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Circular Economy and Waste Management in Eastern Europe

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Apstract: *Eastern Europe aims to address the EU's circular economy policies, despite socio-economic disparities compared to Western Europe. This work aims to provide regional insight into waste management and circular economy prospects with five relevant country analyses in Eastern Europe part of the EU (Romania, Bulgaria) and non-EU countries, but with candidate status (Ukraine, Rep of Moldova, and Georgia). In the latter cases, these countries face particular geopolitical challenges as additional barriers to advancing toward a circular economy transition. Despite these societal challenges, this work highlights some progress towards the circular economy path in each country. However, the landfill-based system prevails but developments of waste management facilities to divert waste from landfills towards recycling, biogas production, and composting supported by source-separation of waste with community involvement is a solid pathway in the near future. These efforts must be supported by authorities (clear regulations, less bureaucracy, waste databases improvement, financial support), business innovation, and the role of environmental NGOs in reducing waste-related pollution threats and waste diversion form multi-sectoral sectors (municipalities, agriculture, industry) to upper circular economy activities.*

Keywords: Waste Management, Circular Economy, Recycling, Eastern Europe, Regional Cooperation, Geopolitical Constraints

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3.1. Introduction

Waste pollution raises concerns around the globe polluting every environmental compartment through waste treatment facilities (conventional landfills, waste incinerations, waste to energy facilities) or mismanagement practices (e.g. illegal dumping sites, open burning practices, littering behavior) involving municipal, industrial, and agricultural waste flows with various intensities related to socio-economic dynamics specific for each country and region (UNEP 2024). The linear economy model feeds such waste pollution and public health threats involving both urban and rural communities including marginalized areas and vulnerable communities (Iacoboaea et al. 2024). The transition to a circular economy presents a vital opportunity to mitigate these adverse impacts by redefining how resources are used and managed (Bianchi and Cordella 2023; Mazur-Wierzbicka 2021). By focusing on reducing waste generation, promoting recycling and reuse, and encouraging sustainable product design, circular economy principles aim to close the loop of product lifecycles (D'Adamo et al. 2024). This approach not only addresses environmental pollution, but also fosters economic growth and job creation (Ahmadov et al. 2022; Ivanova 2020a). For Eastern Europe, embracing circular economy practices can help bridge the socio-economic gaps compared to Western Europe, enhancing resource efficiency and resilience (Stoenoiu, & Jäntschi 2024; Silvestri et al. 2024). Furthermore, it can significantly contribute to public health improvements by reducing exposure to hazardous waste and pollutants, benefiting both urban and rural communities. As countries in the region continue to develop and integrate these practices, they can set a precedent for sustainable development, balancing economic progress with environmental stewardship (Claudio-Quiroga and Poza 2024).

This work aims to provide regional insight into waste management and circular economy prospects with five relevant country analyses in Eastern Europe part of the EU (Romania, Bulgaria) and non-EU countries, but with candidate status (Ukraine, Rep of Moldova, and Georgia). EU policies regarding the circular economy framework could act as a guide for Eastern Europe even for non-EU countries with common goals to provide environmental sustainability and resource-efficient economies while reducing the socio-economic gaps compared to other European regions. For researching this theme, the following methods of research were used: a literature review was conducted to examine existing studies on circular economy and waste management practices in Eastern Europe.

Additionally, previous studies and reports on the socio-economic context and environmental challenges in the region were reviewed. Quantitative data on waste generation, recycling rates, and waste recovery were gathered from national statistics offices, EU databases, and relevant environmental agencies for Romania,

Bulgaria, Ukraine, the Republic of Moldova, and Georgia. A detailed analysis of waste management systems and circular economy initiatives was performed for each of the five countries. This included examining current waste management practices and recycling programs in Romania and Bulgaria, as well as assessing the impact of candidate status on circular economy policies and the challenges due to geopolitical factors in Ukraine, the Republic of Moldova, and Georgia.

3.2. Circular economy and waste management in Eastern Europe

Waste management in Eastern Europe is dominated by linear economy mechanisms where landfilling of waste is still the main option of municipal waste flow. Therefore, this work aims to reveal how landfilled-based countries of Eastern Europe are preparing for the transition towards a circular economy envisioned by the EU as a core environmental policy. This transition requires a paradigm shift from a "take-make-dispose" model to Rs policies and a zero-waste approach (Vajda and Drăgan 2023). However, Eastern European countries must overcome barriers posed by traditional waste management practices such as higher rates of landfilling (>80%) and mixed waste collection schemes that feed the waste pollution of the natural environment. On this background, Zero Waste Europe argues the support for material recovery and mechanical-biological treatment stations (MRBT) to be installed in cities to recover and divert from residual municipal waste fraction valuable recyclable materials (dry recyclables) and to provide stabilized organic matter while reducing the amounts of municipal waste disposed in landfills (Zero Waste Europe 2020a). However, this downstream solution is useful, but in the long-term source separation collection in multiple fractions (4-5 waste streams including biowaste fraction) should be developed at scale across municipalities in Eastern Europe with community participation efforts in decreasing the share of residual waste in total municipal waste fraction flow. Furthermore, there are concerns about some waste incineration projects in the largest cities such as Sofia (Bulgaria) that could stop the future progress towards a circular economy (Zero Waste Europe 2024). Therefore, well-developed source-separation collection schemes, deposit-return schemes, and civic amenity sites could enhance the resource recovery process from municipal waste fraction.

The civic amenity sites have the role of capturing also special waste fractions such as bulky waste (e.g. furniture), e-waste, the hazardous fraction of municipal waste, used oil, or biowaste (e.g. green waste) acting as urban mining centers. Such waste-related facilities could enable the municipalities on the path towards a circular economy transition and achieve zero-waste municipalities' status. In Eastern Europe, there are 12 cities & rural municipalities in Romania, 1 city-

Bulgaria (Svilengrad) engaged to be certified as a zero-waste municipality, but improvements are required in resource recovery and source-separation collection levels in both countries (Zero Waste Europe 2020b). The latest report reveals some positive results in Eastern Europe. For example, in Bulgaria, the Svilengrad separation collection rate increased from 22.67 (2022) to 54.37 (%) and other actions are underway in Blagoevgrad (biowaste collection scheme), Gaborovo municipality (plastic prevention plans) while in Ukraine there is a reopening of the Circular Construction Yard site aimed to provide building materials for reconstruction purposes in Kharkiv region affected by Russian invasion (Zero Waste Europe 2024). The Republic of Moldova is also showing promise, with new initiatives focused on improving waste management infrastructure and promoting recycling programs to enhance its circular economy prospects (Iordachi and Timus 2022; Perciun et al. 2023). Additionally, as a neighboring country, Moldova has the opportunity to contribute to Ukraine's post-war reconstruction efforts by applying waste circular principles and fostering regional cooperation and sustainable development. Besides the waste management services the role of the business sector, industries, and NGOs is critical to initiate circular economy projects at the micro level (business, community level) that can be further developed with the support of local or national authorities (Warwas et al. 2021).

The circular economy requires multi-sectoral collaborations in Eastern Europe including in the water management sector (Mihai et al. 2023, Keremidchiev 2023; Vasylkivskyi et al., 2023) while the pos-war recovery of Ukraine could be embedded in the same framework (Shvedun et al.2023). This work aims to highlight the particular challenges related to the circular economy and waste management topics by examining the relevant policy papers or environmental/technical reports and analysis of some key indicators while taking into account the geopolitical constraints.

3.3. Case studies in Eastern Europe

3.3.1. Ukraine

3.3.1.1. Legislation and main challenges

In Ukraine, waste management is included in several national and regional strategic documents (Strategy of sustainable development of Ukraine until 2030, Strategy of the state environmental policy of Ukraine until 2030, Strategy for the development and implementation of state policy in the field of climate change for the period until 2035, Association Agreement between Ukraine and the EU

(Kidalov et al. 2020). This is a basement for effective waste management and implementing the circular economy principles. However, there are also many regulations not adopted, but are crucial to achieving the strategic goals. First of all, these are draft laws on certain waste categories (waste packaging, waste electrical and electronic equipment, waste batteries, etc.), which should introduce a system of extended producer responsibility, providing financial resources and logistics for the operation of the waste management system. Today, local authorities have limited capabilities due to the lack of local waste management plans, which should have been developed after the National and regional waste management plans. The National waste management plan, approved in 2019, is currently being corrected, taking into account new challenges and, at the same time, delaying the development of local plans needed for waste management system operation. For example, according to the National waste management plan, the extended producer responsibility was supposed to be implemented by 2023 for a majority of waste categories, but to date, no relevant law has even been adopted. While there is significant progress in regulations adopting, the completion of tasks is much more problematic due to the lack of a systematic approach in local communities, lack of sufficient funds, and since 2022 - due to military aggression against Ukraine.

