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Burkovska Anna, PhD (Economics), Assosiate Professor of the Department of Management, Business, and Administration, Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: 0000-0003-0563-6967
e-mail: anna.burkovskaya12@gmail.com

Poltorak Anastasiia, Doctor of Economics, Professor, Head of the Department of Management, Business, and Administration, Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: 0000-0002-9752-9431
e-mail: poltorak@mnau.edu.ua

Burkovska Alla, PhD (Economics), Associate Professor of the Department of Finance, Banking and Insurance, Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: 0000-0003-4158-1721
e-mail: allaburkovska2010@gmail.com

Sukhorukova Anna, PhD (Public Administration), Associate Professor of the Department of Management, Business, and Administration, Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: 0000-0002-6170-4955
e-mail: a.l.sukhorukova83@gmail.com

Pekera Artem, PhD Student, Mykolayiv National Agrarian University, Mykolayiv, Ukraine
ORCID: 0009-0001-4074-1714
e-mail: pekeraart@gmail.com

Circular Material use Management in the European Union: trends, challenges, and Policy Impacts

Abstract. Introduction*. In a world facing mounting pressure from urbanization and population growth, particularly in developing regions, the EU's experiences and policies promoting circularity are valuable examples for global sustainability initiatives. This article not only highlights the progress that has been made, but also the significant challenges that remain, particularly the disparities between member states. This underscores the need for continued investment, policy coherence, and public engagement. Thus, this topic lies at the intersection of environmental policy, economic strategy, and social responsibility, making it critically important for the future of sustainable development within Europe and beyond.*

Purpose*. This study aims to analyze the current state, progress, and challenges of circular material use across the European Union. The study will evaluate the effectiveness of EU member states' transition to a circular economy by examining key indicators, such as the Circular Material Use Rate (CMUR), municipal and packaging waste recycling targets, and waste treatment practices. The study seeks to identify performance disparities among countries, evaluate the effectiveness of policies such as the Waste Framework Directive and the Circular Economy Action Plan, and pinpoint infrastructural, economic, and behavioral barriers to a more circular system. Additionally, the study explores the environmental, economic, and policy implications of improving material circularity. Ultimately, it will contribute to the EU's long-term goals of achieving climate neutrality, sustainability, and resource efficiency.*

Results*. The research confirms that the European Union is steadily strengthening its position as a global leader in sustainability and the circular economy. A key metric of this progress is the Community Material Reuse Rate (CMUR), which rose to 11.8% in 2023. This signals a positive, albeit gradual, shift away from dependence on primary raw materials. However, the data reveal significant disparities among member states. The Netherlands leads with an impressive reuse rate of 30.6%, while Romania lags behind with only 1.3%. This highlights the uneven implementation of circular practices and the urgent need for targeted investments and policy support in less advanced regions. On a global scale, the outlook is even more concerning. If current waste generation trends persist, per capita municipal solid waste could increase by almost 50% by 2050. Nevertheless, the research presents an optimistic scenario in which strong circular economy strategies focused on waste reduction, recycling, and reuse could lower global waste levels to 0.62 kg per person per day - less than in 2020. In sum, while the EU has made measurable progress, the transition to a fully circular economy remains a significant challenge. It demands comprehensive reform, technological advancement, global collaboration, and unwavering political commitment. The potential rewards — in terms of environmental resilience, economic strength, and societal well-being — make this transition necessary and urgent.*

Conclusions*. The findings of this research highlight the progress and complexity of the European Union's transition to a circular economy. Although rising indicators, such as the Community Material Reuse Rate, reflect meaningful progress, stark disparities between member states reveal that circularity is unevenly distributed and heavily dependent on national capacities and political will. To achieve the EU's ambitious sustainability targets, such as higher recycling rates and reduced landfill use,*

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stronger infrastructure and policy coherence are required, as well as greater public engagement and behavioral change. On a global level, the stakes are even higher. Without decisive action, waste generation is poised to surge, further straining fragile ecosystems and urban systems. However, the circular economy offers a viable alternative — a pathway that can curb resource use, reduce emissions, and foster long-term economic resilience. The transition to a circular economy is ultimately not just an environmental imperative but also a strategic opportunity. With sustained investment, innovation, and cooperation, it can deliver far-reaching benefits for Europe and the world. The challenge now is to turn policy ambition into concrete, inclusive, and scalable action.

***Keywords**: circular economy, sustainability, European Union, Community Material Reuse Rate, recycling, waste management.*

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Бурковська А. І., доктор філософії (економіка), старший викладач кафедри менеджменту, бізнесу та адміністрування, Миколаївський національний аграрний університет, Миколаїв, Україна

Полторак А. С., доктор економічних наук, професор, завідувач кафедри менеджменту, бізнесу та адміністрування, Миколаївський національний аграрний університет, Миколаїв, Україна

Бурковська А. В., кандидат економічних наук, доцент, доцент кафедри фінансів, банківської справи та страхування, Миколаївський національний аграрний університет, Миколаїв, Україна

Сухорукова А. Л., кандидат наук з державного управління, доцент, доцент кафедри менеджменту, бізнесу та адміністрування, Миколаївський національний аграрний університет, Миколаїв, Україна

