the data mining analysis in order to realize the proposed comparison.

Within the framework of this work, a data mining type analysis was carried out at the EU level for the year 2018 and the year 2021 regarding the recycling rate of the waste resulting from the disposal of EED. The two moments of time were chosen taking into account the COVID-10 pandemic, the period in which the purchase of electrical and electronic products increased a lot. This increase was especially due to the possibility of working from home. Many employees were not technically prepared to work from home. Thus, these purchases had to be made.

Research questions that this article tries to answer: 1. "Which are the groups of countries in the EU that in 2018 and in 2021 had a similar behavior in terms of the recycling rate of electrical and electronic devices?"; 2. "Which values are the most representative for each individual group?"; 3. "What is the dynamics of the identified groups in relation to the two years chosen, respectively 2018 and 2021"?

In order to obtain the answer to these questions, the data provided by Eurostat (https://ec.europa.eu/eurostat) were used. The data sets were processed and loaded into software dedicated to data mining analysis, using specific clustering algorithms for data processing.

Literature review

The 2030 agenda proposed by the EU represents a global action plan that takes into account sustainable development taking into account three dimensions, namely social, environmental and economic. This is addressed to both developed and developing countries (Fernández et al., 2022; García-Sánchez et al., 2023).

The main component of this agenda is represented by the 17 objectives generically called Sustainable Development Goals (Angheluta et al., 2019). These aim at issues such as no poverty, zero hunger, health, education, gender equality, clean water, accessible clean energy, decent work, industry and innovation, reduced inequalities, sustainable cities, responsible consumption and production, climate action, aquatic and terrestrial life , justice and efficient institutions, partnerships for the achievement of objectives (Ciulli, 2022; Leal et al., 2023; Mogos et al., 2023; DDD, 2023).

Objective no. 12, respectively responsible consumption and production, aims for these two actions to be carried out in a sustainable manner. It is mainly intended to promote the fact that resources are in finite quantity and everything that is produced should be used in the most responsible manner and made from recyclable materials to the greatest extent possible. Also, production carried out in the most efficient manner, sustainable waste management, the lowest possible level of things that are thrown away are actions that must be in accordance with the principles that lead to a high protection of the environment (Marchand & Walker, 2008; Sudhanshu & Richa, 2017; Jacob-John et al., 2021).

In order to fulfill objective 12, namely responsible consumption and production, the concept of circular economy was also developed. The circular economy proposed within the EU by the European Commission takes into account aspects such as (Barcic et al., 2019; Bellemare, et al., 2022):

- The action plan on which the implementation of the circular economy is based at the European level but also at the state level, a plan that takes into account the promotion and highlighting of circularity within the main sectors of activity. The plan mainly aims at strategies for reducing waste, increasing recycling and encouraging the creation of products made from materials that have as little impact on the environment as possible;
- Imposing quotas for waste management and thresholds for the amount of recycled products. These targets are closely related to reducing landfilling, increasing recycling rates, using recyclable materials at an industrial level on an increasingly large scale;
- Identifying and exploiting sources and financing mechanisms for the transition to a circular economy. In this regard, they consider funding for research and innovation, as well as attracting private investments for circular business models.
- Creating a platform for all stakeholders and participants involved in achieving the circular economy. The platform aims to provide assistance and support as well as to facilitate exchange and collaboration between all those involved such as companies, firms, NGOs, public authorities, financial institutions, etc.;
- The creation and implementation of policies that take into account the creation of products from ecological materials that also have an eco-design. These policies must promote products that are as durable, easy to repair, made from as many materials and recyclable components as possible, which have as little harmful impact on the environment. It is also taken into account to obtain a product life cycle that is as sustainable in a large degree;
- Imposing directives to reduce the use of single-use plastic products. These directives have the role of reducing the amount of plastic products that are used too little in relation to the harmful impact they have on the environment. For this reason, it is desired to remove them by restricting their sale and use, replacing them with other alternatives that are more ecofriendly.

An important aspect in the circular economy is represented by the recycling process. This process is a difficult one, especially when it comes to the recycling and reuse of electronic and electrical products. These are in an increasingly large number and specific recycling actions require more and more resources (Lee et al, 2023; Zhang et al., 2021). Among the specific actions that can improve the realization of the recycling process related to electronic and electrical products can be listed (Sommerville et al., 2021; Abdallah et al., 2023):

- Collection and sorting of objects (establishment of special centers where objects can be brought);
- Reuse and refurbishment (establishment of locations in which to carry out their repair and reconditioning);
- The recovery of materials and components that can be reused, the implementation of legislation in which the consumer also has a responsibility regarding the collection of objects,

- Promoting in schools an education regarding the sustainable preservation of the environment as well as the negative impact that certain materials and products can have.

The main gap that the present research tries to fulfill is that based on the obtained results, the leaders of WU may start to address and to develop recycling politics and strategies not for each country from EU (which it may very time consuming and expensive) or for the entire EU (in which cases, some regulations/politics/strategies are not appropriate) but for groups of countries, countries that have a similar behavior from the recycling process point of view. In few research papers there is analyzed also a correlation between countries for a certain category of products that must be recycled.