In Ukraine, waste management is significantly complicated due to the separation of functions among many organizations. The Ministry of Environmental Protection and Natural Resources ensures the implementation of state policy in the field of waste management. The State Agency on Exclusion Zone Management coordinates the collection, transportation, processing, storage, and disposal of radioactive waste. The Ministry of Health provides state sanitary and hygienic inspection (including compliance of waste management activities with sanitary standards). The Ministry for Communities, Territories, and Infrastructure Development coordinates the development of programs and projects in the field of household waste management. The State Environmental Inspection provides a state control over compliance of waste management legislation with the requirements. Thus, a large number of responsible authorities significantly reduces the efficiency of waste management. Unfortunately, many regulation requirements are not met in Ukraine. The separate solid waste collection is implemented fragmentarily. Open burning of solid waste is still partly used in rural areas. The application of the "polluter pays" principle is possible today only by determining the waste generation rate for the entire group of waste producers (for example, the population of multi-apartment buildings), but that excludes an individual approach to each waste producer.

According to Ukrainian legislation, there is a possibility to combine efforts of communities and funds of local budgets for the implementation of joint waste

management projects. At the same time, there is no relevant experience, as well as clear instructions. The choice of the form of municipal cooperation requires a thorough analysis of the advantages and risks of various cooperation options, including trends in improving the legislative framework for municipal cooperation. Thus, it is seen that there are significant obstacles to achieving the strategic goals of waste management in line with circular economy principles (Shpak et al. 2020).

3.3.1.2. Waste generation and waste management options

Waste generation in Ukraine has been growing in recent years until 2022 when there was a significant decline (more than 2 times) due to military actions. In the peak year of 2021, almost 500 million tons of waste (about 11 tons per capita) were generated (Table 3.1). This is more than in any other country in Europe (e.g., Germany generates the most waste in the EU – about 400 million tons/year (Eurostat 2024). Industrial waste covers 98-99% of total waste generation. It is higher compared to other European countries, where the share of industrial waste ranges averagely between 90 and 93% (Marino and Pariso 2020).

Table 3.1. Waste generation in Ukraine, thousands of tons, 2019–2022
Табле 3.1. Генерисање отпада у Украјини, у хиљадама тона, 2019–2022.

Waste	2019.			2020.			2021.			2022.		
	Total	Industry	Households	Total	Industry	Households	Total	Industry	Households	Total	Industry	Households
Hazardous waste	553			532			606	605	1	230	227	3
Non-hazardous waste	440963			461841			492647	487107	5540	203315	198820	4495
Total	441516	n/a	n/a	462373	n/a	n/a	493253	487712	5541	203545	199047	4498

An important note on statistical data has to be made. The data on industrial waste generation are submitted by companies to the State Statistical Service and are very rarely checked, which often leads to the submission of inaccurate data. Besides, non-operating companies, which have previously accumulated significant amounts of waste, do not submit any statistical data.

The reliability of household generation data is also questionable because a) not all households are covered by solid waste collection service, b) waste volume is calculated by the number of trucks used for waste collection, and c) in all villages and small towns, the waste amount is calculated according to theoretical waste generation rate not corresponding to the real situation. Therefore, the available statistical data on waste generation are supposed to be unreliable and probably underestimated, that is, the real waste volume is greater. Because the economy is based on raw materials, a specificity of waste structure in Ukraine is a large share of extractive industry waste (overburden or waste rocks, mineral enrichment waste like slurries, tailings, etc.)–over 85%. Other types of economic activity account for less than 15%. The largest amount of waste is generated by mining companies, as well as metallurgical, coal, chemical, and energy industries. The main method of waste disposal in Ukraine remains landfilling (Makarenko and Burak 2017) accounting for up to 60% of the waste generated (Fig. 3.1). More than 15.6 billion tons of waste has been accumulated in landfills and the territory of industrial companies.

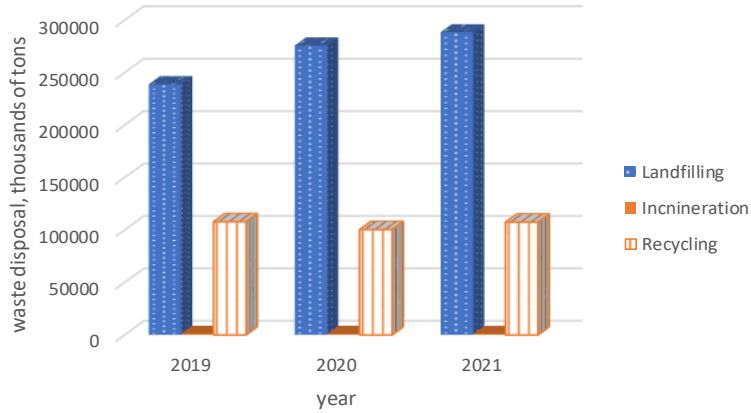


Fig. 3.1. Waste disposal in Ukraine
Сл. 3.1. Одлагање отпада у Украјини

Only 20-25% of waste is disposed of in Ukraine. This is far below the target of 55% that must be achieved by EU countries by 2025 (Hondroyiannis et al. 2024). The share of waste incineration is 0.2% – approximately twice as low as the EU average. In Ukraine, household waste generation is constantly increasing, while being mostly landfilled in more than 6000 landfills and open dumps that very often are located, designed, and operated in the wrong way. This results in a huge negative impact on the environment and human health. Only 5.8% of household waste is processed, including incineration (2.7%), and recycling at waste

processing facilities (3.1%). The rest of the household waste (about 94%) is landfilled (Horbal et al. 2020). In many Ukrainian municipalities, landfills have no enough capacity for further waste disposal and do not meet environmental requirements (Ishchenko and Vasylkivskyi 2020). Some forms of separate waste collection are introduced in regional centers and some smaller towns (e.g., containers for glass, plastic bottles, paper, etc.). However, these efforts are still not enough to establish an effective system. Besides, the information support for separate waste collection is very weak. Thus, household waste management in Ukraine is less efficient compared to EU countries.

A waste category of special attention is expired pesticides and agrochemicals, which cannot be used due to the deterioration of their properties, expiry date, loss of labeling, or mixing. Their treatment remains a big issue since Ukraine lacks appropriate facilities and is forced to export expired pesticides for treatment abroad. Since 2010, the Ministry of Environment Protection and Natural Resources of Ukraine has started implementing a large-scale program of hazardous waste treatment. Despite that, expired pesticide management is still quite problematic. According to various estimates, there are about 9-11 thousand tons of expired pesticides in Ukraine (it is difficult to accurately estimate the amount of pesticides accumulated, because there are no official records, and the data from various sources are very different). These pesticides are stored in more than 800 warehouses located in many villages under inappropriate conditions: very often the warehouses are partly destroyed.

3.3.1.3. Selected waste streams for circular economy

a) Construction and demolition waste

Construction and demolition waste are among the waste with the greatest resource potential. Active building and road construction in Ukraine has led to the generation of a large amount of construction waste in recent years (about 1 million tons/year). Since 2022, due to military actions, a huge amount of destruction waste has been generated additionally (according to various estimates, over 1.2 million tons) that requires management decisions. In the context of the reconstruction needs, this will force the authorities to use waste as potential resources for the reconstruction instead of spending costs for waste disposal. This will also provide the conditions for the development of recycled construction waste markets and increased use of secondary metals. Some components of construction and demolition waste have a high resource value, while others may have a lower value, but could still be easily reprocessed into new

products or materials. According to the current regulations, it is allowed to landfill shredded construction waste along with municipal solid waste in usual landfills. In Ukraine, there are no requirements for the location of companies or facilities for shredding construction waste, as well as for shredding technology. Besides, there are easily available and cheap natural raw materials for the construction industry, in particular quartz sand. The abovementioned and the lack of relevant standards lead to a paradoxical situation where a huge amount of construction and demolition waste is almost completely unused. One of the few examples is the partial replacement of cement clinker with waste like fly ash (a byproduct of burning coal at heat power plants), slag, etc. The role and potential of construction and demolition waste will be significant in post-war Ukraine, and technologies of recycling will be highly demanded.

b) Waste electrical and electronic equipment

According to official statistics (State Statistical Service of Ukraine 2024), waste electronic and electrical equipment (WEEE) generation in Ukraine is about 20 thousand tons/year, while the estimated weight of electronic and electrical equipment on the Ukrainian market is over 800 thousand tons per year. Previous studies (Ishchenko and Sydoruk 2023) have shown a significant discrepancy between the expected WEEE weight and official statistics. Thus, more than 95% of WEEE is not taken into account in waste flows (Fig. 3.2). Taking into account the lifespan of various equipment and the weight of equipment placed on the Ukrainian market in previous years, WEEE generation is estimated at more than 1 million tons/year. The share of household WEEE is estimated at 200 thousand tons/year (5 kg/year per 1 inhabitant), which is slightly lower than in other Eastern European countries. Computers and electronics hold almost half of household WEEE. WEEE collection rate varies from 0.6% (household devices) to 10.4% (batteries), depending on the waste category. This is much lower than in the EU. The lack of WEEE accounting in the household and commercial sectors creates a significant underestimation of WEEE flows in official data in Ukraine. Plastic, metal, and rubber are the components of WEEE that can be easily recovered and are primarily considered as resources. There is a study of the resource potential of some e-waste (Hlavatska et al. 2021). Taking into account the amount of WEEE generation in Ukraine, over 4000 t/year of resources can be easily recovered from the most widespread devices like mobile phones, monitors, etc., including 2000 t/year of plastic, 1200 t/year of metals (mainly steel and aluminum), 900 t/year of glass, 80 t/year of rubber. It is known that the most valuable elements are found in printed circuit boards of electronic devices. The largest weight of printed circuit boards was found in the monitors (over 250 g per monitor), and in terms of relative content – in the mobile phone and computer mouse (14%).

