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Dynamics of Circular Economy Indicators in European Countries

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Abstract. *The study aims to analyze the evolution of the circular economy in the European Union using Eurostat statistical data. The paper investigates key indicators such as private investment, gross value added, number of employees and patents related to recycling and secondary raw materials, in order to understand the progress made by European countries in the transition to a circular economic model. Identifying trends and changes recorded can constitute a basis for proposing new strategies and policies that can support sustainable development and improve the alignment of EU-27 member states with the European sustainable development objectives. The research method used includes quantitative and qualitative analysis, as well as comparative analysis. Private investment in the circular economy during the analyzed period increased by 44.83%, but their share in GDP decreased. Gross value added in the circular economy in the EU increased by 27%, and the number of employees increased by 9%. Circular economy research has regressed, with the number of recycling-related patents at EU level being 42% lower in 2020 than in 2015. The study highlights the need for an integrated strategy, supported by public and private investment, to harness the potential of the circular economy and achieve the European sustainable development goals.*

Keywords: circular economy, indicators, competitiveness, innovation, investments.

Introduction

Focusing on a sustainable approach to resource management that yields economic, social, and environmental benefits, Circular Economy (CE) is achieving more recognition in the European Union in various business and societal domains. CE is a framework that seeks to reconcile economic development with environmental sustainability and offers a divergent avenue from the traditional linear economic pattern. Its core principles include environmental protection, resource efficiency, and a "zero-waste" approach, through practices such as reuse, repair, remanufacturing, and recycling (Nikanorova & Stankeviienė, 2020).

The European Commission describes CE as a production and consumption system that prioritizes the perpetual use of materials and products, thereby extending their life cycle (European Parliament, 2023). This shift is critical for the EU's transition toward sustainable development, with CE models facilitating resource conservation, job creation, and economic growth (D'Adamo et al.,

DOI: 10.2478/picbe-2025-0421

2024; Rajnović, et al., 2023). Notably, the renewable energy sector is crucial for achieving the European Green Deal objectives, including climate neutrality by 2050 (Berevoianu 2021, Rajnović, et al., 2023).

Among EU nations, the Netherlands leads in CE resources, particularly in waste management, emphasizing recycling over other practices like reuse and repair (Panchal & Singh, 2023). The complexity of CE necessitates multidimensional indicators for measuring its impacts, especially at the micro-level (Rossi et al., 2020), while promoting innovative business models in agriculture, urban, and industrial sectors to enhance efficiency in resource use.

In this context, the aim of this paper is to analyse the evolution of the circular economy at the level of the European Union between 2015 and 2023, focusing on competitiveness and innovation. The study aims to highlight the main trends and changes recorded in this field by examining relevant economic indicators, such as the value of private investments, the gross value added generated by the circular economy sectors, the number of people employed in these sectors and the number of patents related to recycling and secondary raw materials.

For this, five research questions were formulated, as follows:

RQ1: How have private investments in circular economy sectors evolved across the EU between 2015 and 2023?

RQ2: What is the relationship between the number of patents related to recycling and secondary raw materials and the economic performance of circular economy sectors?

RQ3: Which EU countries have demonstrated the highest employment growth in circular economy sectors, and what factors contribute to this trend?

RQ4: How does the evolution of gross value added in circular economy sectors compare between highly developed and less developed EU economies?

RQ5: What are the key drivers behind the differences in circular economy adoption and innovation across EU member states?

The corresponding hypothesis to the above mentioned research questions are listed below:

H1: Private investments in circular economy sectors have increased over time, reflecting a growing commitment to sustainable economic practices.

H2: A higher number of patents related to recycling and secondary raw materials is positively correlated with increased gross value added in circular economy sectors.

H3: Countries with strong policy frameworks and incentives for circular economy initiatives have experienced higher employment growth in circular economy sectors.

H4: Highly developed EU economies exhibit faster growth in gross value added from circular economy sectors due to greater financial and technological resources.

H5: Differences in regulatory support, financial incentives, and research and development investments significantly influence the adoption and innovation rates in circular economy sectors.

Literature review

In recent decades, numerous studies have analyzed the progress of the circular economy in the EU, using specific indicators. For example, a recent study highlighted that the Netherlands, Germany, Italy and Belgium are leaders in this field, while countries in Central and Eastern Europe have a slower pace of adopting CE principles (Panchal, & Singh, 2023). These differences are determined by variations in national policies, the degree of investment in circular technologies and the level of economic development (D'Adamo et al., 2024).

Monitoring and supporting the transition from a linear to a circular economy requires a series of specific indicators that can measure progress towards sustainability, taking into account the technical and economic reality of each state or region (Ibáñez-Forés, 2022).

A number of studies have attempted to rank European countries according to their performance in the circular economy (Candan, et al., 2022), using advanced statistical methods such as cluster analysis (Rađenović, 2022). These analyses identified a "multi-speed" Europe, where differences between Member States are significant. For example, Western European countries, such as Germany and the Netherlands, have implemented advanced policies for recycling and reuse, while Eastern Europe faces challenges related to infrastructure and financing (D'Adamo et al., 2024).

Furthermore, the measurement of EC progress is carried out through a series of indicators, such as the rate of use of circular materials, the recycling rate of municipal waste and the level of innovation in resource management (Mazur-Wierzbicka, 2021). At the same time, a recent study highlights the importance of correlating these indicators with the economic growth and competitiveness of Member States, showing that there is a positive relationship between EC performance and Gross Domestic Product (GDP) per capita (Arion et al., 2023).