Figure 1 shows the recycling rate of all waste percent for year 2020 at the EU level for each country. Data are expressed in percentages.

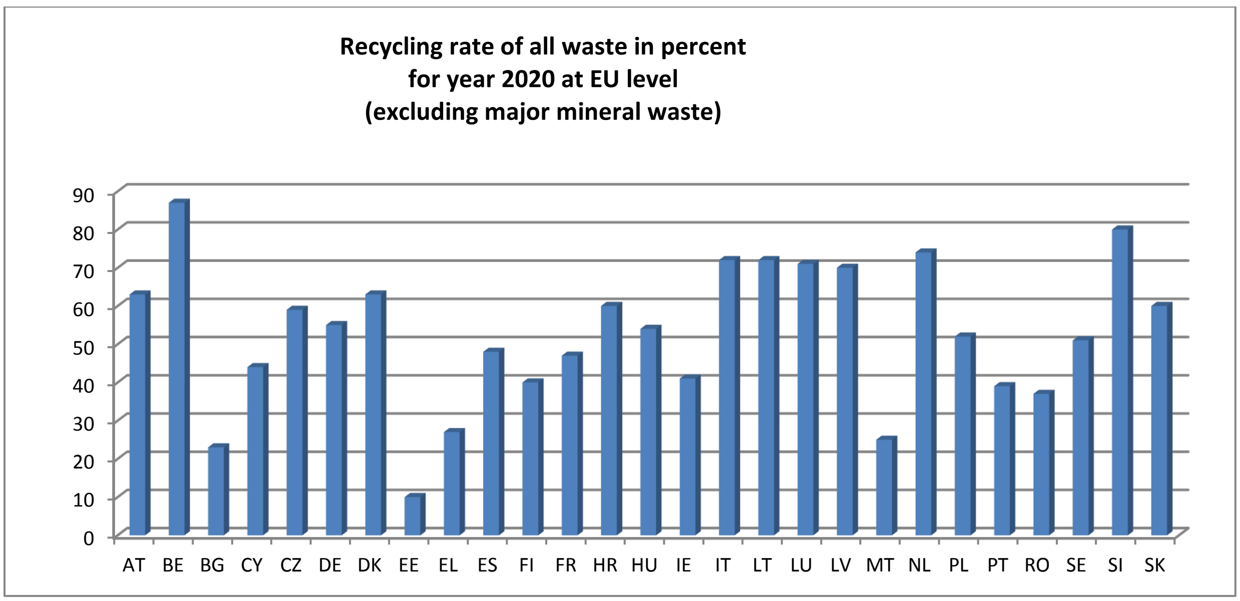

Figure 1. Recycling rate of all waste in percent for year 2020 at EU level
(excluding major mineral waste)
Source: https://ec.europa.eu/eurostat/web/main/data/database.

In the following section, a data mining analysis is performed based on data sets provided by the EU. These data refer to the recycling rate of waste of electrical and electronic equipment. Two moments of time were considered, the year 2018 and the year 2021. The first year 2018 was chosen because it was before the COVID-19 pandemic and the year 2021 being after the way of working from home (work from home, teleworking) was widely adopted (Belostecinic et al., 2022).

Transforming the house into a workplace for the job was not easy (Ladaru et al., 2022). This involved, in addition to the actual arrangement of the space, the purchase of electrical and electronic devices in a much larger number than usual. Within the EU and beyond, a much larger number of such objects have to be managed implicitly and at the recycling level. From this point of view, the analysis aims to identify the groups of countries with similar behavior regarding the rate of waste of electrical and electronic equipment. Also, for the two years taken into account, the dynamics of the groups of countries can be analyzed, highlighting at the same time the way in which the EU countries coped with the sudden increase in the number of electrical and electronic equipment that must be recycled.

Methodology

Data mining analysis represents a process of discovering patterns, trends, correlations or useful information within data sets, elements that are not easy to identify. In order to carry out this data mining analysis, data sets provided by Eurostat were used. For each type of data set, the 27 EU countries were selected, namely Austria, Belgium, Bulgaria, Cyprus, Czechia, Germany, Denmark, Estonia, Greece, Spain, Finland, France, Croatia, Hungary, Ireland, Italy, Lithuania , Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia.

In order to perform the data mining analysis, the CRoss Industry Standard Process for Data Mining (CRISP-DM) methodology was used (CRISP-DM, 2022). The methodology has several phases, respective requirements/business understanding, data understanding and preparation, data modeling, evaluation and deployment. For each stage of the methodology used, there is a question for which an answer must be identified. A brief description of each stage and the questions to be answered are shown in Table 1.