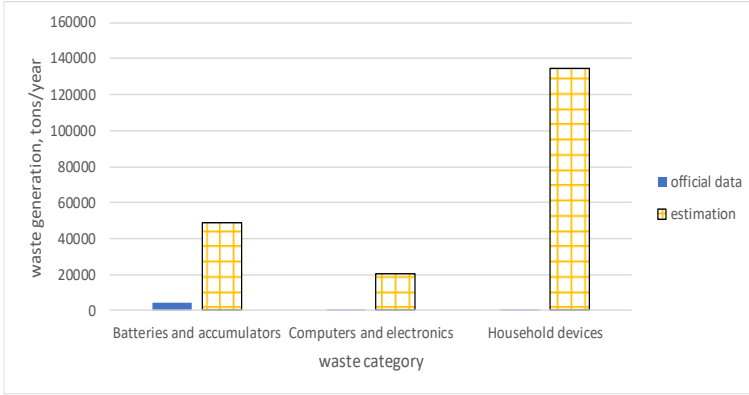


Fig. 3.2. Generation of selected e-waste: comparison of official data and estimation

Сл. 3.2. Генерисање одабраног е-отпада: поређење званичних података и процјена

Thus, more than 600 t/year of resources (primarily, precious metals) can be extracted after applying special processing methods (mobile phones can provide almost half of this amount).

c) Organic waste

The potential of organic waste in the circular economy of Ukraine is very high: the share of organic waste in household waste varies from 40 to 60% by weight (4-5 million tons/year). Even more organic waste is generated in industry: for example, farming produces more than 50 million tons/year. However, this potential is still used very little. In household waste, the organic part is mainly represented by food waste. Food waste is generated mostly in cities and towns. In villages, food residues rarely go outside households as waste – it is usually used as feed for domestic animals (composting is less common). In cities and towns, organic waste is not collected separately and therefore it is delivered to landfills. Only 0.003% of household waste (about 2000 m3) is composted. Therefore, household organic waste is not included in the circular economy. However, organic waste is increasingly used as a resource in industry. A significant increase in biogas capacity (10 times over the last 10 years) is due to government financial incentives (high "green tariff" for the energy produced from biogas). Today, more than 30 biogas plants operate in Ukraine. The majority of them are installed by businesses generating the relevant organic waste (mainly livestock farms). Also, about 20 plants operate at household waste landfills. The potential of biogas production in landfills is about 400 million m3/year. Besides, the energy potential of organic waste is also used: a few examples are oil extraction plants. Despite significant

progress, the recycling rate of organic waste is significantly lower than in EU countries.

d) Hazardous waste

Hazardous waste is mainly known for its danger to the environment. Although some components of hazardous waste (e.g. metals) can be recovered for recycling according to the circular economy principles. Among hazardous waste generated in Ukraine, the highest recycling rate is registered for common sludges (77%), mixed and undifferentiated materials (72%), waste oil (64%), waste acids, alkalis, and salts (59%), and non-ferrous metal waste (53%). Other waste categories are recycled below the 50% level (Ishchenko et al. 2024). There are also some waste categories with zero recycling: mixed waste of ferrous and non-ferrous metals, glass waste, rubber waste, textile waste, discarded vehicles, mineral waste from waste treatment, and stabilized waste and mineral waste generated after processing. Therefore, there still is a high recovery potential after the application of appropriate technologies.

Hazardous components of household waste or hazardous household waste (HHW) is a specific category that needs special attention. The dynamics of the HHW processing are positive: there is a constant increase in the volume (the most significant in 2019-2020). Compared to 2017, the weight of HHW recycled increased by more than 5 times. Sometimes, the volume of treated waste exceeds the generation – probably due to the processing of previously generated waste. The recycling rate has increased the most for waste pharmaceuticals, lead-acid batteries, medical infectious waste, and medical devices and instruments. However, for some waste categories, a decrease is observed (e.g., detergents, fluorescent lamps, and others). It must be noted that higher recycling rates were achieved, first of all, due to the recycling of lead-acid batteries (about 23000 tons/year), which is almost 90% of total waste recycling.

The modernization of the infrastructure of waste recycling facilities is also important for the circular economy. Currently, slow progress is being reported in Ukraine in increasing the volume of waste recycling, and new opportunities for the circular economy will appear due to the future integration of Ukraine into the EU.

3.3.2. Romania

According to the latest environmental status report of the National Environmental Protection Agency, Romania had a recycling rate of 12.25% while the landfill rate was 73.77% in 2021 reflecting the prevalence of linear economy in terms of municipal waste management practices (NEPA 2023). The recycling rate is lower

compared to neighboring countries like Hungary (32.8%) Bulgaria (28%), or Serbia (17.6%) and at same level with Malta while the average of EU27 being 48.6% (Eurostat 2024). These results require improvement of source-separated waste collection schemes for dry recyclables (paper, glass, plastic, metal) in Romania and a better capture rate of organic waste for composting facilities. Development of the urban mining sector through state of art industrial facilities (e.g. Green WEEE) (see Fig. 3.3b) supports metal recovery from e-waste flows while end-of-life vehicles are another key waste stream of urban mining in Romania, but some activities are predisposed to illicit channels (Modoi and Mihai 2023).

Some companies invest and develop new non-plastic packaging materials in Romania as a response to single-use plastic bans and environmental concerns related to plastic packaging in general. Reuse practices and refilling options are mandatory choices for a zero-waste business model approach (e.g., Bistro and restaurants) where food and beverages are delivered without plastic packaging material (Mihai et al. 2022).

Glass bottle reuse in the HoReCa sector is already standard practice in Romania. However, a standardized format for all glass bottle packaging (without any footprint on glass packaging) materials could scale up the reuse and refilling practices combined with well-developed deposit-return schemes for the beverage packaging sector as shown in Fig 3.3a. The scalability of reusing and refilling options for glass packaging should prevail compared to marketing targets of certain brands with support from regulations at EU levels.

Better capture rates of glass, aluminum, and paper cardboard packaging materials from the MSW stream could improve recycling rates reduce the plastic packaging consumption levels in Romania, and decrease the plastic import levels (Mihai and Ulman 2024). Deposit return schemes could enhance the capture rate of glass bottles combined with the development of refilling systems. Alternatives to conventional plastic packaging are provided already by some Romanian companies with a diverse range of packaging products made from corn starch, wood, or sugar cane (Mihai et al. 2022) or current research trying to develop a biodegradable film based on polyvinyl alcohol for potential food packaging (Pop et al. 2024; Peter et al. 2024).

Fig. 3.3. a. Deposit-return site for beverage packaging near a supermarket Iasi city (left) b. Special e-waste collection point in a neighborhood of Iasi city - open once per week (right) Photos: F-C Mihai, May 2024

Сл. 3.3. а. Мјесто за враћање амбалаже за пића у близини супермаркета у граду Јаши (лијево) б. Специјално мјесто за прикупљање е-отпада у насељу града Јаши – отворено једном недјељно (десно) Фотографије: F-C Mihai, мај 2024.

Furthermore, some studies focus on developing edible materials as a solution to replace plastic packaging in meat food products with environmental benefits, such as being fully biodegradable and in line with the zero-waste approach (Puscaselu et al. 2021). Another approach is to develop edible films and coatings based on natural ingredients to provide sustainable packaging solutions for powdered products (Puscaselu et al. 2019). These findings suggest that research and innovation in Romania could provide biodegradable or biobased packaging materials for food products that would reduce the dependence on conventional plastic-based packaging materials in line with circular economy ambitions.

The change of systems from waste collection points to door-to-door systems in settlements along river courses could be taken into account to reduce illegal dumping practices. For example, the environmental campaign “Cleaning Romania” performed in the spring of 2022 collected 564.000 kg of waste from natural and built-up environments via cleaning-up events with the participation of 520 municipalities (GNM 2022). Furthermore, the door-to-door system will increase the waste collection fee rates because it is more difficult for residents to

avoid the fee payments compared to waste collection points. In some localities, the collection fees could be subsidized by local authorities or special programs, but only if source-separation of household waste is provided.

