

## A STUDY ON WASTE MANAGEMENT IN A CIRCULAR ECONOMY

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**Abstract:** Moving from a Linear to the Circular Economy model means far more than simply changing waste management praxis to focus on resource efficiency for mean of disposal. An element of the Framework is a demonstration paper that investigates waste-to-Value frameworks in circular economy outlook including management strategies, material recovery/recycling/reuse methods essential to meet sustainability targets. This study combines the use of both qualitative and quantitative measures to compare different waste management alternatives across for case studies in Europe and Romania. Significant decreases in resource use and waste generation because of the transition to circular economy pathways are observed, leading researchers to consider the potential benefits for environmental and economic development.

**Key words:** circular economy, waste management, recycling

### INTRODUCTION

The Circular Economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing the products having extended life as possible. This extends the life cycle of products. It means literally minimizing waste in practice. Wherever possible we recycle products when they reach the end of their life and keep to materials in the economy. These can be productively re-used over and over, adding more value. That contrasts with the existing linear economy, where raw materials are used to make products that are in turn thrown away when they really cannot be repaired or upgraded. This makes the model dependent on loads of inexpensive resources and power [1,2].

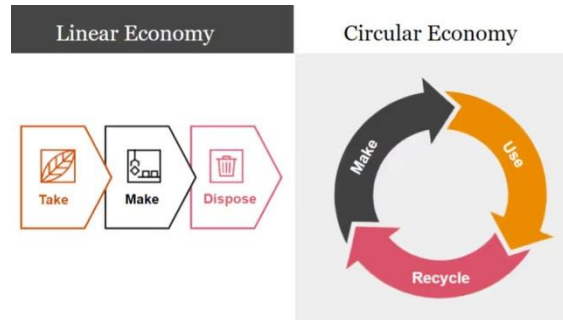
Waste management consists of collection, transport, treatment and disposal; the goal is to provide health protection through integration with environmental benefits or economic optimization for both society and materials [3, 4]. The objectives of waste management are to decrease the adverse effects related with waste (and) enhance resource recovery from solid wastes to reintegrate these resources into economy [23].

Though the linear economy dominates in societies (take — make — dispose), new trends push towards a circular economy (an industrial process that involves greater resource efficiency to decrease waste and pollution) [24].



**Figure 1 The circular economy model: less raw, less waste, fewer emissions**

Source: <https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefitsrculareconomy:definition, importance and benefits | Topics | European Parliament> [25]



**Figure 2 Linear economy and circular economy**

Source: <https://www.pwc.com/gr/en/advisory/risk-assurance/sustainability-climate-change/circular-economy-model.html> [26]

Why do we need to switch to a circular economy?

Reusing and recycling products would reduce the speed that natural resources were used up, limit destruction of landscapes and habitats (although not significantly), help to control biodiversity loss.

In addition to the employment benefits, there is also a decrease in total annual greenhouse gas emissions through the circular economy [6].

This would minimize the high energy and resource usage of our throw-away culture even more effectively, for it is estimated that over 80% of a product's environmental impacts are preset during design.

However, the problem of packaging waste is growing and each year on average 190 kilos per person in Europe are produced [11]. Finally, we hope to reduce over packaging and enhance recyclability through its design.

We live in the world where there are more and more people, so they need things. But the bottleneck is in important raw materials [9, 10].

This necessarily implies that certain raw materials are export dependent for some EU countries. Indeed, as Eurostat data suggest, every European used up to 14.9 tonnes of raw materials [14].

Trade value (imports and exports) of raw materials between the EU and the rest of The World amounts to €165 billion in 2023. Since exports were lower than imports there was a trade deficit of €29 billion [19].

By recycling raw materials, one reduces the risk of supply risks resulting from price volatility, availability or import dependency.

This is particularly true for critical raw materials, which will be used to manufacture the key techs needed in order to meet climate targets (like batteries or electric engines).

But a transition to circular economy could not only increase competitiveness, promote innovation and growth; it will also create jobs [15] (700.000 new ones in the EU by 2030).

This would also incentivize innovation in all industries because of redesigning materials and products for use-and-reuse [16].

It will also allow consumables to be utilized longer with innovative and durable products so that consumers have access on a wider scale and higher quality of life as well in future use cases.