Table 1. CRISP-DM Methodology - Phases

No.	Phase	Description	Question
1	Business understanding	It aims to understand the objective and the requirements of the analysis.	What does the business need?
2	Data understanding	Follows the identification, collection and analysis of data sets that can help achieve the objectives.	What data do we have or need?
3	Data preparation	It aims at preparing the data set and obtaining its final form. Specific tasks for this phase regarding data are: select, clean, construct, integrate and format data.	How do we organize the data for modeling?
4	Modeling	During this phase, the most appropriate modeling techniques will be evaluated and chosen. This phase includes four tasks, respectively: selection of modeling techniques/algorithms, generated test design, build model, assess model.	What modeling techniques should we apply?
5	Evaluation	This phase considers the evaluation of the results of the models and the identification of the most representative one.	Which model best meets the business objectives?
6	Deployment	The result of this phase can be something simple (egg. generating a report) or something complex (egg. implementing a repeatable data-mining process).	How do stakeholders access the results?

Source: https://www.datascience-pm.com/crisp-dm-2 (Hotz, 2023).

For the data preparation stage, it was necessary to obtain an arff data file that was later loaded into the WEKA software (WEKA, 2023), software dedicated to this type of analysis. Cluster algorithms were used in the analysis, algorithms like EM (expectation maximization) and Simple K-Means.

EM (expectation maximization) algorithm was used to identify the recommended number of clusters (groups) for the countries. EM can decide how many clusters to create by cross validation (CV) process. This process consists of (WEKA, 2023):

S1. The number of clusters is set to 1;

S2. The training set is split randomly into 10 folds;

S3. EM is performed 10 times using the 10 folds, the usual CV way;

S4. The final result is averaged over all 10 results;

S5. If the final result has increased, the number of clusters is increased by 1 and the program continues at step S2.

The parameters that could be used as input are: maximum number of iterations (100), minimum allowable standard deviation (1.0E-6), number of clusters (-1 to identify the number of clusters automatically by CV), the random number seed to be used (100). The number of clusters indicated by the EM algorithm was then used as an input parameter for Simple K-Means algorithm.

Simple K-Means algorithm was used to partitioning the data set into K different clusters, each one with different characteristics. Countries with similar behavior will be placed in the same cluster taking into account all the attributes included in the analysis. The steps of this algorithm are:

S1. Determine the value "K", the number of clusters. This value is identified by the EM algorithm and for this analysis is four;

S2. Four distinct centroid are selected randomly (centroids represent new data used for cluster initialization);

S3. The Euclidian distance is measured between each point and the centroid;

S4. Each point is assigned to the nearest cluster;

S5. The mean of each cluster is computed as a new centroid;

S6. Repeat step 3–5 with the new center of cluster.

The parameters that could be used as input are: distance type (Euclidian distance for this analysis), maximum number of iterations (500), number of clusters (4), random number seed to be used (10).

Results and discussions

Following the application of the data mining and clustering methods carried out for the two directions of analysis regarding the recycling rate of waste of electrical and electronic equipment related to the years 2018 and 2021, the results described below were obtained. For each of the two years, the country and the representative value for each cluster are mentioned, as well as the distribution of countries in each cluster. At the end of the section, the differences between the two years at country level are also mentioned.

a) In the first analysis regarding the recycling rate of waste of electrical and electronic equipment related to the year 2018, four clusters were identified. Their description is as follows:

- cluster 0: number of countries allocated in this cluster: 3 (11%), the most representative country: Belgium, recycling rate value: 73.78%, countries: Austria, Bulgaria, Denmark;
- cluster 1: number of countries allocated in this cluster: 4 (15%), the most representative country: Austria, recycling rate value: 80.55%, countries: Cyprus, Greece, Lithuania, Latvia;
- cluster 2: number of countries allocated in this cluster: 5 (19%), the most representative country: Cyprus, recycling rate value: 83.62%, countries: Belgium, France, Malta, Netherlands, Portugal;
- cluster 3: number of countries allocated in this cluster: 15 (56%), the most representative country: Czechia, recycling rate value: 85.95%, countries: Czechia, Germany, Estonia, Spain, Finland, Croatia, Hungary, Ireland, Italy, Luxembourg, Poland, Romania, Sweden, Slovenia, Slovakia.

For an easier analysis, the data were also represented in Table 2.

According to the results obtained, it can be observed that the countries allocated within cluster 2 (rank number 4) have the lowest recycling rate of electrical and electronic equipment with an average of 73.78%. At the opposite pole are the countries from cluster 3 (rank number 1) for which the average is 85.95%. Also, regarding cluster no. 3, it can be stated that it has the highest representativeness. Surprising is the placement of Austria in cluster no. 0, the one with the lowest recycling rate but also the placement in cluster no. 3 of countries such as Estonia and Slovenia that manage to have a high degree of recycling rate of waste of electrical and electronic equipment. In the Figure 2, the cluster allocation of the countries in the EU at the level of 2018 regarding the recycling rate of waste of electrical and electronic equipment is represented.