At the EU level, Romania is facing the highest poverty and social exclusion rate, and the rural regions are the most exposed to such low socio-economic conditions (Eurostat 2023). Therefore, waste collection and transportation facilities must take into account such realities. The circular economy fee will double (160 RON – around 33 euros) in 2024 to encourage source-separation waste collection schemes (EY 2023), but the low fees compared to Western Europe encourage plastic importation through formal or illegal practices (Mihai and Ulman 2024; Modoi and Mihai 2023).

Environmental organizations point out that waste management infrastructure projects should abandon waste-to-energy facilities and adopt suitable alternatives to increase recycling levels (urban mining centers, bio-digestors, centralized composting facilities, home composting support programs) relevant for higher circular mechanisms (Zero Waste Europe 2019).

In Romania, Targu Lapus city and the rural municipality of Salacea reached 2019 a 75% separation collection rate targeting a 90% landfill diversion rate in the future while other enrolled cities in zero-waste municipality certification have lower values such as 33% (Mizil), 15.69% (Iasi), 11.89% (Oradea), Roman (Zero Waste Europe 2020b). The deposit-return system in Romania will play a crucial role in diverting beverage packaging waste from landfills (Cliza and Spătaru-Negură 2021), and also decreasing the plastic importation levels in the domestic market (Ecologic 2024). The circular economy toolkit for diverse business actors shows some progress toward a systematic change at the organizational level (Concordia 2022).Biowaste generated by municipalities and agricultural activities is a key resource to be diverted from landfills towards large-scale centralized composting facilities in urban areas or decentralized systems in rural areas (Mihai et al. 2023a). Improvement of home composting practices would reduce the amounts of waste generated and collected by waste operators with both environmental and economic benefits while supporting local organic farming practices. Water management is another key sector where circular economy practices must be supported by reusing practices in industrial applications to reduce water consumption levels and to properly manage the sewage sludge produced by wastewater treatment plants through biogas production (Mihai et al. 2023b). Biogas production using biowaste as feedstock such as sewage sludge, and agricultural waste including manure is a sustainable alternative to be further supported in Romania because these waste flows receive less logistic attention compared to municipal/packaging waste flows.

This is also the case of agricultural wood-related waste generated by rural households that are uncontrolled disposed of or burnt if not properly collected and treated (chopped) to become a source of energy (heating/electricity) at community levels (Mihai et al. 2021) Furthermore, the construction sector is a key economic development in Romania, therefore, the construction and demolition waste is an emerging waste flow that is not well covered by special collection sites with crushing plants to support reuse, recycling and recovery operations at urban and regional levels (Mihai 2019). Therefore, there are additional waste streams and multi-sectoral approaches that require solid investments to improve all waste management sectors in Romania towards a circular economy pathway.

3.3.3 Republic of Moldova

The Association Agreement with the European Union expressly aims to ensure sustainable development and promote the green economy in the Republic of Moldova. By signing the Agreement, the Republic of Moldova undertakes to harmonize national legislation with European legislation and to ensure the integration of environmental protection provisions, through the rational use of resources and energy efficiency, eco-labeling, eco-innovations, in all sectors of the national economy and social life.

Waste management is an indispensable premise in promoting the circular economy. Therefore, it is crucial to diagnose the current state to develop and implement effective policies in this area. Waste management in the Republic of Moldova has evolved in recent years, reflecting modest progress as well as persistent challenges. To show the progress, we will compare the statistical data for the years 2015 and 2022, which provides a detailed perspective on this evolution. Thus, in 2015, the Republic of Moldova generated 3981.2 thousand tons of waste, of which only 609.9 thousand tons were recycled, resulting in a recycling rate of approximately 15.3%. In contrast, by 2022, the total amount of waste generated has decreased to 264,783 thousand tons, but the recycling rate has not progressed, remaining approximately at the same level. This significant reduction in the total amount of waste can be attributed to several factors, such as changes in data reporting and the introduction of stricter requirements for economic operators since these estimations are based on volumes (m3) rather weighehd values. Also, it underscores the need for more effective policies and infrastructure to improve recycling rates.

By focusing on innovative waste management solutions and fostering regional cooperation, Moldova can enhance its circular economy and support sustainable development, ultimately contributing to the broader goals of the EU's circular

economy initiatives. Analyzing the distribution of waste generated in 2022, waste from agriculture, the following general statements are emphasized (National Bureau of Statistics of Moldova 2023):

1) horticulture and related sectors constituted the largest part, representing 51.1% of the total waste. This reflects the importance of the agricultural sector in the economy of the Republic of Moldova and emphasizes the need for effective waste management strategies in this area.
2) Municipal waste (household waste and assimilable waste, originating from trade, industry, and institutions), including separately collected fractions, constitutes 20.4% of the total waste generated. Municipal waste is a crucial indicator of urban waste management and underlines the importance of collection and recycling infrastructure in residential and commercial areas.
3) Construction and demolition waste (including excavated soil from contaminated sites) represents approximately 7.9% of the total waste generated.
4) Waste from waste treatment facilities, ex-situ wastewater treatment plants, and the preparation of water for human consumption and water for industrial use – 6.8% of the total waste generated. These wastes are associated with industrial and water treatment processes and require special management and disposal measures.
5) Packaging and packaging waste; absorbent materials, polishing materials, filter materials, and protective clothing, not elsewhere specified: Totaling 4,433.07 tons, this category represents 1.7% of the total waste generated.

This distribution highlights the key sectors that contribute to the generation of waste in the Republic of Moldova and emphasizes the need for specific strategies for each category to improve waste management and reduce the negative impact on the environment. Prioritizing material recycling and recovery, especially in agricultural and municipal waste, will be essential to progress toward a circular and sustainable economy.

In terms of waste recovery, waste from packaging and other materials, although it represents only 1.7% of the total waste generated, had a very high recovery rate of 22.6%. This suggests a higher efficiency in the recycling and reuse of these materials. In contrast, construction and demolition waste, which represents 7.9% of all waste generated, had a relatively low recovery rate of 4.5%, suggesting significant potential for improvement in this sector. In 2022, the total waste recovery rate, calculated according to the total volume of waste collected, was only 15.3%. This value is considered extremely low and indicates the urgent need

to improve the waste management system. Municipal waste generation indicators are less than half of the European average (Fig. 3.4).

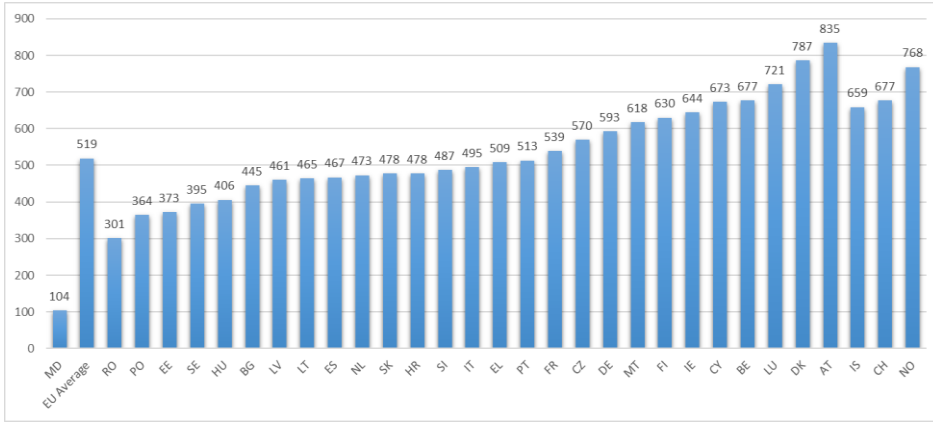


Fig. 3.4. Municipal waste generation per capita in the Republic of Moldova, compared to the EU average (in 2022, in kg/capita) (developed based on Eurostat data)

Сл. 3.4. Генерисање комуналног отпада по глави становника у Републици Молдавији, у поређењу са просјеком ЕУ (у 2022. години, у кг/по глави становника (развијено на основу података Eurostat-а)

This is explained by the low consumption determined by the much lower purchasing power and the fact that the rural population has a large share in the total population. Another explanation would be the small number of the population benefiting from sanitation services, although part of the waste is deposited in dumpsters in open public spaces, leaving an imprint on the waste generation indicator. It is also possible to underestimate the amount of waste collected, because most of the sanitation operators have non-compliant warehouses, mostly without scales, and the record is made based on the volumes transported, the coefficient of 0.25-0.40 being used for the estimated quantity based on waste volumes. At the same time, unstable trends are attested, with an increase in the volumes of waste collected by 7% in the period 2017-2021, in the case of rural localities the generation trends are increasing on average by 131%, and the case of urban localities – the trend is a decrease of about 3% (State Chancellery 2023) (Table 3.2).