The European Union raw material consumption (RMC) or otherwise called material footprint, which is the over one-third of all extracted non-fuel minerals needed to produce the goods and services that are consumed by individual EU residents.

## MATERIALS AND METHODS

The material used in this paper consists in articles – older and more recent – about the implementation of a circular economy with a focus on waste management. The research method is bibliographic, with focus on two main topics: the circular economy model (which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials) and the benefits of implementing such a system on a European scale.

## RESEARCH RESULTS

Romania has shown interest in environmental issues and sustainable development since before joining the EU, even being one of the first to sign the Rio Declaration in 1992 [18].

This early commitment helped pave the way for circular economy practices in Romania's economic and social policies [23]. Despite challenges like financial constraints and differing opinions, Romania has gradually adopted circular economy principles [7].

This paper examines Romania's progress in implementing these principles, comparing its position to the EU average using data from Eurostat and other sources, such as national laws and press statements.

Romania's mineral resources are managed by the National Mineral Resources Agency, which controls research and exploitation licenses but rarely shares detailed information publicly [12]. Romania supplies around 2% of the EU's natural graphite and holds significant deposits of copper, gold, and silver [8]. Other minerals like molybdenum, tungsten, nickel, boron, uranium, magnesium, and rare earths have also been identified, though this information often comes from industry experts rather than official sources [19].

Many mines were shut down decades ago due to environmental concerns and high extraction costs. However, rising raw material prices and advances in cleaner technologies may make these resources more viable, benefiting both Romania and the EU [14], especially for high-demand items like batteries for mobile and electric vehicles [13].

In 2018, Romania introduced a Green Public Procurement Guide, requiring public authorities to meet basic environmental standards across six product and service categories, from furniture to paper. This guide complemented the 2016 Green Procurement Law, but a 2021 analysis found that many of these green purchasing criteria were still largely ignored. For instance, fewer than 10% of local authorities followed the guide's criteria for paper purchases.

According to the guide, public investment projects should adhere to environmental standards, yet over 70% of public authorities do not include these criteria in procurement documents. Green procurement could influence economic shifts, production practices, and public attitudes, but enforcement remains weak. The lack of a monitoring system within Romania's electronic procurement platform (SEAP) means green purchases are not adequately tracked [18].

A 2019 survey among local authorities revealed that only 31% prioritize environmental protection in procurement, while most focus on cost due to limited budgets. Still, 90% of respondents support adding green criteria. However, only 5% of authorities received training on green procurement, mostly in larger cities [23].

The findings highlight a need for updates in Romania's green procurement legislation, a monitoring system, training programs, public education, and increased funding to support sustainable practices [4].

Romania has a strong record in waste management, with municipal waste levels below the European average between 2015 and 2020 (see Figure 3). From 2000 to 2009, Romania ranked second-lowest in per capita waste generation, behind only Slovakia. Municipal waste peaked at 411 kg per person in 2008, then steadily declined, reaching

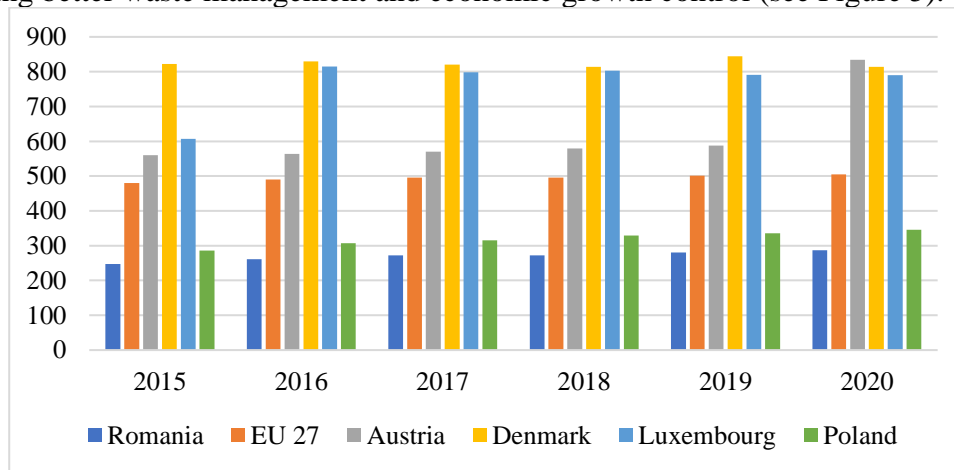
levels between 256 and 287 kg per capita from 2009 to 2020. In 2020, Romania generated significantly less waste per capita than the EU average of 505 kg, with Austria, Denmark, and Luxembourg generating the highest levels. Notably, these countries also had above-average GDPs (see Figure 4), hinting at a connection between economic activity and waste generation.