Пекера А. В., аспірант, Миколаївський національний аграрний університет, Миколаїв, Україна

Управління циркулярним використанням матеріалів у Європейському Союзі: тенденції, виклики та вплив політики

***Анотація.** У світі, який стикається з дедалі більшим тиском урбанізації та зростанням населення, особливо в країнах, що розвиваються, досвід і політика Європейського Союзу щодо впровадження циркулярності слугують цінним прикладом для глобальних ініціатив сталого розвитку. У статті висвітлено не лише досягнутий прогрес, але й значні виклики, що залишаються - зокрема, нерівномірність між державами-членами ЄС, що підкреслює необхідність подальших інвестицій, узгодженості політики та залучення громадськості. Таким чином, тема перебуває на перетині екологічної політики, економічної стратегії та соціальної відповідальності, що робить її вкрай важливою для майбутнього сталого розвитку як у межах Європи, так і за її межами. Метою цього дослідження є аналіз поточного стану, досягнень і викликів у сфері циркулярного використання матеріалів в Європейському Союзі. Дослідження спрямоване на оцінку ефективності переходу країн-членів ЄС до циркулярної економіки шляхом аналізу ключових показників, таких як рівень циркулярного використання матеріалів (CMUR), цілі щодо переробки муніципальних і пакувальних відходів, а також практики поводження з відходами. У роботі розглядаються відмінності у результатах серед країн, оцінюється ефективність таких політичних ініціатив, як Рамкова директива про відходи та План дій для циркулярної економіки, а також визначаються інфраструктурні, економічні та поведінкові бар'єри на шляху до більш циркулярної системи. Крім того, дослідження аналізує ширші екологічні, економічні та політичні наслідки підвищення циркулярності використання матеріалів, зрештою роблячи внесок у досягнення довгострокових цілей ЄС щодо кліматичної нейтральності, сталого розвитку та ефективного використання ресурсів.*

***Ключові слова:** циркулярна економіка, сталий розвиток, Європейський Союз, рівень повторного використання матеріалів (CMUR), переробка, управління відходами.*

***JEL Classification:** Q01, Q53, R11.*

Formulation of the problem. As global urbanization and population growth intensify, particularly in developing regions, the pressure on natural resources and waste management systems continues to increase. A transition to a circular economy could address these challenges by promoting resource efficiency, waste reduction, and sustainable consumption. However, significant disparities persist among European Union member states in terms of material reuse, recycling rates, and waste management infrastructure, despite the EU's recognition as a leader in circular economy policies. These disparities highlight structural, economic, and behavioral barriers that hinder the EU's ability to achieve its circular economy goals. This raises critical questions about the effectiveness of current policies, the allocation of investments, and the role of public engagement in fostering a more circular system. Addressing these issues is essential for the EU's sustainability agenda and as a model for global sustainable development efforts.

Analysis of recent research and publications. Today, managing circular material use in the European Union is an increasingly complex task that requires a comprehensive approach considering a wide range of environmental, economic, and social factors influencing this sector. According to recent studies, the progress of circular material use depends on regulatory frameworks,

technological advances, differences in infrastructure, economic capacities, and public engagement across member states.

The transition to a circular economy, according to researchers [4-6], will continue to be a dynamic and multifaceted challenge, as the EU economy evolves under growing environmental pressures and resource constraints. Scientists emphasize that a notable trend is the growing ambition of EU-wide recycling and reuse targets, which aim to reduce dependency on primary resources and reduce landfill waste. However, studies [7] reveal significant disparities between countries, with some achieving high rates of circular material use while others lag behind. This emphasizes the need for tailored policy support and investment.

Notable trends in the development of the circular economy, as noted by researchers [8-10], include the increasing importance of innovation in waste treatment technologies and resource recovery systems. Improved sorting technologies, digital monitoring tools, and new business models for product lifecycle management are driving efficiency gains and enhancing circularity. While these innovations contribute to meeting EU goals, they require coordinated efforts among stakeholders and integration into existing infrastructure.

Despite technological progress, research underscores the importance of addressing behavioral and societal barriers to circularity. Public participation, awareness, and consumer behavior significantly impact the effectiveness of recycling and reuse initiatives. Scientists argue that technological and policy efforts alone will fall short of achieving desired sustainability outcomes without increased engagement and education.

Furthermore, studies highlight the critical need to ensure that circular economy strategies align with broader environmental and social objectives, such as climate neutrality and social equity. Researchers warn that, without careful planning, the shift toward circularity could exacerbate inequalities or lead to unintended environmental consequences.

Thus, managing circular material use within the EU requires an integrated approach that combines policy coherence, technological innovation, infrastructure investment, and social inclusion. According to experts, successful implementation of a circular economy depends on balancing economic growth with environmental stewardship and fostering collaboration between governments, businesses, and citizens.

Looking ahead, researchers emphasize that flexible, adaptive strategies are key to the future of circular economy management, as they can respond to emerging challenges and opportunities. Innovation, resource efficiency, and stakeholder engagement will remain key drivers while maintaining a focus on sustainable development goals. Scientists predict that the EU can only achieve a resilient, equitable, and truly circular economy through this holistic approach.