The structure of municipal waste is relatively the same during the analyzed period (2017-2021), and of the total municipal waste collected, 61-63% represents

municipal waste generated by the population, 30-32% is similar waste (generated by public institutions, economic agents) and 3-6% is street waste (NBS 2022).

Table 3.2. Activity data regarding the volume of municipal waste collected, thousand m^3

Табела 3.2. Податак о активностима у вези са запремином прикупљеног комуналног отпада, хиљада m^3

	2018.		2019.		2020.		2021.	
	Municipal waste, thou. m^3	Population served, thou. pers.	Municipal waste, thou. m^3	Population served, thou. pers.	Municipal waste, thou. m^3	Population served, thou. pers.	Municipal waste, thou. m^3	Population served, thou. pers.
Total	3176,1	1152,590	3445,4	1284,568	3576,1	1441,858	3519,7	1531,924
From urban areas	1172,0	1012,020	3098,7	1043,232	3067,4	1057,486	2922,5	1044,413
From rural areas	295,1	140,570	348,3	241,336	507	384,457	594,1	492,243

Source: made by the author based on data of State Chancellery 2023

In 2022, according to data provided by the Customs Service (Section VII, Chapter 39 of the Combined Nomenclature of Goods), 97.2 thousand tons of plastic materials were imported, while 16 thousand tons were exported (Fig. 3.5). The import of larger amounts of plastic materials than the one exported in the Republic of Moldova indicates a significant dependence on external resources for domestic production and consumption needs. This situation underlines the need to improve the recycling and reuse of plastics at the national level to reduce dependence on imports, lessen the impact on the environment, and promote a sustainable circular economy.

Observing the generation of municipal waste at the level of the country and districts, the largest share is held by the capital (municipality of Chisinau) - 58% of the total, and the other localities represent an insignificant share of generated waste. But this statistic is rather produced by the lack of municipal waste collection infrastructure in rural localities, as well as the lack of adequate records of collected and separated waste. In the municipality of Chisinau, the collection of municipal waste is covered in the dry areas of the municipality, so 98% of the

population benefits from the weekly waste collection service, there being 895 collection platforms.

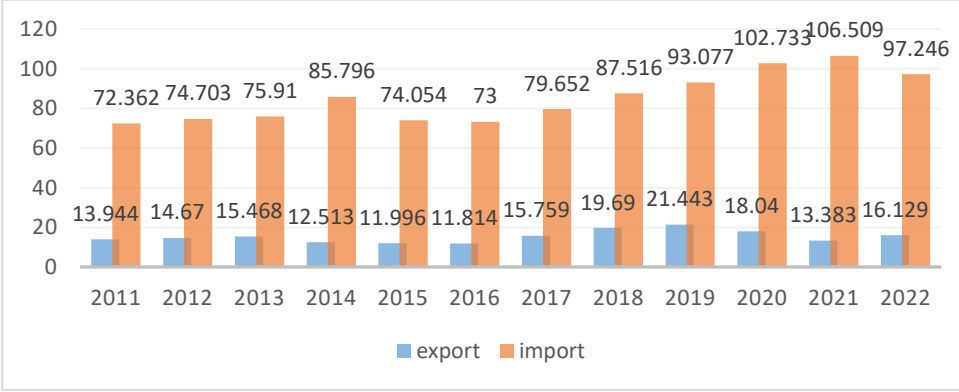


Fig. 3.5. Quantity of Plastic Materials Export-Import (tons) (made by author based on UNDP (2023) data)

Сл. 3.5. Количина пластичних материјала извоз–увоз (тоне) (ауторска израда на основу података UNDP (2023))

Over the years, pilot projects for the selective collection of waste at source have been implemented in Chisinau. City residents participated in these initiatives but were not convinced of the efficiency of the collection and recycling services and thus these projects were not very successful. There are about 10 private companies that collect recyclables from large waste generators such as supermarkets or other manufacturers and retailers whose waste comes from packaging.

Analyzing the degree of coverage with the municipal waste collection service, we note that only 48% of the population benefits from the municipal waste collection service (1257.8 thousand people) according to the situation at the beginning of the year, 2020, benefiting from the municipal waste collection service 544824 homes (Iordachi 2021).

Thus, nearly 200 services specialized in waste collection and disposal are organized and operating in the republic (out of which the major part in the rural sector). Analyzing the organization of the sanitation service in the country, we notice an enormous discrepancy between the urban and rural sectors. The organization of the sanitation service in the municipalities is carried out at an insufficient but satisfactory level, while in the localities there is a low number of operators providing sanitation services, but also a low number of vehicles used for sanitation work. Municipal waste collection activity in urban areas is organized according to the "door-to-door" system from individual houses and through

collection points at platforms or waste evacuation tubes, from housing blocks, while in rural areas, collection is mainly carried out "door-to-door" and sometimes from collection points. Sanitation operators are expanding their services from urban to rural localities, as the volume of collected waste is increasing. Consequently, the rate of waste generation per capita will have a slow growth trend, with an average annual increase of 2.5% expected in the period 2021-2030 and 1% for the period 2031-2035 for rural localities and those urban (State Chancellery 2023).The separate collection of recyclable waste into 3 fractions (paper/cardboard, plastic/metal, and sometimes glass) is partially carried out, only in some urban localities, in collection points equipped with 1.1 m^3 or 1m^3 container, and in some localities more small bins of 240 l or 120 l are used or the waste is collected in bags. The low tariff does not cover the expenses required for the separate collection of recyclable waste and biodegradable waste, and as a result, the unsorted collection of waste contributes significantly to the increase of recycling costs, especially of packaging waste, and in many cases makes this process impossible. In most localities, the tariffs for waste collection and treatment do not cover the costs, and some expenses of sanitation operators are subsidized from local budgets or the account of grants offered within the framework of technical assistance projects for the development of the collection infrastructure.

Although data from the field of management indicate a large number of operators involved in waste management activities (about 200), the quality of these services as well as performance indices show modest results:

1) 4-10% of waste is recycled, and 90% is buried;
2) the rate of population sanitation coverage in urban areas is approximately 75-90%;
3) in rural areas, approximately 15-20% of the population has a sanitation service;
4) REP implementation activities are initiated only for WEEE, B&A, packaging being in "standby" mode;
5) in the absence of waste recycling capacities, there are tendencies to increase exports.

The vast majority of non-hazardous municipal and industrial waste is disposed of in landfills, as it is the cheapest type of waste management; therefore, waste is managed without taking into account the priority order of waste prevention and management, and the selective collection of recyclable waste and biodegradable waste, as well as their recycling and reuse, is economically unattractive. Recycling and waste recovery rates are still very low. Despite the decrease in the total volume of waste generated in the Republic of Moldova during the analyzed

period, the progress in their management is not obvious. Although the absolute amount of waste has registered a significant reduction, we must note that recycling and recovery rates remain low and do not progress compared to 2015. In 2022, out of the total waste collected of 1,122,044.74 tons, only 172,212, 59 tons were recovered, which equates to a recycling rate of approximately 15.36%. This suggests that, despite efforts to reduce waste, efficiency in recycling and recovery requires significant improvements to promote sustainable resource management and reduce environmental impact in the Republic of Moldova. According to data offered by the Inspectorate for Environment Protection, about 90% of the amount of municipal waste collected by the sanitation services was disposed of by storage, selective collection being partially organized in the municipality of Chisinau and some district centers (The environmental Protection Inspectorate 2021). In Chisinau and near Chisinau 2 waste sorting stations sort approximately 100 tons of waste each day. The separation of waste from plastic, paper, glass, and organic fractions allows their subsequent recycling.

In total, 6 sorting stations are designed, four of which will be built. The total number of sorting stations in the surroundings of Chisinau was estimated based on the volume of waste produced by the city's residents. The low recovery rate has primarily technical causes (the lack of separate collection and sorting infrastructure in most areas of the country, respectively the lack of recycling capabilities for certain types of materials such as electrical waste and electronic), but also economic (lack of financial instruments to stimulate or oblige sanitation operators to deliver the collected waste to treatment/recovery facilities and not to elimination). At the same time, for certain types of waste, there are practically no viable recycling options at the national level (for example, for glass, there is both a relatively low technical capacity of glass factories to process waste and a lack of interest, considering the quality poor amount of glass waste provided, respectively the additional costs that would be necessary for a obtain waste of appropriate quality). The interest in recycling is greater in the case of metal, plastic, and paper, but relatively important quantities are recorded here as well collected separately and then transported outside the borders of the Republic of Moldova for recycling proper. Private companies are hampered by antiquated legislation and the difficulty of working in the sector where public participation is of utmost importance, therefore they shy away from it and the few that enter the system cannot reach increased levels of development due to the many obstacles they face.

Overall, waste management in the Republic of Moldova has not made significant progress and continues to face key challenges. It is crucial to check and correct the data to get a clear and accurate picture of the current situation. The discrepancy between waste generated (264,783.92 tons) and collected (1,122,044.74 tons)

can be attributed to differences in reporting methodologies and the sectors covered by these reports.