Analyzing the data from 2015–2020 highlights a few trends:

- **Economic Influence:** Higher GDP often correlates with increased waste generation, but this is also affected by factors like waste collection methods, sustainable product availability, and public awareness.

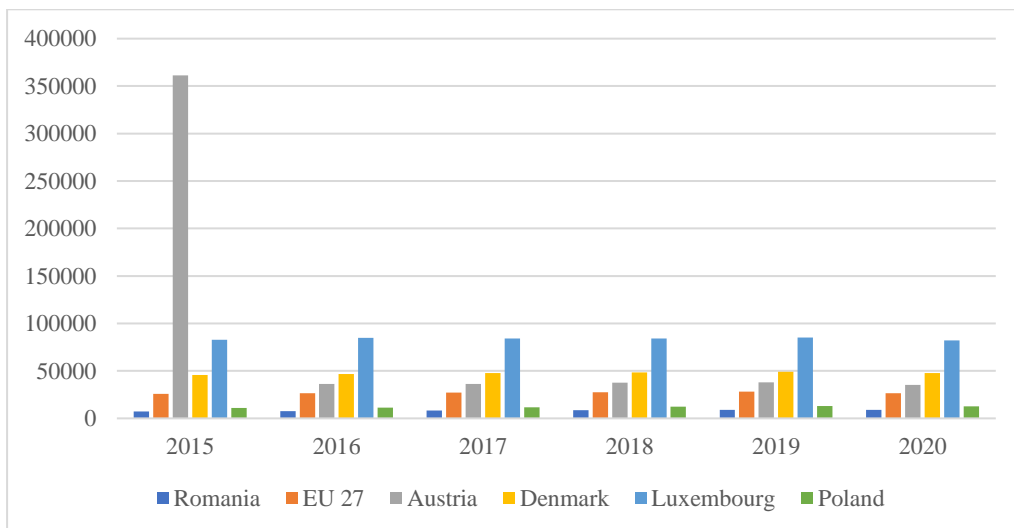
- **Decoupling Waste from Growth:** From 2015 to 2019 (excluding 2020 due to pandemic effects), Romania’s waste output grew by 4.3%, while GDP rose 8.1%, signaling progress in reducing waste intensity according to circular economy goals.

- **Waste Intensity per GDP:** Romania’s waste intensity is higher than the EU average, similar to other emerging economies. However, recent data shows a decline, indicating better waste management and economic growth control (see Figure 5).



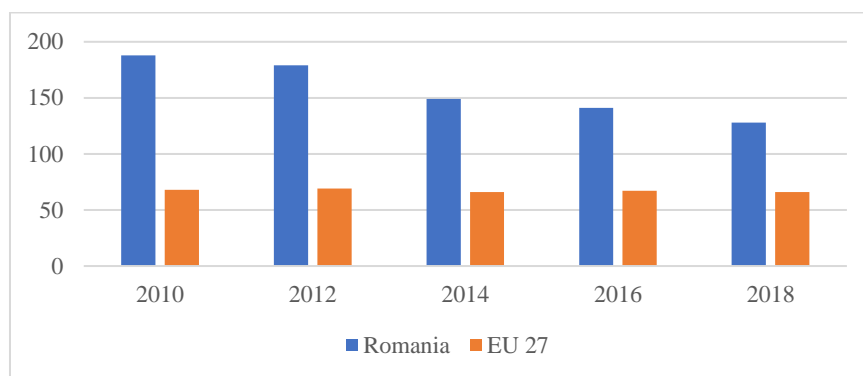
**Figure 3 Generation of municipal waste per capita (kg per capita)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/sdg\\_08\\_10/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en) [27]