In the study conducted by Lee et al., (2024), the effectiveness of circular economy indicators and their elements in the context of a circular supply chain was analyzed. Of the 63 indicators and 23 circular economy elements identified, three manage to assess all five dimensions of circularity, and 40% of circular economy indicators do not include the essential actors in the circular supply chain (Lee et al., 2024).

There are three levels of indicators for assessing the circular economy: macro (global, national, regional, urban), meso (industrial symbiosis, eco-industrial parks) and micro (a firm, specific product). Kristensen & Mosgaard (2020), examined 30 circular economy indicators at the micro level, these being focused on: recycling, prefabrication, and the fewest indicators referred to disassembly, life extension, waste management, resource efficiency or reuse. Although these indicators have been identified, there is no common standard method for measuring the circular economy at the micro level.

A recent study systematically reviews nano- and micro-level circular economy (CE) indicators to assist decision-makers in evaluating circularity. The authors identified 58 circularity indicators (38 at the nano level, 14 at the micro level, and 6 applicable to both). The study revealed that most existing metrics focus on environmental aspects, particularly material and resource recovery strategies, with a secondary emphasis on economic factors. However, social aspects of circular economy indicators remain largely underexplored (Oliveira et al., 2021). Micro-level indicators can also include other circular economy strategies that can adopt a life cycle thinking (LCT) perspective. European indicators focus on used materials, without taking LCT into account (Moraga et al., 2019). However, micro-level circular economy indicators are still in their early stages of development and do not sufficiently integrate specific aspects of biological systems. The indicators currently used address aspects related to the quantity of resource flows, with a focus on their efficiency of use and the degree of recycling. However, most indicators exclude the share of renewable resources, not taking into account the share of renewable resources and organic recycling (Gursel et al., 2023).

Drastichová & Filzmoser, (2025) conducted a study that assesses the performance of 31 countries, including Norway, Iceland, Switzerland and the United Kingdom, in the context of the United Nations (UN) 2030 Agenda for Sustainable Development (SD) and the 17 Sustainable Development Goals (SDGs) for the period 2012-2020. The results indicated that Norway,

Switzerland, the Netherlands and Sweden stand out in terms of sustainability performance. Norway and Switzerland are among the countries that adopt the principles of global sustainability, while the Netherlands and Italy stand out for making significant progress in implementing the circular and green economy. In the context of the circular economy, rural development plays a key role in creating jobs and supporting vulnerable populations. Implementing sustainable practices can revitalize rural communities, providing economic opportunities and improving quality of life (Oprea et al., 2023).

The review of the existing literature in the field of circular economy highlights the significant progress recorded at the level of the European Union and beyond. The aforementioned studies identified the leading countries in the implementation of the circular economy, such as the Netherlands, Germany and Sweden, but also the challenges faced by the countries of Eastern and Central Europe. This paper makes an important contribution to the understanding of the circular economy in the EU-27, through the analysis of the indicators taken into account, but also the identification of differences in the pace of adoption of the circular economy between the member countries, the research offers perspectives on improving economic strategies and policies.

Methodology

The methodology used in the study integrates quantitative and qualitative methods to answer the research questions and the formulated hypotheses. The study is based on a series of data published by Eurostat, which are official and updated information on circular economies in the European Union.

The indicators selected for the analysis of the circular economy in this study are the following: private investments; gross value added generated; number of employees; number of patents related to recycling and secondary raw materials. Statistical data for each indicator were extracted for the period 2015-2023, depending on their availability.

Research methods used:

•Quantitative analysis, which is carried out by calculating descriptive statistics, in order to obtain a general picture of the evolution of the analyzed indicators.

•Qualitative analysis, which has the role of examining trends and major changes in the evolution of the circular economy.

•The comparative analysis was used to assess the progress of the European Union member states in adopting the circular economy, based on selected indicators.

The interim analysis, which compared the indicators from the first year of analysis and the last available year, highlighted the main changes and trends for each indicator. This evaluation aimed during the analyzed period: increase/decrease in the values of the indicators; identification of the triggering factors of the highlighted changes.

For the processing and analysis of the data, Microsoft Excel software was used as a statistical tool.

Ensuring the validity of the data is based on information extracted from official sources (Eurostat) and comparison with the data available in published studies and research reports.

Results and discussions

Analyzing the value of private investment in circular economy sectors is essential to understand the degree of involvement of the business environment in the transition to sustainable economic models. This indicator provides a clear perspective on the level of financing of innovations,

recycling and efficient use of resources, highlighting the differences between countries and the progress made at European level. Comparing data from 2015 and 2021, we can observe growth trends, the impact of public policies and EU regulations, as well as identifying countries that have managed to attract significant capital for the development of the circular economy.

Private investment in the circular economy increased in most European countries between 2015 and 2021, indicating a growing interest of the private sector in sustainable economic models. The growth can be correlated with national and European strategies on the circular economy, such as the European Green Deal and the European Commission's Circular Economy Action Plan. At the European Union level, private investments in circular economy sectors worth 121,578 million EUR were recorded in 2021. This year an increase of 44.83% was highlighted, from 83,946 million EUR in 2015 (Figure no. 1).