The category of collected waste, being the most representative of current waste management and mainly reflecting waste generated by the population, provides a more accurate basis for assessing recycling rates. At the same time, these statistical discrepancies can be attributed to fundamental problems in the waste reporting and management system. Ambiguous interpretations of concepts such as "deposit" versus "storage", and "municipal waste" and the lack of clearly defined terms such as "facility for waste management operations" or "municipal waste management region" contribute to inconsistencies in reporting and administration. These problems, together with the deficiencies in the application of Law No. 209/2016 on waste, underline the need for clearer regulation and uniform procedures to improve waste management. The proposed bill aims to address these gaps, to create a more efficient and transparent waste management system.

Although the Waste Management Strategy in the Republic of Moldova for the years 2013-2027 was the strategic framework for the creation of the Integrated Waste Management System and, in this context, waste management was regionalized through the territorial division of the country into 8 regions, the Republic of Moldova. The almost non-existent infrastructure, stagnant since the Soviet period, does not correspond to the current environmental protection requirements. Over the years, concrete measures to create the infrastructure of the integrated waste management system in the regions have not yet been implemented. Among the key issues are the lack of funding, the developing regulatory framework, and inconsistent statistics, all against the backdrop of an increase in the volume of waste generated. Being a public service sector that did not benefit from sufficient financial sources, waste management developed very sporadically and insufficiently. It is imperative to increase the degree of involvement of local authorities in carrying out the collection of separated municipal waste, at the source of organic waste, both through awareness and coercion. The aim is to increase the amount of recyclable waste, especially post-consumer, which they want to be recycled or reused. In this sense, we believe that the realization of a vision is important and integrated, in the medium and long term, at the level of local public administrations on the circular economy.

3.3.4. Bulgaria

Analyzing the state and progress of Bulgaria in the transition to a circular economy and particularly efficient waste management, a serious lag in the process of ecological transformation emerges. Based on a set of four indicators and in the

absence of a single composite indicator, the trends in the dynamics of each of the selected indicators for Bulgaria and the EU average are derived. The period covers 2010-2022, based on available statistical data that allow for comparative analysis. To achieve the objectives of this study, it is important to cover different aspects of the circular economy. For this reason, a total of 4 indicators were selected to analyze the status and progress of the transformation: (i) Resource Productivity (RP) + DMC; (ii) Generation of waste excluding major mineral wastes per GDP unit (in euro) (iii) Circular material use rate (%) (iv) Recycling rate of all waste (%)

Resource Productivity + DMC, which is part of the Sustainable Development Goals Target 12 (Sustainable Production and Consumption), has also been added to the EC indicators as it provides insight into the efficient use of resources - one of the immediate tasks in a circular economy. Over the past 12 years, resource productivity in the EU has increased by 16.4% to reach 2.12 euro/kg (2022).

At the same time, domestic material consumption (DMC) has decreased by 7.8%.

Of course, this positive trend must be interpreted carefully and in a complex way, as this change is unlikely to be due solely to the successful environmental policies of the countries.

The decline in DMC is likely due to the effects of the economic crisis (2008) and the slow recovery from it in some countries (also in Bulgaria). With declining economic activity, it is logical that there would be a faster decline in the production of raw materials. Unlike the EU-28 average indicator, which shows a gradual, steady upward trend over the period under review, in Bulgaria, there has been virtually no significant growth (3.1%). The absolute values of this indicator (measured as GDP in euros per kg of domestic consumption of resources) also indicate an unfavorable trend and a serious slowdown in the change of the business model from resource-intensive to resource-saving. For 2022, the RP in Bulgaria is only 0.33 euros/kg and is the lowest in the EU, where the average reaches 2.12 euros/kg as shown in Fig. 3.6. This can be attributed to the ineffectiveness of the measures implemented in the country and to the poor performance of the innovative transformation in resource productivity (Ivanova 2021). Therefore, the focus of the transformation of business models into circular models is the serious reduction of the waste share.

Despite the EU's efforts in this direction and numerous measures, especially since 2018 and the adoption of the Plastics Strategy, the overall level of waste generated per unit of GDP in Bulgaria remains unjustifiably high (Fig. 3.7). Compared to the European average, the level in Bulgaria is 7.2 times higher and with no clear downward trend (except for 2020). Even after 2016, it has risen by 13.1%, which is probably a consequence of the steady recovery of economic

growth after the global recession of 2008. In 2022, according to national statistics, 85673403 tons of total waste was generated. Of this, only 3832107 tonnes(4.4%) were handed over for recovery.

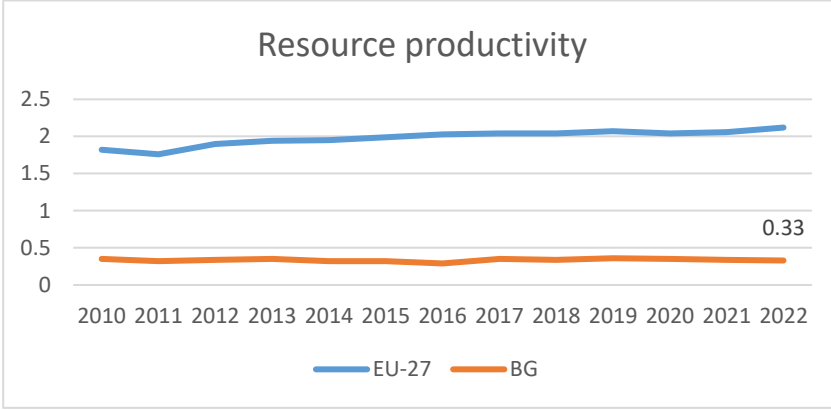


Fig. 3.6. Resource *productivity+ DMC (*Eurostat and author's calculations)
Сл. 3.6. Продуктивност ресурса + DMC (Eurostat и ауторски прорачуни)

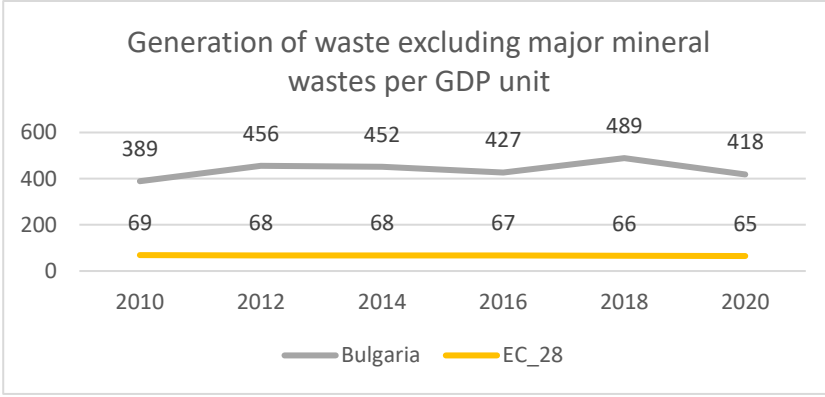


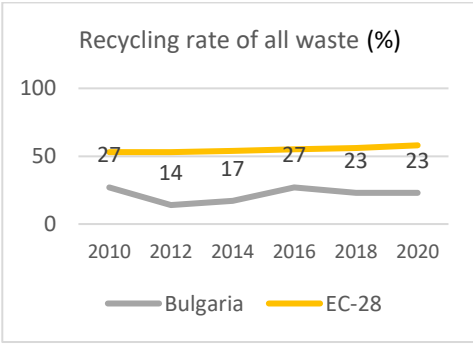
Fig. 3.7 Waste generation per unit of GDP (kg/tonne euro) (Eurostat and author's calculations)
Сл. 3.7 Генерисање отпада по јединици БДП-а (кг/тона евро) (Eurostat и ауторски прорачуни)

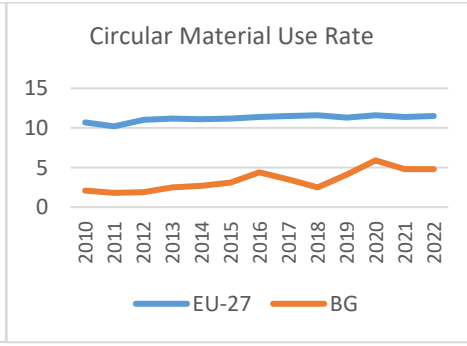
This correlation of growth with the increase in waste generation indicates a lack of progress in the transition from a linear to a circular model and a poor performance of the technological and innovation transformation of production processes in the country as a whole (Sterev and Ivanova 2021. This risks not only worsening the competitiveness of Bulgarian manufacturing but also leaving the

country behind in terms of environmental transition. Recycling is the final phase in the circular economy, allowing waste (industrial or municipal) to be reused in production as a raw material. An important factor in creating a dynamic market for secondary raw materials is sufficient demand, which depends on the use of recycled materials in products and infrastructure. Secondary raw materials still represent only a small part of the production materials used in Bulgaria. Their use in the economy faces significant obstacles, for example, due to uncertainty about their composition. Standards need to be put in place to ensure the quality of these secondary raw materials and to create confidence in their suitability for use.