Formulation of research goals. This research aims to analyze the current state, progress, and challenges of circular material use within the European Union. This study will evaluate the EU's progress in transitioning to a circular economy by examining key indicators, such as the circular material use rate, municipal and packaging waste recycling rates, and waste treatment practices. The study also seeks to identify disparities among member states and explore the structural, economic, and policy factors contributing to these differences. Additionally, the study will assess the impact and implementation of existing EU policies, such as the Waste Framework Directive and the Circular Economy Action Plan, on advancing material circularity. Furthermore, the study investigates infrastructural, technological, and behavioral barriers hindering higher recycling and reuse rates. The economic and financial aspects of investments in the circular economy are examined to understand their role in supporting sustainable development. Finally, the study considers the broader environmental and socioeconomic implications of increasing circular material use, including its contribution to climate neutrality, resource efficiency, and social responsibility. Through this comprehensive approach, the study aims to provide insights to guide policy coherence, investment decisions, and public engagement to accelerate the EU’s transition to a circular economy.

Presentation of the main research material. The European Union is widely recognized as a global leader in environmental policy and sustainability. The transition to a circular economy is one of the EU's most ambitious and critical goals. Central to this transition is the concept of circular material use, referring to the extent to which materials are reused, recycled, and reintegrated into the economy instead of being discarded as waste. The circular material use rate (CMUR) is a key indicator that measures this effort and offers insight into how efficiently resources are recirculated. While the EU has made incremental progress in increasing its CMUR in recent years, the path to a fully circular economy is fraught with structural, economic, and policy-related challenges.

In 2023, approximately 11.8 percent of the material resources consumed in the European Union (EU-27) came from recycled waste materials. This figure reflects the EU’s ongoing efforts to enhance resource efficiency and reduce dependency on virgin raw materials by implementing circular economy principles. Over the past two decades, the EU’s CMUR has shown an upward trajectory, increasing from approximately 8.2% in 2004 to 11.8% in 2023 (Fig. 1). This positive trend signals gradual progress toward closing material loops, though the pace of improvement has been modest and varies among member states [1].

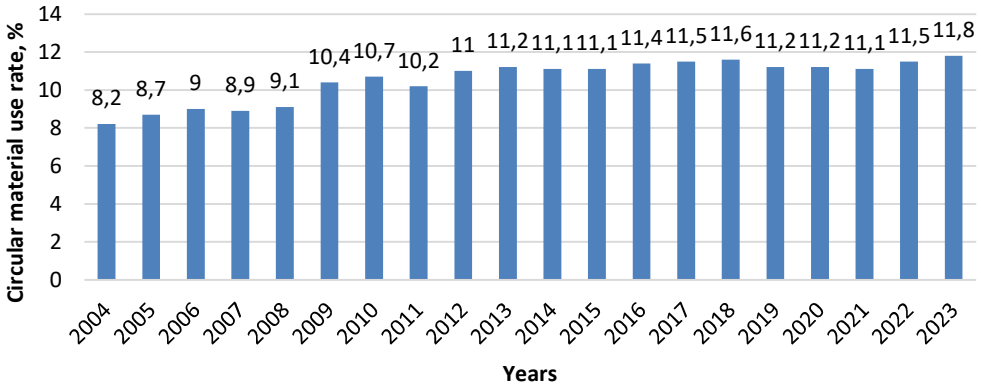

Figure 1 – **Circular material use rate in the European Union (EU-27) from 2004 to 2023**

Source: developed by the author using [1].

The circular material use rate, also known as the circularity rate, is a key sustainability indicator. It represents the proportion of total material inputs into the economy that come from processed waste instead of newly extracted raw materials. A higher circularity rate indicates more effective reuse, recycling, and reintegration of materials into production cycles. This contributes to lower environmental impact, reduced waste generation, and improved resource security. Increasing this rate is central to the EU's broader objectives under the European Green Deal and the Circular Economy Action Plan, which aim to create a climate-neutral, resource-efficient, and competitive economy. However, achieving substantial gains in circularity requires technological advancements in recycling and material recovery, as well as systemic changes in product design, consumption behavior, and industrial processes.

According to the European Commission's Waste Framework Directive, all EU member states must significantly increase the recycling and reuse of municipal waste in the coming years. Specifically, by 2030, each country must ensure that at least 60% of municipal waste is recycled or prepared for reuse. The target becomes more ambitious by 2035, when Member States will be required to reach a minimum recycling rate of 65% (Fig. 2). These legally binding goals are designed to drive the transition toward a more sustainable and circular waste management system across the Union [3].

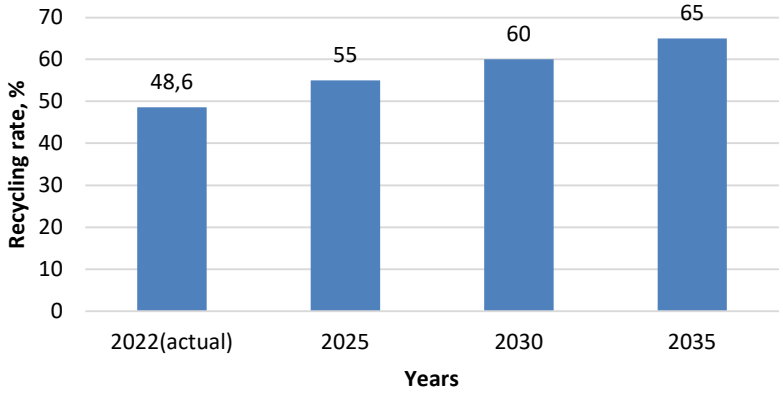

Figure 2 – **Municipal waste recycling rate in the European Union (EU-27) in 2022, and targets from 2025 to 2035**

Source: developed by the author using [3].