Analyzing the value of private investments in circular economy sectors across European countries, Germany stood out as the country that made the most investments. During the analyzed period, an increase of about 95% in the value of investments was observed in Germany, from 16,201 million EUR in 2015 to 31,507 million EUR in 2021. In the top five countries by value of private investments in circular economy sectors, alongside Germany, are France (20,405 million EUR in 2021), Italy (12,423 million EUR in 2021), the Netherlands (8,700 million EUR in 2021) and Belgium (7,251 million euro in 2021). This development can be attributed to the early implementation of circular economy strategies. For example, Germany implemented several policies and initiatives to promote the circular economy: Waste Management Act (2012), transposed the EU Waste Framework Directive into German law, with a focus on waste prevention and the promotion of recycling; Resource Protection Program (2012) by the Federal Ministry for the Environment aimed to conserve natural resources by making material use more efficient and promoting recycling and Circular Economy Action Program (2016), Germany aimed at improving waste management and promoting the reuse and recycling of materials, in line with the objectives of the European Union. These initiatives paved the way for the adoption of the NCES in 2024, reinforcing Germany’s commitment to the transition to a circular and sustainable economy.

Similarly, France adopted policies such as the 2018 "Roadmap for the Circular Economy", which includes 50 measures for the transition to a circular economy.

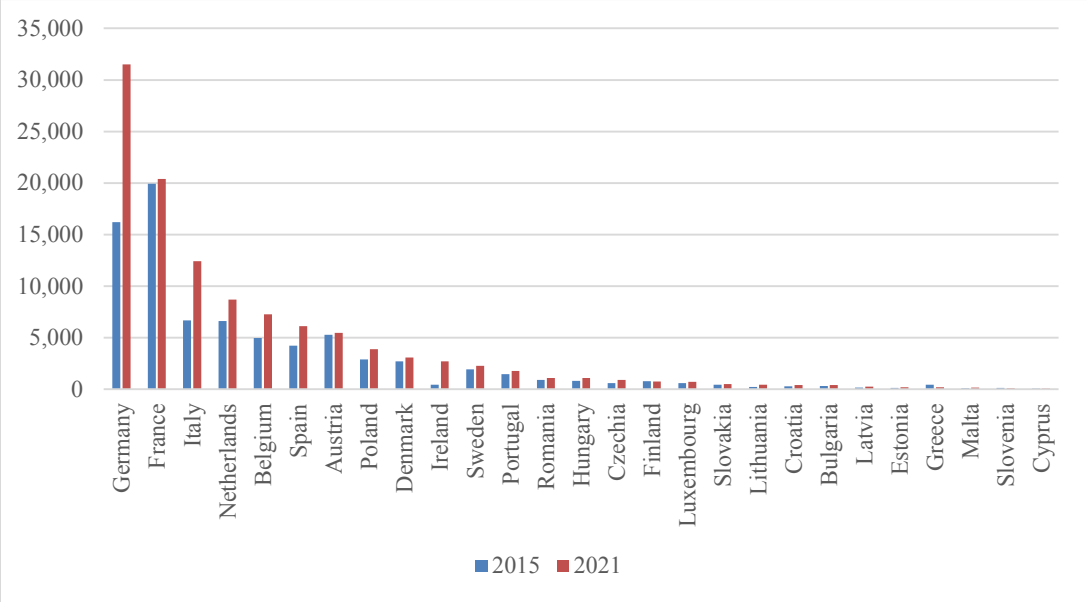

Figure 1. The value of private investments in circular economy sectors across European countries - million eur

Source: Eurostat data, accessed in 10.02.2025; Online data code: cei_cie012.

At the opposite pole, the countries with the lowest value of private investments in circular economy sectors were Malta (166 million EUR in 2021), Slovenia (108 million EUR in 2021) and Cyprus (51 million EUR in 2021) (Figure no. 1). Romania ranks 13th in the top European countries when it comes to private investments in circular economy sectors (Figure no. 1)

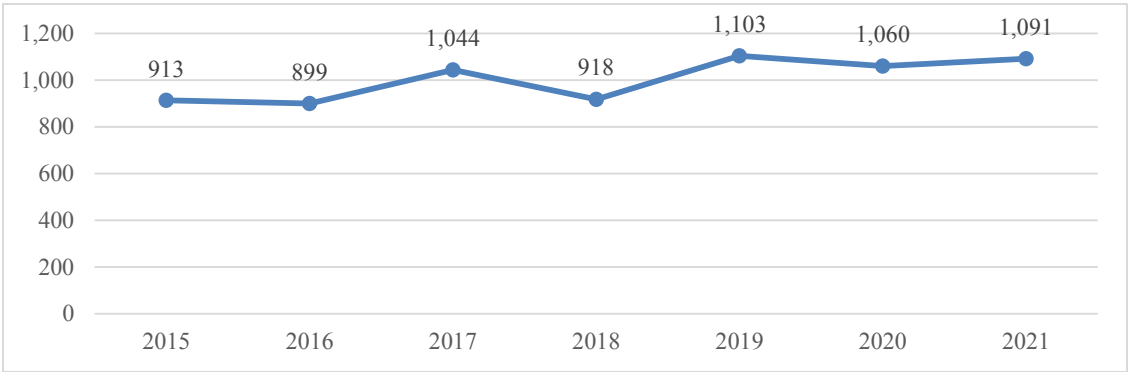

Figure 2. Dynamics of the value of investments in circular economy sectors in Romania, million eur

Source: Eurostat data, accesed in 10.02.2025; Online data code: **cei_cie012**

In the analyzed period, the value of investments in the circular economy sectors in Romania varied between 913 million EUR in 2015 and 1,103 million EUR in 2019. In 2021, investments reached 1,091 million euros, showing an increase of approx. 20% compared to the value recorded in 2015 (Figure no. 2).