**Figure 4 Real GDP per capita (euro per capita)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/sdg\\_08\\_10/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en) [27]

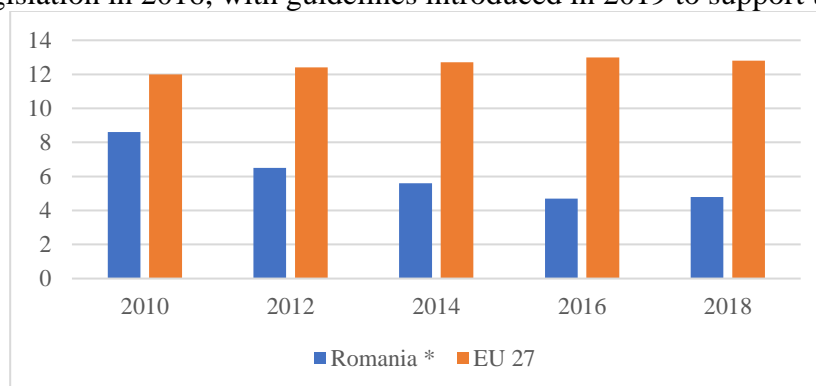


**Figure 5 Generation of waste excluding major mineral wastes per GDP unit in (kg per thousand euro)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_pc032/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_pc032/default/table?lang=en) [27]

Romania is one of the EU's top performers in minimizing waste relative to domestic material consumption (Figure 5). Between 2010 and 2018, Romania improved significantly in raw material use efficiency, producing less waste per unit of raw material.

Food waste remains a pressing issue globally. In 2019, around 932 million tons of food were wasted worldwide, with households accounting for 61% of this total. In the EU, an estimated 88 million tons of food are wasted annually—about 118 kg per person—with Romania producing a lower-than-average 70 kg per capita. Romania passed food waste reduction legislation in 2016, with guidelines introduced in 2019 to support this effort.



**Figure 6 Generation of waste excluding major mineral wastes per domestic material consumption in Romania and EU average (%)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_pc033/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_pc033/default/table?lang=en) [27]

Romania's 2007 EU accession brought the adoption of the Union's sustainable development initiatives, including the recent National Strategy for Sustainable Development 2030, which aligns with the UN's 17 socio-economic and environmental goals, covering circular economy and waste management.

Romania has largely integrated EU waste management directives into its national laws, although sometimes with delays. Key regulations include the Waste Directive 2008/98/EC implemented by Law 211/2011, Law 249/2015 on packaging waste management, and Ordinance 5/2015 for electronic waste. Later updates in 2018 and 2021 further emphasized waste prevention, recycling, and reduction to support circular economy goals. Given challenges with some waste targets, the 2021 Ordinance allows extended deadlines for meeting 2025 and 2030 recycling goals for paper, cardboard, and glass.

Due to Romania's economic and social adjustments, it also secured exemptions under the 2012 WEEE Directive, allowing lower electronic waste collection targets until

2021. However, in 2016 and 2017, Romania’s recycling rate for electronic waste remained low at 25%, as reflected in EU reports.

In 2021, Romania enacted Emergency Ordinance no. 6 to implement EU Directive 2019/904, banning certain single-use plastics. Earlier efforts include the National Waste Management Strategy (2013) and Plan (2017), key to assessing Romania's circular economy progress through waste management indicators.

In line with EU recommendations, Romania included waste management in its National Recovery and Resilience Program and committed to a National Circular Economy Strategy by September 2022.