Despite their progressive nature, recent data underscores the scale of the challenge ahead. In 2022, the EU-27's overall municipal waste recycling rate was 48.6%. While this is a significant improvement compared to earlier years, it falls short of the upcoming benchmarks. Achieving these future targets will require accelerated efforts at both national and local levels, including the expansion of recycling infrastructure, improved waste separation at the source, stronger public engagement, and the adoption of innovative

technologies in waste processing [4]. Furthermore, effective implementation and enforcement mechanisms are essential to ensure compliance and address disparities in performance among member states. Reaching the 2030 and 2035 goals will not only contribute to environmental protection and resource conservation but also support the EU's broader commitments under the European Green Deal and the pursuit of climate neutrality [3].

According to the European Commission's Packaging and Packaging Waste Directive, member states must significantly increase their packaging waste recycling rates in the coming years. By the end of 2025, at least 65% of all packaging waste must be recycled, and this threshold will rise to at least 70% by the end of 2030 (Fig. 3). However, these targets are not uniform across all materials because the directive recognizes the varying levels of recyclability and processing infrastructure required for different packaging types [5].

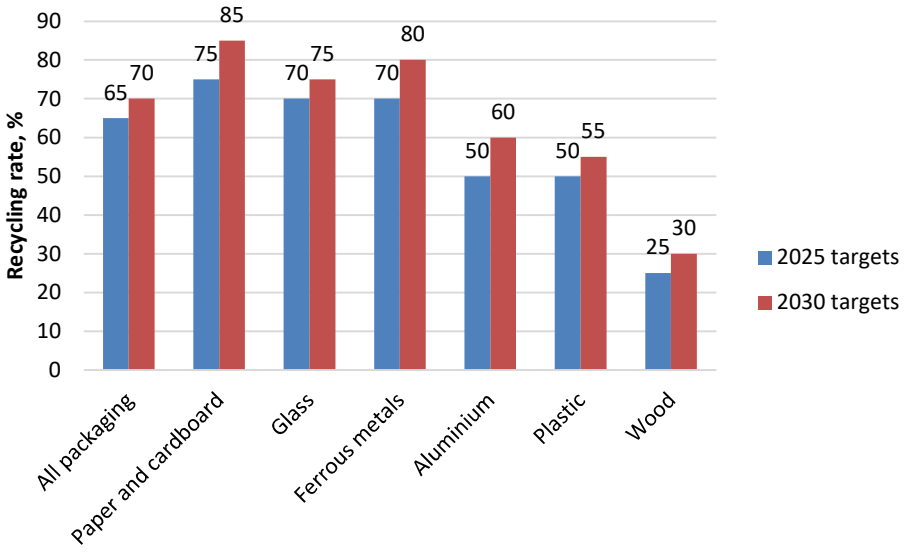

Figure 3 – **Packaging recycling targets in the European Union (EU-27) in 2025 and 2030, by type**

Source: developed by the author using [5].

The directive stipulates that the recycling rate for ferrous metal packaging must reach at least 80% by weight by 2030, reflecting the EU's push to recover more value from metals. Paper and cardboard packaging are expected to achieve a recycling rate of at least 75%, reflecting their high recyclability and widespread collection systems. However, plastic packaging presents more complex challenges due to its diversity and lower collection rates. Consequently, the target for plastic packaging is more modest at 55% by 2030 [5].

Alongside these material-specific goals, the European Union's Circular Economy Action Plan outlines a broader, long-term vision for packaging sustainability. One of its core objectives is to ensure that, by 2030, all packaging introduced to the EU market is reusable or recyclable in an economically feasible manner. This ambition underscores the EU's commitment to reducing environmental impacts, promoting resource efficiency, and supporting the transition to a circular economy where waste is minimized and materials are kept in use for as long as possible [6].

Circular material use rates vary significantly across the European Union, reflecting different levels of progress in implementing sustainable practices among member states. Since 2010, however, most EU countries have shown a positive trend of gradually increasing their use of recycled and reused materials to promote a circular economy (Fig. 4).

In 2023, the Netherlands emerged as the leading nation in this regard, achieving a remarkable circular material use rate of approximately 30.6% — the highest in the EU. This indicates that nearly one-third of the materials consumed in the Netherlands originated from recycled sources, showcasing the country's strong commitment to sustainability and resource efficiency [7].

In stark contrast, Romania recorded the lowest rate among EU members, with only 1.3% of its materials coming from secondary sources. This highlights uneven progress across the region and underscores the need for targeted policy support and infrastructure development in certain areas.