Table 2. Clusters based on recycling rate of waste of electrical and electronic equipment for year 2018

Cluster no.	No. of countries allocated	The most representative country from the cluster	Recycling rate percent value	Countries allocated per cluster	Cluster rank (1 – the best, 4 – the worst)
0	3 (11%)	Austria	80,5%	Austria, Bulgaria, Denmark	3
1	4 (15%)	Cyprus	83,62%	Cyprus, Greece, Lithuania, Latvia	2
2	5 (19%)	Belgium	73,78%	Belgium, France, Malta, Netherlands, Portugal	4
3	15 (56%)	Czechia	85.95%	Czechia, Germany, Estonia, Spain, Finland, Croatia, Hungary, Ireland, Italy, Luxembourg, Poland, Romania, Sweden, Slovenia, Slovakia	1

Source: Authors' own research.

b) In the second analysis regarding the recycling rate of waste of electrical and electronic equipment for the year 2021, four clusters were identified. Their description is as follows:

- cluster 0: number of countries allocated in this cluster: 8 (30%), the most representative country: Austria, recycling rate value: 82.06%, countries: Austria, Cyprus, Estonia, Greece, Hungary, Ireland, Lithuania, Latvia;
- cluster 1: number of countries allocated in this cluster: 6 (22%), the most representative country: Denmark, recycling rate value: 75.58%, countries: Denmark, Spain, France, Netherlands, Romania, Sweden;
- cluster 2: number of countries allocated in this cluster: 10 (37%), the most representative country: Bulgaria, recycling rate value: 89.13%, countries: Bulgaria, Czechia, Germany, Finland, Croatia, Italy, Luxembourg, Poland, Slovenia, Slovakia;
- cluster 3: number of countries allocated in this cluster: 3 (11%), the most representative country: Belgium, recycling rate value: 60.73%, countries: Belgium, Malta, Portugal.

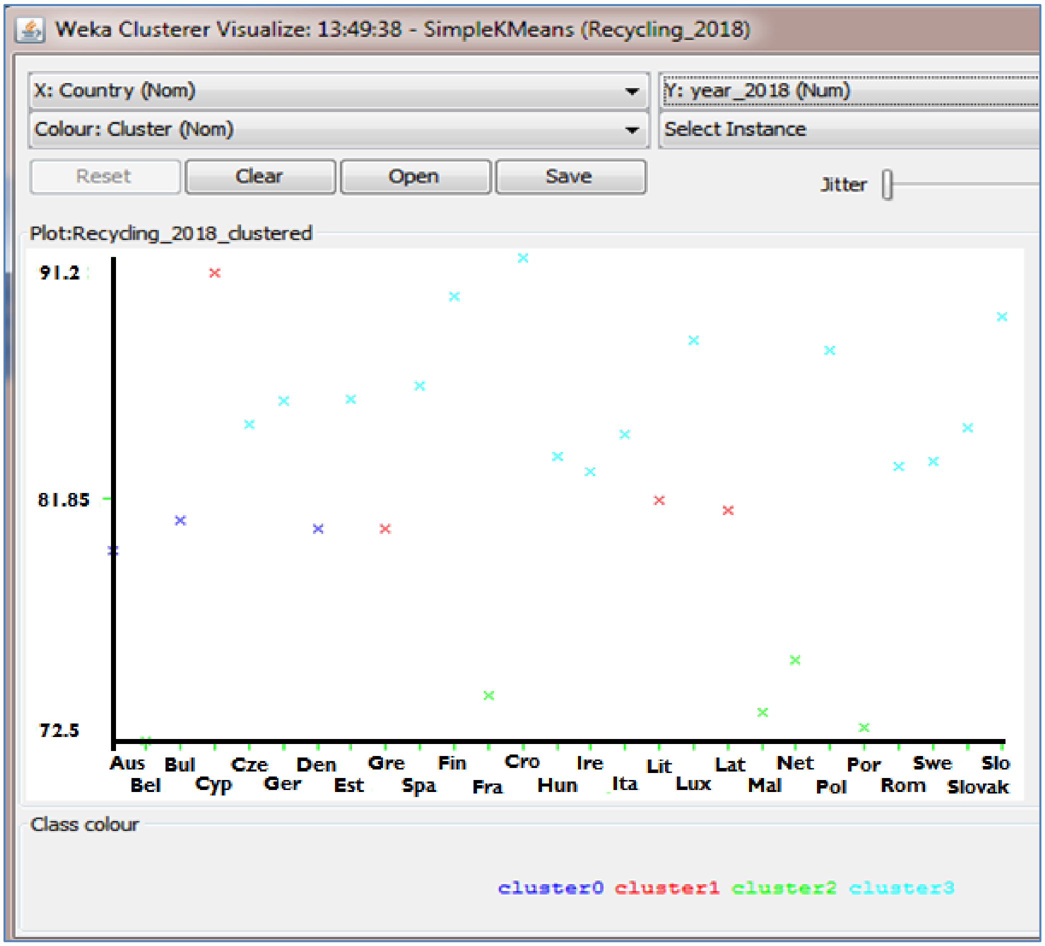

Figure 2. Recycling rate of waste of electrical and electronic equipment - Cluster allocation for year 2018

Source: Authors' own research.

For an easier analysis, the data were also represented in Table 3.