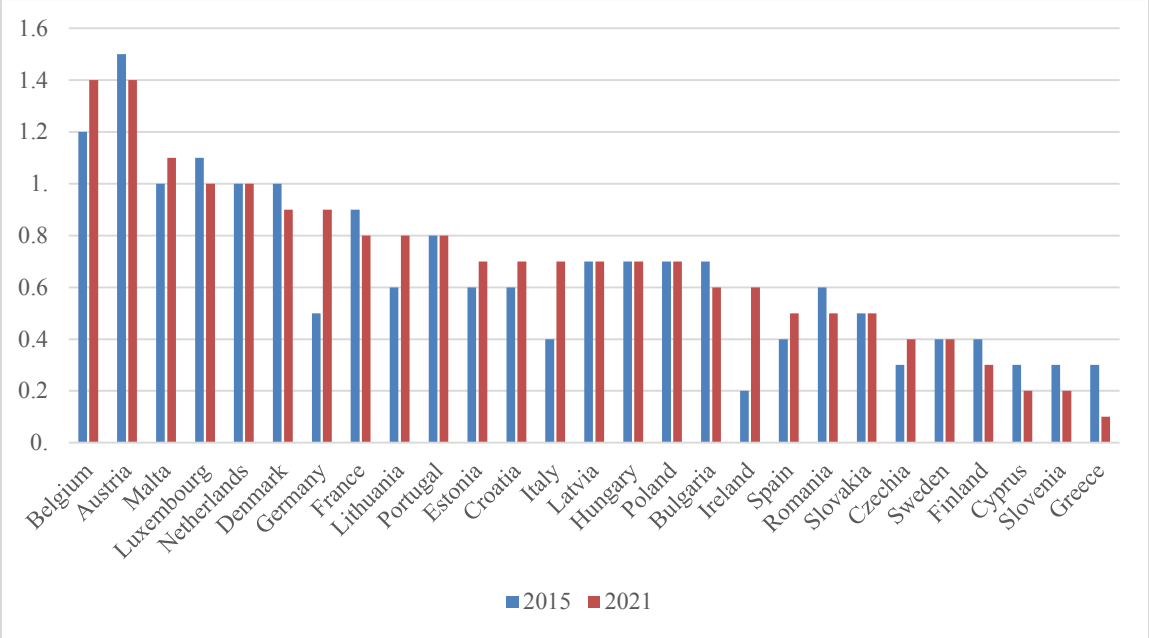

Figure 3. Percentage in gross domestic product (GDP) of investment in circular economy sectors in European countries – (%)

Source: Eurostat data, accessed in 10.02.2025; Online data code: cei_cie012

Analyzing the percentage of Gross Domestic Product (GDP) dedicated to investment in the circular economy is essential to understand each country's economic commitment to the transition to a sustainable development model. It provides key indicators of the level of financial involvement, the effectiveness of public policies and the degree of integration of the circular economy into the national economic structure.

A high percentage of GDP allocated to the circular economy shows that a country is actively investing in sustainable technologies, recycling, waste reduction and resource efficiency. Comparing yearly series highlighted growth or stagnation trends, helping to identify countries that are accelerating the transition and those that are lagging behind

Austria was the country with the highest share (1.5% in 2015 and 1.4% in 2021), followed by Belgium (1.2% in 2015 and 1.4% in 2021). In Romania, the percentage of gross domestic product (GDP) of investments in circular economy sectors was 0.6% in 2015, reaching 0.5% in 2021, thus showing a reduction of approx. 17 percentage points (Figure no. 3).

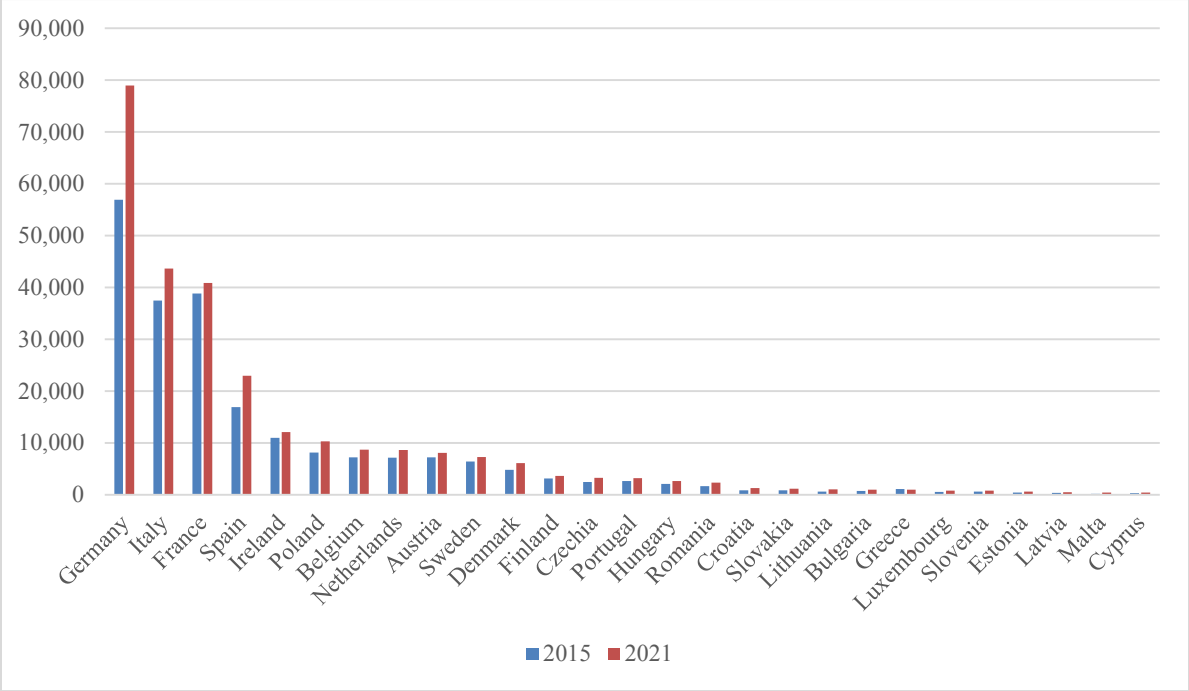

Figure 4. Gross value added from circular economy sectors – million eur

Source: Eurostat data, accessed in 10.02.2025; Online data code: cei_cie012.