The European Union's average circular material use rate in 2023 was 11.8%. This means that nearly 12% of the total materials used throughout the EU-27 were recovered and reintegrated into the economy rather than being discarded as waste — a modest yet meaningful step toward reducing environmental impact and conserving natural resources.

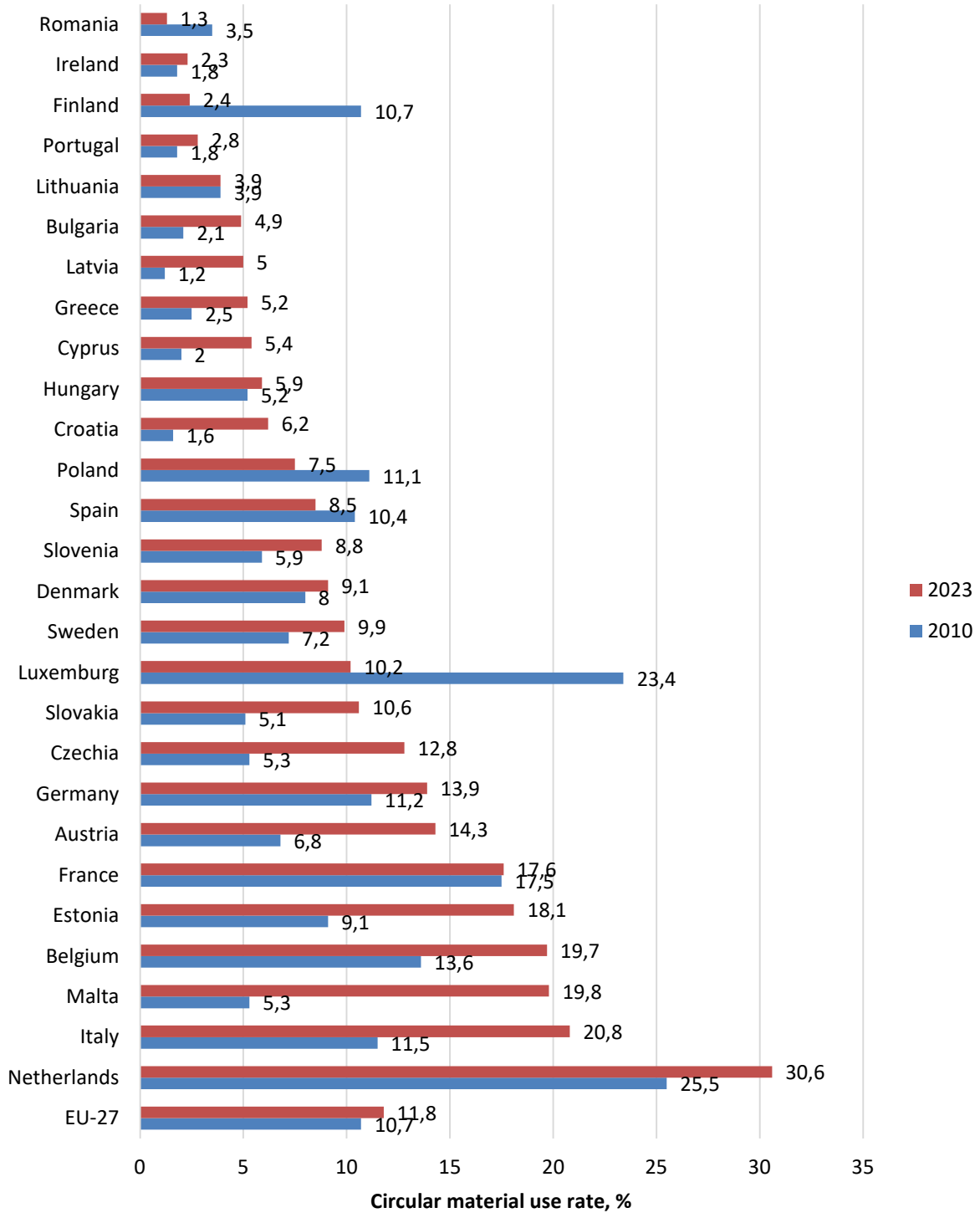

Figure 4 – **Circular material use rate in the European Union (EU-27) in 2010 and 2023, by country**

Source: developed by the author using [7].

Waste treatment practices across the European Union (EU-27) vary widely, reflecting significant disparities in infrastructure, policy implementation, and environmental priorities among member states [8]. These differences affect how effectively each country manages its waste and transitions toward a more sustainable, circular economy (Fig. 5).