In Bulgaria, for the analysis period, the dynamics of the recycling rate are too volatile (Fig. 3.8). Following the adoption of the European calculation and correction methodology in the NSI data (2012), a very significant progress of 92.8% emerged and peaked in 2016. This coincided with the start of the operation of the Sofia waste plant. A slight decline followed and in 2020 the recycling rate in Bulgaria is 23% compared to the EU average of 58%. The recycling gap in Bulgaria is more than double. The country ranks last in this indicator. The reason has to be found in the lack of a serious market for secondary raw materials and the still very low landfill charges. Another serious obstacle is the underdeveloped infrastructure related to the recycling process.

One of the most important indicators to measure the extent of the circular economy is the Circular Material Recovery (CMR). It shows how much of the materials used come from secondary consumption. The EU average for 2022 is 11.5%, which suggests that the circular economy model is not yet prevalent. For Bulgaria, the CMR is only 4.8% (Fig. 3.9) and, although it more than doubles over the whole period, remains among the lowest in the EU.





Source: Eurostat and author's calculations

Fig 3.8. Recycling rate wastes
Сл. 3.8. Стопа рециклирања отпада

Fig. 3.9. Circulation rate of materials
Сл. 3.9. Стопа кружења материјала

This indicator in Bulgaria is highly volatile and with a changing trend. This clearly shows the economy's attachment to the linear model, the lack of progress in breaking away from this dependence, and the very serious lag in terms of green transformation.

The reasons are complex and relate to the low recycling rate, the small market share of secondary raw materials, the lack of tradition and knowledge in waste recovery on the part of companies, and the lack of opportunities and price incentives for the repair and reuse of products.

In the absence of a well-developed network of services in the field of repair, purchase, and degradation for reuse of individual components, the majority of products in Bulgaria end their life cycle as waste. This leads to unjustifiably high consumption of primary raw materials and slows down the process of ecological transformation of the economy. The analysis of the main indicators of the circular economy and especially those related to waste management, efficient and circular use of the material in Bulgaria leads to the conclusion that the country's economy is still not making serious progress in the transition to a circular model, is seriously lagging the leading countries in the environmental transformation in the EU and needs a much more focused policy in this area. These conclusions are confirmed by other studies (Pancheva 2023; Ivanova 2020; Zhelyazkova 2020) revealing the barriers and challenges in the transition to a circular economy.

This provides a basis for making some recommendations to better and faster integrate circular economy principles into new business models.

1) Develop strategy and long-term goals. It needs to be more comprehensive and encompassing and go beyond just waste management. Unfortunately, the measures for a circular economy in the Recovery and Sustainability Plan are also very insufficient;
2) Promoting projects (also through economic incentives) involving technological innovation of processes, new products, and materials that lead to "greener" industrial production and extended product life cycles. There is a need to create more incentives for projects that favor the use of fewer resources and allow longer product life cycles and easier repair and recycling, as well as the sustainable development of an innovation ecosystem for start-ups and industrial parks. The grant should focus on the risk part of investments in this area, with an emphasis on the creation of new products and services, technology transfer and commercialization, strengthening cooperation with knowledge-generating units and enterprises, and ensuring full participation in the development of the science and innovation ecosystem.

3) Creating an enabling environment for increased participation in separate waste collection by both consumers and producers. This would facilitate the supply of quality materials to recyclers and significantly increase the efficiency of the process;
4) More active use of regulatory and market-based instruments such as eco-standards, and eco-taxes, removing subsidies for negative activities, mobilizing public and private financial resources, investing in skills and green jobs.

3.3.5. Georgia

Georgia is at the initial stage of implementing a circular economy. From November 2020 to October 2022, an assessment of the circularity level of the Georgian economy was conducted through the initiative of the Government of Georgia and with the support of the Government of Sweden. This assessment, based on a comprehensive analysis of resource flows in 14 sectors with the highest potential for developing circular economy models, considered the specific characteristics of Georgia. The sectors and their respective rates of used/recycled waste are as follows (GSNE Orchis 2022): Cultivation of annual crops: 10%, Cultivation of perennial crops: 12%, Viticulture and wine production: 0%, Animal husbandry: 0%, Forestry, and wood product production: 5%, Fishing and aquaculture, fish processing: 0%, Mining industry (excluding oil and natural gas extraction): 0%, Energy production and transmission: 0%, Natural gas extraction: 0%, Land transport and transportation by pipelines: 0%, Tourism, provision of facilities, and food supply: 5%, Wholesale and retail trade: 0%, Waste management: 17%.These evaluations provide a baseline for developing and implementing circular economy practices tailored to Georgia's unique economic and environmental context.

The analysis of target industries revealed that the current rate of circularity in each sector is low, resulting in an overall circularity level of only 1.3% for Georgia. This indicates a predominantly linear economy where most consumed resources are of primary origin. Georgia's economy consumes over 315 million tons of resources annually, translating to approximately 78 tons per capita, with this figure on the rise in recent years. Furthermore, the high consumption of raw materials is closely linked to emission-intensive processes. Despite the significant volume of resource consumption and waste generation, the 1.3% circularity does not imply that 98.7% of resources used in the economy end up as waste. The breakthrough in Georgia's circularity involves several key elements.

A significant portion of raw materials, approximately 40 million tons, is incorporated into tangible assets such as buildings and infrastructure. Additionally, about 1.4 million tons of biomass have recycling potential. The study

identified the circular development potential and priorities for each sector examined. The target for the next 5-10 years is to increase the current circularity rate from 1.3% to 6.6% (Prasek et al. 2022).

Currently, with the support of UNDP Georgia and the Embassy of Sweden in Tbilisi, the Georgian government is developing a national circular economy guide. This guide aims to formulate a circular economy strategy and establish circular economy principles in Georgia. It outlines the steps Georgia should take toward circular transformation, with a particular emphasis on leveraging high technologies in production to enhance efficiency, reuse waste, and more. In the world, along with the growth of the population and the improvement of the standard of living, the amount of waste also increases, based on the dynamics of the amount of solid household waste in Georgia in 2010-2017, the mentioned increase is 1.7% per year (Remissia, n.d). Developed countries, including Georgia, are actively working to develop waste minimization/reuse/recycling and safe and economical waste management methods following the principles of circular economy. In recent years, the Government of Georgia has actively addressed waste management issues. The first legislative framework, the "Waste Management Code," came into force in January 2015. This law regulates waste management practices, including the secondary use of waste (Law of Georgia, n.d). Based on this Code, the "2016-2030 National Waste Management Strategy and 2016-2020 Action Plan" was enacted by a government decree on April 1, 2016. This strategy and action plan aims to promote the rational use and minimization of waste within the specified timeframe (Ministry of Environment Protection and Agriculture of Georgia, n.d.a). Unfortunately, the activities outlined in the initial plan were not completed within the specified timeframe. Consequently, in August 2022, the resolution was amended, resulting in a revised document titled the "2016-2030 National Waste Management Strategy and 2022-2026 Action Plan" (Ministry of Environment Protection and Agriculture of Georgia, n.d.b). This updated strategy emphasizes promoting circular economy approaches in waste management, conducting needs assessments, developing appropriate programs, and implementing pilot projects by 2026/2030. Additionally, the Second National Action Plan for Waste Management (2022-2026) includes measures to improve the management of hazardous, plastic, biodegradable, and inert construction and demolition waste, which were not addressed in the First National Action Plan (2014-2020). In 2022, the Georgian government approved "Vision 2030," the development strategy of Georgia, which identifies the promotion of waste management and the circular economy as one of the country's crucial tasks (UNFCC 2023). This task entails the implementation of separate waste collection, adoption of reuse, recycling, and recovery technologies, enhancement of environmental practices across all stages of product life cycles (including

producers, distributors, consumers, collectors, dismantlers, recyclers, and exporters), reduction of landfill waste, and fostering the establishment of new enterprises and job opportunities in the circular economy sector. To facilitate the effective implementation of producer responsibility, the government adopted four technical regulations in 2020 covering waste oils, waste tires, and electrical and electronic equipment waste. Furthermore, regulations about the extended obligation of manufacturers to manage waste batteries and accumulators, as well as regulations addressing the management of packaging waste and end-of-life motor vehicles, are also scheduled for adoption (FAO 2022).