Regarding the gross value added in the circular economy sectors, at the European Union level it ranged between 235,338 million EUR in 2015 and 299,527 million EUR in 2021, showing an increase of approx. 27%.

As in the case of investments, Germany is in first place in the top of European countries in terms of gross value added in the circular economy sectors, recording a value of 79,000 million EUR in 2021, showing an increase of approx. 40% compared to the value in 2015, respectively 56,939 million euros. This was followed by Italy (43,646 million EUR in 2021), France (40,873 million EUR in 2021), Spain (22,931 million EUR in 2021) and Ireland (12,118 million EUR in 2021). At the opposite end, the countries with the lowest gross value added in circular economy sectors are: Latvia (493 million EUR in 2021), Malta (419 million EUR in 2021) and Cyprus (386 million EUR in 2021) (Figure no. 4).

In 2021, Romania ranked 16th in terms of gross value added in circular economy sectors, with 2,344 million EUR (Figure no. 4).

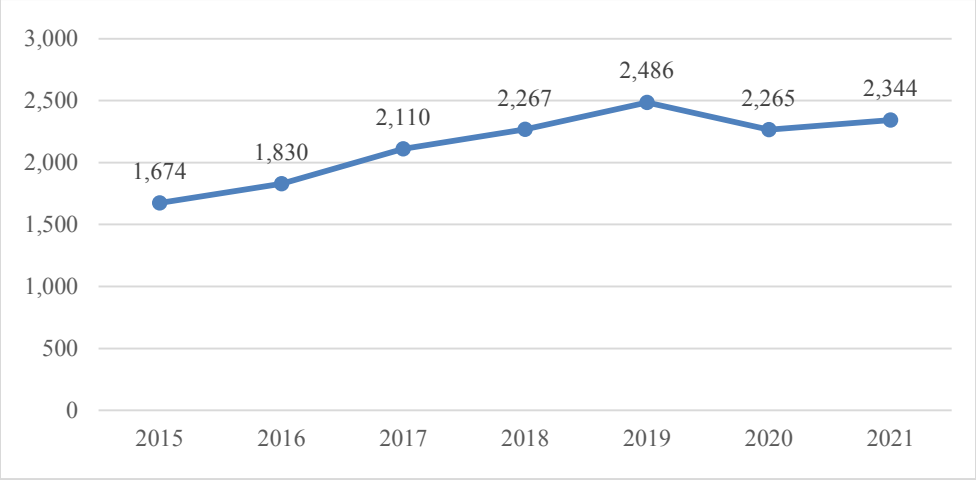

Figure 5. Dynamics of gross value added in circular economy sectors in Romania, million eur

Source: Eurostat data, accessed in 10.02.2025; Online data code: cei_cie012.

During the analyzed period, an increase in gross value added in Romania of approximately 40% was observed, from 1,674 million EUR in 2015 to 2,344 million EUR in 2021. The gross value added in the circular economy sectors reached a maximum of 2,486 million EUR in 2019 (Figure no. 5).

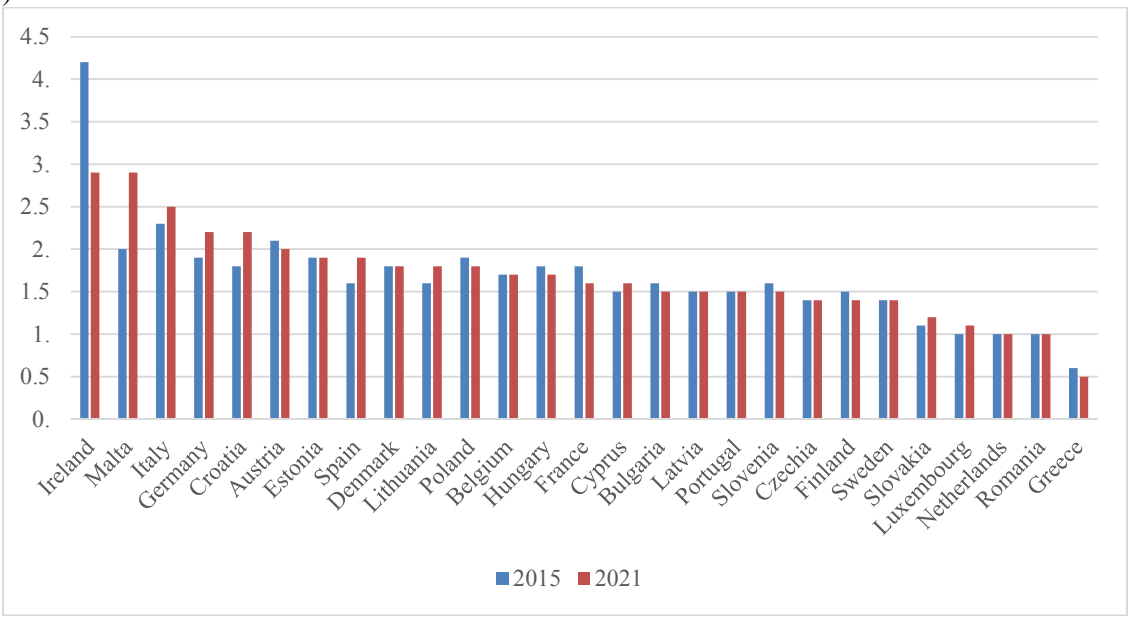

Figure nr. 6. Percentage of gross domestic product (GDP) of gross value added from circular economy sectors in European countries – (%)