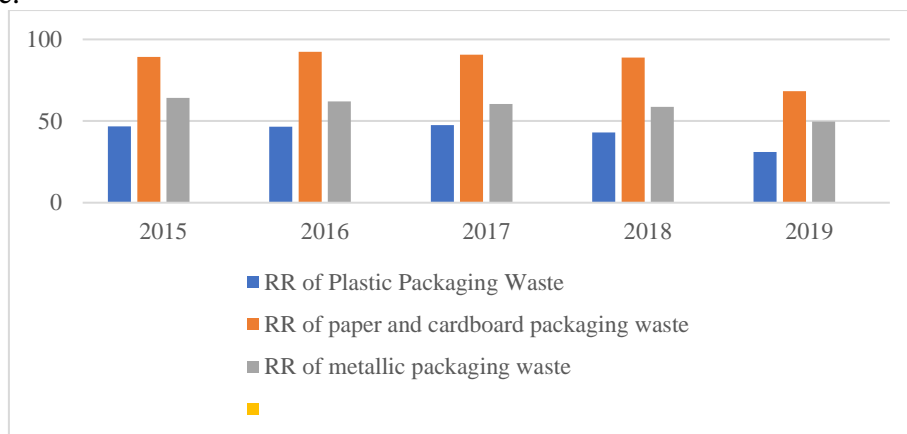
Household recycling is low, at 13.7% in 2020, partly due to poor waste sorting practices. Delays in updating national laws in line with EU directives led to European Commission infringement procedures. These include the Landfill Directive (implemented in 2021 by Ordinance no. 2), Waste Framework Directive (GEO 92/2021), and Packaging Waste Directive (GO no. 1/2021). Slow legislative alignment, lack of public awareness, and weak enforcement contribute to low recycling rates and unusual data patterns.

Construction and demolition waste recovery has seen significant growth, reaching 85% in 2016 before declining slightly. Overall, recycling rates excluding major mineral waste are on a gradual rise, reaching 30% in 2016 and 29% in 2018. However, recycling rates for packaging and biowaste are declining, affected by legislative gaps and lack of composting standards.

Ordinance no. 6 (August 2021) aims to reduce plastic waste by phasing out plastic packaging and single-use items by 2026, with plastic cutlery removed from circulation as of September 2021. Order no. 417/2021 also standardized recycling practices for electronic waste, effective from March 2021.

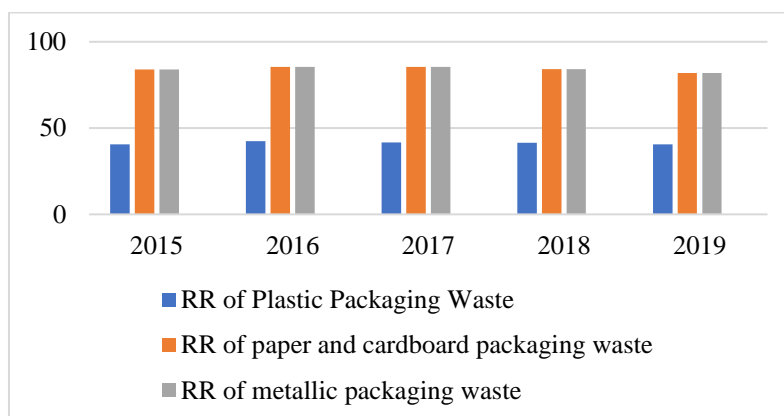
To assess Romania’s packaging recycling performance relative to other EU countries, Eurostat data on packaging waste recycling rates by material type is shown in Figure 7.

Packaging waste refers to materials used to protect products throughout their journey from manufacturing to the consumer. These materials include plastic, paper and cardboard, wood, metal, and glass. Each EU member state reports annual data on collected and recycled packaging waste, making it publicly available through European statistics. Figure 7 and 8 shows Romania’s packaging recycling rates compared to the EU-27 average.



**Figure 7 Recycling Rate (RR) in Romania**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm020/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm020/default/table?lang=en) [27]



**Figure 8 Recycling Rate (RR) in EU**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_wm020/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_wm020/default/table?lang=en) [27]

From 2015 to 2018, Romania exceeded the EU average for plastic packaging recycling - an achievement in its circular economy efforts. However, the COVID-19 pandemic in 2019 impacted packaging collection and recycling rates, causing a decline across both Romania and the EU.

Romania also performed above the EU average in recycling paper and cardboard packaging, except in 2019. Recycling of wooden packaging has improved, with a rise from 69.5% in 2015 to 81.8% in 2018, placing Romania in 14th among EU nations. Metal packaging recycling rates are lower; Romania recycled 80.8% in 2015, dropping to 70.8% in 2018, putting it in 24th place, while countries like Belgium achieved over 98%.