According to the results obtained, it can be observed that the countries assigned within cluster 3 (rank number 4) have the lowest recycling rate of electrical and electronic equipment with an average of 60.73%. At the opposite pole are the countries from cluster 2 (rank number 1) for which the average is 89.13%.

As an observation based on the results obtained, it can be stated that Portugal is distributed in cluster no. 3, cluster with the lowest value for recycling rate of waste of electrical and electronic equipment. In the Figure 3, the cluster allocation of the countries in the EU at the level of 2021 regarding the recycling rate of waste of electrical and electronic equipment is represented.

Table 3. Clusters based on recycling rate of waste of electrical and electronic equipment for year 2021

Cluster no.	No. of countries allocated (cluster percent)	The most representative country from the cluster	Recycling rate percent value	Countries allocated per cluster	Cluster rank (1 – the best, 4 – the worst)
0	8 (30%)	Austria	82,06%	Austria, Cyprus, Estonia, Greece, Hungary, Ireland, Lithuania, Latvia	2
1	6 (22%)	Denmark	75,58%	Denmark, Spain, France, Netherlands, Romania, Sweden	3
2	10 (37%)	Bulgaria	89,13%	Bulgaria, Czechia, Germany, Finland, Croatia, Italy, Luxembourg, Poland, Slovenia, Slovakia	1
3	3 (11%)	Belgium	60.73%	Belgium, Malta, Portugal	4

Source: Authors' own research.

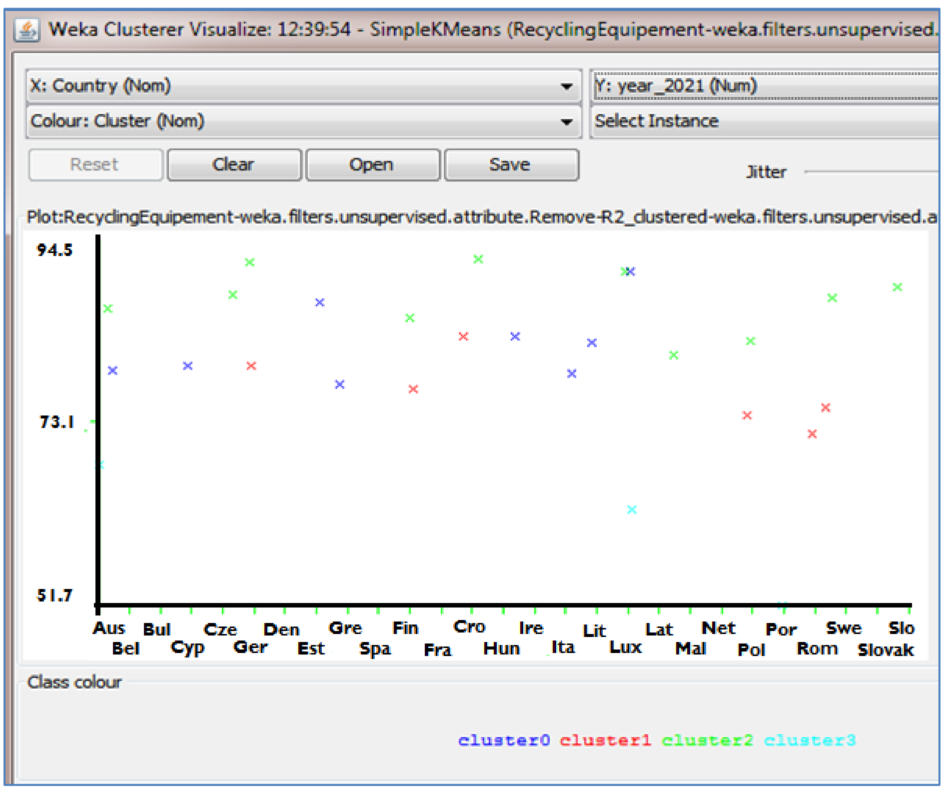

Figure 3. Recycling rate of waste of electrical and electronic equipment - Cluster allocation for year 2021

Source: Authors' own research.

Within tables 1 and 2 there is a column named Cluster_rank which has values from 1 to 4, 1 meaning the best cluster, with the highest recycling rate value and 4 the cluster with the lowest

DOI: 10.2478/picbe-2024-0078, pp. 898-912, ISSN 2558-9652 |
Proceedings of the 18th International Conference on Business Excellence 2024

rate value. In table 4 Based on the information obtained and mentioned in tables 1 and 2, the following statements can be made:

- Out of the 27 countries, 10 countries were classified in a different cluster in 2021 compared to 2018. From this point of view, it can be stated that there is a great dynamic of the countries taking into account that around a third were classified differently from one year to another;
- Of these 10 countries, only 4 moved into a better cluster, respectively: Austria (from 3 to 2), Bulgaria (from 3 to 1), France (from 4 to 3) and the Netherlands (from 4 to 3). The biggest difference can be seen in Bulgaria, which managed to increase the degree of recycling by almost 9 percent;
- Also from the 10 countries, the 6 that moved to a lower cluster are: Estonia (from 1 to 2), Spain (from 1 to 3), Hungary (from 1 to 2), Ireland (from 1 to 2), Romania (from 1 in 3) and Sweden (from 1 in 3). It can be observed that the biggest jump in negative terms was made by Spain, Romania and Sweden.