Source: Eurostat data, accessed in 10.02.2025; Online data code: **cei_cie012**

Analyzing the percentage of GDP of gross value added generated by circular economy sectors is helpful in understanding the economic transition towards sustainability, the real impact of the circular economy and the growth potential of this sector, acting as an indicator of circular economy sector performance. A higher value of GVA in the circular economy indicates that these sectors contribute significantly to GDP, which suggests an economic model that is less dependent on primary resources and more oriented towards sustainability. If GVA in the circular economy

increases, it means that innovation, recycling, reuse and resource efficiency are increasingly integrated into the economic structure.

The highest percentage of gross domestic product (GDP) of gross value added in circular economy sectors was recorded by Ireland (4.2% in 2015, respectively 2.9% in 2021), which showed a reduction of 31 percentage points over the period. Malta also stood out for having the highest percentage of gross domestic product (GDP) of gross value added in circular economy sectors in 2021, being 2.9%, 45 percentage points more than the percentage recorded in 2015. In Romania, the percentage of gross domestic product (GDP) of gross value added in circular economy sectors was constant over the analyzed period, being 1% (Figure no. 6).

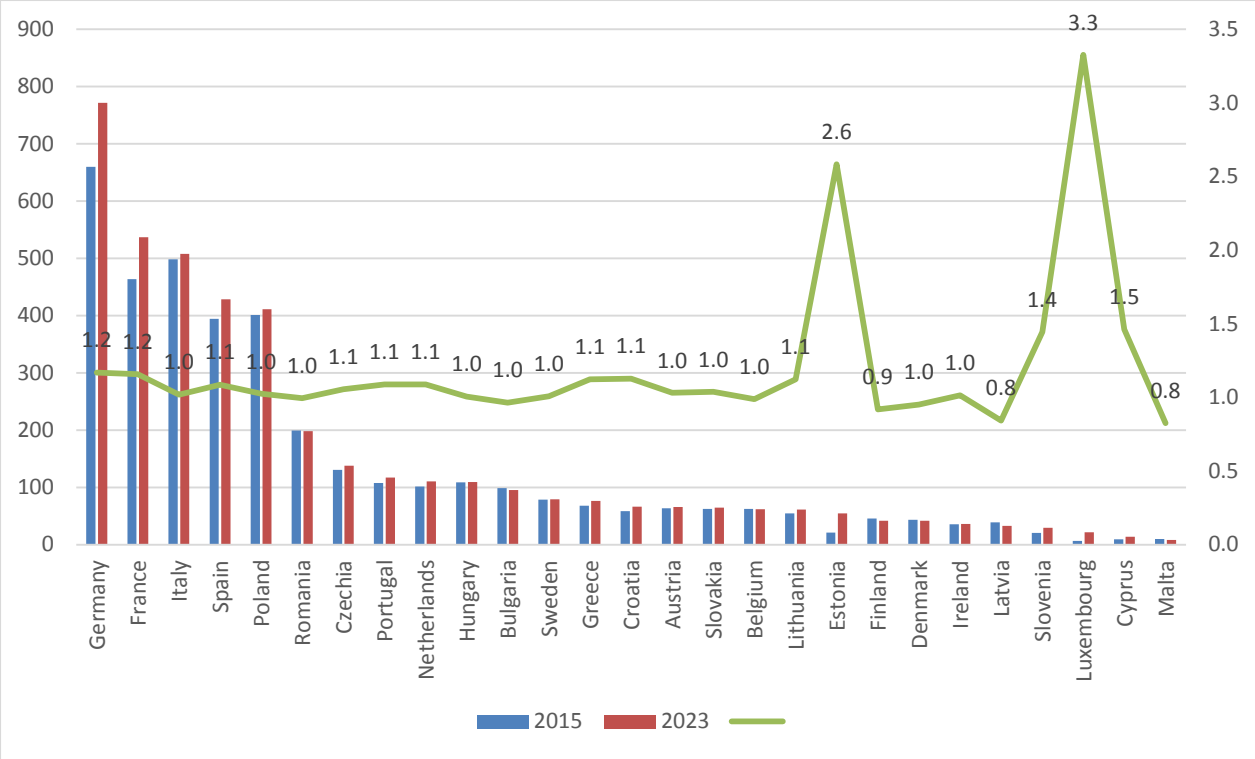

Figure 6. Dynamics of people employed in circular economy sectors across European countries – thousand persons FTE

Source: Eurostat data, access in 10.02.2025; Online data code: cei_cie011

Regarding people employed in the circular economy sector,in most countries, the number of employees in the circular economy increased from 2015 to 2021 of aprox. 9%, indicating increased interest and accelerated adoption of circular economy principles in Europe. The increase reflects the implementation of European policies aimed at stimulating the circular economy and creating sustainable jobs. In 2023, Germany remains the clear leader, with the highest number of employees in this sector respectively 772 th people, followed by France (537 thousand people), Italy (508 thousand people) and Spain (428 thousand people)

Slovenia recorded the highest percentage increase in circular economy employment, 3.3 times compared to 2015, indicating the country's significant interest in the sector. Slovenia was one of the first countries in the European Union to adopt a national circular economy strategy, focusing on recycling, reuse and technological innovations in waste management. This rapid

growth can also be explained by an initially low number of employees in 2015, which makes any subsequent progress seem spectacular in percentage terms.