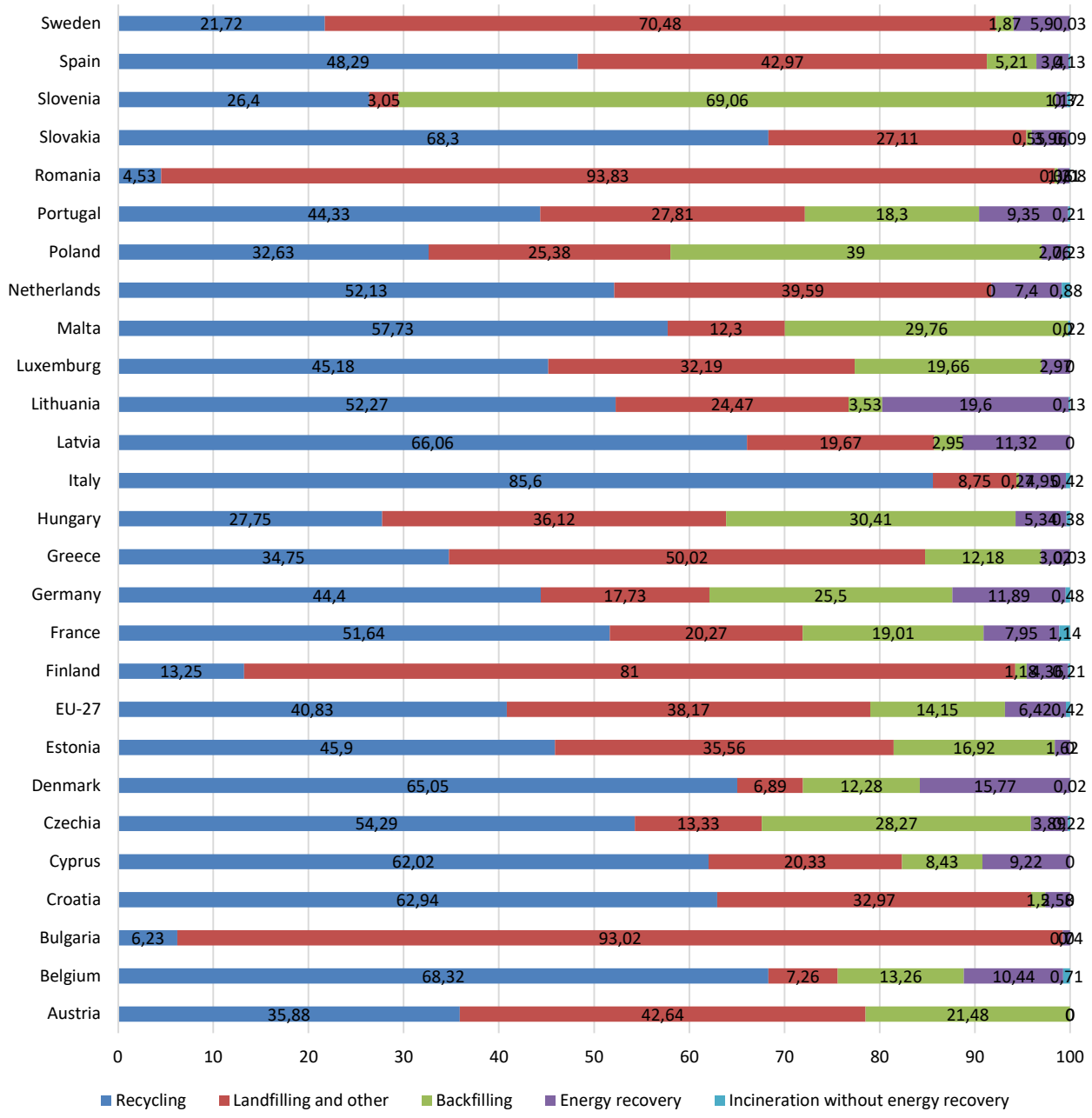

Figure 5 – **Distribution of waste treated in European Union (EU-27) countries in 2022, by treatment method**

Source: developed by the author using [9]

In 2022, Italy led the EU in recycling efficiency with an impressive rate of 85.6%. Belgium followed closely behind, having also made considerable investments in modern waste management systems and public awareness initiatives. These nations exemplify how strategic policies and infrastructure development can lead to highly effective waste recovery and recycling outcomes [9].

In contrast, several EU countries, including Romania, Bulgaria, and Finland, still rely heavily on landfilling as their primary method of waste disposal. This reliance on landfilling not only limits the potential for resource recovery but also poses environmental risks, such as soil and water contamination, and contributes to greenhouse gas emissions [9].

EU-wide, about 61% of the total waste generated in 2022 underwent recovery operations, including recycling, composting, and energy recovery. This indicates that the majority of waste was diverted from landfills and utilized in processes that return materials or energy to the economy. While this figure demonstrates progress, it also underscores the need for continued efforts to harmonize waste treatment practices across the EU and minimize the environmental footprint of waste management [10].

In 2023, approximately 22.4% of municipal waste generated in the European Union (EU-27) was disposed of in landfills, which is a slight decrease from 22.8% in 2022. Although this reduction seems modest, it reflects an ongoing downward trend in landfilling as member states adopt more sustainable waste management practices. This decline aligns with the EU's commitment to promoting the principles of the circular economy and minimizing environmental harm from waste disposal (see Fig. 6).