Table 4. Clusters' dynamics for 2018 and 2021 for recycling rate of waste of electrical and electronic equipment

Country	Country code	2018	Cluster rank_2018	2021	Cluster rank_2021
Austria	AT	79.8	**3**	81.6	**2**
Belgium	BE	72.5	4	72.2	4
Bulgaria	BG	81	**3**	89	**1**
Cyprus	CY	90.6	2	81.6	2
Czechia	CZ	84.7	1	94.5	1
Germany	DE	85.6	1	86.1	1
Denmark	DK	80.7	3	79.9	3
Estonia	EE	85.7	**1**	81.6	**2**
Greece	EL	80.7	2	80.9	2
Spain	ES	86.2	**1**	73	**3**
Finland	FI	89.7	1	88.1	1
France	FR	74.2	**4**	77.2	**3**
Croatia	HR	91.2	1	92	1
Hungary	HU	83.5	**1**	79.6	**2**
Ireland	IE	82.9	**1**	83.4	**2**
Italy	IT	84.3	1	87.1	1
Lithuania	LT	81.8	2	84.3	2
Luxembourg	LU	88	1	89	1
Latvia	LV	81.4	2	83.5	2
Malta	MT	73.6	4	58.3	4
Netherlands	NL	75.6	**4**	71.1	**3**
Poland	PL	87.6	1	85.9	1

Country	Country code	2018	Cluster rank_2018	2021	Cluster rank_2021
Portugal	PT	73	4	51.7	4
Romania	RO	83.1	**1**	76	**3**
Sweden	SE	83.3	**1**	76.3	**3**
Slovenia	SL	84.6	1	87.1	1
Slovakia	SK	88.9	1	92.5	1

Source: Authors' own research and https://ec.europa.eu/eurostat/web/main/data/database.

Considering the first two research questions, namely "Which are the groups of countries in the EU that in 2018 and in 2021 had a similar behavior in terms of the recycling rate of electrical and electronic devices?" and "Which values are the most representative for each individual group?", the answers are provided in Tables 1 and 2.

Regarding the third research question, namely "What is the dynamics of the identified groups in relation to the two chosen years, 2018 and 2021?" it can be stated that there is a great dynamic, more than a third of the countries initially classified in 2018 in one group were assigned in 2021 to another group. Of the 10 countries that were classified differently, only 4 managed to improve the Recycling rate of waste of electrical and electronic equipment, moving into a group with a better rank.

One of the explanations that justify this dynamic is that due to the COVID-19 pandemic, many employees had to arrange their home space in order to carry out their work from the office. In this sense, a lot of electrical and electronic equipment has been purchased, many replacing older ones and others may fail as soon as they are out of warranty. For this reason, a much larger number of equipment had to be properly collected, taken to specially arranged centers and recycled to the greatest extent. Many of the processing centers did not have the necessary capacity to deal with such a large number of equipment, many of these are remaining not properly recycled.

Another reason would be the fact that many employees, although they did not work with electrical and electronic devices, had to buy and learn to use them. Being at the beginning with the use of this equipment, many damaged the purchased equipment prematurely.

After the analysis, it can be seen that developed countries like Spain and Sweden did not do well in terms of recycling rate of waste of electrical and electronic equipment, but countries like Bulgaria managed to have a very good rate.

In order to support the recycling process and implicitly to improve the rates regarding waste of electrical and electronic equipment, a series of modern technologies could be developed and implemented on an increasingly large scale at the EU level and beyond. Among the main technologies of this type it can be mentioned (RTTI, 2023): internet of waste (strong related to Internet of things – IoT, could improve waste management and recycling process very much by reducing the inefficiencies in waste logistics; for example assisting and monitoring fill levels in garbage containers may allow collection facilities to ensure the pickup at the right moment of time.), analytics and big data (they are used in the recycling industry in order to allow recycler companies to identify process inefficiencies and processes that could be improved and also to facilitate flow management), green waste management (it tries to identify and develop solutions in order to up cycle organic waste into stabilized organic compounds, methane and carbon dioxide), material life cycle extension, artificial intelligence (could allow plastic recycling machines to use an automate process for specific tasks regarding the materials, tasks like sorting and picking), the use of recycling robots. All these new technologies may help also into the development and implementation of the circular economy for the EU countries.

The policies and strategies that should be developed having as a core the circular economy and also the improvement of the recycling process, should be designed taking into account the specifics of each individual country but also of the groups of countries that can be formed.

The countries within a group should have similar behavior regarding the recycling capacity, the vision on this aspect, its integration within the circular economy.

The decision-makers both at the European level and at the country level should take into account: a) the responsibility of firms and companies regarding the recovery and reuse of products and used technology; b) the responsibility of consumers to be actively involved in the product recycling process.