Currently, Georgia hosts approximately 100 waste processing enterprises; however, their technologies often fall short of modern environmental requirements and standards. Notably, there is a lack of infrastructure for processing biodegradable waste. The recycling of municipal waste types remains minimal, with paper being repurposed for the production of packaging cardboard and toilet paper. Plastic recycling involves 25 companies with a combined projected capacity of approximately 184,000 tons annually. Several companies in Georgia are engaged in the collection and processing of ferrous and non-ferrous metals, while glass waste collection and processing amount to approximately 1,000 tons (Ministry of Environment Protection and Agriculture of Georgia, n.d.b). As previously noted, only 1.3% of waste generated in Georgia undergoes recycling, with the majority being disposed of in various landfills. Presently, Georgia maintains 37 solid household waste landfills, managed by the solid waste company alongside numerous illegal landfills (Dzebisashvili et al. 2021). Up to 90% of solid household waste is deposited without any treatment in Georgia. The amount of municipal waste generated in cities and rural settlements for 2020 and 2021 was calculated using the waste generation index, which is based on the amount of municipal waste collected and placed in landfills per capita. In 2020, the waste generation index averaged 0.95 kg/person/day for cities and 0.54 kg/person/day for rural settlements. The total municipal waste generated in 2020 amounted to 1,061,007 tons, with 760,942 tons generated in cities and 300,065 tons in rural areas.

In 2021, the total municipal waste generated increased to 1,104,952 tons, with 768,257 tons generated in cities and 336,695 tons in rural areas (Ministry of Environment Protection and Agriculture of Georgia, n.d.b). In reality, the per capita household waste generation in Georgia is likely higher than reported, as the calculations do not account for waste deposited in illegal landfills. By 2017, it was estimated that approximately 18% of waste was disposed of in illegal landfills (Dzebisashvili and Sikharulidze 2017).

In addition, it should be noted (Buachidze et al. 2021):

1) Based on the municipal waste management plans, 90-100% of urban and 40-50% of rural areas are covered by waste collection services.
2) The population of Tbilisi (capital city) is served by Ltd. "Tbilservice Group" of Tbilisi city hall.
3) Solid Waste Management Company (SWMC) of Georgia covers almost the whole territory of the country, except the Adjara region, Tbilisi, and occupied territories by Russia.
4) In total SWMC and Ltd. "Tbilservice Group" serve approx. 3,245 thousand persons, which is 87% whole population of the country.

The results of a study on the morphological composition of waste generated throughout Georgia reveal that food waste (47.8%), plastic (14%), and paper (12.4%) constitute the largest portion compared to glass (2.8%) and metal (2.1%) while hazardous fraction is estimated at 0.7% and other fractions, such as hygienic, textile, rubber, leather, wood, green and FF of waste total - 20.2% (Dzebisashvili et al. 2023, Dzebisashvili et al. 2024). It is important to note that the waste composition study was conducted independently and does not represent an exhaustive list of waste fractions subject to separation in Georgia. Currently, waste separation practices in Georgia are less developed and typically involve sorting a small portion of generated waste into fractions such as paper, plastic, glass, and organic waste.

Indeed, hazardous waste management in Georgia faces significant challenges. Currently, there is no separate collection system for municipal hazardous waste, resulting in its disposal alongside other municipal waste, posing environmental and health risks. Although authorized private companies collect hazardous waste from industrial and commercial facilities, the recycling infrastructure for this waste is inadequate, and permanent/temporary disposal facilities are nonexistent. Medical waste management within medical institutions is governed by contracts with waste management operators, with regulation and oversight conducted by multiple ministries. However, despite these measures, some medical waste may still end up in landfills without proper treatment. Additionally, over 2 million tons of inert, construction, and demolition waste are generated annually in Georgia. The limited scale of the inert waste processing industry and insufficient business interest contribute to uncontrolled disposal practices, with municipalities sometimes resorting to using waste for filling measures (Ministry of Environment Protection and Agriculture of Georgia, n.d.a).

These challenges underscore the pressing need for a comprehensive waste minimization, separate collection, and eco-friendly recycling system nationwide. Such initiatives are vital for transitioning Georgia from a linear economy to a more sustainable circular economy model.

3.4. Conclusions

Eastern Europe is characterized by landfill-based countries and few municipalities have taken the responsibility to achieve the zero-waste status. Low landfill fees in Romania, Bulgaria, Rep of Moldova, Georgia combined with insufficient urban mining centers affect the secondary materials development market to catalyze circular activities between a diverse range of waste materials and industrial stakeholders. However, some good practices are revealed at the micro-level (business, NGOs) or some municipalities that proved that cumulative efforts between stakeholders and community participation could achieve positive results in increasing waste diversion rates from landfills into circular economy actions. The zero-waste municipalities certification recognizes such efforts in EU policies in implementing relevant solutions to achieve a circular economy transition. Ukraine's preoccupations with suitable waste management practices are on track despite the heavy burdens related to the Russian invasion. Some key waste streams (construction and demolition waste, e-waste, organic waste, hazardous waste) provide great opportunities for recycling and urban mining development in Ukraine and beyond. Eastern Europe has particular socio-economic and political challenges (Ukraine, Rep of Moldova, Georgia) that must be considered when examining the performances related to waste management performances in line with circular economy principles. Furthermore, Eastern Europe (e.g. Romania, Bulgaria, and Rep of Moldova) is exposed to EU waste importation flows that can put additional pressure on domestic waste management infrastructures with negative impacts on the environment. Besides municipal waste management flow, there are other key waste-related sectors (agriculture, industry, water management) in Eastern Europe that need a better regulatory framework, special policies, development of waste databases, and monitoring procedures to assess their sectoral transition towards a circular economy pathway. Overall, the progress towards a circular economy is modest since landfills are still the main option in waste management systems, but some positive results are seen in regulations following EU policies, development process of waste management infrastructures, increasing waste collection services rates to reduce the amounts of waste leaked into natural environments in the first phase and then to divert the waste flows from landfills towards material recycling, biogas production or composting operations. Recommendations to accelerate progress towards a circular economy in Eastern Europe include: (i) Implementing stricter regulations aligned with EU policies to incentivize waste reduction, recycling, and resource recovery. (ii) Developing urban mining centers and modernizing waste management facilities to support efficient material recovery and processing (iii) Encouraging more municipalities and industries to pursue zero-waste

certification, recognizing and rewarding their efforts in waste minimization and resource efficiency. (iv) Establishing specialized policies and regulatory frameworks for key waste sectors like agriculture, industry, and water management, along with robust monitoring and reporting mechanisms. (v)Tailoring waste management strategies to the socio-economic and political contexts of countries like Ukraine, the Republic of Moldova, and Georgia, considering their specific challenges and needs. (vi) Developing strategies to manage and minimize the environmental impact of EU waste import flows, ensuring they do not overwhelm domestic waste management capacities.

By adopting these recommendations, Eastern Europe can make significant strides towards reducing reliance on landfills, enhancing environmental sustainability, and fostering economic resilience through circular economy principles. These efforts not only mitigate waste pollution but also position the region as a leader in sustainable development within the broader European context. At the same time, Eastern Europe, particularly Ukraine, faces unique challenges in waste management exacerbated by geopolitical factors such as the Russian invasion. The reconstruction efforts in Ukraine, especially in managing construction and demolition waste, present a crucial opportunity for integrating circular economy principles. By promoting cooperation among international organizations, neighboring countries, and local stakeholders, Eastern European nations can support Ukraine in rebuilding sustainably. Initiatives could include establishing circular construction practices, promoting material reuse and recycling, and implementing innovative waste management technologies. This collaborative approach not only facilitates post-conflict recovery but also strengthens regional solidarity and promotes sustainable development across borders.

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Кружна економија и управљање отпадом у Источној Европи

Флорин-Константин Михаи, Виталиј Ишченко, Викторија Јордаки, Ваниа Иванова, Натела Џебисашвили

Сажетак

Источна Европа тежи да се усагласи са политикама кружне економије ЕУ, упркос социоекономским разликама у односу на Западну Европу. Овај рад има за циљ да пружи регионални увид у управљање отпадом и перспективе кружне економије кроз анализу пет релевантних земаља у Источној Европи које су дио ЕУ (Румунија, Бугарска) и земаља ван ЕУ, али са статусом кандидата (Украјина, Република Молдавија и Грузија). У случају ових посљедњих земаља, оне се суочавају са посебним геополитичким изазовима као додатним препрекама за напредовање ка транзицији ка кружној економији. Упркос овим друштвеним изазовима, овај рад истиче одређени напредак ка путу кружне економије у свакој земљи. Ипак, систем базиран на депонијама и даље доминира, али развој постројења за управљање отпадом, како би се отпад преусмјерио са депонија на рециклажу, производњу биогаса и компостирање уз подршку одвојеног сакупљања отпада уз учешће заједнице, представља солидан пут у блиској будућности. Ове напоре морају подржати власти (јасни прописи, мање бирократије, побољшање база података о отпаду, финансијска подршка), иновације у пословању и улога еколошких невладиних организација у смањењу пријетњи загађења повезаног са отпадом и преусмјеравања отпада из мултисекторских сектора (општине, пољопривреда, индустрија) ка вишим активностима кружне економије.

Кључне ријечи: управљање отпадом, кружна економија, рециклажа, источна Европа, регионална сарадња, геополитичка ограничења