Lithuania also recorded a substantial increase of 2.6 times, reflecting the adoption of sustainability policies and an active transition to circular economic models. The Lithuanian government has implemented subsidy schemes for companies promoting the green economy and developed educational programs aimed at accelerating the transition to a more sustainable economic system. EU funds for the circular economy have been effectively targeted at small and medium-sized enterprises and local initiatives, contributing to job creation in the sector.

Luxembourg has recorded a 1.5-fold increase in its investment, suggesting an accelerated transition to the circular economy. This positive development can be attributed to strong investments in green finance and public-private partnerships, which have facilitated the development of key sectors such as eco-design, recycling and resource efficiency. These measures have significantly contributed to job creation and to establishing Luxembourg as a major player in the European circular economy.

Romania ranks sixth in this top, after Poland (411 thousand people in 2023) with a number of 198 thousand people employed in circular economy sectors in 2023. (Figure no. 6).

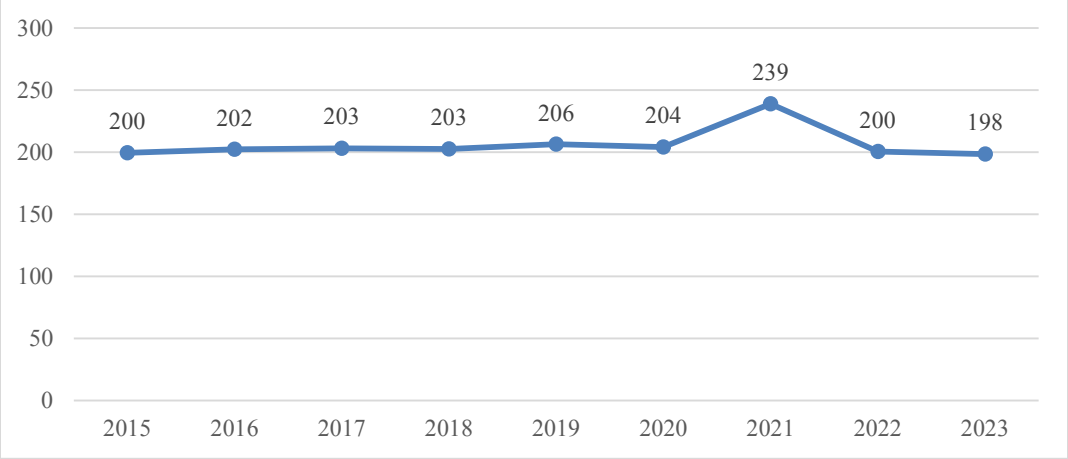

Figure nr. 7. Dynamics of people employed in the circular economy sectors in Romania, thousands of full-time equivalent (FTE) persons

Source: Eurostat data, access in 10.02.2025; Online data code: cei_cie011.

In Romania, a reduction of people employed in the circular economy sectors in 2023 of approx. 0.55% was observed compared to the number recorded in the reference year, namely 2015 (200 thousand people) (Figure no. 7).

The last indicator analyzed in this research measures the number of patents related to recycling and secondary raw materials. The attribution of recycled and secondary raw materials was done using the relevant codes from the Cooperative Patent Classification (CPC). According to the specifications provided by Eurostat about the analyzed dataset, the term patent refers to patent families, which include all relevant documents for a single invention, thus preventing multiple counting. Eurostat also specifies that a fraction of the family is allocated to each applicant and the relevant technology.

Regarding the number of recycling and raw materials patents in the period 2015-2020, in the European Union their number reached 206.55 patents in 2020, highlighting a decrease of approx. 42% compared to the number registered in 2015, respectively 357.28 patents.

At the level of European countries, Germany stood out as the country that registered the highest number of patents in 2020, respectively 45.67 patents. This was followed by France (27.09 patents), Italy (21.51 patents), Spain (21.34 patents) and Poland (17.25 patents). At the opposite pole, the countries that registered the lowest number of patents in 2020 were Slovenia (1 patent), Greece and Latvia (0.5 patents) (Figure no. 8).