Glass packaging recycling is improving, with Romania recycling 55.4% in 2015 and reaching 80.8% in 2018, although still below the EU average. Belgium led with 100% glass recycling in the same period, while Romania's rate growth shows potential to reach the EU average.

In summary, Romania surpassed the EU average in two packaging indicators, is progressing in glass packaging recycling, and lags behind in metal and wooden packaging recycling, with slight fluctuations below the EU benchmark. For electronic waste (WEEE), Romania's grace period ended in August 2021, but only 20% of electronic waste is officially recycled. In 2020, a 46.42% collection rate surpassed the 45% target, according to the Environ Association.

Biowaste recycling remains Romania's weakest area due to inconsistent waste policy, lack of infrastructure for food waste composting, and limited public awareness. In 2020, Romania ranked near the bottom in biowaste recycling, though it generates low municipal waste per capita, which impacts the biowaste recycling rate.

Law no. 181, passed in 2020, emphasizes composting of household biowaste, aiming to reintegrate it into the economy or natural environment. Implementation has been delayed due to a lack of technical guidelines and composting facilities.

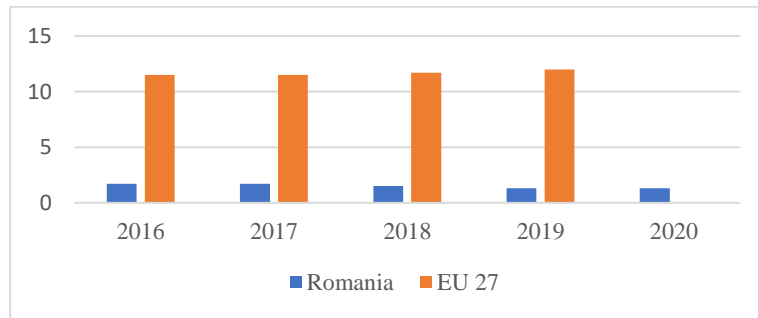
Construction and demolition waste recovery is growing quickly, although Romania remains below the EU average. In 2016, it achieved 97.7% of the EU average for this indicator, falling to 84.1% in 2018, ranking 22nd among EU nations.

Romanian regulations, under GEO 92/2021, aim to reuse or recycle 70% of this waste, although limited crushing and processing facilities make this target challenging [21].

Reintroducing secondary raw materials into the economy offers numerous advantages, from conserving natural resources and boosting EU self-sufficiency to advancing environmental protection and circular economy goals. Two key indicators in

this area are the *End-of-life Recycling Input Rates* (EOL-RIR) and the *Circular Material Use Rate* (CMU).

EOL-RIR assesses recycling rates across the EU as a whole, without country-specific data. The CMU indicator measures the share of recycled materials in the total materials entering the economy, including raw and fossil-based materials. However, the CMU’s effectiveness as a circular economy measure has limits—if both recycled and total material usage rise simultaneously, CMU percentages may appear static despite actual progress (see Figure 9).

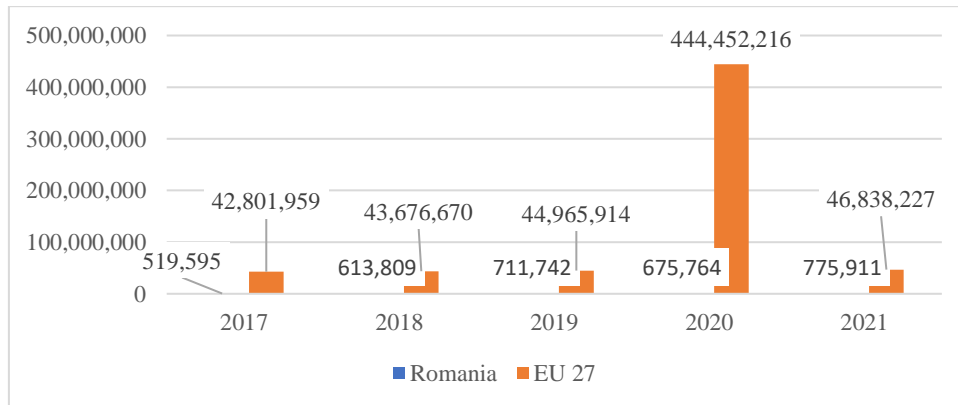


**Figure 9 Circular material use rate (%)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_srm030/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_srm030/default/table?lang=en) [27]

Romania's recycling rates have generally fallen short compared to the EU average, consistently ranking last in CMU from 2016 to 2020, with rates ranging from 10.1% to 14.7% of the EU average. The country also ranks low in the trade of recyclable raw materials, with just 1.2% of the EU average in 2017 and 1.65% in 2021 (Figure 10).