The decision-makers should impose some targets both in the medium and long term and to be achieved as much as possible. These measures will cover both the process of re-use and recycling of e-waste. Depending on the characteristics of a country or, more simply, of a group of countries, these targets that must be reached can be imposed. Some more developed countries can reach certain targets more easily than others.

It would also be useful for governments to impose some laws and implicitly some immediate sanctions in order to implement the recycling process. France, for example, has implemented a program called the Repairability Index through which consumers have access to information based on which they can repair the purchased products themselves. Such a project would be recommended to be implemented at the European level.

Another possible solution that decision-makers can apply is to force companies to standardize certain products that can be used regardless of context. For example, a universal phone charger would be useful, a charger that can be used regardless of the type or brand of phone.

The adoption and implementation of the circular economy in close connection with the recycling process represents the core of green recovery for both companies and businesses as well as for the government.

Conclusion

The 2030 Agenda together with the circular economy at the EU level represent two elements that will bring a major change regarding the perception of citizens and companies on how the environment must be preserved and protected in a sustainable manner. In this sense, the 17 Sustainable Development Goals were developed to provide a map of the main directions that should be taken into account. In this article, the main characteristics of the 2030 Agenda, its objectives, as well as the main aspects underlying the circular economy were presented. A data mining analysis was carried out using clustering algorithms to determine which are the groups of countries in the EU that in 2018 and in 2021 had a similar behavior in terms of the recycling rate of electrical and electronic devices, being also identified the most representative values for each individual group. Another objective of the analysis consisted in identifying the dynamics of the identified groups in relation to the two moments of time, 2018 and 2021 in order to be able to analyze how the EU countries coped with the very large number of electrical and electronic equipment that were purchased, which greatly affected the recycling process. The results showed that some developed countries failed to manage the recycling process very well, but less developed countries succeeded. Around two-thirds of the EU countries managed to maintain a constant rate of recycling of electrical and electronic equipment before and after the pandemic.

Among the limitations of the analysis, we can mention the fact that some recycling rates in the data set were estimated, the data not being able to be collected in full. A future direction of analysis would consist in correlating the recycling rate for electrical and electronic equipment with other factors such as the recycling capacity at the country level, the number of employees in the field, the breakdown and replacement rate of the equipment.

References

Abdallah, A., Dauwed, M., Aly, A.A., Felemban, B.F., Khan, I. & Madsen, D.O., (2023). Industrial Recycling Process of Batteries for EVs, Cmc-Computers Materials & Continua, Publisher name Tech Science Press, Volume 74, Issue 2, pp. 4571-4586, https://doi.org/10.32604/cmc.2023.032995

Alpopi, C., Burcea, Ș. G., Popescu, R. I., & Burlacu, S. (2022). Evaluation of Romania's Progress in Achieving SDG 11: Sustainable Cities and Communities. *Applied Research in Administrative Sciences, 3(2), 76-87.*

Barcic, A.P., Kuzman, M.K., Haviarova, E. & Oblak, L., (2021). Circular Economy & Sharing Collaborative Economy Principles: A Case Study Conducted in Wood-Based Sector, Digitalisation and Circular Economy: Forestry and Forestry Based Industry Implications, pp. 23-28, Edited by Chobanova, R.

Bellemare, M.F., Martin-Dery, S., Ziegler, R., Vézina, M., Raufflet, E. & Walsh, A., (2022). Synergizing Social Economy and Circular Economy, Canadian Journal of Nonprofit and Social Economy Research, Volume13, Issue 1, pp. 106-110, https://doi.org/10.29173/cjnser591

Belostecinic G., Mogoș R.I., Popescu M.L., Burlacu S., Rădulescu C.V., Bodislav D.A., Bran F. & Oancea-Negescu M.D., (2021). Teleworking – An Economic and Social Impact during COVID-19 Pandemic: A Data Mining Analysis. International Journal of Environmental Research and Public Health. 2022; 19(1):298, https://doi.org/10.3390/ijerph19010298

Burlacu, S. (2018). The Role of Green IT for Sustainable Governance in Romania, *The 32nd IBIMA conference in 15-16 November 2018 in Seville, Spain*

Burlacu, S., Bran, F., Rădulescu, C. V., & Bodislav, D. A. (2022). The circular economy-Romania's paradigm from the perspective of EU principles and directions for 2050. In *Proceedings of the International Conference on Business Excellence* (Vol. 16, No. 1, pp. 278-284).

Ciulli, E., (2022). Tribology and Sustainable Development Goals, Proceedings of I4SDG Workshop 2021: IFTOMM for Sustainable Development Goals, Volume108, pp. 438-447, https://doi.org/10.1007/978-3-030-87383-7_48, Edited by Quaglia, G., Gasparetto, A., Petuya V., Carbone, G.

CRISP-DM, (2022). Accessed November 5, 2023, https://www.datascience-pm.com/crisp-dm-2/

DDD, (2023). Accessed October 27, 2023, https://dezvoltaredurabila.gov.ro/web/obiective/

EU, (2023); EU's circular material use rate slightly up in 2022, accessed January 2024, https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20231114-2.