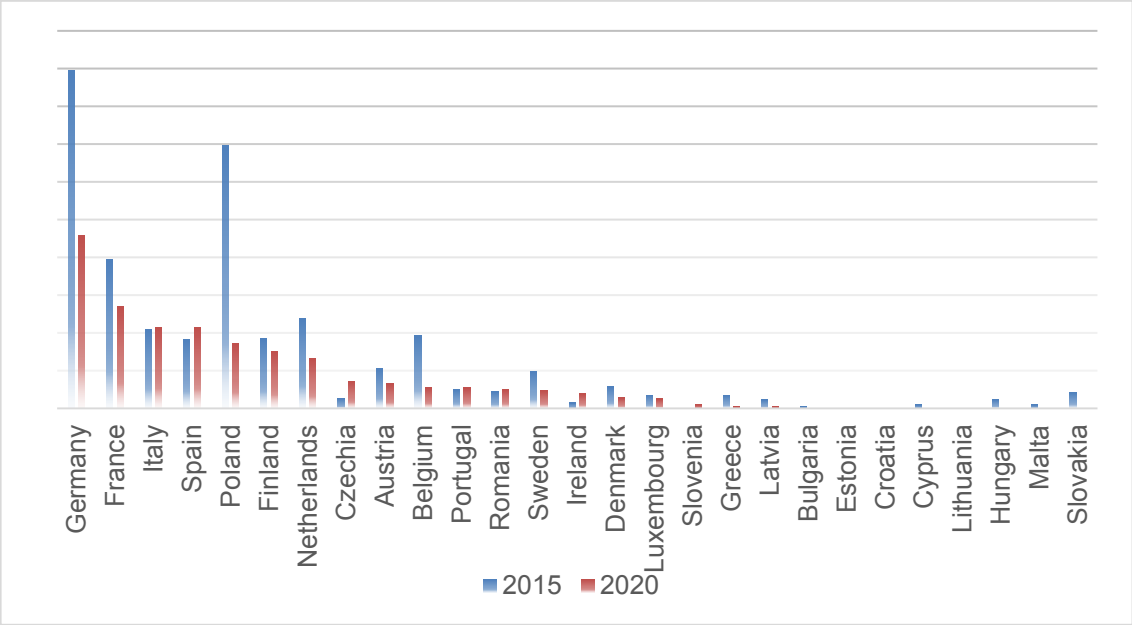

Figure 8. Dynamics of recycling patents and secondary raw materials – climate change mitigation technologies related to wastewater treatment or waste management, number

Source: Eurostat data, access in 10.02.2025; Online data code: cei_cie020

In Romania, 5 patents were registered in 2020, ranking 23rd among European countries in terms of recycling and secondary raw materials patents – climate change mitigation technologies related to wastewater treatment or waste management. During the analyzed period, the number of patents in Romania varied between 4.5 in 2015 and 9.5 in 2018 (Figure 9).

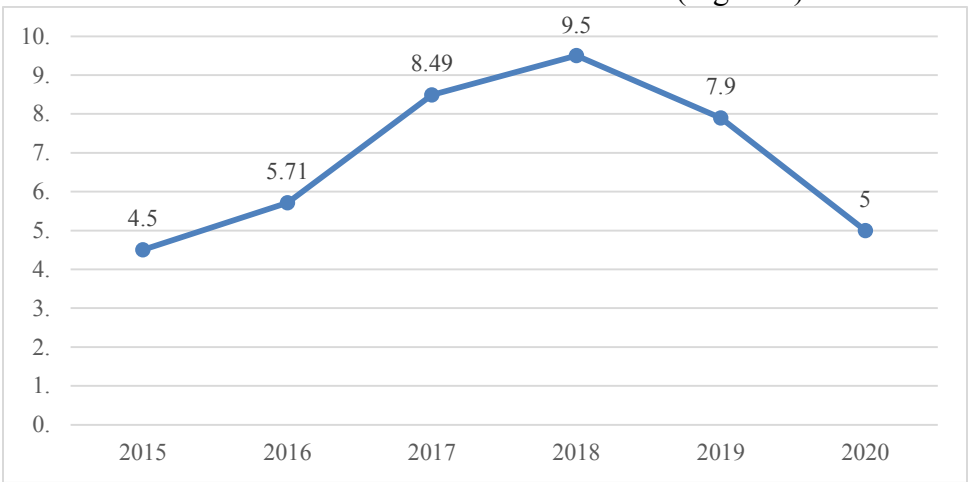

Figure nr. 9. Dynamics of recycling patents and secondary raw materials – climate change mitigation technologies related to wastewater treatment or waste management in Romania, number

Source: Eurostat data, access in 10.02.2025; Online data code: cei_cie020.

Conclusion

The transition to a circular economy in the European Union represents an important opportunity for the development of sustainability, promoting resource efficiency, environmental protection and innovation, but more coherent policies and massive investments are needed to ensure progress in all Member States.

Private investments in the circular economy at European level increased by 44.83% in the period 2015-2021, but their share in GDP decreased, indicating the need for additional measures. Germany, France, Italy and Spain remained leaders in private investment in the circular economy, thanks to strong economies and advanced sustainability policies. Eastern European and Baltic countries recorded the highest percentage increases, suggesting a gradual alignment with EU standards. Some countries have significantly increased the percentage of GDP dedicated to the circular economy, which suggests effective policies, strategic investments and private sector involvement

The largest investments were recorded in Germany, France, Italy and the Netherlands, while Romania recorded a decrease in the share of investments in GDP of approximately 0.5%, although it increased by 19.5% overall.

The gross value added in the European Union from the circular economy increased by 27%. Countries with high percentages of GVA in the circular economy (Malta, Italy, Germany, Austria) demonstrate a strong integration of this economic model. Increases in Spain, Poland and Lithuania show an accelerated development trend, probably due to national strategies and EU funds. Ireland and Luxembourg recorded significant decreases, suggesting a repositioning of economic priorities. Romania and Greece continue to have low values, indicating a slow pace of transition to the circular economy.

In terms of employment at European level, the number of employees in this sector increased by 9% between 2015 and 2023. Romania had 198,000 employees in 2023, ranking 6th. The number of recycling and secondary raw materials patents in the European Union decreased by approximately 42% between 2015 and 2020. Germany was the leader in this field, with 45.67 patents, followed by France, Spain and Poland. The fewest patents registered were in Slovenia, Greece and Latvia. Romania registers a low number of patents related to recycling and secondary raw materials, signaling a deficit in research and innovation. Fully exploiting the potential of the circular economy and aligning with the European sustainable development objectives requires an integrated strategy supported by both public and private investments, policies and concrete measures to stimulate innovation in this field.

Acknowledgements

This work has benefited from support through the ADER 2023-2026 Sectoral Projects financing contract 22.1.4/2023.

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