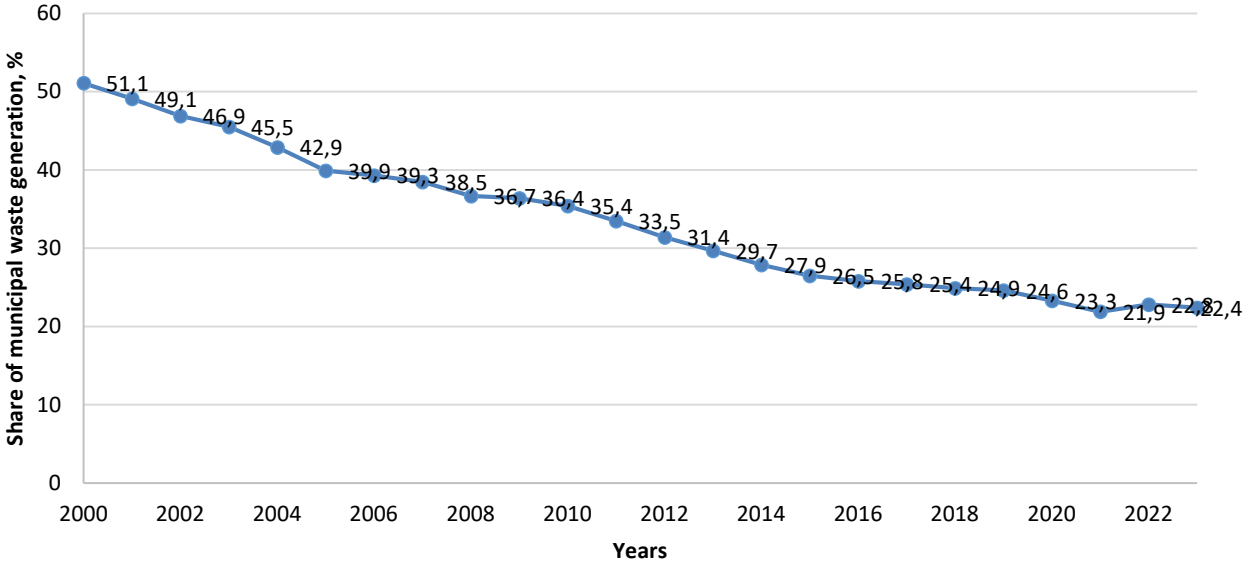

Figure 6 – **Share of municipal waste sent to landfills in the European Union (EU-27) from 2000 to 2023**

Source: developed by the author using [11]

Notably, 2021 was a historic year, marking the lowest landfilling rate in the EU since the beginning of the 21st century. This achievement underscores the effectiveness of waste reduction strategies, investments in recycling infrastructure, and heightened public awareness of sustainable practices [11].

Looking ahead, the European Union has set an ambitious target for 2035: reducing the amount of municipal waste sent to landfills to no more than 10% [11]. To achieve this goal, coordinated efforts are required at both the national and EU levels. These efforts include stricter regulations, incentives for recycling and composting, and continued innovation in waste processing technologies.

This shift is crucial for mitigating the environmental impacts of landfilling, including greenhouse gas emissions, soil degradation, and groundwater contamination, and for conserving valuable materials that can be reintegrated into the economy [12]. Progress toward this target will be a key indicator of the EU's commitment to sustainability and resource efficiency.

A 2019 survey of professionals primarily from the supply chain industry provided valuable insights into the motivations behind corporate investments in the circular economy. The survey, which gathered responses from various global regions, revealed a growing awareness of the dual benefits - ethical and financial - associated with embracing circular principles [13].

Around 30% of respondents from Asia and Australia indicated that their organizations invest in circular economy initiatives because these practices align with their ethical values and because they generate measurable financial returns (Fig. 7). This dual motivation highlights an evolving business mindset where environmental responsibility is increasingly viewed as compatible with, and beneficial to, long-term profitability.

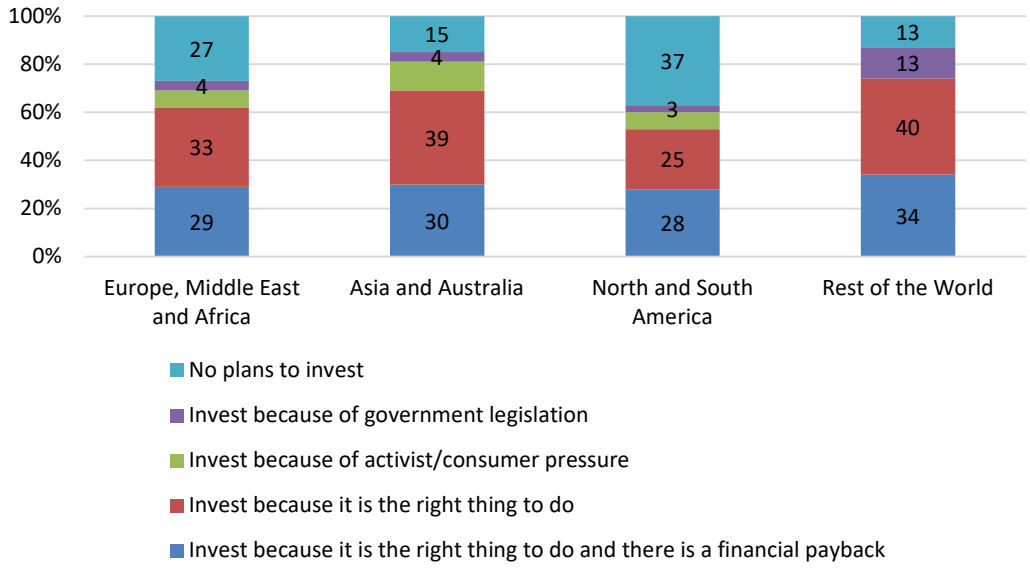

Figure 7 – **Circular economy investment motives and decisions worldwide in 2019, by region**

Source: developed by the author using [13]

These findings highlight a significant shift in how companies perceive sustainability, moving beyond mere regulatory compliance or corporate social responsibility to embrace integrated strategies that foster innovation, cut costs, and boost brand value. In the Asia-Pacific region, where resource efficiency and waste reduction are critical challenges, these investments strengthen supply chain resilience and competitiveness [13].