Fernández, J.O., Iniesta, R.P., Sánchez-Fuentes, A.J., A Quantitative summary of compliance with the 2030 Agenda in the European Union. 2030 Agenda compliance in the EU. Papeles de Europa, Univ. Complutense Madrid, Volume 35, https://doi.org/10.5209/pade.83760, Published 2022

García-Sánchez, I.M., Amor-Esteban, V., Aibar-Guzmán, C. & Aibar-Guzmán, B., Translating the 2030 Agenda into reality through stakeholder engagement, Sustainable Development, Publisher name: WILEY, Volume31, Issue 2, pp. 941-958, https://doi.org/10.1002/sd.2431

Hotz, N. (2023), What is CRISP DM? Data Science Process, Accessed January 2024, https://www.datascience-pm.com/crisp-dm-2

Jacob-John J., D'Souza C., Marjoribanks T. & Singaraju S. (2021). Synergistic Interactions of SDGs in Food Supply Chains: A Review of Responsible Consumption and Production. Sustainability. 2021; 13(16):8809, https://doi.org/10.3390/su13168809

Ladaru, R. G.; Burlacu, S.; Guţu, C.; Platagea G. S. (2022) Human resources management - labor crisis. In: 30 years of economic reforms in the Republic of Moldova: economic progress via innovation and competitiveness, pp. 187-194. ISBN 978-9975-155-60-1. https://doi.org/10.53486/9789975155649.29 CZU: 005.952(498)

Leal, W., Trevisan, L.V., Eustachio, J.H.P.P., Dibbern, T., Apraiz, J.C., Rampasso, I., Anholon, R., Gornati, B., Morello, M. & Lambrechts, W., (2023). Sustainable supply chain management and the UN sustainable development goals: exploring synergies towards sustainable development, TQM Journal, https://doi.org/10.1108/TQM-04-2023-0114

Lee, J.Y., Chung, K.W., Myung, S.S., Kim, S.K., Kim, H.I., Jeon, H.S. & Jyothi, R.K., (2022). Rewas 2022: Developing Tomorrow's Technical Cycles, Vol. I, pp. 285-295, https://doi.org/10.1007/978-3-030-92563-5_30, Edited by Lazou, A, et al.

Marchand A., Walker, S. (2008). Product development and responsible consumption: designing alternatives for sustainable lifestyles. Journal of Cleaner Production, Volume 16, Issue 11, July 2008, pp. 1163-1169, Elsevier.

Mogoș R.I., Petrescu I., Chiotan R.A., Crețu R.C., Troacă V.A. & Mogoș P.L. (2023). Greenhouse gas emissions and Green Deal in the European Union. Front. Environ. Sci. 11:1141473, https://doi.org/10.3389/fenvs.2023.1141473

Mogos, R. I., Negescu–Oancea, M. D., Burlacu, S., & Troaca, V. A. (2021). Climate Change and Health Protection in European Union. *European Journal of Sustainable Development* (2021), 10, 3, 97-108 ISSN: 2239-5938, https://doi.org/10.14207/ejsd.2021.v10n3p97

Rădulescu, C. V., Angheluță, P. S., Burlacu, S., & Kant, A. (2022). Aspects Regarding Renewable Sources in the European Union. *European Journal of Sustainable Development*, *11*(3), 93-93.

Rădulescu, C. V., Bran, F., Bodislav, D. A., & Burlacu, S. (2022). Circular Economy in Infographics. In Proceedings of the International Conference on Business Excellence (Vol. 16, No. 1, pp. 420-426).

Rădulescu, C. V., Mănescu, C. O., Popescu, M. L., & Burlacu, S. (2023). Sustainable Development in Public Administration: Research, Practice, and Education. *European Journal of Sustainable Development*, *12*(4), 27-27.

RTTI, (2023), Top 8 Recycling Technology Trends & Innovations in 2024, Accessed January 2024, https://www.startus-insights.com/innovators-guide/recycling-technology-trends-innovation/

Sommerville, R., Zhu, P.C., Rajaeifar, M.A., Heidrich, O., Goodship, V. & Kendrick, E., (2021). A qualitative assessment of lithium ion battery recycling processes. Resources Conservation and Recycling, Volume165, https://doi.org/10.1016/j.resconrec.2020.105219, Publisher name ELSEVIER.

Sudhanshu G., Richa, A., (2017). Environmentally Responsible Consumption: Construct Definition, Scale Development, and Validation, Corporate Social Responsibility and Environmental Management, Volume 25, Issue 4, p. 523-536, Wiley Online Library.

WEKA, (2023). https://www.cs.waikato.ac.nz/ml/weka/

Zhang, J., Zhao, L.J., Hu, S.Q., (2021). Visualizing recycling: Promoting recycling through mental simulation. Resources Conservation and Recycling, Volume174, https://doi.org/10.1016/j.resconrec.2021.105783. Publisher name ELSEVIER.