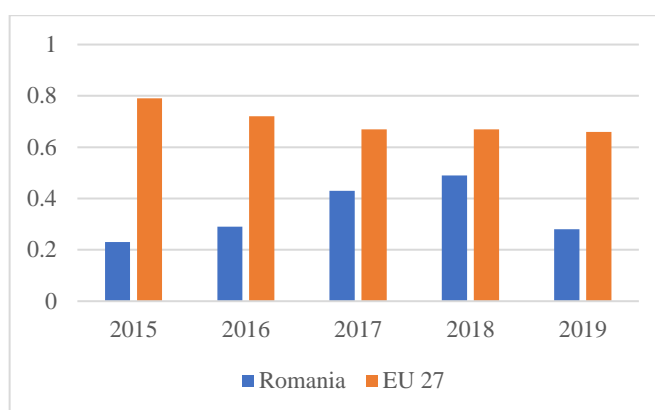
Key obstacles for Romania include a lack of sufficient recycling facilities, high operational costs, low technological efficiency, and limited operators in the recycling sector.



**Figure 10 Trade in recyclable raw materials (tonne)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_srm020/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_srm020/default/table?lang=en) [27]

The circular economy requires new approaches to product design, manufacturing, and waste valorisation, fostering innovation, and rethinking business development. These efforts—driven by creativity, intelligence, and financial investment—aim to build a more competitive economy, create jobs, and promote a healthier environment. The European Commission monitors competitiveness and innovation in the circular economy, and its indicators track each country's progress. In Romania, jobs in circular economy-related fields grew by 2% from 2015 to 2019, while the EU as a whole saw an 8% increase. In 2019, Romania’s employment in this sector was 88% of the EU average, ranking it 21<sup>st</sup> [22].



**Figure 11 Patents related to recycling and secondary raw material (per million inhabitants)**

Source: Eurostat: [https://ec.europa.eu/eurostat/databrowser/view/cei\\_cie020/default/table?lang=en](https://ec.europa.eu/eurostat/databrowser/view/cei_cie020/default/table?lang=en) [27]

The underdevelopment of waste management and material recovery sectors in Romania correlates directly with low competitiveness indicators. Investment in waste processing, recycling, and material recovery technologies remains modest [17]. Though legislation exists, prioritizing these sectors and offering fiscal incentives could accelerate growth.

The "Patents related to recycling and secondary raw materials" indicator (Figure 11) highlights Romania's position relative to the EU, measured in total patents and patents per million inhabitants [20, 5]. Romania consistently ranks below the EU average, achieving 29% of the EU average in 2015 and 42.4% in 2019, placing 18th. Limited funding for research institutes and significant brain drain contribute to this gap. Private companies in this field also lack the financial strength to support advanced research labs. However, university-led research is underway, and increased public-private partnerships could significantly advance the sector.

## CONCLUSIONS

In conclusion, Romania's journey toward adopting circular economy principles has been gradual yet promising. Despite its early commitment to sustainable development, the country faces challenges in areas such as waste management, green procurement, and recycling infrastructure. Economic and regulatory constraints, combined with limited public awareness, have impacted Romania's ability to fully align with EU circular economy benchmarks.

Nonetheless, Romania has achieved notable progress in some areas, like municipal waste management, certain packaging recycling rates, and reducing per capita waste. Legislative efforts, including bans on single-use plastics and support for food waste reduction, indicate positive steps. However, inconsistent enforcement and delays in updating national laws hinder momentum.

To further advance its circular economy goals, Romania must prioritize investments in recycling technologies, enforce green procurement criteria, and strengthen public-private partnerships for research and innovation. Addressing these gaps could accelerate Romania's shift toward a more sustainable economy, positioning it as a competitive player in the EU's circular economy framework.

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