As the circular economy model gains global momentum, it is crucial to understand the various incentives behind its adoption, including moral imperatives, economic benefits, and risk management, to accelerate its implementation across industries [14].

Without decisive action to reform current consumption and waste management patterns, the amount of municipal solid waste generated per capita is expected to increase dramatically in the coming decades. Projections indicate that, by 2050, the average person could produce nearly 50% more municipal waste each day, exceeding one kilogram. This alarming trend reflects the consequences of continued urbanization, rising living standards, and linear economic models based on the principles of take-make-dispose [15].

In contrast, a shift toward a circular economy model offers a far more sustainable alternative. Under such a scenario, global municipal waste generation would not only stabilize but actually decline, returning to 2020 levels by 2050 (Fig. 8).

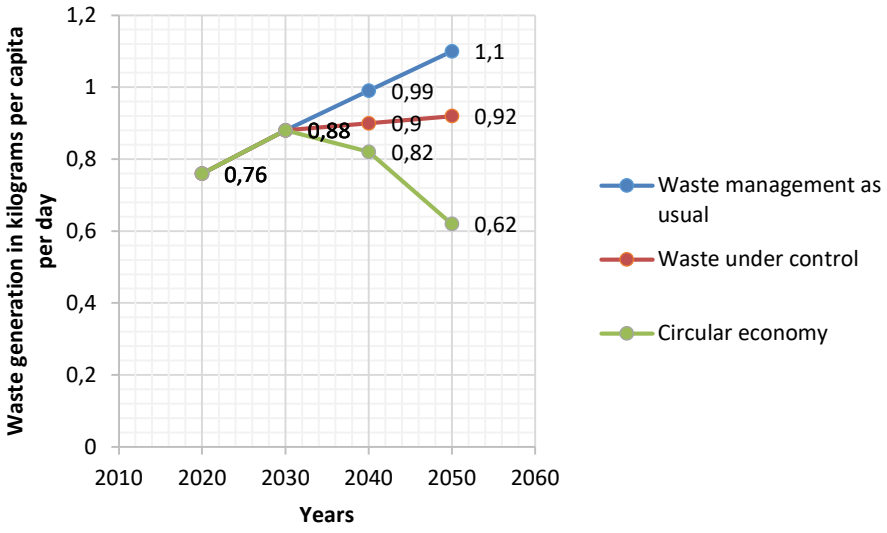

Figure 8 **– Municipal solid waste generation per capita in 2020, and projections from 2030 to 2050, by scenario**

Source: developed by the author using [15]

Per capita waste generation could drop significantly, reaching approximately 0.62 kilograms per day by mid-century. This would be achieved through strategies such as waste prevention, product reuse, materials recycling, and more efficient resource use throughout the entire product life cycle [16].

This transition is particularly urgent, given the current demographic trends. The global population is expected to increase by approximately two billion by the end of the 21st century, primarily in Africa. This shift will put extra strain on waste management systems, particularly in rapidly urbanizing regions where infrastructure development often lags behind population growth [15].

Therefore, implementing circular economy principles globally can play a crucial role in mitigating the environmental impacts of population growth while fostering economic resilience, social well-being, and sustainable development across all regions.

Conclusions. The European Union continues to solidify its position as a global leader in sustainability and the circular economy. The Community Material Reuse Rate (CMRR), a key indicator, reached 11.8% in 2023, reflecting gradual progress in reducing reliance on primary resources. However, improvements are uneven. The Netherlands showed the highest rate (30.6%), while Romania showed the lowest (1.3%). This points to structural and policy differences between Member States that require targeted support and investment in infrastructure.

EU recycling directives have been a significant advancement towards sustainability. By 2035, 65% of municipal waste should be recycled, and no more than 10% should be sent to landfills. Despite legal efforts, however, current recycling rates (48.6% in 2022) are still far from the target. This underscores the necessity of accelerating the development of separate collection systems, upgrading recycling facilities, and increasing public participation.

The situation remains alarming at the global level. If current trends continue, the amount of municipal solid waste per person could increase by nearly 50% by 2050. However, the circular economy scenario shows that, with effective waste reduction, recycling, and reuse strategies, this figure could decrease to 0.62 kg per day — below the 2020 level.

Despite the progress made, the path to a fully circular economy remains challenging. This transition requires large-scale reforms, technological innovation, international cooperation, and sustained political will. However, the potential benefits of this transition - in terms of reduced environmental burdens, stronger economies and improved quality of life - make these efforts vital.

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